MANAGEMENT MANUAL

June 2023

Protecting Fairy and Little Tern breeding habitat in Australia: A resource toolkit for land managers

Recommended citation:
Adams, A.L. (2023). *Protecting Fairy and Little Tern breeding habitat in Australia: A resource toolkit for land managers*. BirdLife Australia report, Carlton, Victoria.

This project is supported by Melbourne Water through funding from the State Government.

Photos: Front cover: John Hutchison; Above: Mark Lethlean.

Acknowledgments

I would like to express my sincere gratitude to everyone that has been involved with Fairy and Little Terns in some capacity around Australia who have contributed their knowledge, expertise and experiences to this resource toolkit: Robert Andrew, Geoff Barrett, Kerri Bartley, Jeff Campbell, Maureen Christie, Nic Dunlop, Claire Greenwell, Greg Johnston, Simon Kennedy, Geoff Lacey, Clare Manning, Andrew Murray, David New, Kaitlyn O'Brien, Marc Perri, Daniel Rogers, Clint Schipper, Deb Sullivan, Adam van der Beeke, Mike Weston and Eric Woehler. Your contributions have, and will continue to, help conservation efforts for these precious birds. I would also like to thank Grainne Maguire for feedback on the draft version of this document.

Thank-you to those that have also contributed photos for use throughout the manual.

Finally, I am thankful to Melbourne Water and the State Government for providing BirdLife Australia with financial support to compile and produce this resource toolkit for land managers.

Contents

Purpose of this toolkit

Beach-nesting birds, such as the Fairy Tern (*Sternula nereis*) and Little Tern (*Sternula albifrons*), breed during spring and summer when beaches and islands attract recreationalists and holidaymakers typically in large numbers. These birds face a multitude of threats, some of which are natural to their ecology, but the bulk of these threats are presently human-related. Consequently, breeding success is often poor resulting in population declines. For the Fairy Tern, these declines have been significant enough to trigger listing as 'Vulnerable' under national legislation (Environment Protection and Biodiversity Conservation Act 1999), as well as being uplisted to 'Critically Endangered' in Victoria in 2021 (Flora and Fauna Guarantee Act 1988) and listed as 'Vulnerable' (Western Australia, Tasmania) and 'Endangered' (South Australia) in multiple states. The Little Tern is being assessed by the Department of Climate Change, Energy, the Environment and Water for listing under national legislation (Environment Protection and Biodiversity Conservation Act 1999) as nationally 'Vulnerable' with the assessment period to conclude by October 30 2023, is listed as 'Critically Endangered' in Victoria and 'Endangered' in Tasmania and New South Wales. BirdLife Australia's Beach-nesting Birds Program has been working since 2006 towards improving the population trajectory of beach-nesting bird species by mitigating threats to breeding birds through on-ground management and beach-user education, to improve breeding success.

This resource toolkit has been developed by BirdLife Australia for land managers, with the aim of being a reference guide for understanding best practice approaches to managing small tern breeding habitats in Australia. Information contained within this document apply to both Fairy Terns and Little Terns due to the similarity in breeding habitat and behaviours of both species and the occurrence of mixed breeding colonies in some locations throughout Australia.

Any management of breeding sites needs to occur with appropriate permissions in place, including ethics, permits and cultural heritage assessments, and with careful consideration of the costs and benefits to the birds and the local community. It must be emphasised that anyone undertaking on-site management is required to have training or adequate experience, and must adhere to the strict guidelines for minimising risks of egg and chick crushing or disturbance of these highly sensitive, breeding seabirds (e.g. see *Fairy Tern monitoring guidelines*; Adams, 2020).

Courting Fairy Terns (photo: C. Greenwell).

Introduction

Species information

The Fairy Tern and Little Tern are two of Australia's smallest (20-24 cm) and most threatened seabirds. They are dependent on both marine and terrestrial coastal habitats: foraging out at sea and roosting and nesting on nearby shores. There appear to be two main populations of Fairy Terns in Australia: the western (Western Australia) and eastern (south-eastern Australia) populations, with the population in Western Australia appearing more stable, and in larger numbers, than the south-eastern Australia population (Higgins & Davies, 1996; DAWE, 2020). Little Terns within Australia can also be divided into two major breeding populations: the northern (north-western Western Australia through to northern Queensland) and south-eastern (eastern and south-eastern coasts including Tasmania) populations (Higgins & Davies, 1996). Both species are at least partly migratory. The western population of Fairy Terns consists of a sedentary winter-breeding population and a partially migratory spring/summer breeding population which migrates south to breed (Dunlop & Greenwell, 2020), while the majority of the south-eastern populations are migratory, moving away from their breeding sites over winter (Higgins & Davies, 1996; DAWE, 2020). The eastern population of Little Terns is migratory, leaving their southern breeding colonies to move northwards in late summer/autumn and returning in late winter/early spring (Higgins & Davies, 1996). However, the non-breeding range of both species is poorly known.

Fairy and Little Terns breed during spring and summer (September to March). Both Fairy and Little Terns prefer to nest in colonies which can range from a few pairs to thousands of birds and can sometimes nest in mixed colonies when distributions overlap. However, some pairs breed solitary, especially as population numbers decline. They typically nest on islands, estuaries, spits, wide coastal beaches, coastal wetlands and estuarine or lacustrine (lake) islands with nesting colonies being located within a couple of kilometres of their food source (Higgins & Davies, 1996; DAWE, 2020). Site selection, persistence and success of a nesting colony is therefore reliant on a locally abundant source of small fish (Baker-Gabb & Manning, 2011). Nesting sites can be used repeatedly between seasons, but they will also move between sites (both during and between seasons) even if they have experienced breeding success at the site previously. This is thought to be a predator avoidance strategy (Dunlop, 2018). During the breeding season, movements between sites often occur if nesting has failed at one site and the birds attempt to re-nest (Higgins & Davies, 1996).

Nests consist of shallow scrapes in the sand above the high-tide mark in open areas, which can be lined with small shells and/or vegetation, and females typically lay one to two eggs (sometimes three). Their well-camouflaged eggs are extremely difficult to spot and take an average of 21 days to hatch, and once hatched, chicks cannot fly for three weeks, during which time they are fed by their parents. During this time, the birds are highly sensitive to disturbances. Pairs can re-nest during a season if a nesting attempt fails, but they will only have one successful breeding event per season (Higgins & Davies, 1996). Once chicks have fledged, the terns will depart the breeding site, however post-breeding movements are poorly understood.

Why management is needed

Fairy and Little Terns are experiencing declines across much of their Australian range, with significant population declines occurring in the south-eastern populations, particularly in the absence of active management (DAWE, 2020). In some instances, historically important breeding sites are no longer being used, attributed to a combination of natural and human-induced threats (DAWE, 2020). Nest sites are often tidally inundated (via king tides, storm events and rising water levels) while continuing coastal development contributes to habitat loss and an increase in the distribution of weeds as well as native and introduced predators such as foxes and cats. Inappropriate sand and water management around breeding sites are also threatening processes which can negatively impact food availability and nesting site availability. People, unleashed dogs, horses and vehicles on beaches not only pose a direct threat of crushing eggs and chicks, but they also disturb incubating and brooding adults, resulting in temporary nest and chick abandonment (whereby the adults leave the nest and chicks in order to maximise camouflage of the eggs/chicks and will only return once the threat has departed the area) which exposes eggs and chicks to harsh temperatures, wind, and avian predators such as ravens, magpies and gulls. Chick survival is often low at sites in the absence of conservation efforts. Even sites which are considered remote are often within human reach, especially via boats, jet skis and off-road vehicle access. If the adult birds are frequently disturbed while nesting, they will abandon their nests to protect themselves. The continuation of threats at traditional breeding sites are resulting in terns abandoning these sites in some instances and moving to sub-optimal sites which also acts to decrease breeding success (DENR, 2011; DAWE, 2020).

When considering the current state of development of Australia's coastline, it becomes very clear that isolated and inaccessible areas suitable for breeding seabirds are rare and will become more so in the future. Existing habitat needs to be maintained and managed to enable breeding seabirds the opportunity to successfully breed during the breeding season – that is produce fledglings (Ratcliffe et al., 2000). Conservation of both species thus requires active protection and management of breeding habitats in order to achieve the immediate conservation goal of increasing the number of fledglings each year. Without effective management of the species' and their breeding habitats to enhance breeding success and recruitment, there is a real risk that local extinctions will occur.

The implementation of conservation activities however requires a comprehensive understanding of the species ecology, as well as site-specific habitat characteristics and threats (Knight & Haddon, 1982). While species-specific habitat management is required at the site-level to manage threats to Fairy and Little Terns, management actions can encompass the needs of several beach-nesting bird species at once and can improve the overall coastal environment.

How should sites be selected for management?

Due to the level of variation in breeding habitat used by Fairy and Little Terns across their distributional ranges, it is not possible to generate a single detailed definition of what critical habitat is (DAWE, 2020). Instead, the habitat critical for survival and breeding success is a mosaic of coastal habitats centered around sandy coastlines and offshore islands and adjacent waters (for foraging) (DAWE, 2020). Effective application of management activities therefore requires site-specific knowledge about individual breeding sites including how many breeding birds use the site, what breeding success is achieved at the site, what is the pattern of site

use and what variables impact breeding success at the site (Smith, 1990). Regular monitoring of sites leading up to, and during, the breeding season will help identify important tern habitat in an area and determine the local degree of inter-annual variation in site use and colony size (DAWE, 2020). It is important to regularly survey sites as areas constituting important habitat may not have birds present every year due to the tendency of terns to move between sites (DAWE, 2020). Historical records should also be considered when assessing the importance of a site.

Recently, it has been suggested that for tern species which move between sites, multiple breeding sites need to be managed within a larger conservation unit instead of only managing individual sites as it isn't beneficial to invest in a single site due to the varying use of sites between and within breeding seasons (Fujita et al., 2009). Hence, knowledge of the dispersal ranges of the species is required to determine the conservation unit (Fujita et al., 2009). Furthermore, improving breeding success of small terns not only requires management of the nesting site to minimise threats but also the conservation and management of buffer areas adjacent to nesting habitat including surrounding foraging habitat as food availability impacts survival rates of chicks (Fujita et al., 2009; DAWE, 2020).

For colonially nesting species, the criterion used for allocating resources and deciding where management will occur has commonly been the number of breeding pairs nesting at a given location, that is, the size of the colony. Because of the dispersed nature of beach-nesting seabirds, and their tendency to move between nesting sites, it becomes difficult to identify where management priorities should be focused. Do areas with only the highest densities of breeding terns need protecting? Do only historically important sites need to be managed? Should we focus on maintaining the traditional range of the species' or on currently used areas? Due to the declining number of breeding sites and population numbers of both Fairy and Little Terns, there is a justification to assess and manage all sites where breeding occurs within Australia to enhance breeding success. It is especially important to target conservation measures at sites where the species' regularly occur as these are likely to have high resource availability and thus higher potential for breeding success (DAWE, 2020). Previous experience has demonstrated that intensive management of breeding sites and colonies results in increased breeding success via the recruitment of juveniles into the population (DENR, 2011). When resources are limited, it is recommended to direct these at managing sites with larger colonies and/or sites with a higher probability of success than at sites associated with high levels of disturbance or prone to tidal inundation which are harder to protect (Owen, 1990). While naturally unsuitable sites which are subject to tidal inundation may not be the most practical to commit resources to in a given year, high levels of disturbance at a site is no longer a valid reason to avoid site management, especially with the current population declines. This manual demonstrates that management of human-based threats can be extremely effective at highly disturbed sites where there is compliance.

Maintaining robust, well-distributed sub-populations should reduce variance in survival and productivity of the population as a whole, facilitate interchange of genetic material between subpopulations and promote recolonisation of any sites that have experienced declines or local extinctions due to habitat changes and/or low productivity.

Factors influencing choice of site for management

One point which must be considered when managing tern habitat is that individuals/colonies do not nest at exactly the same location within a site between years (and sometimes between seasons). Site selection may partly be due to environmental variables including vegetation composition/complexity, substrate, food availability and weather conditions (Willig, 1981). This should therefore be factored into management and monitoring programs whereby larger areas of suitable habitat may require regular monitoring to detect presence of terns, and protection/active management.

A land manager should begin by considering the attributes of the breeding site and how these will affect management decisions:

Site morphology

- The location of the nesting colony and layout of the beach/island will be important to the decision of whether to manage the nesting colony and also to the type of management implemented. For example, a remote, hard to access island may only require assessment of predators and weeds and subsequent eradication measures, but no active management of any human-based threats. While a highly accessible peninsula or beach may require active management of recreationists, however the approach may be different based on the width of beach available, points of access to the beach, and availability of adjacent recreational areas.

- Site morphology will also influence access logistics and therefore influence the type of managements implemented, as management actions which require frequent checks or adjustments are unlikely to be suitable for sites on islands or sites that are difficult to reach.

Human utilisation

- The location of the site itself will be important to management, not only from the perspective of how frequently the site will be accessed/visited/monitored, but also in terms of the social characteristics of the people using the site and the style of education that will be effective, the likelihood of vandalism of implemented management and the opportunities available for effective community education and communication.

- If the breeding site is near a major population centre, then the visitor base will be diverse and it may be difficult to target educational programs, particularly with tourists where English is not their first language. Infrequent visitors to beaches/islands can either be: 1) less likely to comply with signage as they are essentially on 'vacation from responsibility' and do not feel that the consequences will affect them or English is not their first language thus there is a communication barrier; or 2) they can be more likely to read and comply with signage as the visit is a novel experience, enhanced by signs that draw their attention to the environmental values of the area they have selected to visit (Maguire, 2008). Sites with a broad reaching visitor base will require ongoing and clear education programs.

- It is likely the frequency and mix of visitors using a site will change throughout the course of the breeding season (e.g. often week days, spring and late summer users are predominantly local, while visitor use peaks during summer and around holidays and weekends).

Threat profile of site

- Threats to beach-nesting birds can vary dramatically with geographic location. This relates to the types of recreation that are more common in different areas, the size of the visiting human population, and the presence of avian and mammalian predators.

- It is important to prioritise the impact of threats and to address those which are having the most immediate and severe impact on breeding success. This may require the need to address multiple threats simultaneously before an outcome of investment can be achieved.

- It is essential for a land manager to target communication to key audiences, that is, to understand the recreational purpose of visitors to a site in question, and to weight these recreational groups according to frequency and intensity of threat when wording signage and formulating an educational program and materials.

How intensive should management be?

Potential negative impacts of managing nest sites should always be considered and caution taken when implementing a new management action at a site or trialling a new technique. Consideration of not only the effectiveness of the management technique for addressing a given threat, but also the response of the birds themselves and other threats present in the area, needs to occur.

It is crucial to research and understand site selection and use at the site level before deploying invasive management techniques, such as the use of decoys, to avoid attracting nesting colonies to sub-optimal sites even though the site/s may appear optimal to people. This could potentially result in further breeding failures by attracting birds away from sites where breeding success would have been higher due to factors unknown by researchers.

Management should aim to solve the overall problem posed by a threat rather than temporarily delay it. The effectiveness of techniques, regardless of how commonly used they are, should always be monitored, evaluated and adapted over time at the site level, and less invasive techniques should always be opted for in the first instance.

How important is timing?

Timing is crucial when it comes to protecting the nesting sites of colonial beach-nesting species. Disturbance to nesting colonies during early colony formation and site prospecting, as well as during nesting, is thought to be one of the biggest threats small terns face, negatively impacting breeding success. Early intervention at nesting sites has proven to maximise small tern breeding success (Reside et al., 1989; C. Greenwell, pers. comm.). Failure to protect early nesting attempts of Little Tern often resulted in a low number of fledglings as well as a prolonged and scattered breeding season (Reside et al., 1989). Awareness of early colony behaviour

is required to enable the implementation of management activities as soon as possible to protect nesting colonies to increase their chances of breeding success while avoiding disturbance at a critical stage in breeding.

For sites that are heavily visited by people, it is essential that signs and fencing are erected around the nesting colony as soon as possible after the nesting colony is discovered/reported but care must be taken to avoid disturbance during the egg-laying phase as this is when birds are the most sensitive to disturbance and abandonment. If possible, fencing and signs should be erected at a site as soon as birds appear to be prospecting it. It may be beneficial to fence an area or erect signs at locations that are frequently used by nesting Fairy and Little Terns (i.e. in previous seasons) prior to egg-laying as it is possible the birds will re-nest in the same location and thus this will avoid disturbing the colony during the courtship and egg-laying phases when they are the most prone to disturbance.

Weeding, erosion control, vegetation planting, rubbish collection and other activities that involve walking on the upper beach can be risky activities if undertaken during the breeding season. In all instances, these types of activities should be conducted during the non-breeding season prior to the breeding season commencing as they pose a significant disturbance risk to nesting terns which can cause site abandonment. During the breeding season, these works should only occur when there are no nesting birds present.

During times of peak human activity (e.g. weekends, public events, holidays) at nesting locations, it is useful to inform staff (e.g. weekend rangers, surf-life savers, boat operators etc) who are likely to be working in the area of any active nesting colonies and to provide them with brochures or other educational material to distribute to visitors to increase awareness of the nesting birds. Or alternatively, have site wardens in place to educate and communicate with members of the public.

If colonies are known to breed by estuaries/river openings, and an artificial opening is scheduled, it is vital that the site be visited beforehand to determine whether there are any active nests or chicks in the vicinity. These works should be planned to occur during the non-breeding season, prior to birds returning to nest.

Do land managers need training?

Nesting tern species are extremely sensitive to disturbance and their eggs and chicks are prone to being crushed by beach users. For any area where nesting terns breed, regardless of whether special effort will be made to protect the nesting colony, managers need to be aware of the risks that their everyday management of the land may pose to the nesting birds.

It is extremely important that anyone who will be working with threatened tern species, either monitoring or managing them, have the appropriate training. Even the task of putting up signs is a great risk if the person is unaware of how their behaviour affects the birds and/or do not know where all of the nests within the colony are located, as well as being unaware of the extra measures that are needed if chicks are present due to the risk of crushing both eggs and chicks and causing predation events.

Ideally, all participating management staff and volunteers must receive appropriate training to be able to identify the birds and their nesting behaviours. For this purpose, BirdLife Australia developed Fairy Tern monitoring guidelines and an online Fairy Tern induction (found on the Beach-nesting Birds Hub:

https://beachvol.birdlife.org.au) to assist with training of volunteers and land managers involved at Victorian and South Australian Fairy Tern sites but which can be adopted elsewhere. In other States with existing small tern projects and Project Coordinators, training workshops and associated guidelines specific to those projects are provided to active volunteers. It is advised that all staff and volunteers associated with small tern monitoring and management works attend a training workshop prior to commencing and be provided with informative brochures or guidelines. In addition, all staff should be kept up-to-date with active nesting colonies and locations. Advice for any proposed changes to management techniques should be sought from the relevant experts for that species. Nests and colonies have been known to fail when managers make well-intentioned, on-the-spot decisions, but without seeking expert advice.

The breeding season of terns is often lengthy, especially as colonies will re-attempt nesting if previous attempts fail. This may occur nearby or at a different site entirely. It is likely that staff members responsible for protecting the nests and chicks will take some leave during this time. It is important that there is a stand-in for this staff member and that this person has, or receives, all of the appropriate training required.

When events such as fun runs/swims or festivals are planned for during the breeding season, approvals and permit conditions need to highlight the impact to nesting terns and include instructions for event staff on how to alleviate these impacts. If terns are actively nesting at the proposed site, it may be necessary to insist on an alternative location or delay the event. It would never be appropriate to approve events such as horse riding or dune buggy events during the breeding season, for example.

Breeding Little Terns (photo: J. Hutchison).

Management options in detail

To successfully implement conservation management actions for threatened species, important habitat must first be identified, and a comprehensive assessment of threats must be conducted. Strategies to minimise these threats to increase the breeding success at these locations can then be designed and implemented.

At almost all but the most pristine small tern nesting sites, management actions will likely be required to reduce the probability or impact of threats. Various management options are described in this section, however not all will be required at each site. Before deciding on what management actions should be implemented at a Fairy or Little Tern nesting site, all of the active and potential threats should be identified and the management objectives for the site decided on. Some threats will be able to be determined from a single site visit, while others may take several site visits to become evident. Sites should be visited multiple times at different times of the days to establish threats which may include predation, human-related disturbance activities and natural processes such as tidal inundation. It is also important that threat assessments involve discussions with local land managers and volunteers or community members with knowledge of the site in order to capture their understanding of how threats vary during and between breeding seasons, and to assist with identifying key stakeholder groups.

As a general rule when working at tern colonies, it is best to perform management actions prior to the breeding season commencing. If this is not feasible, any direct disturbance should be delayed until after at least 14 days of the birds' incubating eggs if possible (C. Greenwell, pers. comm.). Site attachment increases with time and there is less potential for site abandonment later in the incubation period (C. Greenwell, pers. comm.).

Habitat management should be treated as an evolving process and be able to be adapted as knowledge of the species and sites improve through ongoing monitoring (observational and remote cameras, Appendix A) which is a vital component of any conservation program (Smith, 1990). The capability of recording the number of breeding pairs within a colony, as well as determining the outcome of each nesting attempt, is vital for identifying threats at sites and evaluating the effectiveness of implemented management actions to inform subsequent management decisions. These outcomes will enable improvements to be implemented to the management activity to enhance breeding success at the site. Care should be taken when determining monitoring regimes to ensure minimal disturbance to nesting birds (e.g. see Adams (2020) for Fairy Tern monitoring guidelines).

Table 1 provides a reference summary table outlining each management action available and what threat it addresses for protecting the nesting sites of small terns. Further detail for each management option can be found on the relevant pages listed in Table 1.

Table 1: Summary of each management action presented and the threats they address for protecting small tern nesting sites.

Potential Management Action	Sub-category of Management Action	Threats addressed by Management Action	Pages
Signage	Temporary	Human-related activities (including vehicles and accompanying dogs) causing disturbance and crushing.	15-24
	Permanent	Human-related activities (including vehicles and accompanying dogs) causing disturbance and crushing.	
Fencing	Guidance/people fences	Human-related activities (including vehicles and accompanying dogs) causing disturbance and crushing.	24-33
	Electric fences	Human-related activities (including vehicles and accompanying dogs) causing disturbance and crushing; egg predation by dogs and foxes	
Predator control		Predation of eggs, chicks and adults (or disturbance causing abandonment) by foxes, cats and avian predators (e.g. gulls, ravens).	33-40
Nest cages		Predation of eggs by foxes, gulls, birds of prey.	40-42
Chick shelter	Artificial	Lack of cover from predators, disturbance, and thermal extremes.	42-48
	Natural	Lack of cover from predators, disturbance, and thermal extremes.	
Vegetation management		Loss or degradation of habitat for breeding.	48-53
Substrate replenishment		Tidal inundation of eggs/nests and chicks, loss or degradation of breeding habitat.	53-59
Habitat creation		Continual loss of optimal breeding habitat.	59-71

Potential Management Action	Sub-category of Management Action	Threats addressed by Management Action	Pages
Sandbagging		Tidal inundation of eggs/nests.	71-74
Influencing site selection	Nest destruction	Nesting at sub-optimal breeding habitat.	75-79
	Flagging	Nesting at sub-optimal breeding habitat.	
	Decoys	Nesting at sub-optimal breeding habitat.	
Site wardens		Human-related activities causing disturbance to nesting colonies.	79-83
Site closures		Human-related activities (including vehicles and accompanying dogs) causing disturbance.	84-86
Public education		Human-related activities (including vehicles and accompanying dogs) causing disturbance.	86-91

Fairy Tern chicks (photo: C. Greenwell).

Signage

Human presence and associated recreational activities (including dog walking) at beaches over summer coincide with peak breeding times for tern species. Nesting Fairy and Little Terns become agitated when people are close to their nesting colonies (Higgins & Davies, 1996). Disturbance events expose eggs and chicks for extended periods of time, leaving them vulnerable to predation (particularly to avian predators which can linger at the edge of colonies awaiting such opportunities) and thermal stresses (overheating/cooling) due to the absence of an incubating/brooding adult who won't return until the disturbance event has left the area. Continued disturbance or a significant one-off disturbance event can lead to colony abandonment by the adults including the abandonment of eggs and chicks (Higgins & Davies, 1996). Most coastal users mean no harm to beach-nesting birds and generally only need to be informed about the potential impacts their presence and behaviour may be having to nesting birds.

Signs are a valuable tool a land manager has for protecting nesting tern colonies as they notify people to the presence of a threatened species as well as informs them on how they should behave to minimise disturbance to the nesting birds. In areas where there is a high number of non-English speaking tourists during peak breeding times, it may be worthwhile for land managers to utilise tourism (Shire) and visitor centre data to identify the common non-English speaking languages frequenting the area to create multi-lingual signage. If no attempt is made to educate or warn beach users that they are about to enter a breeding area and that they are a potential danger to the nesting birds, then the impacts of human recreation in the short and long-term will not be alleviated at the site, and breeding success will be due to chance (and often lower than that at a managed site).

While signage design and content are important, particularly when signs are read for the first time, the presence of a sign can begin to act as a visual cue for behaviour change once the community recognise that the presence of signs means there is active nesting (BirdLife Australia social research, In Prep.).

Implementation

There are two types of signs that can be used at nesting sites, temporary and permanent interpretive signs:

Temporary signs

- **Purpose:** to alert people to the presence of an active nesting tern colony in an area and outline restrictions currently in place to protect the colony. This includes instruction for users of the area to keep away from the nesting area.

- **Placement:** Signs should be placed around the colony area as well as at all major access points/paths to the site to ensure people accessing the area will pass them (Owen, 1990; Schipper & Mitchell, 1999; Keating & Jarman, 2004). For vehicle or horse accessed sites, the nearest vehicle or horse access points. For boat accessible sites, the nearest boat launching areas or as floating marker buoys near landing points (Reside et al., 1994; Schipper & Mitchell, 1999). They should be far enough away from nesting areas to give sufficient warning to people allowing them to react to the message before nesting birds are disturbed. Factors influencing distance from colony include the flight initiation distance (the distance at which an incubating bird leaves the nest due to a perceived threat), high tide, and the size of the site. It is suggested

signs be placed a minimum distance of 10-50+ m from the edge of the colony, with the optimal spacing being between 60-100 m if the site morphology permits to prevent the flight initiation response of incubating birds (C. Greenwell, pers. comm.; R. Andrews, pers. comm.; K. O'Brien, pers. comm.; G. Barrett, pers. comm.). In some instances, especially at highly disturbed sites, signs may be placed closer to the colony edge due to size constraints (i.e. when the high tide mark is closer than 10 m to the edge of the colony thus it may be appropriate to place signs 5 m from the edge of the nesting colony).

- **Content considerations:** message of active nest or chicks in area of a rare/threatened species, date range of nesting (e.g. November to February), brief instructions on what to do to avoid disturbing the nesting birds (e.g. keep dog on leads; walk below the high tide mark), photo/picture of the birds to assist with identification.

- **Size:** typically A4-A3 size and large enough that the text is easily readable. The height of the tide and width of the beach will also determine how visible the signs will be from the water's edge, thus how large the signs should be.

- **Materials:** options include horizontal corflute, laminated heavy paper mounted onto exterior plywood, laminated sheet metal or aluminium composite. Choice of material will depend on budget, how quickly signs are needed, and how much exposure to strong winds the site receives. Signs can be affixed to infrastructure already present at the site (e.g. fence post or gate) or onto a wooden stake/star picket hammered into the ground. Colour printed signs will be more attention grabbing and engaging.

Permanent interpretive signs

- **Purpose:** to provide more detailed information to the public about the birds, their habitats, and of their plight including the threats they face.

- **Placement:** around high public use areas near important nesting sites such as boat ramps, car parks, the start or end of beach access points/paths, viewing platforms or lookouts where people will automatically pass by the sign and are likely to notice it or naturally pause at that location.

- **Content considerations:** species profile including conservation status, importance of the local site, identification information, seasonal requirements and information on how the public can 'share the coastline' with the birds.

- **Size:** the size of a free-standing sign will in part depend on the specifications set by the land manager and consistency with any other signs at the site. If there are existing signs or noticeboards, information could be integrated into these rather than the need to create additional signage. The sign needs to be obvious to site visitors and the text large enough to read with ease. The text on the sign should not be too cluttered, so the more text you have, the larger the sign required.

- **Materials:** signs need to be made of materials that withstand coastal conditions (e.g. corrosion from salt spray), are durable over time and are graffiti resistance (e.g. Perspex). Signs can be framed by timber or

metal/aluminium and mounted on one or two treated timber posts or metal posts anchored deep in the ground in cement.

Recommended sign content and design

- It is important to provide the reasoning behind compliance. Signs that purely instruct beach users to behave in a certain way are less effective than signs which provide some context or education as to why someone should alter their behaviour.

- Signs should try to include content about: 1) How threatened the birds are (why should I care?); 2) What are the threats the species faces (how does this relate to my behaviour?); and 3) How can I help the birds?

- Information included on signs need to be accurate. Information should be sourced from credible sources including the Handbook of Australian, New Zealand and Antarctic Birds (HANZAB), recovery plans and research articles published in peer-reviewed journals.

- Instructions/guidelines for protecting the birds need to be clear and unambiguous. Jargon and scientific expressions should be avoided.

- Instructions should focus on the positive rather than the negative to maximise compliance. For example, instead of saying 'Do not…' use 'You can help by…'.

- Instructions should use the active rather than passive voice such as 'We/You can help by…' instead of terms such as 'Ways to help..'.

- Text on signs should be kept to a minimum but not at the expense of accuracy or provision of enough content to educate the beach user. A useful way to direct people to further information is by providing a QR code that links to a website for example.

- Paragraphs should be kept short, ideally between 40-65 characters.

- Font size should be large and attention grabbing. Bolding and italicizing text can be incorporated to reinforce important ideas. Avoid writing sentences in capitals.

- There should be a strong contrast between the text and the background to ensure the message stands out.

- Information needs to flow in a logical order.

- Signs should include a photo or illustration of the birds to assist people in identification. These pictures should evoke interest or empathy. A size scale should be included as many people will be unfamiliar with terns.

- Signs need to include logos of land managers and funding bodies (permission is required and style guidelines adhered to). It is useful to provide a contact number or website for further information.

Decision-making trigger

Due to the threatened status of Fairy and Little Terns, the majority of publicly-used nesting sites would benefit from the presence of temporary and/or permanent signs. Many monitoring programs install temporary signs at all known Fairy or Little Tern nesting sites once nesting is detected regardless of colony size.

The factors of most importance in determining the use of signs will be the accessibility of the site (largely related to the distance from access points), location of the nesting area relative to population centres and the level of disturbance likely to occur in the area due to recreational activities. For example, when a nesting colony is located on an island not typically frequented by people, signs may not be required. However, if the nesting colony is on an island/beach likely to be used by people for recreational purposes (which may only occur at peak times of year for example on an island), management including the use of signs would be recommended to notify the public to the presence of breeding birds and to provide education as to how they can avoid disturbing the nesting colony. Signs are also often installed at sites associated with first-time use by nesting colonies (D. Rogers, pers comm.). Permanent signs are often only erected at breeding sites where terns regularly return to and nest. This is based on both historic and continued monitoring of the site.

Signs should always be used with fencing to reinforce areas which are off-limit to people due to the presence of nesting birds (refer to the 'Fencing' section for further details).

Timing and suggested frequency

Signs are generally installed at sites as soon as nesting activity is detected which is usually during the site prospecting stage or early scrape-making/egg-laying phase to alert the public to the presence of nesting birds as early as possible (Keating & Jarman, 2004; Campbell & Christie, 2007; NPWS, 2019; C. Schipper, pers. comm.; D. Rogers, pers. comm.; E. Woehler, pers. comm.; K. Bartley, pers. comm.; K. O'Brien, pers. comm. M. Christie, pers. comm.). However, signs can be installed at later colony stages (e.g. late chick stage) upon colony discovery (E. Woehler, pers. comm.). The number of signs can be increased around nesting colonies throughout the breeding season in response to recreational events occurring nearby due to the higher levels of disturbance associated with their running (NPWS, 2019). Where appropriate, temporary signs should be used at nesting sites annually.

At sites where nesting has been a regular occurrence over multiple years and the general location of the nesting area is known, temporary signs can be installed at sites prior to the expected arrival of breeding birds (Reside et al., 1989; C. Greenwell, pers. comm.; G. Barrett, pers. comm.). If breeding birds do turn up and have selected a site away from the signs, they can then be moved as soon as possible. Temporary signs should be removed from a site once chicks have fledged and all breeding birds have left the site (including in instances of nesting failure/site abandonment).

Permanent signs are best installed at sites where terns regularly nest prior to the breeding season commencing (i.e. between April and September) to avoid disturbing breeding birds once they arrive. If the location of the permanent sign is not near the nesting site (e.g. in a carpark or at a boat ramp) then installation can occur at any time. However, installation should still ideally occur before the start of the breeding season to enable the community time to read and respond to the sign content. Permanent signs should be monitored for reduced legibility due to fading and be replaced accordingly.

Advantages

Temporary signs

- Alerts visitors to the presence of a, often cryptic, nesting colony and provides information as to why the area is currently off-limits with clear instructions on how to behave around the site (C. Schipper, pers. comm.; D. Rogers, pers. comm.).
- Are installed/removed in response to real-time nesting events which gains the interest of visitors and signals that the colony is being monitored.
- Can be placed around the colony so that they are visible from all major approach routes.
- Prevents/reduces people and dogs from entering the nesting area aiding compliance with restrictions (G. Barrett, pers. comm.; K. O'Brien, pers. comm.).
- More signs can be installed at breeding locations throughout the breeding season in response to increases in the number of people frequenting the site (Reside et al., 1989).
- Can be installed by trained project volunteers.
- Are species- and site-specific, containing relevant information applicable to individual sites.
- Signals that changes to site access are only temporary, increasing community uptake and associated compliance levels.

Permanent interpretive signs

- Provides public education through inclusion of why the species is declining and how you can help protect them.
- Adds weight to temporary signage by providing extra information.
- Gives people prior warning to management activities that they may observe at the site.
- Permits greater investment in the sign, thus can be attractive and eye-catching.
- Generally require less maintenance and have a longer "shelf-life" than temporary signs.

Disadvantages

Temporary signs

- Signs need to be installed/removed in real-time in response to nesting activity thus the site needs to be regularly visited by volunteers or staff.
- Difficulties in mounting temporary signs in a way that resists wind and tide damage and still be visible and in the appropriate location for viewing.
- Signs can be lost due to tidal inundation and may require more regular checks/maintenance (K. O'Brien, pers. comm.).
- Signs can be vandalised, damaged or destroyed (Sullivan, 2019; D. Rogers, pers. comm.; K. O'Brien, pers. comm.). Instances where wooden stakes have been used for bonfires on beaches.
- Signs alone can be ineffective at preventing people from entering the colony area (Willig, 1981; Murray & Reside, 1995).
- Often compliance with the regulations contained on the sign are not policed (M. Christie, pers. comm.).
- Time required designing the sign and installation (G. Barrett, pers. comm.).
- Public complaints of signs being an eye-sore (K. O'Brien, pers. comm.).
- Presence of signs can attract attention and attract people closer to the colony area due to wanting to read the sign (Keating & Jarman, 2004; C. Schipper, pers. comm.; K. O'Brien, pers. comm.). This is why the placement of the sign is critical to avoid/minimise disturbing the nesting colony. At highly disturbed sites, the presence of a sign often outweighs the risk of having no sign due to the associated potential of accidental crushing of eggs/chicks by people who are inadvertently in the colony area.

Permanent interpretive signs

- Are more expensive than temporary signs.
- Time required designing the sign and installation (G. Barrett, pers. comm.).
- They lose effectiveness over time as regular visitors to the site become habituated to the signs. Hence, permanent signs may have the most value at sites where visitor bases vary over time e.g. tourist areas, sites close to major cities. It can also be useful to reposition the signs over time, to remind people that the issue is still relevant.
- Are usually more generic than temporary signs and may not be species-specific, instead containing information relating to generic shorebird breeding areas (Keating & Jarman, 2004).

Case studies

Numerous sign designs have been implemented around nesting colonies of Fairy and Little Terns throughout Australia. Below are some examples:

Examples of temporary signs used around Fairy and Little Tern nesting colonies in Australia (photos: A. Adams, C. Greenwell, K. O'Brien).

Further examples of temporary signs used around Fairy and Little Tern nesting colonies in Australia (photos: G. Barrett, C. Greenwell, R. Andrews).

Example of a floating marker buoy installed off Point Walter to prevent boat landings (photos: C. Greenwell, G. Barrett).

Examples of permanent signs used around regular Fairy and Little Tern nesting sites in Australia (photos: C. Greenwell, K. Bartley, K. O'Brien, S. Coutts).

In Western Australia, a competition to design a sign has been run in the community and the winning sign was used around the nesting colony during the breeding season. This raised awareness of the nesting Fairy Terns within the community (C. Greenwell, pers. comm.). In Victoria, pamphlet boxes containing additional information on the breeding Little Terns were attached to sign posts on the beach as an initiative to further

promote public education (Reside et al., 1989; Smith, 1990). In New South Wales, wildlife protection signs have also been utilised at some Little Tern nesting sites which outlines the restrictions to 4WDs and dogs, preventing their presence around nesting areas (Keating & Jarman, 2004).

Recommendations

- Temporary signs should be installed at nesting sites accessible and frequented by members of the public to minimise disturbance events.

- Cultural heritage permission should be attained prior to the arrival of breeding birds at regular breeding sites so temporary signs can be installed as soon as possible once birds arrive. Permission should be attained for all possible breeding sites in a region.

- At known, regular breeding sites which are frequented by people, temporary/permanent signs can be installed prior to the expected arrival of breeding birds. Otherwise, signs should be installed as soon as a breeding colony is detected.

- Signs should be visible from all major access routes to the colony and where possible be located outside of the colonies flight-initiation distance.

- If printing signs on corflute, ensure the flute runs horizontal to avoid wind damage. Ensure permanent signs are graffiti-proof and protected against corrosion from the salty coastal environment.

- Temporary signs should include information about the species, their conservation status and simple, clear instructions on how people should behave to minimise disturbance to the nesting colony.

- Where possible, temporary signs should be used in conjunction with temporary fencing to increase compliance and reduce the number of people entering the colony area. Signs should always accompany a temporary fence.

- Replace permanent signs when they begin to fade to ensure they remain legible.

Fencing

As described in the above '*Signage*' section, disturbance events including recreational activities at beaches and other coastal sites, whether continued or a significant one-off event, can cause terns to abandon a nesting attempt. The majority of coastal users causing disturbance are likely to be unaware of the presence of nesting seabirds and are likely to comply with any instructions when informed about how their presence/behaviour is impacting breeding birds. With early intervention being key to increasing the breeding success at nesting sites, fences, which are generally used in conjunction with signs, are a simple yet effective visual tool to reduce human disturbance that land managers can utilise to protect nesting tern colonies (Willig, 1981; Owen 1990, 1991; Waldengrave-Knight et al., 1997; Schipper & Mitchell, 1999). At nesting shorebird sites, the use of fencing in addition to signs, significantly increases hatching success (Cullen et al., 2020; Maguire et al., 2018).

Fences can be used to manage the movement of people around nesting sites. They act as a visual cue, reinforcing the message of nearby signs, to make people stop before they get too close to nesting areas. Fences serve two purposes: 1) to prevent people walking through the active colony site and crushing nests, eggs and chicks; and 2) to provide a buffer between incubating birds and site visitors, so that disturbance is minimised.

Implementation

There are two types of temporary fences that can be used at nesting sites, guidance/people fences and electric fences (excludes predators):

Guidance/people fences

- **Purpose:** to indicate areas of restricted access to the public keeping them (and dogs or vehicles) a safe distance away from nesting birds in order to minimise the risk of crushing nests and to reduce disturbance to the nesting colony.

- **Placement:** Ideally erected at the colonies 'settling' distance (where birds will incubate their eggs or feed their chicks) (Smith, 1990). Factors influencing distance from colony include the flight initiation distance (the distance at which a bird leaves the nest due to a perceived threat), high tide, and beach width (including not overly restricting public access to the site, K. O'Brien, pers. comm.). Suggested minimum distance of 10-50+ m from the edge of the colony to provide enough space for the nesting birds as well as chicks and runners, with up to 60-100 m preferred (Willig, 1981; Owen, 1991; Schipper & Mitchell, 1999; Smith & Smith, 2001; Keating & Jarman, 2004; Baker-Gabb & Manning, 2011; C. Greenwell, pers. comm.; E. Woehler, pers. comm.; G. Barrett, pers. comm.). In some instances, fences can be closer to the colony edge due to size constraints (i.e. when the high tide mark is closer than 10 m to the edge of the colony thus it may be appropriate to place fences 1-2 m from the edge of the nesting colony; C. Greenwell, pers. comm.; C. Schipper, pers. comm.; K. Bartley, pers. comm.). Where the colony is near the water, fences can be placed in the water to deter boats from landing at the nesting site (Schipper & Mitchell, 1999). People can be discouraged from walking too close to nesting colonies by extending fences to below the low tide water mark, however this is only possible where either a person is available to extend and reduce the fence with the tide height on a given day, or where beach users do not need to pass the area at high tide (Reside et al., 1989). The foreshore should be kept clear so that runners/chicks are able to go down to the water's edge.

  Where there are no size constraints due to beach morphology and allowing for continued beach user access, the flight-initiation distance can be used as a guide for individual colonies to determine the minimum distance from the nearest nest to the fence boundary to minimise disturbance from people walking past (Owen, 1990).

- **Size:** Dependent on the size of the colony and available habitat (see above for boundary placement recommendations). Size of the enclosed area can be expanded as the nesting colony expands (Dunn & Jorgensen, 2008; C. Schipper, pers. comm.). Here it can be useful to use knowledge of previous colony sizes at the site and to make the fence bigger, if the morphology of the site allows, in the first instance to account for colony growth.

- **Materials:** Commonly constructed using 1-2 strands of 4 mm plastic wire, soft-grip wire, rope, coloured twine or orange-mesh strung typically at waist height between plastic star pickets, wooden tomato stakes, fibreglass poles or H posts (placed 4-10 m apart). Permanent fences can be constructed using hardwood posts and thick metal wire or ringlock fence wire (C. Greenwell, pers. comm.; M. Christie, pers, comm.). Bright orange rope should be used for all fences preventing vehicle access in order for the fence to be clearly visible to drivers (C. Greenwell, pers. comm.).

  It is important that the fence is not constructed of material that will flap in the wind as this will cause site abandonment by the adults. Fences should be clearly visible to avoid accidents. Temporary signs should accompany all temporary fences, placed at regular intervals along the fence length, to inform the public why the area is currently off-limits (Smith, 1990; Smith & Smith, 2001; C. Greenwell, pers. comm.; M. Christie, pers, comm.).

Electric fences

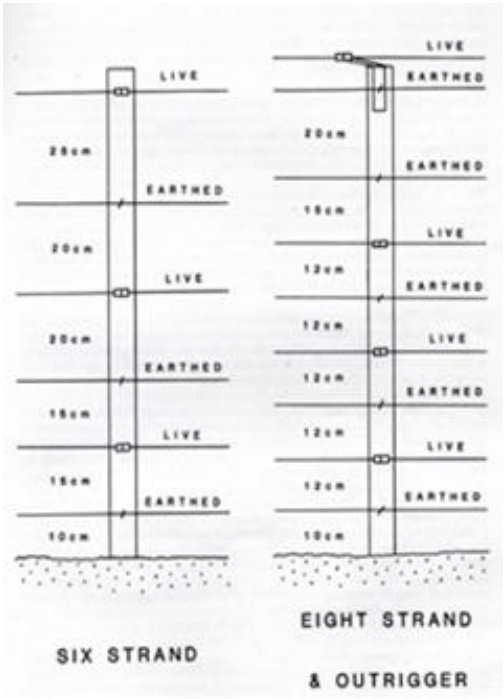
- **Purpose:** to prevent predation of eggs and nests by foxes and dogs when considered a significant threat at a breeding site by excluding them from the nesting area through the delivery of an electrical shock (Keating & Jarman, 2004).

- **Placement:** Where possible, the fence should be no closer than 20 m to the nearest nest and should be erected at the colonies flight-initiation distance (Smith, 1990).

- **Size:** Dependent on the size of the colony and available habitat. These fences should be installed at least 5-20 m inside a temporary guidance/people fence to reduce the chances of people getting an accidental electrical shock (Schipper & Mitchell, 1999; DECC, 2008).

- **Materials:** Typically 4-8 strands of electric wire strung between plastic and/or fibreglass posts with a 6- or 12-volt battery connected to a pulse charger set at maximum capacity (batteries should be replaced weekly where feasible; Smith, 1990; Keating & Jarman, 2004; DECC, 2008). Eight strands are more effective at excluding foxes due to gap size (see diagram for gap sizes) (Smith, 1990). Pre-season site assessments can be used to determine the number of strands to use based on predator sign (Smith, 1990).

  Fibreglass or plastic posts are used in preference to steel star pickets as more can be carried and the fence can be erected more quickly (Smith, 1990). The fence generally consists of live wires alternating with earthed wires thus mammalian predators trying to gain access through the gaps will receive an electrical shock when it touches both the live and earthed wires (Smith, 1990). The bottom wire should be earthed as is often covered by sand or water.



Suggested design for electric fences to protect small tern colonies (sourced from Smith, 1990).

Temporary warning signs for the public should be placed on electric fences at several locations along the perimeter attached to posts warning of the danger of electrical shocks (Smith, 1990; Schipper & Mitchell, 1999). A guidance fence composed of brightly coloured rope should also be erected around the electric fence to keep people away from both the electric fence and the nesting area and be outside of the colonies 'settling' distance (Smith, 1990).

During construction of fences, it is important that disturbance to the nesting birds is kept to a minimum (Smith, 1990). The fence should take no more than 30 minutes to erect otherwise this could affect the viability of the eggs and increase predation risk. If construction can't be completed within this time frame, take at least a 30-minute break to allow the birds to come back and incubate undisturbed before returning to complete construction (Smith, 1990). If a predator comes in close proximity to the colony area while the fence is being constructed, you should leave the area and not return until the predator has left.

Once runners are present in the colony, where possible the guidance fence should be extended to include nearby areas of dense vegetation that chicks would utilise as shelter (Smith, 1990).

Decision making trigger

Due to the threatened status of Fairy and Little Terns, and the declining number of breeding sites around the country, often the presence of a nesting colony or pair in a location subject to human visitation, triggers the erection of a temporary fence (Keating & Jarman, 2004). Fencing is often erected at all Fairy and Little Tern nesting sites which experience regular disturbance to prevent humans, dogs and vehicles from entering the colony (Smith, 1990; C. Schipper, pers. comm.; D. Rogers, pers. comm.; K. Bartley, pers. comm.). Nesting sites where fences do not occur are usually those that are hard to access or have low visitation rates and thus there is a minimal likelihood that human-related disturbance will occur.

The factors of most importance in determining the use of fences at a site will be the location of the nesting colony relative to population centres and the levels of visitation (which can vary based on time of year), accessibility of the site and the colony location relative to the space available at the site (e.g. fences can't be erected if the beach is too narrow and public access becomes restricted at high tide). For example, fences would be recommended at nesting sites located on islands/beaches that are regularly visited by people to protect the colony from disturbance. In some instances, temporary fences are erected at sites prior to the expected arrival of breeding birds. This generally occurs at sites where nesting has been a regular occurrence over multiple years and the general location of the nesting area is known. Permanent fences are often only erected at breeding sites where terns regularly return to and nest. This is based on both historic and continued monitoring of the site. These fences should encompass the largest area possible (C. Greenwell, pers. comm.).

Signs should always be used with fencing to reinforce areas which are off-limit to people due to the presence of nesting birds (refer to the '*Signage*' section for further details).

Timing and suggested frequency

Where appropriate, temporary fencing should be erected at sites annually as soon as nesting activity is detected which is usually during the site prospecting stage or early scrape-making/egg-laying (Smith, 1990; Keating & Jarman, 2004; Campbell & Christie, 2007; D. Sullivan, pers. comm.; C. Greenwell, pers. comm.; E.

Woehler, pers. comm.; G. Barrett, pers. comm.; K. O'Brien, pers. comm.; M. Christie, pers. comm.). Fencing should occur before the hatching of eggs (K. Bartley, pers. comm.). At sites where nesting occurs annually, temporary fences can be erected prior to the birds arriving to breed (Reside et al., 1989; Owen, 1990; Owen, 1991; Murray & Reside, 1995; Waldengrave-Knight et al., 1997; Schipper & Mitchell, 1999; Dunn & Jorgensen, 2008). Not all sites will have forewarning of fencing needs, and it may be that a nesting colony at various stages (eggs and/or chicks) are discovered and in urgent need of protection, e.g. during the peak of summer. In these cases, achieving the optimal timing for fencing may not occur and the immediate need for protection will take precedence.

Fencing should be conducted in mild weather conditions and should not be erected in adverse weather (extreme heat, cold, rain or windy conditions).

Temporary fencing should be removed from the nesting site once chicks have fledged and the post-breeding colony has left the area or soon after nesting failure as indicated by the adult birds having left the site (Smith, 1990; Keating & Jarman, 2004; C. Schipper, pers. comm.; D. Rogers, pers. comm.; E. Woehler, pers. comm.; M. Christie, pers. comm.). Alternatively, fencing can be removed once chicks are no longer using the fenced area (K. O'Brien, pers. comm.), although be careful if chicks have not fledged not to remove the 'cue' for beach users that the area still has vulnerable chicks/active breeding. It may instead be an option to reconfigure the fencing and remove once chicks have fledged.

Advantages

- Often increase compliance rates among the public than just signs alone (Murray & Reside, 1995; Keating & Jarman, 2004; BirdLife Australia social research, In Prep).
- Provides a buffer around the nesting colony to keep people at a safe distance from nesting birds reducing the incidence of egg/chick crushing and minimising/eliminating disturbance events (Keating & Jarman, 2004; C. Greenwell, pers. comm.; C. Schipper, pers. comm.; K. O'Brien, pers. comm.).
- Prevents vehicles from driving through the colony area.
- Can enhance breeding success at a site (Keating & Jarman, 2004).
- Electric fences are effective at preventing access to the nesting area to predators such as foxes and dogs (Reside et al., 1989; Murray, 2000; D. Rogers, pers. comm.). High survival rates of eggs and chicks in NSW are generally attributable to the use of electric fences in conjunction with fox control efforts (Jarman, 2006).
- Provides habitat protection.
- Even more effective if also patrolled by a site warden (Smith, 1990).

Disadvantages

- Any type of fencing can provide a perch for avian predators which could potentially increase predation risk.

- Do not provide a true barrier to access/disturbance, especially from unleashed dogs which can run underneath rope barriers.

- Nests laid after fences are erected can fall outside of the fenced area. These nests either remain unprotected or the fence needs to be moved which can disturb the colony.

- Chicks and runners are not confined to within the fence boundary thus can leave the protection that the fence offers (Murray & Reside, 1995). Can result in constant adjustments made to the fence (K. O'Brien, pers. comm.).

- If fences remain erected when chicks are present, people can mistakenly think that the chicks are restricted to within the fenced area and therefore aren't as diligent at looking out for chicks outside of the fenced area. This can lead to accidently crushing chicks. Consider erecting chick signs indicating that chicks are in the area and can be located outside of the fenced area.

- Labour intensive to install (K. O'Brien, pers. comm.).

- Requires regular checking and maintenance.

- Poly rope deteriorates and natural rope is difficult to work with and likely doesn't last as long (K. O'Brien, pers. comm.).

- Dynamic tides can result in fences being washed away (K. O'Brien, pers. comm.).

- Known instances where members of the public have interfered with and/or removed/stolen temporary fences (Murray, 2000; Keating & Jarman, 2004; D. Rogers, pers. comm.). To minimise this potential, consideration of public response to the presence of fencing should be factored into the communication and education plan for the local community. If vandalism does occur, this should be followed up with an investigation and appropriate actions.

- Electric fences can experience battery failures and loss of voltage due to damaged fencing tape from the exposed nature of the sites and debris (Reside et al., 1989; Owen, 1990; Dunn & Jorgensen, 2007).

- Animals (such as kangaroos or sea lions) or adverse weather can cause the tangling of fence wires and/or dislodging of posts (Reside et al., 1989; Owen, 1990; C. Greenwell, pers. comm.). Understanding site use by other native mammals can be important for deciding the presence, type of materials and placement of the fencing. For example, electric fencing may not be appropriate at sites with a large number of native mammals due to the potential for entanglement. If entanglement does occur, fences will need to be removed. These sites may also require more regular maintenance checks.

- Foxes can become accustomed to receiving an electric shock and will enter through these to depredate eggs and chicks (Keating & Jarman, 2004; NPWS, 2019).

- Electric fences require daily checking to clear away or fill in sand around the bottom wires and ensure that the fence is working correctly (Owen, 1990).

Case studies

Numerous fence designs have been implemented around nesting colonies of Fairy and Little Terns throughout Australia to minimise disturbance by preventing human and dog/predator access. Below are some examples:

Western Australia:

Pyramids Beach. Top: a combination of orange-mesh (outer) and rope (inner) fencing is used around the nesting Fairy Tern colony. Signs are placed at regular intervals along the orange-mesh fence. Bottom: the inner rope fence (photos: C. Greenwell).

Point Walter. The temporary fence is installed prior to the breeding period and extends out into the sea to prevent landings. The fence was extended 50 m closer to the mainland in 2019/20 to open up more nesting habitat due to disturbance from people walking along the sandbar. Consequently, the colony size doubled from ~70 breeding pairs in 2018/19 to ~140 breeding pairs in 2019/20 (photos: C. Greenwell).

Examples of permanent fences encapsulating regular nesting areas of Fairy Terns (photos: G. Barrett (left) and C. Greenwell (right)).

South Australia:

Example of a temporary fence where regular patrols enforce compliance (photo: K. Bartley).

Victoria:

During the 1994/95 breeding season, a new type of fence was trialled at Seagull Point in East Gippsland due to the exposed positions of the Little Tern nest scrapes and the perceived threat from predators and people (Murray & Reside, 1995). A one square meter enclosure was created by driving 4 star pickets into the sand. Chain mesh fencing (50 mm diameter) was then secured to the star pickets 20 cm below the ground in order to prevent animals from burrowing underneath and 50 cm above the ground while the top was left open. Construction took 5 minutes and Little Tern adults were back on their nests within 20 minutes. Adult birds were observed landing both inside the enclosure and outside where they then squeezed through the mesh to access their nests. A guidance fence and signs were also erected. Chicks from the nests hatched but did not fledge from the site (Murray & Reside, 1995).

A swash fence was also implemented at Sydenham Inlet during the 1996/97 breeding season (Waldergrave-Knight et al., 1997; Murray, 2000). This consisted of 50 cm lengths of shade cloth placed along the seaward

side of the enclosure and held in place by being nailed to wooden pales. The fence was also partially buried. This fence formed a wind break causing a build-up of sand against the fence. During rough weather, water would be required to breach this sand build-up to reach the Little Tern nests. During minor storms, the amount and velocity of water entering the colony was greatly reduced due to the mesh (Murray, 2000). This resulted in less nests being inundated (Waldergrave-Knight et al., 1997). The fence could also be used to prevent chicks from leaving the protected colony area (Waldergrave-Knight et al., 1997).

Alerted by a concerned community member, in response to farm stock wandering over to the Fairy Tern nesting area on Rams Island, the Lands Department and Fisheries and Wildlife Division both agreed to supply fencing material so that fencing could be erected along the foreshore reserves (it was deemed that it wasn't financially practical to insist on the farmer to cover this cost). The barbed-wire fence was then erected by voluntary labour over two days and was successful at preventing stock access to the Fairy Tern breeding site (Swan, 1977).

New South Wales:

Examples of temporary fences around Little Tern colonies which have increased fledgling success in NSW colonies (Dunn & Jorgensen, 2008; photos: K. O'Brien).

Examples of small electric fences used around individual Little Tern nests to effectively prevent mammalian (dog/fox) predation of eggs (Keating & Jarman, 2004; Jarman, 2006; Dunn & Jorgensen, 2007; Dunn & Jorgensen, 2008. Photos: F. Bray (left, sourced from NPWS, 2019) and J. Whitley (right, sourced from Dunn & Jorgensen, 2007).

Recommendations

- The area surrounding a nesting site/colony that is fenced off should be as large as possible to reduce disturbance from the public. This should be a minimum distance of 10-50+ m away from the edge of the colony, providing a buffer for the nesting birds against disturbance with between 60-100 m preferred. The flight-initiation distance (the distance at which a bird leaves the nest due to a perceived threat) can be used as a guide for individual colonies to determine the minimum distance from the nearest nest to the fence boundary to minimise disturbance from people walking past.

- Temporary signs should always be installed when erecting a temporary fence to educate the public about why the area is currently off-limits.

- When logistical constraints of the location limit the area that can be fenced, the largest practical area should be fenced.

- At known, regular breeding locations, temporary fences can be installed prior to the breeding birds arriving to minimise disturbance once site prospecting and egg-lying commence (Reside et al., 1989; Schipper & Mitchell, 1999). If required, the fence boundary can be increased if the colony falls outside of the fence.

- Posts should be placed between 4-10 m apart.

- Ensure that the fencing material cannot flap in the wind (including any accompanying signs). This movement can cause site abandonment.

- Permanent fences, while erected at some sites around Australia, are not advisable due to the variable selection of nesting sites between breeding seasons (Willig, 1981; Smith, 1990) as well as the degree of sand movement that can occur meaning infrastructure lifespan can be limited.

- Anti-perching wire devices can be fitted to fence posts if required to minimise the occurrence of avian predation.

Predator Control

The ground-nesting behaviours of terns leaves them extremely vulnerable to both egg and chick predation. Predation levels from both introduced mammalian and native avian species have increased over time associated with increasing human use of coastal sites and growing predator populations. Red foxes (*Vulpes vulpes*), Black Rats (*Rattus rattus*) and avian species such as gulls, ravens and raptors cause significant losses of eggs and chicks at tern colonies and can cause the complete failure of colonies (Higgins & Davies, 1996; Keating & Jarman, 2004; Bishop et al., 2009). For example, Australian Ravens (*Corvus coronoides*) predated 37 Little Tern eggs on Towra Spit Island during one season (Priddel & Ross, 1996). The presence of predators can also displace nesting colonies, and birds can move to sub-optimal breeding habitat including moving from islands to the mainland where they can be subject to increased human disturbance and mainland predators (Kress, 1983). In Victoria, the Fairy Tern colony on Mud Island declined when the Silver Gull (*Chroicocephalus novaehollandiae*) population exploded on the island and the Fairy Terns subsequently began to nest on the mainland (Lane, 1981).

As a single predator can have a considerable impact on a nesting colony, including complete failure and abandonment, attempting to control feral animals when they are first identified is critical to colony success (C. Greenwell, pers. comm.). A number of control methods can be implemented at nesting sites, dependent on the predator, timing and location of the site to reduce predation risk to the colony.

Implementation

The threat from predators at a nesting site can be assessed through direct observation (including remote camera) or by the presence of tracks in the sand. Threat assessments, including the presence of predators, should always be conducted when performing a monitoring survey of a colony. Repeated visits to a nesting site at different times of the day across multiple days should occur to help maximise the probability that predators will be detected if they are present. If there are signs of colony failure, it is important to assess the nesting area looking for prints around nests and remains of egg shells to attempt to determine if and what predator was responsible for failure. This can provide partial evidence of colony failure, although there could be scenarios where predation of eggs occurs after another threat such as abandonment or disturbance. Gathering this type of evidence can aid in reducing further losses to the colony through the implementation of appropriate predator control methods (Baker-Gabb & Manning, 2011).

The main predators that are controlled around small tern nesting colonies are red foxes, feral cats, rats and avian species such as Silver Gulls and ravens. Common predator control methods implemented include baiting, trapping and shooting, although this varies dependent on whether the predator is introduced or native. Any implemented control method needs to comply with strict regulations.

Foxes:

Foxes are a key predator to nesting Fairy and Little Terns. As resources are generally limited, fox control should primarily be focused around core nesting areas. Foxes can be quite resilient to conventional control methods and reinvasion of areas after control measures have been conducted can be rapid.

It is generally recommended to use a mixture of fox control options to effectively target the behavioural variation that occurs in fox populations (i.e. some individuals are wary of baits while others are trap shy). These include baiting, shooting, trapping and den destruction (Smith, 1990). Control programs should be carried out in early spring to coincide with the peak fox breeding season to help achieve long-term population reductions and reduce the reinvasion potential. Targeting the breeding season results in the removal of parents and their offspring (Urquhart & Teoh, 2001). A follow up control program targeting young dispersing foxes can also be implemented in late summer (February-March) if resources are available.

Baiting is the most commonly used control option for foxes in Australia. This generally consists of initially free baiting an area (use of non-toxic baits) to attract foxes to the bait station before baiting with toxic baits such as 1080 (Keating & Jarman, 2004; Waldegrave-Knight et al., 1997; D. Rogers, pers. comm.). Where possible, bait stations are placed at main access points to colony areas (Keating & Jarman, 2004). Several factors will determine the effectiveness of a baiting program including the timing and frequency of baiting and the scale at which the baiting occurs over (Keating & Jarman, 2004). Large-scale, continuous baiting programs which begin prior to the breeding season and continue throughout will be more effective than smaller, less-frequent

programs (Keating & Jarman, 2004; Bishop et al., 2009). However, when resources are limited, baiting should be targeted to either prior to and/or during the Fairy and Little Tern breeding season (Keating & Jarman, 2004).

The use of cage or soft-jaw traps is another widely used technique to control foxes in coastal environments (Maguire, 2008). Scent lures or food are often used to attract foxes to the traps. However, these will be ineffective in areas where there are unleashed dogs as they will interfere with the scent (Maguire, 2008). A highly trained trapper is required when using scent lures (Maguire, 2008).

Another more recent control method is the installation of a 'Felixer' grooming trap which uses rangefinder sensors to distinguish target cats and foxes from non-target wildlife and humans, and sprays targets with a measured dose of toxic 1080 gel. A unit was successfully trialled to protect breeding Fairy Tern colonies on an island in a peri urban environment, 20 km from the Adelaide CBD and could be considered a viable option for inclusion as part of other integrated fox control programs (K. Bartley, pers. comm.). Once installed, they are a low maintenance option but distance restrictions do apply in relation to their placement and the number of Felixer's required would vary depending on project aims (K. Bartley, pers. comm.). Further information and support can be found at https://thylation.com/.

Shooting has generally only been implemented to complement baiting programs and to target bait wary or problematic individuals (Keating & Jarman, 2004; Dunn & Jorgensen, 2007). This can only be carried out by a qualified professional shooter and be well-advertised to the community prior to the shooting being carried out to avoid public access to the area on the night. Shooting is generally avoided in highly populated areas.

Dens are generally fumigated and destroyed during the middle to end of the fox breeding season. The use of den detection dogs is becoming more common for improving efficiencies around locating active dens.

Implementation of fox control programs will be influenced by the proximity to residential areas as well as the number of people predicted to access the tern nesting area (Jarman, 2006; DECC, 2008). Baiting and/or trapping programs will not be able to be implemented in highly populated areas or generally within 500 m of a settlement (Keating & Jarman, 2004). Instead, other options such as den destruction, cage trapping and/or electric fences around nests should be considered (Keating & Jarman, 2004).

Best-practice guidelines for fox control are available in the Threat Abatement Plan for Australia: https://www.dcceew.gov.au/environment/biodiversity/threatened/publications/tap/predation-european-red-fox.

Avian species:

Native avian species including gulls, ravens and raptors are key predators to nesting Fairy and Little Terns, having the ability to cause complete colony failure. In some instances, avian control is required to minimise the frequency of nest depredation through methods including shooting, poisoning, egg destruction or relocation.

Culling involves the targeted shooting of problematic individuals (those that continuously remove eggs and chicks) observed within a colony area (Reside et al., 1994; Schipper & Mitchell, 1999). Shooting individuals

has had mixed results around the country. At one location in NSW, the shooting of problematic Silver Gulls yielded amazing results where the affected Little Tern colony began to thrive (Jarman, 2006) and has been effective in reducing the depredation of eggs by ravens (Ross & Jarman, 2001). Conversely, in Victoria, shooting gulls had no impact on the predation of a Little Tern colony (Murray & Reside, 1995). Avian predators are also native species protected by legislation thus special permissions will be required to shoot these species.

Poisoning is commonly used overseas to control avian predators such as corvids by injecting boiled eggs or meats with 3-chloro-4-methylbenzenamine HCL. Once consumed, this poison will cause death within four days due to the depression of the central nervous system or kidney failure (Liebezeit & George, 2002). In Australia, populations of Silver Gulls have been controlled using the central nervous system depressant alpha chloralose (Skira & Wapstra, 1990; Baxter, 2003).

The impacts of gulls on nesting Fairy and Little Terns can be reduced by destroying their eggs/nests through removing the eggs from nests or pricking or oiling the eggs to prevent hatching. Removal or pricking of eggs is likely to be ineffective as gulls can replace a lost clutch within 12 days and can lay multiple replacement clutches (Higgins & Davies, 1996). Oiling eggs can reduce the hatching success of gulls to zero as adults will continue to incubate the unviable eggs (Christens et al., 1995; Martin et al., 2007; Harrison, 2010). The outcome of this technique for protecting breeding terns is considered a long-term management strategy for reducing the size of the avian predator population as will not likely have an immediate impact on reducing pressure on the colony in a given season.

An alternative method to lethal control is the live-trapping and relocation of problematic birds away from nesting sites (Smith, 1990).

Decision-making trigger

Predator control is generally implemented at a nesting site when there is evidence of predators present in the area that pose a high threat to the success of the colony/nesting outcomes. At known, regular nesting sites this is often implemented prior to the breeding season starting, before the birds arrive at the site. During the breeding season, predator control is generally implemented if there is evidence that predators are negatively impacting colony success and control methods are available to be implemented (Reside et al., 1989; Waldegrave-Knight et al., 1997). Note the decision to control an introduced predator is as simple as understanding the threat posed and acting, however when it comes to native predators, the decision becomes more complex. The type of native predator, consideration of whether that native predator population has increased due to human modifications to the landscape and thus likelihood that predation has been enhanced beyond levels the birds would have evolved with, and the impact control of that predator will have on its population need to be considered. Alternatives for some native predators may be required in place of lethal control, for example repellents or exclusion techniques.

Timing and suggested frequency

Regular breeding sites should be inspected for evidence of predators annually in winter/spring prior to the expected arrival of breeding birds to determine the necessity of predator control programs (Smith, 1990; Owen, 1991).

If predators such as foxes are detected and they are likely to cause nest failures, predator control programs should commence before the birds arrive at the site to reduce predator numbers prior to nesting beginning (Smith, 1990; Owen, 1991; Reside et al., 1994; Keating & Jarman, 2004). This will also avoid control programs running during peak visitor numbers to sites over summer. Sites where baiting is conducted in winter/early spring tend to have lower frequencies of fox depredation (Keating & Jarman, 2003; 2004). The presence of predators (e.g. direct observations, tracks, scat) should be continually monitored once a colony has established at a site to determine if a control program or additional implementation of measures is required during the breeding season to reduce the risk of predation to the active colony (Reside et al., 1989; Reside et al., 1994; Waldegrave-Knight et al., 1997; Keating & Jarman, 2004).

Timing of school and public holidays, as well as public events such as festivals, will also impact the timing that control measures are able to be implemented (K. O'Brien, pers. comm.).

Advantages

- The severity of predation on nesting colonies is reduced when effective management strategies are implemented at a site through the temporary reduction in predator numbers in the vicinity of the nesting area which can result in increased breeding success (C. Greenwell, pers. comm.; K. O'Brien, pers. comm.).
- Ability to deal with problematic individual animals (K. O'Brien, pers. comm.).
- Use of traps or shooting indicates exact number of predators captured/controlled.
- It may take new individuals (e.g. foxes) more time to learn about the presence of nests (K. O'Brien, pers. comm.).
- Demonstrates to the community/volunteers that active management and protection measures are being implemented to protect vulnerable nesting colonies (K. O'Brien, pers. comm.).

Disadvantages

- Control methods can be very costly and time consuming to implement (G. Barrett, pers. comm.; K. O'Brien, pers. comm.).
- Predator control options may be very limited or may not even be able to be implemented at sites in close proximity to residential areas (Jarman, 2006; DECC, 2008).
- Limited options may be available for native predators and acquiring approvals can be challenging.
- Improved knowledge to guide decision-making criteria still need to be developed to appropriately inform native predator control.
- Predators can still cause colony failure despite implemented predator control programs (D. Rogers, pers. comm.).

- Potential for baits to unintentionally poison domestic off-leash dogs.
- Bait stations are subject to flooding or being taken by ravens (Weston & Morrow, 2000).
- Traps need to be checked daily requiring intense resource allocation. This will limit the extent of the area that can be trapped to the number of traps that can be checked daily (Maguire, 2008).
- School holidays/public events can limit the timing when control methods can be employed (K. O'Brien, pers. comm.).
- May need to negotiate access to private property to implement effective control measures (K. O'Brien, pers. comm.).
- Extremely difficult to quantify the effectiveness of implemented predator control programs at individual sites/colonies and to accurately compare their efficacy across sites, especially when non-retrievable baits are used (R. Andrews, pers. comm.).
- Animal welfare issues can surround lethal predator control methods, as well as having negative public perceptions (e.g. negative public perception surrounding the use of 1080 baits).

Case studies

Western Australia:

Wildlife cameras and CCTV systems have been implemented across several sites during the Fairy Tern breeding season to monitor for the presence of predators in conjunction with volunteer monitoring of sites (C. Greenwell, pers. comm.). This has resulted in the targeted trapping and/or baiting of feral cats and foxes at several sites by local councils which has in some instances prevented the complete failure of nesting colonies (C. Greenwell, pers. comm.). Rat baiting in sea walls has also occurred across several sites (C. Greenwell, pers. comm.; G. Barrett, pers. comm.).

South Australia:

In the Coorong, extensive fox baiting programs (baits every 300 m for up to 30 km from priority nesting sites, monitored every 2-3 days and replaced accordingly) have been undertaken by the SA National Parks and Wildlife Department, with a 35-50% uptake (Baker-Gabb & Manning, 2011; DENR, 2011). An intensive aerial 1080 baiting program is also implemented annually around November on the Younghusband Peninsula in an effort to reduce fox numbers in the Coorong National Park to help protect shorebirds including nesting Fairy Terns and if required, can also occur at specific sites once a colony has been detected (D. Rogers, pers. comm.; K. Bartley, pers. comm.; R. Andrews, pers. comm.). Despite these baiting programs, colonies can still fail due to the presence of a single individual fox (DENR, 2011).

As part of the planned management of Bird Island, a program aimed at reducing the population density of rats, thus level of rat predation on Fairy Terns, occurred between 2014 and 2016 and was later replaced by an intensive rat control program in Nov-Dec 2017 consisting of 142 bait stations across the island (Johnston,

2018). The program had no measurable effect on rat activity or the breeding activity of six species of birds on the island (Johnston, 2018). It is unlikely that long-term removal of rats can be achieved on Bird Island due to the ability of rats to re-invade islands from within 1km of a mainland source population (Johnston, 2018).

Victoria:

During the 1990s, fox and feral dog control programs at known Little Tern nesting sites typically commenced in September in East Gippsland. These generally consisted of a week of free feeds, followed by baits if the free feeds were taken (Reside et al., 1989; Schipper & Mitchell, 1999). Numerous buried bait stations were used at each site and baits were checked on a weekly basis (Murray & Reside, 1995; Schipper & Mitchell, 1999). These baits were lifted in October prior to the breeding birds arriving on site (Reside et al., 1989; Schipper & Mitchell, 1999).

Active Silver Gull control has been implemented in East Gippsland at colonies where nearly all chicks were predated by Silver Gulls (Murray & Reside, 1995). Numerous individuals were shot while the colony had chicks. This seemingly made the remaining Silver Gulls wary and consequently, they left the colony area. However, more gulls arrived at the nesting site over the following weeks. Shooting of Silver Gulls continued but predation of the Little Tern colony also continued. It was concluded that shooting a number of gulls was pointless as it did not seem to prevent predation by the remaining gulls (Murray & Reside, 1995).

New South Wales:

Multi-faceted fox control programs including a combination of trapping, baiting, shooting and den destruction has contributed significantly to reducing the rate of fox predation at Little Tern colonies at most monitored sites in NSW (Keating & Jarman, 2004). Control methods have been either implemented by NPWS staff and trained wardens or contracted out to independent contractors. Baiting programs are the primary fox control method used and begin in August prior to the Little Tern breeding season commencing and continue into the breeding season based on the presence of foxes at each location. Cage traps, soft jaw traps and den destruction methods are used instead of a baiting program at nesting sites close to residential areas or when baiting programs are ineffective (Keating & Jarman, 2004). Shooting is only used to augment baiting and occurs when fox prints are sighted near active colonies or when individuals are observed on the monitoring cameras (Keating & Jarman, 2004; K. O'Brien, pers. comm.).

Baiting programs targeting Black Rats have also been implemented at various Little Tern nesting sites around NSW where rats are perceived to be a predation risk to nests (e.g. Bishop et al., 2009). For example, Bromakil (a toxic bait) has been used by field staff in December on Towra Spit Island on two occasions to help manage the rat populations here (Bishop et al., 2009).

Recommendations

- Fox control methods such as poisoning should occur before the birds arrive at a site to breed, ideally in September/October coinciding with peak fox breeding times (Reside et al., 1989).

- A range of techniques should be engaged where affordable to maximise success.

- Additional support to nesting colonies in ways that allow for their persistence even with the risk of predation being present should be considered e.g. appropriate hydrology regimes to ensure isolated island colonies remain inaccessible to terrestrial mammalian predators such as foxes (D. Rogers, pers. comm.).

- Monitoring of threats at the site should occur during the breeding period and if a problem predator is detected, an emergency control response should be implemented. Working on a response plan ahead of the breeding event to ensure agreement and approvals are in place, and roles defined, could ensure that a rapid response can occur at the site.

- Research investigations to inform native predator control options and decision-making triggers should be undertaken.

Nest Cages

Nests of Fairy and Little Terns are extremely vulnerable to predation from both introduced mammalian (e.g. foxes, dogs, cats) and native avian (e.g. gulls, ravens, raptors) species. The impacts of predation are often more severe in smaller colonies due to the absence of a successful group defence mechanism (adults will mob the perceived threat until it leaves the colony area). Therefore, a single predator can cause complete colony failure when only a small number of nests are present.

Predator exclusion cages (known as nest cages) have been used at various Little Tern nesting sites in an attempt to reduce predation rates and increase hatching success (Keating & Jarman, 2004). While the use of similar nest cages have in some instances been associated with an increase in the hatching success of other shorebirds (e.g. Melvin et al., 1992; Dann & Baird, 1997), there is also evidence that the use of cages can cause an increase in adult and chick mortality rates, or lead to nest abandonment, despite the improved hatching success (France, 2006, 2007; Dunn & Jorgensen, 2008; Maguire, 2008; M. Weston, pers. comm.).

Implementation

Wire nest cages can be used around tern nests to prevent egg predation when other protective measures such as electric fences have been ineffective (Keating & Jarman, 2004). This is achieved by placing a circular cage approximately 1 m in diameter around individual nests with a mesh size of 100 mm x 100 mm x 100 mm (Keating & Jarman, 2004). These dimensions enable adults to walk in to the nest from all sides as well as fly-off the nest while preventing access to predators including raptors (Keating & Jarman, 2004).

Decision-making trigger

Once eggs have been laid, nests are assessed once mammalian or avian (raptor) predators are detected around the nesting area to determine risk of predation. Nest cages are installed if they are thought that they will reduce predation risk.

Timing and suggested frequency

Installing nest cages around individual nests would occur during the breeding season in response to the potential threat of predation (eggs have already been laid and birds are incubating). Monitoring the risk of predation should occur throughout the breeding season at all known nesting sites.

The need for nest cages around nests at sites should be assessed annually and in response to the current threat profile at the site.

Advantages

- Effective at excluding mammalian predators especially if electric fences have failed (Keating and Jarman, 2004; Dunn & Jorgensen, 2007; 2008).
- Can be used when predator control programs can't be implemented at a site (e.g. due to close proximity of residential areas) to reduce predation risk (Jarman, 2006).
- Can offer additional protection to nests from crushing by beach users (Dunn & Jorgensen, 2008).

Disadvantages

- Little Terns have been documented abandoning caged nests in some instances e.g. 26% of eggs from caged nests were abandoned at one site in one season (Keating and Jarman, 2004). There appears to be higher abandonment rates when caging one-egg nests (Keating and Jarman, 2004).
- Can increase avian predation as the cages can act as a visual cue (Murphy et al., 2003; Pauliny et al., 2008).
- Can attract unwanted attention from members of the public.
- Are only effective at the egg stage, as once chicks are mobile, they will no longer be offered protection.
- Cages in species such as shorebirds have been associated with predator ambush attacks (by foxes and ravens) and adult deaths, as well as increased predator attention which may increase vulnerability of chicks to predators. Cages can also reduce the speed of escape of the incubating adult from predators (M. Weston, pers. comm.).

Case studies

Nest cages are used at several sites throughout New South Wales in an effort to alleviate the impacts of Little Tern egg predation by native avian predators particularly by Swamp Harriers (*Circus approximans*) and Gull-billed Terns (*Sterna nilotica*) (Keating & Jarman, 2004). Circular cages have been designed approximately 1 m in diameter to allow Little Terns to walk in from all sides (100 mm x 100 mm x 100 mm mesh size) and fly-off the nest (the exit hole is large enough to enable the adult tern to fly through but small enough to exclude raptors from entering (Keating & Jarman, 2004). Mixed success has been reported including up to 26% of single egg nests being abandoned at one site while nest cages were effective at preventing predation by Swamp Harriers at another (Keating & Jarman, 2004).

Examples of nest cages installed around Little Tern nests in NSW (photos: A. Jorgensen (left) and NPWS (right) sourced from Dunn & Jorgensen, 2007; 2008).

Recommendations

- Only use nest cages when other techniques for targeting and controlling predators are not available or effective.
- Only utilise nest cages on nests with complete clutches (i.e. 2-3 eggs are present) to minimise risk of abandonment at single egg nests (Keating & Jarman, 2004).
- Include an external skirt of mesh footing around the nest cages to prevent mammalian predators from tunnelling underneath (Keating & Jarman, 2004).
- Ensure dimension of mesh allows for easy access by adult Fairy and Little Terns for walking in and out of the cage.
- Couple use of cages with active and targeted predator control measures to provide increased survival for chicks. The outcome of a nesting attempt from egg to fledging must be considered.
- Monitor cages to assess predator attention and enhanced risk of predation for adults and chicks. If adult deaths occur, or if predator use of area increases, cease use of cages.

Chick Shelter

The preferred nesting sites of Fairy and Little Terns can sometimes lack natural vegetative cover which can decrease the chances of chick survival. This is because mobile chicks require shelter for shade as well as to hide from predators and disturbance events such as beach users once they leave the nest (Baker-Gabb & Manning, 2011). Prior to becoming mobile, small chicks within a couple days old are often brooded continuously by a parent, although both parents can leave chicks unattended for short periods of time to go fishing particularly if there are two or three chicks in the nest (C. Greenwell, pers. comm.). Parents often do not leave chicks unattended when the sun is directly overhead or during the hottest parts of the day (C. Greenwell, pers. comm.). Once mobile, chicks are known to move up to 150 m from their nest site to seek shelter, with native vegetation often being used as crèches (Smith, 1990; Baker-Gabb & Manning, 2011). In

NSW, additional protection for chicks, such as the provision of branches or chick shelters, are provided at 25% of known Little Tern nesting sites (Keating & Jarman, 2004).

Providing artificial shelter, or boosting the natural cover at nesting sites, for chicks to use as shelter from extreme weather conditions, predators or as cover to hide under when disturbed have widely been used to improve breeding success of terns around the globe. For example, in Massachusetts, chick shelters decreased avian predation in a Least Tern (*Sternula antillarum*) colony (Jenkins-Jay, 1982), while the use of A-frame chick shelters reduced gull predation of Common Terns (*Sterna hirundo*) to zero (Burness & Morris, 1992).

Implementation

Chick shelters are a simple technique that can be utilised at nesting sites with inadequate natural cover. There are two types of chick shelters that can be used at Fairy and Little Tern nesting sites, artificial or natural cover:

Artificial cover

- **Purpose:** to provide protection to chicks from predation, disturbance events and adverse weather conditions within the general breeding colony area.

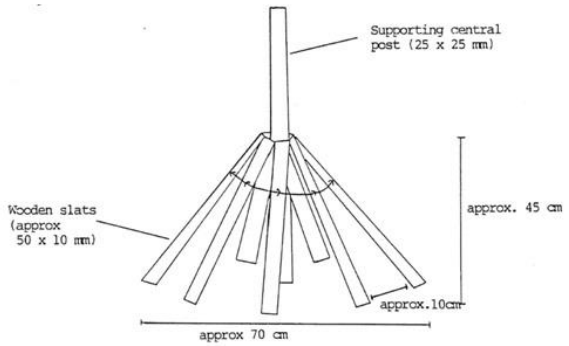
- **Quantity:** dependent on the colony size and density, resources available and the site characteristics (size and availability of natural cover). Ideally begin with trialling a smaller number first within a colony (e.g. installing 10 shelters in a colony with 40 breeding pairs).

- **Placement:** scattered throughout the colony area ideally in open areas which have few other options for cover available in close proximity to nests (Keating & Jarman, 2004; C. Greenwell, pers. comm.). In areas with no vegetation, where possible, one shelter should be placed near each nest but no closer than 3 m (Smith, 1990). Chick shelters can also be placed outside of fenced areas to provide extra protection for chicks (NPWS, 2019).

  When putting out chick shelters at a site, keep in mind that adults and chicks will tend to take up residence at a particular shelter and will initially defend this against other birds (adults will aggressively defend their perceived site from other terns while their chicks are quite small).

- **Materials:** Several options exist for constructing chick shelters including wooden teepees (10 cm apart at the base to enable easy access for the chicks, see below diagram), wooden A-frames (construction and dimensions found on pages 104-107 of Maguire, 2008), pot plants half buried in the sand, and broken ceramic/terracotta/PVC piping (Reside et al., 1989; 1994; Smith, 1990; Waldegrave-Knight et al, 1997; Keating & Jarman, 2004; Brooks et al., 2011; NPWS, 2019; K. O'Brien, pers. comm.). Thermal benefits of the differing types of shelters should be tested before use as differing designs and materials differ in their insulative properties, in particular their ability to remain cool in hot weather (Maguire et al., 2011).

Wooden teepees:



Suggested design for a wooden tee-pee chick shelter for Fairy or Little Terns (sourced from Reside et al., 1989).

Half-buried pot plants:

Little Tern chicks sheltering in a half-buried pot plant shelter (Photo: J. Dunn; sourced from NPWS, 2019).

Natural cover

- **Purpose:** to provide additional natural protection to chicks from predation, disturbance events and adverse weather conditions within the general nesting area.

- **Quantity:** dependent on the colony size and density, resources available and the site characteristics (size and availability of natural cover already present within the colony area). Ideally begin with adding a smaller amount first within a colony.

- **Placement:** scattered throughout the colony area ideally in open areas which have few other options for cover available and in close proximity to nests (Keating & Jarman, 2004; C. Greenwell, pers. comm.). In areas with no vegetation, where possible, vegetation should be placed near each nest but no closer than 3 m (Smith, 1990). Cover can also be placed outside of fenced areas to provide extra protection for chicks (NPWS, 2019).

- **Materials:** Several options exist for providing natural shelter for chicks within the colony area. These include the use of driftwood/branches, beach-washed debris, and kelp (the use of kelp however warrants further investigation to determine if avian predators, such as ravens which like to forage around kelp, are attracted to these areas) (Reside et al., 1989; 1994; Keating & Jarman, 2004; Sullivan, 2019; C. Greenwell, pers. comm.). These materials should be partly buried in the sand to prevent them from blowing away and where possible any foliage should stick out from the sand like an umbrella (Waldegrave-Knight et al, 1997; Schipper & Mitchell, 1999).

When placing chick protection within an active nesting colony, it is important to keep an eye out for predators and installation should only proceed in the absence of predators (Reside et al., 1989). Care must be taken to avoid standing on any eggs or chicks.

When installing artificial shelters at a site, it is important to inform the community of their presence and their purpose through a media story and/or signs. This can be an opportunity to remind the public about the presence of vulnerable nesting birds as well as any local restrictions surrounding the nesting area.

Native vegetation can also be planted at nesting sites which are used annually and which are devoid of natural cover to provide shelter for chicks. This can include planting small areas of Sea Rocket, Spinifex Grass, Coastal Fireweed and Saltbush (Reside et al., 1994; Waldegrave-Knight et al, 1997). However, care must be taken that this vegetation doesn't become overgrown causing terns to abandon the site as a nesting location.

Decision-making trigger

The provision of chick cover is only required at nesting sites where natural vegetation cover is lacking or completely absent to provide shade on hot days and protection from predators and disturbance events (Reside et al., 1989; 1994; Owen, 1991; Keating & Jarman, 2004; G. Barrett, pers. comm.; K. O'Brien, pers. comm.). Further cover may be required at a site if chicks are moving away from the central nesting area or fenced area to seek cover (Murray & Reside, 1995).

Timing and suggested frequency

If a nesting site is regularly used and is devoid of natural vegetation (e.g. dredge spoil sites), chick shelters/natural cover can be installed prior to the start of the breeding season commencing allowing the colony to establish around the shelters/cover (Reside et al., 1989; Owen, 1990; C. Greenwell, pers. comm.; G. Barrett, pers. comm.). Otherwise, chick shelters or cover should be added to the nesting area immediately prior to or after eggs hatch – this can help guide placement as nest locations can vary within a site between years (Smith, 1990; Waldegrave-Knight et al., 1997; DSE, 2003; C. Greenwell, pers. comm.).

The provision of chick shelters at nesting sites should occur based on regular monitoring of the site throughout the breeding season and should be assessed on an annual basis.

Advantages

- Provides chicks with shelter from predators and disturbance events (Murray & Reside, 1995; K. O'Brien, pers. comm.).
- Provides shade reducing the risk of thermal stress (Murray & Reside, 1995; C. Greenwell, pers. comm.). Some chick shelter designs have been shown to offer a thermal insulation benefit (Maguire et al., 2011).
- Provision of artificial or natural cover within fenced areas can encourage chicks to stay inside the fenced area thus decrease the chance of accidental crushing from humans (Smith, 1990; Murray & Reside, 1995; Keating & Jarman, 2004).
- Provision of artificial shelter can be easier than moving natural debris from far away (K. O'Brien, pers. comm.).
- Wooden A-frames are stackable and easy to transport and store (Maguire et al., 2011; C. Greenwell, pers. comm.).
- Chicks may prefer the cover of natural vegetation due to the added protection it offers especially from avian predators as well as the increased visibility (Murray & Reside, 1995; Waldegrave-Knight et al., 1997).

- Chicks of all ages use shelters from within a few days of hatching to post-fledgling (Reside et al., 1989; C. Greenwell, pers. comm.).

- Local school children and community groups have been involved in building chick shelters which has been great at promoting awareness and engaging a younger demographic (Sullivan, 2019; C. Greenwell, pers. comm.).

Disadvantages

- The associated costs with producing artificial chick shelters (G. Barrett, pers. comm.). Although often men's sheds, schools or councils can contribute materials and labour to making shelters.

- Creation and installation of artificial chick shelters can be labour-intensive (G. Barrett, pers. comm.; K. O'Brien, pers. comm.). Although note that often men's sheds, schools or councils can contribute labour to making and installing shelters.

- Can be difficult attaining the correct temperature and humidity within the shelter as different materials have different thermal properties (Maguire et al., 2011). For example, plastic piping can get too hot and may not have the same thermal benefits as wooden shelters.

- During strong winds, the natural cover items can be blown away and can get tangled in the surrounding fences (Murray & Reside, 1995).

- Artificial shelters often have lower visibility and protective capabilities than natural cover (Waldegrave-Knight et al, 1997).

- Artificial shelters can get buried or filled with sand over time and require at least monthly adjustments to ensure there is adequate height inside for the chicks to use (K. O'Brien, pers. comm.).

- Terracotta and plastic pipes can be associated with low visibility (e.g. of approaching threats) thus are least preferred by chicks (Waldegrave-Knight et al, 1997).

- Wooden teepees may not provide sufficient protection from predators and severe weather conditions (Waldegrave-Knight et al, 1997).

- Construction materials (e.g. marine plywood) may not be able to be sourced at short notice (K. O'Brien, pers. comm.).

- The use of artificial shelters may draw unwanted attention to the nesting colony from members of the public (Smith, 1990).

- If chicks spend long periods in the same shelter, there is potential for predators to learn to associate a shelter with a prey item. This can be partially mitigated by shelters being present pre-nesting so that they are present in the environment in the absence of chicks. This can also be monitored and if such an

association is detected (e.g. a raven travels from one shelter to the next predating or attempting to predate chicks), use of shelters should cease at the given site.

Case studies

Numerous artificial chick shelter designs have been implemented around nesting colonies of Fairy and Little Terns throughout Australia to provide shelter and protection from predators and disturbance events. Below are some examples:

Clockwise: A wooden A-frame shelter being used by chicks (C. Corker); Community-made A-frame shelters made from old pallets (C. Greenwell); A PVC pipe between stakes (C. Greenwell); A boardwalk panel cut off (C. Greenwell).

Recommendations

- Provide some form of artificial or natural chick shelter for chicks to utilise if nesting site lacks natural vegetation cover.
- Provide some form of artificial or natural chick shelter for chicks to utilise if nesting site lacks natural vegetation cover.
- Artificial chick shelters should ideally be constructed prior to entering the nesting colony and only require placement within the nesting area.
- No longer than 20 minutes should be spent within the nesting colony placing chick shelters.

- Chick shelters should only be installed within the nesting colony if there are no predators present in the area.
- Trial a smaller number of chick shelters in the first breeding season to determine use and efficiency.
- Chick shelters need to be partially buried to avoid the wind flipping them over.
- Materials of different artificial shelter designs should be thermally tested prior to use on real birds.

Vegetation Management

Small terns prefer to nest in open, unvegetated areas or early succession habitats comprised of bare sand or shell grit with less than 20% vegetation cover and will not nest in close proximity to dense or tall vegetation (Hill, 1990; Higgins & Davies, 1996; DECC, 2008; Bishop et al., 2009; Baker-Gabb & Manning, 2011; Andrews, 2020). This provides nesting birds with wide visibility enabling a clear view of approaching threats (Andrews, 2020). Nesting sites can gradually become unsuitable for nesting terns through the natural process of vegetative succession (the natural process where patches of bare sand are replaced by low vegetation including weed species) and encroachment. Alternatively, habitat degradation and modification of coastal areas through human use can accelerate the process resulting in once optimal tern breeding habitat becoming heavily vegetated through the introduction of weed species and inadequate vegetation management. Dense vegetation growth can make it difficult for adults to manoeuvre around the nesting area, make the eggs less camouflaged, obstruct the view of approaching predators, and can lead to windblown sand becoming trapped and building up at sites as well as covering shell grit nesting substrate (Hill, 1990; Smith, 1990; Owen, 1991).

Encroaching vegetation on nesting sites is a key threat impacting the successful nesting of small terns around the country and traditional nesting sites are abandoned if they become too overgrown (Morris, 1979; Smith, 1990; Smith & Smith, 2001; Baker-Gabb & Manning, 2011; Andrews, 2020). For example, encroaching vegetation at Tamboon Inlet in Victoria consisting primarily of Hairy Spinifex (*Spinifex hirsutus*) excluded Little Terns from nesting on the more elevated sites which were more protected from tidal inundation (Murray, 2000). Fairy Tern colonies have also abandoned nesting sites when vegetation has encroached into traditional nesting areas. Colonies have returned to these nesting sites to successfully breed after the removal of this vegetation and replacement of shell grit (Lane, 1981; Owen, 1991). Furthermore, the breeding success of a Little Tern colony vastly improved when the colony relocated to an estuarine dredge-spoil island that was clear of vegetation (Hill et al., 1988; Minton, 1988).

Encroaching vegetation can also threaten nesting tern colonies due to the presence of ants which can cause chick mortality (Priddel & Ross, 1996; Bishop et al., 2009). Previous reports have recommended the removal of encroaching vegetation, such as species of *Acacia* which ants feed on, to reduce the number of ants present within nesting sites (Bishop et al., 2009).

Removal of vegetation, both weeds and native species, is a simple management action that can be implemented at sites to maintain site use by breeding birds, especially at sites associated with previous breeding success, by increasing the substrate available for nesting.

Implementation

Coastal areas are sensitive environments in which to perform vegetation control due to a range of issues including non-target impact of herbicides, erosion potential, cultural heritage values and disturbance to beach-nesting birds. The key to successful vegetation management is to:

- Plan (areas, methods, timing, resources)
- Implement the vegetation control program
- Monitor re-growth
- Review methods in planning follow-up action

Integrated vegetation management, which employs a range of methods and strategies to control vegetation to protect sites, will have the greatest chance of long-term success. Vegetation removal should be selective, carefully controlled and results monitored (Willig, 1981; Schipper & Mitchell, 1999). Removal strategies include manual (hand pulling/digging out), mechanical and chemical options and use should be assessed on a site-by-site basis (Keating & Jarman, 2004). All vegetation manually removed from a site should be placed in a bag and disposed of appropriately off-site. If using herbicides, it is advisable to use ones with low toxicity and persistence, particularly in aquatic landscapes, and avoid contact with non-target plants (Smith, 1990).

The amount of vegetation cleared is generally variable among sites but usually all weed species are removed (C. Greenwell, pers. comm.). In some instances, native vegetation requires removal if it is encroaching on tern nesting habitat. For example, the local council planted Melaleuca and Eucalypts at Point Walter in Western Australia and these later required removal to ensure the site remained a viable breeding area for Fairy Terns, Red-capped Plovers and Pied Oystercatchers (C. Greenwell, pers. comm.). In these cases, permits may be required to remove native vegetation. It is also important to leave some vegetation throughout the nesting area for chick shelter. Ideally, this should be retained as small, scattered clumps (Smith, 1990; Keating & Jarman, 2004).

Decision-making trigger

Generally, vegetation cover of more than 10-20% of a nesting site is considered sub-optimal as small tern breeding habitat and will require removal (Hill, 1990; Smith, 1990; Baker-Gabb & Manning, 2011). Often, all weed species are removed from a nesting site regardless of coverage. Small clumps of native vegetation should be left throughout the nesting area to provide shelter for chicks (Smith, 1990; Keating & Jarman, 2004).

Timing and suggested frequency

Encroaching vegetation should be removed during the non-breeding season anywhere between June through to September prior to the expected arrival of breeding birds (Reside et al., 1989; Smith, 1990; Murray & Reside, 1995; Keating & Jarman, 2004; C. Greenwell, pers. comm.; D. Sullivan, pers. comm.; E. Woehler, pers. comm.). This allows the sand to settle and stabilise, as well as allows the surface substrate to begin eroding, prior to nesting commencing (Bishop et al., 2009).

If some weed removal is required during the breeding months, an assessment of the use of the site by beach-nesting birds must first be conducted. Any areas where birds are actively nesting should be avoided completely.

Vegetation removal from a site typically lasts for one season only. Annual vegetation management works are therefore considered essential in maintaining sites suitable for nesting Fairy and Little Terns. Weeding and removal of encroaching vegetation at known nesting sites will need to be assessed annually prior to the breeding season and works repeated in response to growth and environmental conditions (Reside et al., 1989; Murray & Reside, 1995).

Advantages

- Nesting habitat consists of more open substrate due to the presence of fewer weeds increasing the attractiveness of the site to breeding birds (C. Greenwell, pers. comm.; G. Barrett, pers. comm.).
- Vegetation removal and subsequent management of important nesting habitat which has become overgrown (and subsequently abandoned by breeding birds) can become viable nesting habitat again (Sullivan, 2020).
- Improves visibility for nesting birds and thus could assist with early predator detection and avoiding predator ambush.
- Provides more available nesting habitat and maximises the amount of suitable habitat available above the high tide mark (Bishop et al., 2009).

Disadvantages

- Is labour intensive to achieve optimal weed and vegetation control at nesting sites (Murray & Reside, 1995; G. Barrett, pers. comm.).
- Requires ongoing maintenance (generally annually) to clear vegetation from nesting sites.
- Removal of one weed can enable another weed species to flourish requiring additional control measures (C. Greenwell, pers. comm.).
- Can be costly to remove vegetation depending on the method and area requiring removal/control (G. Barrett, pers. comm.).
- Removal of native vegetation may require additional approvals.

Case studies

South Australia:

Aerial weed control is carried out annually in an effort to control the invasive African Boxthorn (*Lycium ferocissimum*) in the Coorong National Park which encroaches on important bird habitat (R. Andrews, pers. comm.). Additionally, a small number of plants are cleared manually in September.

On Bird Island, Outer Harbour an annual site plan is developed by land managers guided by the Biodiversity Action Plan for the site including vegetation management. Target species include Sea Wheat-grass (*Thinopyrum junceiforme*) as if left unmanaged, it will invade onto the dune face and on to higher ground amongst the Fairy Tern breeding areas. Follow up revegetation of native spinifex (*Spinifex hirsutus*) is planted to stabilise the sand and provide cover for chicks (K. Bartley, pers. comm.).

Victoria:

Weeds, including Sea Spurge (*Euphorbia paralias*), Broadleaf Plantain (*Plantago major*) and Scotch Thistle (*Onopordum acanthium*) are removed annually in August when possible on Rams Island which is an important Fairy Tern nesting site in Victoria (Willig, 1981; G. Lacey, pers. comm.). Small amounts of native vegetation near potential nest sites are also occasionally removed when they are in close proximity to the nesting site, but the majority is retained to provide shelter for chicks from predation (G. Lacey, pers. comm.). The devegetation of Rams Island in the past has been successful at enticing breeding Fairy Terns to recolonise their former nest sites here (as well as at the Spit in Werribee) (Willig, 1981).

L-R: The Fairy Tern nesting site on Rams Island prior to weeding and after weeding, 2017 (photos: S. Monks).

During the 1987/88 breeding season, the spreading of Marram Grass (*Ammophila arenaria*) and the prolific growth of single bushes of Sea Rocket (*Cakile maritime*) on the sandspit of Rigby Island was causing the Little Tern nesting site to become densely vegetated and areas of shell grit were being quickly buried by the establishing Sea Rocket (Reside et al., 1989; Owen, 1991). After the breeding birds left the site, the warden spent one week slashing the Marram Grass and hand pulling bushes which were heaped up and burnt to kill the fresh seed (Reside et al., 1989). The following season there was an increase in the distribution of Little Tern nests across the sandspit (Reside et al., 1989). Following the 1989/90 breeding season, further hand pulling of Sea Rocket was carried out and plants were again burnt (Owen, 1991).

Prior to the 1988/89 breeding season, work was carried out to reduce the spread of the Common Reed (*Phragmites australis*) and grass (*Festuca* sp.) which were invading the previously successful Little Tern colony site on the dredge spoil on Crescent Island (Reside et al., 1989). Work crews used rake hoes to dig up the plants and roots. However, this was only partially successful as both species re-colonised from rhizomous material that was left in the sand (Reside et al., 1989). The vegetation cover subsequently became extensive across the nesting site and no breeding occurred since (Owen, 1991). This example demonstrates the requirement for follow up treatment to maintain the site attractiveness to breeding terns.

A trial to measure the effectiveness of vegetation removal by hand and the response of breeding Little Terns to cleared areas was employed on Crescent Island during the 1994/95 breeding season (Murray & Reside, 1995). All vegetation, including roots, were completely removed from trial plots of 1.5 x 2 m along the western side of the dunes both inside and outside of protective electric fences (Murray & Reside, 1995). The plots remained clear of vegetation for three months. Little Terns did not nest on the cleared plots, but this was thought to be primarily due to the location of the plots which were based on the edge of the dunes (Murray & Reside, 1995). The trial clearing of invasive vegetation was primarily to demonstrate that the area could remain clear of vegetation for numerous weeks after removal (Murray & Reside, 1995).

After the 1996-98 drought, grass became dense in some areas and vegetation grew tall and bushy on Crescent Island (Schipper & Mitchell, 1999). Volunteers weeded the site and subsequent Little Tern colonies were primarily located within the areas where vegetation had been removed (Schipper & Mitchell, 1999).

New South Wales:

Spinifex, *Lomandra* and *Acacia* species have been removed from above the high tide mark on Towra Spit Island which is a significant nesting site for Little Terns to create areas of bare sand for nesting (DECC, 2008). Vegetation is maintained around the perimeter of the cleared nesting site to provide adequate shelter for chicks (DECC, 2008).

L-R: Towra Spit Island prior to vegetation removal; Towra Spit Island after vegetation removal creating more suitable nesting habitat for Little Terns (photos: A. Bianchi (left) and N. Izquierdo (right) sourced from DECC, 2008).

Recommendations

- Timing of weed and vegetation removal is important, completely avoiding the period when birds are actively prospecting and nesting.

- Planning, monitoring and repeated follow up visits are critical to effective weed and vegetation removal programs. Special effort to reduce future reinfestations should be undertaken.

- Further research should be conducted to better understand the specific habitat requirements of breeding terns, improving understanding of optimal density/coverage and heights of vegetation, as well as interacting habitat variables that influence site choice and breeding success at the site.

Substrate Replenishment

Nesting and roosting sites of beach-nesting birds are under continual threat of degradation and disturbance from increasing recreational pressures, coastal developments and resource competition (e.g. sand extraction). Furthermore, the topography of sand islands and beaches is dynamic, changing over time due to natural coastal processes which can cause sub-optimal nesting conditions and even cause habitat to disappear completely (Alluvium, 2020; Andrews, 2020; D. Sullivan, pers. comm.). This applies to small tern nesting sites with traditional sites increasingly being abandoned due to the breeding habitat becoming unsuitable (e.g. overgrown vegetation, steep dunes) or after multiple breeding failures due to repeated disturbance, predation and/or tidal inundation (Babcock & Booth, 2020). Fairy and Little Terns display site fidelity between breeding seasons, highlighting the need to effectively manage and maintain known nesting sites to ensure continued use of these sites and to enhance breeding success.

Habitat restoration is a key management action for the conservation of Fairy and Little Terns to ensure current breeding habitat is maintained in optimal conditions to maintain, and even enhance, breeding success (Andrews, 2020; Babcock & Booth, 2020). Restoring or modifying existing tern nesting habitat has widely been used to improve the breeding success of colonies around the world, with active intervention improving fledging success. For example, the availability and quality of the Little Tern nesting habitat at Langstone Harbour had declined over a period of time (Babcock & Booth, 2020). The harbour contained protected littoral mud and saltmarsh vegetation thus new habitat could not be created. Therefore, work was conducted to replenish the shingle caps on the existing islands within the preferred nesting areas. The existing areas of shingle were raised by 1-1.5 m and shingle was also extended to cover areas where shingle was previously unsuitable (Babcock & Booth, 2020). Crushed cockle shells were spread over the shingle to give the areas a naturalised feel and to further increase the attractiveness of the site to breeding terns. Electric fences were placed around the replenished area for the duration of the breeding season (Babcock & Booth, 2020). Following the habitat modification works, the Langstone Harbour colony had one of its most productive years with all of the recorded chicks fledging from the restored areas compared to only one fledging recorded in the area over the previous three breeding seasons (Babcock & Booth, 2020). In Australia, Little Tern nesting habitat has been enhanced through the deposition or renourishment of sand on low-lying areas of major breeding locations in New South Wales and Victoria (Keating & Jarman, 2004; Andrews, 2020; Alluvium, 2020). In Victoria, sand grit has been regularly added to numerous traditional Fairy Tern breeding sites to

improve breeding success and attract breeding birds back to these traditional sites (Schipper & Mitchell, 1999; G. Lacey, pers. comm.).

Implementation

Habitat modification projects first require knowledge of the ecological requirements of the target species (Babcock & Booth, 2020). Once these are understood, sub-optimal habitat conditions can be identified and a feasibility study and plan developed to rectify these (Babcock & Booth, 2020). Common habitat modification works include the addition of appropriate nesting substrate, including the addition of sand, shingle and/or shell grit, to replenish depleted levels at nesting sites or habitat renourishment where dredge spoil is used to restore and increase nesting habitat to its previous state (Andrews, 2020). Often dredge spoil renourishment occurs in conjunction with an existing local dredge operation to reduce costs. Prior to implementing habitat works, a range of technical site assessments should be conducted including feasibility, soil suitability and hydrology to ensure that ecological values of the area are maintained and restored appropriately (D. Sullivan, pers. comm.). It is likely that site-specific vegetation will need to be planted at renourished sites to provide some natural cover for chicks and to help stabilise the added sediment. Vegetation also helps to retain and stabilise the sand profile, increasing the longevity of the works (Alluvium, 2020). Careful consideration should be given when selecting which species to plant to avoid excessive regrowth and/or seed dispersal such as Knobby Club Rush (*Ficinia nodosa*). In doing so, the need for labour-intensive management activities such as vegetation control in the following years will be minimised (D. Sullivan, pers. comm.).

Renourishment works will benefit from the implementation of restrictions to minimise disturbance to the site (e.g. large herbivores such as deer, boat wash, recreational activities) to maximise the longevity of the works, as disturbance can enhance the rate of sand loss (Alluvium, 2020). Often other management activities will be required in conjunction with habitat modification works, such as long-term vegetation management and predator control (refer to the '*Vegetation Management*' and '*Predator Control*' sections for further details).

It is imperative that pre- and regular post-habitat assessments are conducted in relation to the implementation of habitat works to enable optimal conditions to be maintained at the site and to help inform the frequency and nature of future works (Alluvium, 2020). For example, the key and ongoing intervention required and implemented to support the Coorong Fairy Tern population is the maintenance of appropriate hydrology which results in adequate density of prey fish species close to preferred nesting islands and is achieved through the delivery of environmental water via the barrages (D. Rogers, pers. comm.).

Any habitat modification works will require the permission from the land manager as well as appropriate permits from all relevant statutory organisations.

Decision-making trigger

Habitat modification works are generally required when a previously successful nesting site has not been used by nesting terns for more than 2-3 consecutive years or at sites where nesting colonies have been tidally inundated over several consecutive breeding seasons. Annual habitat assessments of the site will help identify habitat condition and indicate sub-optimal conditions requiring attention (e.g. declining substrate availability).

Timing and suggested frequency

All habitat modification works should be conducted during the non-breeding season and be completed prior to the expected arrival of breeding birds.

Habitat assessments of nesting sites should be conducted annually to determine the state of specific habitat variables to determine if any management action is required to prevent the quality of the nesting habitat declining. Habitat renourishment is likely to be required every 2-4 years depending on local environmental conditions and the subsequent rate of decline to maintain the condition of the site (Alluvium, 2020). Once vegetation has become established at a nesting site, it will likely require management annually. It is unlikely that any habitat modification works implemented at a site will be a one-off measure.

Advantages

- Investment of resources into a site/s where successful breeding has previously occurred, with a high probability that breeding birds will return to the site once optimal habitat has been reinstated.
- Habitat renourishment is an effective tool for creating substantial areas of optimal nesting habitat for small terns (Alluvium, 2020).
- Can increase habitat for many species, including nesting terns, other beach-nesting bird species and roosting migratory species (D. Sullivan, pers. comm.).
- Restoring and maintaining previously used, natural breeding sites is generally cheaper and less labour intensive than creating alternative artificial habitat (Catry et al., 2004).

Disadvantages

- Time and labour intensive to implement.
- Is a huge logistical exercise e.g. movement of heavy machinery and equipment, planning, mobilising a large number of people, transfer of vegetation.
- Revegetation of sites at time of habitat renourishment can become overgrown if not managed appropriately and become a deterrent for small tern breeding in the future (Alluvium, 2020; D. Sullivan, pers. comm.). A long-term plan for the site needs to be considered.
- Over time, there is likely to be a progressive loss of optimal nesting habitat (e.g. loss of sand, changes to sand profile, increased vegetation) with routine nourishment likely required every 2-4 years to maintain the areas of habitat originally modified (Alluvium, 2020).
- Environmental (e.g. storm events) and disturbance events (e.g. herbivores, recreational activities including proximity of boats) can negatively impact the longevity of the renourishment works by contributing to the rate of sand loss (Alluvium, 2020).

- Requires continued monitoring (of nesting success/failure) and maintenance to retain optimal nesting habitat for small terns and understanding of when the renourishment of the site starts to lose its value as a nesting site (D. Sullivan, pers. comm.).

- Continued expenses associated with ongoing replenishment and modification of the breeding habitat to maintain optimal nesting conditions (Baker-Gabb & Manning, 2011).

- Works will require appropriate permits from the relevant statutory organisations which can be time consuming, requiring forward planning to ensure they are in place prior to the desired time period that works will be carried out.

Case studies

Victoria:

Rams Island:

In some years, shell grit from the nearby beach is added to the Fairy Tern nesting site on Rams Island in August to replenish the substrate available prior to the breeding season commencing (G. Lacey, pers. comm.). This occurs immediately after the area is cleared of vegetation (which usually occurs annually). The amount of shell grit available at Little Tern nesting sites in East Gippsland has been increased at various times over the last 30 years including the use of scallop shells purchased from a scallop processor (Schipper & Mitchell, 1999).

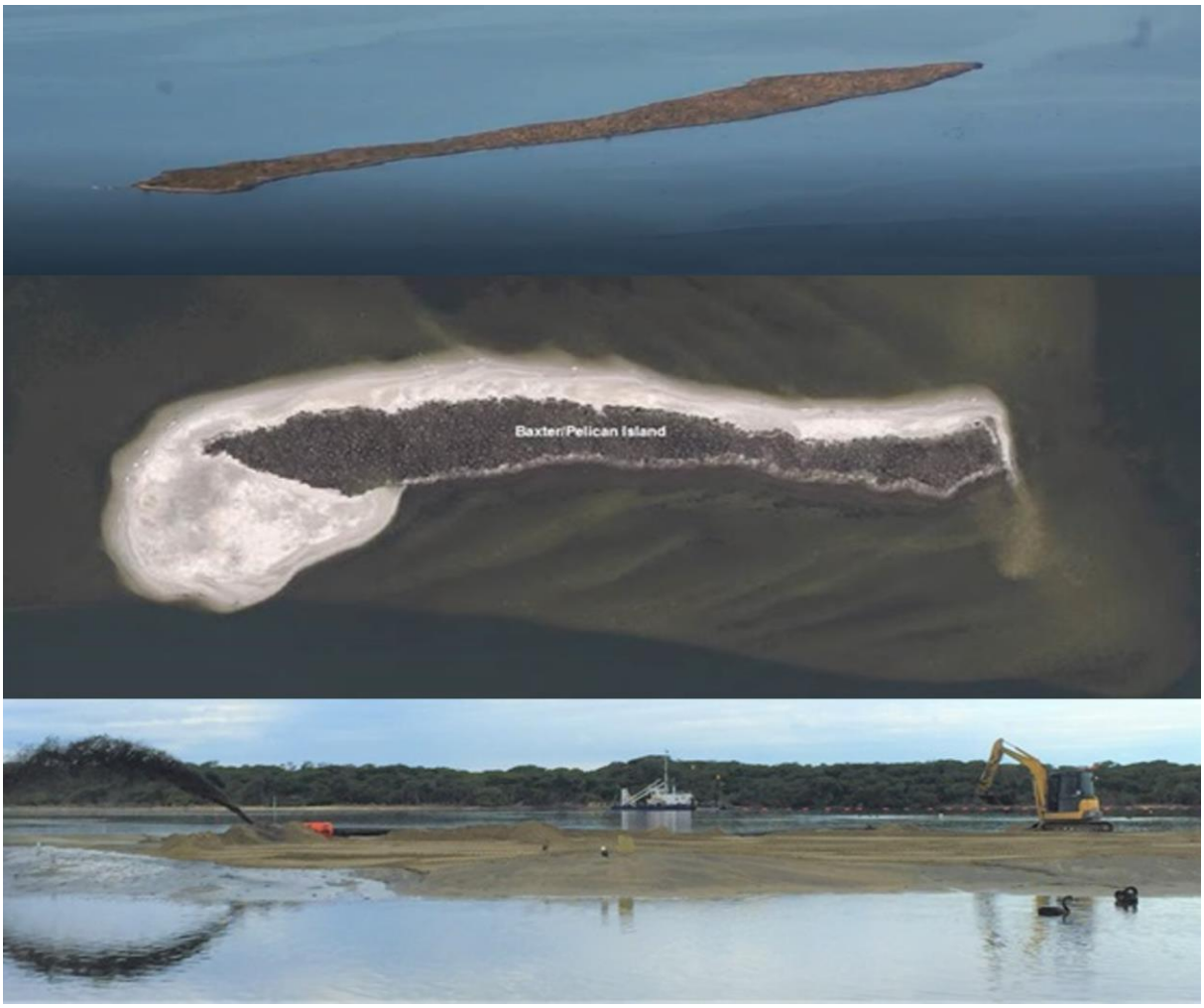
L-R: The Fairy Tern nesting site on Rams Island comprising of sea wrack prior to habitat modification works; addition of shell grit from the nearby beach to the traditional Fairy Tern nesting area on Rams Island (photos: A. Browne).

Gippsland Lakes:

Habitat restoration using sand renourishment has been implemented at various locations in the Gippsland Lakes between 2014 and 2017 through a partnership with Parks Victoria, DELWP and the Gippsland Ports (Sullivan, 2019; Alluvium, 2020; Andrews, 2020; Sullivan, 2020). The objective of the habitat works was to establish or maintain areas identified as vital nesting habitat for small terns (Alluvium, 2020). This was achieved by using sand dredged from the adjacent Steamer and Grange navigation channels.

Pelican Island:

Prior to renourishment, Pelican Island had a centre of established vegetation and a thin sand beach which had been eroding away, particularly on the north side of the island, and no suitable nesting tern habitat (Alluvium, 2020). In April 2016, 15,500 m3 of sediment was added to the island over an area of 33,500 m2 creating open beach with gentle slopes (Alluvium, 2020) and 5,000 indigenous seedlings were planted (D. Sullivan, pers. comm.). Fairy and Little Terns had breeding success at the site in the following breeding season, with the first records of Fairy Terns nesting on Pelican Island producing 51 fledglings and 47 in the following breeding season (D. Sullivan, pers. comm.). By 2017, the area of beach above the mean water level had increased (Alluvium, 2020). Planted vegetation had become well established and dense leading to the accretion of sand creating steep slopes and higher elevations around the vegetated areas (Alluvium, 2020). This vegetation also provided perches for avian predators (Alluvium, 2020; D. Sullivan, pers. comms). Due to the presence of the overgrown vegetation, tern nesting ceased on the island in 2020 (Alluvium, 2020). However, the birds have returned to the island each year since to scout for suitable nesting sites and have been regularly seen loafing on the water's edge (D. Sullivan, pers. comm.).



Top to bottom: Pelican Island prior to renourishment works showing central vegetation extending to the shoreline and no beach or sand habitat available for nesting birds; Pelican Island post nourishment works showing the extent of the habitat created for beach-nesting birds; the suction cutter dredge and 5-tonne excavator in action (photos: D. Sullivan).

Horries Spit:

Prior to renourishment, Horries Spit (which is connected to Crescent Island) was completely submerged (Alluvium, 2020). In July 2015, 13,000 m3 of sediment was added to the spit over an area of 10,050 m2, reconnecting the island and creating open beach with gentle slopes (Alluvium, 2020). In 2017, the area was fragmented and centred around the vegetation that had been planted (Alluvium, 2020). The sand was lower in most parts of the spit with some sediment building up on the northern side (Alluvium, 2020). By 2019, low growing vegetation, moderately interspersed with Knobby Club Rush (*Ficinia nodosa*) had become well established along the length of the spit and there was a slight increase in the slope however the beach had lost height overall (Alluvium, 2020). The nesting tern habitat had become very disconnected and dispersed along the length of the spit (Alluvium, 2020). However, both species of small terns established a small breeding colony along the spit in 2021/22 as well as in the 2022/23 season. Small fragments of shells were used to line individual nests scraped out amongst the low vegetation on the higher slope. Both species produced fledglings in 2021/22. Nests situated on the lower slopes and close to the water line were inundated during storm surges that occurred across both seasons. No chicks survived to fledgling age in 2022/23 (D. Sullivan, pers. comm.).

An excavator conducting the renourishment works on Horries Spit (photo supplied by: Gippsland Ports).

The North-west area on Horries Spit before (top) and after (bottom) renourishment (photos supplied by: Gippsland Ports).

Crescent Island:

Prior to renourishment, Crescent Island was a low-lying island with established vegetation and a wet sand spit which extended out to the east. In June 2015, 10,500 m3 of sediment was added to the island over an area of 15,200 m2 creating open beach with gentle slopes and no vegetation above the median water level (Alluvium, 2020). By 2017, optimal nesting habitat had decreased due to a decrease in the volume of sediment, high erosion caused by storm surge and boat wake (D. Sullivan, pers. comm.). By 2019, the size of optimal nesting habitat had further reduced and the vegetation had become quite established resulting in sub-optimal tern nesting habitat (Alluvium, 2020). In 2019/20 both small tern species nested at Crescent Island but just days after the first Fairy Tern eggs hatched, storm surges and boat wake eroded the beach up to the edge of the colony. The birds were not seen at the site in any of the following monitoring surveys (D. Sullivan, pers. comm.).

New South Wales:

Minor remediation works have previously been implemented at Botany Bay through the creation of levees via an excavator in an effort to increase the height of several islands (Ross & Jarman, 2001). Breeding Little Terns relocated to these areas, abandoning the low-lying, uncleared Towra Spit Island (Keating & Jarman, 2004). Following these results, volunteers and staff have re-distributed the sand on Towra Spit Island, as well as cleared vegetation, in an effort to increase the elevation of the nesting area, create levees to protect nests from high tides and to make the overall site more attractive to prospecting birds prior to their arrival (Bishop et al., 2009).

Recommendations

- Due to significant costs and the logistics of substrate modification projects, prioritisation of sites should occur across the landscape prior to investment.

- Sites historically used and of high value (e.g. demonstrated to have had high breeding success in the past) should be prioritised for restoring or enhancing habitat.

- A long-term management plan for a site where substrate renourishment will occur should be created that considers future vegetation control and management of disturbance and recreational impacts to ensure a holistic investment that maximises long-term breeding success.

Habitat Creation

A key threat faced by Fairy and Little Terns is the continual loss of nesting habitat due to coastal developments, vegetation growth, increasing sea levels, storm events, and increasing disturbance from recreational activities (Murray, 2000; Fujita et al., 2009; Babcock & Booth, 2020). The natural creation of new nesting habitat is also declining largely due to the constraint of natural coastal processes (Babcock & Booth, 2020). The combination of these processes has led to the abandonment of traditional sites with breeding terns resorting to nesting at sub-optimal locations (e.g. high levels of disturbance and predation, overgrown vegetation).

Terns, however, can readily adapt to artificially created habitats provided their nesting requirements are met (Andrews, 2020; Babcock & Booth, 2020). Habitat creation is thus becoming increasingly important in tern conservation due to the continued reduction in the quantity of natural breeding habitat available to nesting terns (Erwin et al., 2003; Babcock & Booth, 2020). The artificial creation of primarily islands as nesting locations for small terns has occurred globally including in Australia (NSW NPWS, 2003; Campbell & Christie, 2007; Golder et al., 2008; Andrews, 2020; Babcock & Booth, 2020). These artificial habitats (primarily constructed using dredge-spoil) can mimic their natural counterparts, providing optimal habitat which can support large and highly successful breeding colonies of terns when created under appropriate conditions (Reside, 1988; Waldergrave-Knight, 1997; Schipper & Mitchell, 1999; NSW NPWS, 2003; Guilfoyle et al., 2006; Golder et al., 2008). For example, colony size and breeding success of Little Terns in Finland was higher in artificial habitat (82%) compared to natural habitat (58%) (Pakanen et al., 2014). The artificial port habitat experienced less disturbance events due to being off-limits to the public and was above flood zones thus nests did not experience tidal inundation (Pakanen et al., 2014). Providing these alternative, safe nesting sites when natural habitat is lacking is important as provides nesting terns with a greater chance of breeding success (Murray, 2000).

While artificial nesting sites are highly valuable in tern conservation, they should not be considered the sole solution to the continued problem of ongoing habitat loss and degradation (Pakanen et al., 2014). Rather, they should be implemented as additional sites for the target species to buffer against the loss of natural habitat while management actions to restore and maintain natural habitat are formulated and implemented (Pakanen et al., 2014).

Implementation

Habitat creation projects first require knowledge of the ecological requirements of the target species and how they select nesting habitat to ensure the new sites are designed appropriately, having the correct habitat characteristics present (Ratcliffe et al., 2008; Brooks et al., 2011; Babcock & Booth, 2020). Dredge spoil, often from localised works to minimise costs, is the most common method used globally to create new nesting habitat for terns (Fraser, 2017). When planning potential tern nesting habitat creation projects, it is important to consider:

- Location: the historical and current spatial distribution of the target species should be well understood to ensure sites are created in regions where nesting birds are located and ideally in/close to areas where they have bred successfully before (Murray, 2000; Babcock & Booth, 2020). New sites should ideally be created in proximity to other currently used nesting sites, to ensure they fall into a wider colony network of nesting sites which can be used interchangeably, particularly when conditions such as prey availability is poor at one site (Murray, 2000; Fujita et al., 2009; Baker-Gabb & Manning, 2011; Brooks et al., 2011; Babcock & Booth, 2020). Close proximity to current nesting sites has been critical in successfully establishing new Fairy Tern breeding sites in New Zealand (Brooks et al., 2011). Furthermore, sites should ideally be located in areas associated with low threat levels, including disturbance by humans, with areas situated away from human settlements having lower impacts on nesting terns (DECC, 2008; Brooks et al., 2011).

- Future site resilience: impact of natural coastal processes on the site and the overall sustainability of the site in the future e.g. erosion, sediment accumulation (Babcock & Booth, 2020).

- Size: the created habitat needs to be of sufficient size to support a nesting colony (Baker-Gabb & Manning, 2011; Brooks et al., 2011). For example, sites need to be large enough to accommodate large colony sizes which helps in predator defence (Fujita et al., 2009). However, larger islands can be attractive to other species of terns and gulls, which can result in competitive exclusion of small terns and/or increased predation pressures (Ratcliffe et al., 2008; Babcock & Booth, 2020).

- Substrate: the appropriate substrate, both in texture and colour, such as shell grit, is required (Treadgold, 2000; Fujita et al., 2009; Baker-Gabb & Manning, 2011; Brooks et al., 2011). For example, predation rates of Little Tern eggs were lower in artificial habitat with crushed concrete as opposed to artificial habitat with brown sludgerites (brown granules 2-3 mm in diameter made from reclaimed sewage-ash) which is thought to be due to the paler colour of the crushed concrete providing more effective camouflage for the eggs (Fujita et al., 2009). Dredged material contains shell materials which provide a natural camouflage to Fairy and Little Tern eggs reducing the risk of predator detection.

- Elevation: the elevation of the site should be based on the height of high and king tides and water level fluctuations to eliminate or minimise tidal inundation of nests (Baker-Gabb & Manning, 2011; Brooks et al., 2011; Babcock & Booth, 2020).

- Topography: terns prefer an open aspect thus low, flat sandy islands/areas are often best (Baker-Gabb & Manning, 2011; Brooks et al., 2011; Babcock & Booth, 2020).

- Prevailing wind direction: the site should be protected from the prevailing wind direction to prevent erosion and lessen exposure to wind drive sand dunes (Brooks et al., 2011; Babcock & Booth, 2020).

- Shelter: in the absence of vegetation, chick shelters or natural debris should be placed throughout the newly created site to offer shelter to chicks from extreme temperatures and predation (refer to the '*Chick Shelter'* section for further details).

- Local availability of food within the species foraging range (~2-4 km for Fairy and Little Terns). If there is no locally available food source, then nesting habitat which is otherwise optimal will be unable to support a successful tern colony (Ratcliffe et al., 2008; Brooks et al., 2011; Babcock & Booth, 2020).

- Location in relation to use: sites located near popular fishing spots or holiday spots will experience higher levels of disturbance (Reside et al., 1989).

- Vegetation: often site-appropriate vegetation is planted at the time of habitat creation to help stabilise the sediment and to offer shelter for chicks. The amount and species of vegetation needs to be carefully considered.

- Risk of predation and how this will be controlled. If mammalian predation is likely to occur, anti-predator fencing should be incorporated into the site design (Babcock & Booth, 2020).

- Associated cost of initial and ongoing maintenance works and resources including ongoing labour, advocacy, vegetation management, replenishment of substrate, and where appropriate fencing, signage and wardening (Baker-Gabb & Manning, 2011; Brooks et al., 2011; Babcock & Booth, 2020).

- Level of human disturbance and how this will be minimised (Babcock & Booth, 2020).

- The required technical site assessments (e.g. hydrology, sediment suitability, feasibility) required prior to designing the artificial habitat to ensure the ecological values of the area are maintained (D. Sullivan, pers. comm.).

- Landowner permission: sites will only work if all land managers are completely on board with the works and will accommodate the needs of the birds (Pakanen et al., 2014; Babcock & Booth, 2020).

- Land tenure: need to ensure the newly created site is protected long-term from human development (e.g. potential for residential development through land use zoning) and recreational activities (Brooks et al., 2011).

- The type of legal protection status of the area (e.g. dog control, visitor access, recreational activities) and the level of enforcement of these restrictions (Brooks et al., 2011). What will the tenure of a new island be for example and who will take on responsibility for ongoing management and protection?

- An ongoing management and monitoring plan for the site including habitat profiling to determine how the habitat changes over time due to natural processes (wind, rain, waves) to inform future renourishment works which will be required due to sediment depletion and/or inappropriate sand accretion (Baker-Gabb & Manning, 2011; Brooks et al., 2011; Andrews, 2020; Alluvium, 2020).

- Logistics, including community interests (e.g. boating, recreational activities), and legal requirements including permits and licenses (e.g. existing management plans, national designations, crown estates). For example, construction may be unfeasible at a desired location as could create a hazard to marine navigation or there are conflicting land use designations (Ratcliffe et al., 2008; Babcock & Booth, 2020).

When working with contractors to create an artificial site, detailed site specifications should be provided to ensure correct site design, and staff should work closely with contractors to ensure conservation values are upheld as many machine operators are used to designing sites in straight lines (Babcock & Booth, 2020).

Signage should accompany newly created sites to inform the public about the significance of the site and restrictions around access to it (refer to the '*Signage*' section for further details).

Once created, decoys and call playback can be used to attract nesting terns to newly created sites during the prospecting phase of nesting which may increase the probability of the site being used by breeding birds (Ratcliffe et al., 2008; Babcock & Booth, 2020; refer to the '*Influencing Site Selection*' section for further details).

Decision-making trigger

Creation of new nesting habitat is generally required if there is no natural habitat in optimal condition available to nesting terns and terns haven't breed in a region over multiple, consecutive years. Habitat condition of natural nesting sites can be assessed through annual habitat assessments.

Timing and suggested frequency

The best time to create breeding habitat for Fairy and Little Terns is during winter and early Spring (July-October) coinciding with the non-breeding season, especially if the site is in close proximity to other utilised sites to prevent disturbance to nesting colonies (Babcock & Booth, 2020). Planning, which will be extensive, should be completed prior to works beginning and can occur during the breeding season prior to works being constructed. Works should be completed before the end of October prior to the expected arrival of breeding birds so that it is available for prospecting birds.

Habitat management for artificially created habitat, particularly dredge spoil islands, is ongoing and is generally required every 3-7 years to ensure the site remains adequately elevated above the high tide mark, sufficient substrate is still available and to ensure there is <15% vegetation cover (Golder et al., 2008). The most effective way to maintain the early successional habitat within these habitats is through periodic nourishment with freshly deposited sand and shell grit (Baker-Gabb & Manning, 2011). Habitat assessments ideally should occur annually to determine the condition of the habitat and evaluate whether any maintenance work is required to maintain habitat quality.

Advantages

- Provision of an alternative nesting site for breeding birds providing often optimal nesting habitat (Murray, 2000; Golder et al., 2008; G. Barrett, pers. comm.).
- Dredge spoil islands can improve nesting conditions as are generally free of mammalian predators and have lower human visitation rates due to typically being a more remote location (accessible only by boat) (Golder et al., 2008).
- Dredge spoil islands generally have a higher elevation compared to naturally occurring islands, minimising the risk of tidal inundation (Treadgold, 2000; NSW NPWS, 2003; Golder et al., 2008).
- Fencing likely not required on dredge spoil islands due to remoteness and predator-free status (Erwin et al., 2003).
- Intensively managed artificial sites can achieve higher breeding success than natural nesting sites (Pakanen et al., 2014).
- Habitat creation can play a critical role in establishing a network of breeding sites for terns with sites used interchangeably in response to temporal variability in resources such as prey items (Murray, 2000; Babcock & Booth, 2020).

Disadvantages

- Requires intensive review and planning to ensure artificially created habitat addresses all of the nesting requirements of the target species.

- Can be extremely expensive to implement especially if there is no *in situ* dredge operation occurring (Smith, 1990; Baker-Gabb & Manning, 2011; G. Barrett, pers. comm.).

- Lack of knowledge regarding habitat variables influencing site selection by a species can result in newly created sites not being used as nesting habitat (Fujita et al., 2009).

- Labour intensive to plan and construct (G. Barrett, pers. comm.).

- Requires ongoing active management including fencing, wardening and weed and predator control as sites can become rapidly overgrown and unsuitable for nesting terns (Smith, 1990; Treadgold, 2000; Baker-Gabb & Manning, 2011; Pakanen et al., 2014; G. Barrett, pers. comm.).

- Dredge spoil islands created in open water can experience rapid rates of erosion due to prevailing wind, boat traffic and wave wash, reducing the lifespan of the site (Andrews, 2020; Baker-Gabb & Manning, 2011). It is likely that the spoil will need to be replenished every 3-7 years to maintain the sand profile (both in height and area), therefore requiring ongoing funding and resources (Smith, 1990; Golder et al., 2008). Alternatively, sand can accumulate with the sand profile becoming swale like requiring levelling off (Murray & Reside, 1995).

- The micro-climate and/or topography of the artificially created habitat may be inappropriate for nesting terns (Murray, 2000).

- Substrates can be unstable, have inappropriate humidity levels and/or overheat causing nest failure and site abandonment (Owen, 1991; Andrews, 2020).

- Artificially created sites are generally devoid of natural cover, particularly when first created, thus requires addition of chick protection measures (e.g. shelters) (Smith, 1990).

- Requires prior approvals and permits from relevant landowners and government agencies.

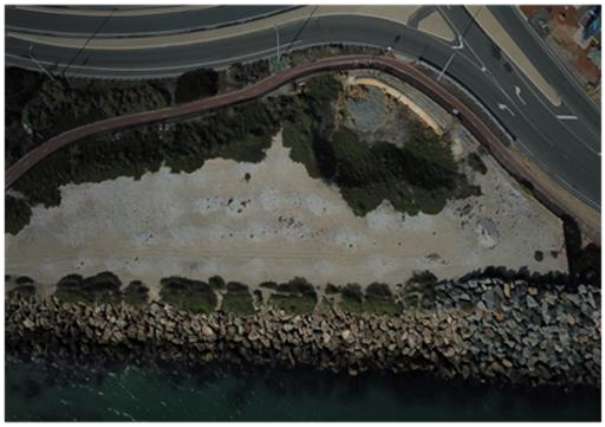
- Nesting terns will not always use the created sites (Fujita et al., 2009).

- Sites can be attributable to lower breeding success and abandon the site if nesting requirements aren't completely met (e.g. size too small to sustain a colony of sufficient size to defend against high predation pressures; Fujita et al., 2009).

Case studies

Western Australia:

Rous Head Fairy Tern Sanctuary:



The artificially created Rous Head Fairy Tern Sanctuary (photo: C. Greenwell).

In 2013, Fremantle Ports, in consultation with relevant conservation authorities (e.g. Conservation Council of Western Australia, BirdLife Australia, Western Australian Museum) and with community consultation and support, created the Rous Head Fairy Tern Sanctuary to overcome a lack of suitable Fairy Tern nesting habitat in the port area and to prevent terns nesting on sites cleared from port development (Freemantle Ports, 2022; C. Greenwell, pers. comm.). The flat, elevated site (27 hectares in size) was created on reclaimed land (through the deepening of the Fremantle Inner Harbour and Entrance Channel), adjacent to the ocean and an abundant food source, with a layer of beach sand and dredged shell material added to the surface of the site to enhance the attractiveness of the site to breeding Fairy Terns (Freemantle Ports, 2022; C. Greenwell, pers. comm.). The shell grit was again replenished before the commencement of the 2017/18 breeding season (Freemantle Ports, 2022). The steep slope away from the sea wall was vegetated with low coastal plants, providing shelter for chicks. A permanent fence fully encapsulates the site reducing human disturbance, access is restricted and signage is installed and replaced/updated when necessary. A comprehensive predator control program is conducted by Fremantle Ports in the lead-up to each breeding season and vegetation is managed by volunteers annually (Freemantle Ports, 2019; Freemantle Ports, 2022; C. Greenwell, pers. comm.). Decoys were used to originally attract breeding birds to the site following creation.

Prior to the creation of the site, Fairy Terns continually tried to nest within the vacant reclaimed land at Rous Head in small groups or pairs and eggs were vulnerable to crushing from dogs, humans and vehicles, with high breeding failure recorded (Freemantle Ports, 2022). This indicated that this site was a prime nesting location particularly due to the proximity of a reliable prey source and that nesting sites were limited in the region. Since the sanctuary was created, Fairy Terns have nested at the site every year with the local breeding population increasing from 90 breeding pairs in the 2013/14 breeding season to a peak of 250 breeding pairs in the 2018/19 breeding season (Freemantle Ports, 2022). It is now an important breeding site for Fairy Terns within the Perth metropolitan region and has been the most successful breeding site for a number of years (Freemantle Ports, 2022; C. Greenwell, pers. comm.). Ongoing research is conducted at the site by the Murdoch University and the Conservation Council of WA to further enhance knowledge about the population dynamics and life-history of Fairy Terns. A Fairy Tern Network was established with the creation of the sanctuary, including a dedicated Facebook page, to encourage and coordinate community monitoring of Fairy Terns, as well as providing an opportunity for community education, and is supported by Fremantle Ports (Freemantle Ports, 2022). Fremantle Ports continues to manage the sanctuary and supports the Conservation Council of Western Australia to manage a community volunteer-based monitoring program (Freemantle Ports, 2019).

Boundary Island:

Fairy Tern decoys within the fenced area of the newly created Boundary Island nesting site (photo: G. Barrett).

In 2020, in response to the apparent difficulty of Fairy Terns to find suitable nesting sites within the Swan/Peel Harvey neighbourhood, the Department of Biodiversity, Conservation and Attractions (DBCA) took out a 5-year lease on a portion of the dredge spoil Boundary Island (Crown land located south of Mandurah) to construct a trial Fairy Tern breeding site (Barrett, 2022; G. Barrett, pers. comm.; C. Greenwell, pers. comm.). The aim of this habitat construction was to provide an alternative safe nesting area for breeding Fairy Terns from the nearby (~6 km away) Pyramids Beach nesting site (G. Barrett, pers. comm.; C. Greenwell, pers. comm.). The site was selected as it was within an area where Fairy Terns have previously bred, although breeding had not been recorded at this site in the past 10-20 years (G. Barrett, pers. comm.; C. Greenwell, pers. comm.). A semi-permanent fence (encapsulating 50 m x 150 m area) was installed around the nesting area to exclude dogs and people, weeds were removed, fox control was implemented and signage was installed (Barrett, 2022; G. Barrett, pers. comm.). An artificial shoreline was created using bags of donated shell grit (Barrett, 2022). Initial works were carried out between October and November with ongoing fox and weed control occurring (G. Barrett, pers. comm.). While the majority of breeding birds (300 pairs) nested at the traditional Pyramids Beach site, 6 pairs of Fairy Terns were attracted to Boundary Island using decoys within the fenced area and call playback and nested there (Barrett, 2022; G. Barrett, pers. comm.). Of these, one pair was successful, with the remaining nests predated by a fox (G. Barrett, pers. comm.).

Victoria:

Rigby Island:

Rigby Island, situated in the Gippsland Lakes, has undergone substantial change since the 1980s due to drastically changing sand profiles, having received the longest, successive layering of dredge spoil in Victoria largely through dredging and spoil disposal associated with the maintenance of the entrance to Lakes Entrance by the Port of Melbourne Authority (now known as Gippsland Ports) (Waldergrave-Knight, 1997; Schipper & Mitchell, 1999; Andrews, 2020). In 1986, in an effort to attract breeding Fairy and Little Terns to Rigby Island, dredge spoil was placed on the south-eastern sandspit during winter to create nesting habitat. Additional dredge spoil was added to the area during winter in 1987 which significantly raised the level of the sandspit increasing the availability of optimal nesting habitat (Reside, 1988; DSE, 2003). As a result, both Fairy and Little Terns successfully bred at the site during the 1987/88 breeding season (25 Fairy Tern fledglings and 64 Little Tern fledglings; Reside, 1988). A further 6,000 m3 of dredge spoil was added in to the sandspit in 1988 to help partially fill in a flood prone depression on the southern side of the spit and to further enhance the tern nesting habitat (Reside et al., 1989; DSE, 2003).

Between 1989 and 1990, the Ports Management Authority implemented works that drastically altered the sandspit profile creating large mounds of unstable sand and covered the shell grit layers established by the

previous dredging works (DSE, 2003). Small terns proceeded to nest on the dredge spoil but all nests were subsequently abandoned without apparent cause and breeding success was significantly lower over the following two breeding seasons (Owen, 1990; 1991). Consequently, it was recommended that further dredging work should ensure that a small area of the original dune substrate remained exposed for nesting birds as insurance against the newly added spoil being unsuitable as nesting substrate (Owen, 1990).

In 1991, further dredge spoil from the Hopetoun Channel was pumped onto the sandspit during routine channel works by the Port of Melbourne Authority (Owen, 1991). The dredged sand was spread over the majority of the original sandspit aiming to increase the potential small tern breeding area to ~2 ha. The area of shell grit where Fairy and Little Terns had nested in the previous season was left uncovered following previous recommendations (Owen, 1991). Further precautions were also taken to ensure that the shallow inlet to the west of the sandspit was not filled in or cut off from Hopetoun Channel as this inlet has previously been an important feeding area for the nesting small terns (Owen, 1991). Following the early rehabilitation works in the 1990s, Rigby Island became one of the most productive small tern breeding sites in eastern Australia (Waldegrave-Knight, 1997; Schipper & Mitchell, 1999).

By 1994, over 90,000 cubic meters of sand had been deposited on the tern nesting area on Rigby Island, increasing the sandspit height by over 2 m in some places (Reside et al., 1994). However, the mountainous shape the site had developed made it more vulnerable to coastal weather conditions and was identified as a major contributing factor for the Little Tern breeding failure from 1992 to 1994 (Reside et al., 1994; Murray & Reside, 1995). When the terns had successfully bred on the island, the topography had been much flatter. It is thought that the changes to the topography had negatively impacted breeding success due to poor micro-climatic conditions and poor visibility (Murray, 2000). A plan to restore the natural profile of the sandspit was formulated with the Port of Melbourne Authority agreeing to undertake the works (Reside, 1994; Murray & Reside, 1995). Over several weeks across August to September, sand was bulldozed off the previous nesting area to create a series of 5 dune ridges with intervening swales (Murray & Reside, 1995). This work reduced the height of the site by up to 2 m in some places (Murray & Reside, 1995).

In 2009, the sand profile of Rigby Island was again lowered to a gently undulating profile from a swale-like dune system. Successful breeding occurred at the site in the following breeding season. In August 2017, the sand at the south-eastern end, which had become a dune system over a period of 7 years due to the prevailing winds, was flattened using a D6 dozer to increase the habitat suitability for nesting Fairy and Little Terns, as well as for other beach-nesting bird species (Sullivan, 2019; 2020). However, by 2019 the beach was losing height and the average slope across the island was starting to increase again (Alluvium, 2020).

Albifrons Island:

In 1992, the Port of Melbourne Authority created an island known as Albifrons Island as part of a dredging program implemented to clear the Gippsland Lakes navigation channels (DSE, 2003). Little Terns nested nearly immediately on the island after dredging ceased (DSE, 2003). By 1995, ongoing sand loss had caused a significant reduction in the size and height of the island requiring addition of further dredge spoil to maintain nesting habitat (Murray & Reside, 1995). This was an ongoing management issue at the site, unable to be addressed due to the costs (no funding) and the schedule of channel deepening works (Murray & Reside, 1995).

In July 2015, renourishment works were undertaken on Albifrons Island which had essentially become an area of wet sand only exposed at low tides (Alluvium, 2020). Approximately 8,000 m3 of sediment was added to the island over an area of 12,600 m2 creating open beach with gentle slopes and vegetation was planted (Alluvium, 2020). By 2017, the majority of the added sand was again below the spring tide level (Alluvium, 2020). Steep slopes had formed around the edge of the sand bank and sand undulation had increased across the site (Alluvium, 2020). By 2019, only a few scattered square meters of the added sand remained and the site had become unsuitable for nesting terns (Alluvium, 2020). Planted vegetation did not establish well here resulting in a greater loss of sand (Alluvium, 2020). However, the site has remained a popular location for loafing small terns and migratory shorebirds (D. Sullivan, pers. comm.).

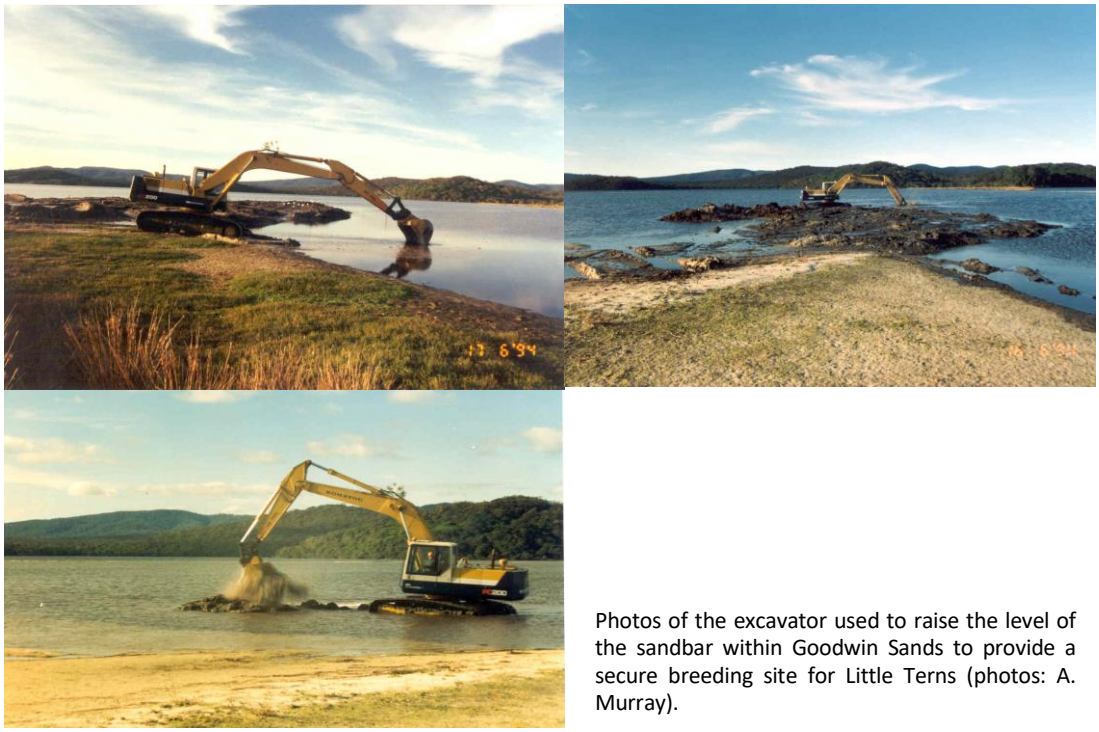
Goodwin Sands:

In 1994, a sand bank was built as an extension to an existing island within the Goodwin Sands (an area of low-lying sand islands situated within the Mallacoota Inlet) to provide a secure breeding site for Little Terns free from mammalian predators with a significantly lower risk of tidal inundation than surrounding areas (Newnham & Murray, 1994; Murray, 2000). The created sand bank was 60 m in length, 20 m wide and 1.5 m high to reach above the minor flood level to minimise the risk of tidal inundation and the general area has a history of being used as a nesting site by Little Terns (Newnham & Murray, 1994; Murray, 2000). It was thought that more birds would nest in the area if a site was made more attractive to prospecting birds (Murray, 2000). Goodwin Sands was identified as a preferred area for habitat creation due to:

- Having natural protection from mammalian predators due to the natural water barrier;
- Associated with low visitor numbers (boat access is limited due to the large area of very shallow water surrounding the island);
- Greater protection from wave action during storms;
- Site is fairly stable with little change occurring in the composition of the sands over the previous 20 years;
- Regular monitoring is achievable.

An excavator was walked across Goodwin Sands from "Lake View" in June 1994 (Murray, 2000). The excavator collected spoil from shallow water and added it to an existing small sand spit. This successfully increased the height of the sand spit which remained above the level of the inlet, while not significantly altering the appearance in relation of other nearby spits (Murray, 2000). However, Little Terns have not established a regular nesting colony on the newly created site which is thought to be due to several factors (Murray, 2000). One of the most significant problems was the composition of the spoil added to the site to increase the height. The substrate tended to be darker than the fine white sand on the surface of naturally occurring sandbars and had a higher clay and organic material content, making it unsuitable for nesting terns (Murray, 2000). Consequently, it is recommended to create a stockpile of fine white sand for distribution onto the surface of the added spoil once construction is completed (Murray, 2000). However, caution is required when deciding on the amount of fine sand to add to the surface as fine sand can bury eggs during periods of strong winds (Andrews, 2020). Additionally, during the first breeding season after construction, the mouth of the inlet was

closed resulting in an extremely high water level in the region. Within Goodwin Sands, the artificially constructed sand bank was the only exposed land and was subsequently used by a large number of roosting birds including swans and pelicans preventing nesting by small terns (Murray, 2000). A successful Pelican breeding colony has since established at the site when environmental conditions are suitable, while other species also successfully nest here including Caspian Terns (*Hydroprogne caspia*), Silver Gulls and Black Swans (*Cygnus atratus*) (Murray, 2000). The presence of these larger species has likely further prevented small terns from nesting at this location (Murray, 2000). Furthermore, Goodwin Sands is often subject to water inundation, especially before the inlet breaks open to the sea. Rising water levels in the inlet reach flood point before breaking through (D. Sullivan, pers. comm.) which may also negatively impact small tern nesting attempts at this site.



Photos of the excavator used to raise the level of the sandbar within Goodwin Sands to provide a secure breeding site for Little Terns (photos: A. Murray).

New South Wales:

The artificially created Bird Island within Lake Illawarra constructed by the Lake Illawarra Authority (LIA) as a nesting site for Little Terns (photo: LIA; sourced from Dunn & Jorgensen, 2008).

The Lake Illawarra Authority (LIA) used dredge spoil from their construction of a northern breakwall at Lake Illawarra and the subsequent dredging of the entrance channel to create an artificial 'Bird Island' just offshore from the lake's edge, with the island being accessible at low tide (Dunn & Jorgensen, 2008). Throughout their work, the LIA saved shell grit which was then distributed onto the newly created habitat as nesting substrate (Dunn & Jorgensen, 2008). Public access was restricted to the island and signs stipulating no entry were installed. Following completion, nesting began in November on Bird Island. Upon detection of Little Tern nests, temporary signs and fences were installed. Half buried plant pots covered with seaweed were also distributed throughout the nesting area to provide shelter for chicks in addition to the Sea Rocket plants that had become established (Dunn & Jorgensen, 2008). The first year produced 14 fledglings which was considered a great success (Dunn & Jorgensen, 2008).

New Zealand:

Due to the declining Fairy Tern population in New Zealand, the four currently used breeding sites were assessed and it was concluded that alternative sites that are predator and people free should be created. Artificial nesting sites have been created in an area that was historically (1930s) a breeding site for Fairy Terns (Beveridge, 2018; DoC, 2020). Construction involved transporting 50 tonnes of locally sourced shell by helicopter carried out by the New Zealand Defence Force (DoC, 2020). The new habitat was placed in the rear of the sand dunes which provides more protection for incubating adults and chicks (DoC, 2020). Decoys were positioned throughout the newly created sites to attract overwintering birds (Beveridge, 2018). These sites are deemed safer for nesting Fairy Terns as are protected from tidal inundation and sand blow (DoC, 2020). The Department of Conservation employs summer rangers during the breeding season to monitor and protect Fairy Tern nests, generally one ranger per breeding site (DoC, 2020).

Recommendations

- Due to significant costs and the logistics of habitat creation projects, prioritisation of sites should occur across the landscape prior to investment and ideally be associated with pre-existing dredge operation works.

- Sites should be selected based on fulfilling all (or near to all) of the breeding requirements of the target species to maximise breeding success and long-term site use. Refer to the '*Implementation*' section above for detailed information pertaining to required site characteristics (e.g. size, elevation, topography, wind direction, vegetation requirements, diet requirements, shelter).

- Newly created sites should fall into a wider colony network of nesting sites (i.e. created in close proximity to other currently used nesting sites) to provide breeding birds with alternative options when conditions are unfavourable at one site.

- A long-term management plan for sites where habitat is created should be produced and implemented that considers future vegetation control, substrate renourishment and management of disturbance and recreational impacts to ensure a holistic investment that maximises long-term breeding success.

Sandbagging

The dynamic nature of small tern nesting sites poses natural threats to nesting colonies. Fairy and Little Terns regularly nest just above the high tide mark which are subject to tidal inundation in periods of king tides and storm surges, with high tides often being the most common cause of nest failure (Smith, 2000; A. Adams, pers. comm.). Tidal inundation of tern nests due to higher tides, larger swells, rising sea/river levels and more frequent storm events are increasing due to the effects of climate change (Von Holle et al., 2019; Andrews, 2020). For example, 17% of known Little Tern eggs were lost in one season in NSW due to tidal inundation (Keating & Jarman, 2004, 2006). Sea level rise and disturbances from increased storms are also predicted to decrease the nesting habitat available to beach-nesting bird species due to coastal erosion and wind erosion processes (Von Holle et al., 2019; Andrews, 2020).

Measures to combat the increasing threat of tidal inundation of tern nesting sites, especially during the incubation and chick stages, are now being thought about in an effort to lessen this threat to nesting colonies. Sandbagging of individual nests or colonies is one such measure which can mitigate the impact of tidal inundation by either raising individual nests and their egg contents above the predicted water level or placing sandbags around the edge of the entire colony, and which has been successfully employed at several locations in both Australia and New Zealand (Jarman, 2006; DECC, 2008; Northern Advocate, 2015).

Implementation

Sandbagging is achieved by carefully moving the eggs from within a nest and either placing them on top of a mound of sandbags which are covered in loose sand or by making a circle with sand bags and filling the enclosed area up with sand and placing the eggs on top of the sand (DECC, 2008; Bishop et al., 2009). Alternatively, nests have been picked up by a shovel, sand bags placed around the site and the middle filled in with sand to create a raised platform of sand. The nest is then placed back in the same position, albeit raised (Smith, 1990). Extreme care is required if this technique is to be employed, particularly to avoid eggs being partially covered by the nest substrate when moved. It is important to also install sandbag 'ramps' to enable chicks to move between the nest and the rest of the beach (Keating & Jarman, 2006). Dykes or sandbag walls have also been constructed around vulnerable nests to reduce the impacts of storm surges by diverting the water away from the nests (Keating & Jarman, 2004; Keating & Jarman, 2006).

Decision-making trigger

Nests located at flood-prone locations are continually monitored and the habitat condition and proximity to the high-tide mark assessed. Nests/eggs are moved onto sandbags (elevated above the predicted water mark), or dykes/sandbag walls are constructed around nests, prior to predicted king tides or storm surges if there is

a high likelihood of losing the nests to inundation, or if nests have already been lost in the area (Jarman, 2006; K. O'Brien, pers. comm.). Sandbagging can also occur when nests are situated in known flood-prone areas as a preventative measure (Keating & Jarman, 2004). Implementation of these measures is also dependent on the ability to access the site and the assistance available at the time that sandbagging is required to protect the nests (K. O'Brien, pers. comm.).

Timing and suggested frequency

Sandbagging occurs throughout the breeding season where appropriate in response to threats of tidal inundation (eggs have already been laid and birds are incubating; K. O'Brien, pers. comm.). Occurs at times of king tides, predicted storm activity and in areas prone to flooding.

Nesting sites should be assessed annually for the risk of tidal inundation. Monitoring the risk of inundation should occur throughout the breeding season in areas prone to flooding.

Advantages

- Nests and eggs are raised above the level of tidal inundation and have a higher probability of avoiding being washed out.
- Sandbagging provides more time and is particularly favourable when eggs are close to hatching to ensure they hatch (K. O'Brien, pers. comm.).

Disadvantages

- Extremely invasive and could cause nest abandonment especially for birds/colonies where this hasn't been performed before. Nest desertion has been documented when nests have been raised in Britain (Haddon & Knight, 1983).
- Risk of predation while adults are disturbed off their nests when work is being conducted (K. O'Brien, pers. comm.).
- Highly trained staff required to perform nest/egg movement.
- Significant time and labour is required (K. O'Brien, pers. comm.).
- Inundation of nests can still occur due to unanticipated storm surges and/or high winds. Inundation of the colony area post-hatching can also lead to chick mortality due to the risk of drowning.
- Raised nests may increase predator detection (Hill & Montague, 1985).
- There is a greater need to understand site selection by prospecting terns and whether terns learn about site suitability from past inundation events and past successes at a given site (e.g. could interventions lead to terns re-selecting sites that are fundamentally unsuitable?).

Case studies

Victoria:

In the late 1980s, 10 Little Tern nests located at Lake Tyers in East Gippsland were raised and sand bagged in response to a severe depression over the Tasman Sea which was associated with heavy rain, high winds and rough seas. The site warden enlisted a work crew to construct sand bagged mounts onto which the 10 nests were raised by digging up the sand around and under the nest scrape to avoid handling the eggs (Owen, 1990). This work took 30 minutes to complete with a 15-minute break half way through. The incubating adults returned to the nests minutes after the work was completed. A couple of these nests survived the storm event and one went on to hatch, however did not fledge (Owen, 1990). The area was ultimately abandoned due to the continuing adverse weather (Owen, 1990). In other instances, raised nests have failed due to predation with predators potentially attracted to the raised nests (Hill & Montague, 1985).

New South Wales:

In an effort to overcome Little Terns nesting at locations subject to tidal inundation, sandbagging strategies have been utilised at several flood-prone sites (e.g. Bega River mouth, Wallaga Lake, Brow Lake, South Tuross Head, Shoalhaven Heads, Botany Bay and Sawtell, Lake Conjola). Up to 94% of nests at sites vulnerable to flooding have been managed with mixed success being reported (Keating & Jarman, 2004). Inundation of nests still occurred in some instances due to high winds and unanticipated storm surges (Keating & Jarman, 2004). For example, 212 Little Tern eggs were tidally inundated during the 2001/02 breeding season due to adverse weather conditions (Keating & Jarman, 2002; Keating & Jarman, 2004). The construction of sandbag walls and elevation of Little Tern nests onto sandbags at Botany Bay have also been unsuccessful (e.g. Ross & Jarman, 2001; Keating & Jarman, 2004). However, the sandbag mounds at South Tuross Heads during the 2002/03 breeding season protected 82 Little Tern nests resulting in 65 fledglings for the site reflecting the most fledglings for this site on record (Keating & Jarman, 2003). During the 2003/04 breeding season, 47 of the 50 Little Tern eggs that were elevated onto sandbags remained protected from tidal inundation (Keating & Jarman, 2004).

Examples of sandbagged Little Tern nests with incubating adults in NSW (photos: NPWS (left) and B. Nelson (right) sourced from Dunn & Jorgensen, 2007; 2008).

In 2008, a few nesting pairs of Little Terns remained on the low lying spit at Lake Conjola which had been inundated a few weeks earlier. These nests were raised onto sandbags due to the predicted high tides throughout summer (Dunn & Jorgensen, 2008). During December, the incubating adults remained on the sandbags and successfully hatched chicks (Dunn & Jorgensen, 2008).

More recently, remote cameras have been placed around nests that have been sandbagged to monitor nest outcomes. Camera footage has revealed that sandbagged Little Tern nests have survived 2 m tides (K. O'Brien, pers. comm.).

New Zealand:

The Department of Conservation have employed sand bagging Fairy Tern nests and digging trenches around nests to minimise the risk of tidal inundation and protect nests from higher than normal tides (Northern Advocate, 2015).

Rangers building a sand wall at Waipu in an attempt to shelter Fairy Tern nests (photo: V. Lepper sourced from Northern Advocate, 2015).

Recommendations

- Preferable to move nests rather than raise them up (Smith, 1990).
- Potentially more beneficial to sandbag and trench an area than to sandbag individual nests due to still maintaining camouflage of the nesting area for predators.
- A need to investigate improved triggers for implementing this highly invasive, reactive management technique, that is, the best time of season to utilise this technique, predictive modelling of tide heights and forecasted number of days of inundation to assess likelihood of success.
- Investigating proactive responses to improving resilience of habitat to tidal inundation may be preferable and offer a more sustainable approach to mitigating this threat type.

Influencing Site Selection

Habitat loss and degradation through coastal developments poses a significant threat to beach-nesting birds including tern species. Once optimal breeding sites are now experiencing increases in predator numbers and disturbance events due to increasing visitation by humans as populations continue to grow. Sites are also becoming too vegetated, while climate change is causing higher tides and a higher frequency of storm events resulting in tidal inundation of colony areas. As traditional breeding sites continue to disappear, sub-optimal breeding sites are being selected by nesting terns which can result in high levels of breeding failure. Various methods aiming to influence site selection by prospecting terns have been used at nesting sites around the world in an attempt to increase breeding success by enticing breeding birds to nest at sites deemed more safer from threats and more likely to achieve breeding success.

Implementation

There have been several methods employed to attract or prevent prospecting Fairy and Little Terns to/from particular nesting sites within Australia:

Nest destruction

- **Purpose:** to encourage breeding birds to move locations when nesting has begun at an undesirable location where nesting failure is perceived to be high, such as sites prone to tidal inundation, high levels of predation or disturbance (Schipper & Mitchell, 1999). This method is currently **not** recommended.

- **Method:** disturb nesting birds to encourage them to abandon the site. This can include walking through the colony site and removing/destroying eggs and nests (Schipper & Mitchell, 1999). Flagging is erected after the destruction of nests to deter birds from re-nesting at the site (Schipper & Mitchell, 1999).

Flagging

- **Purpose:** to prevent breeding birds from nesting at locations considered undesirable where nesting failure is perceived to be high, such as sites prone to tidal inundation, high levels of predation or disturbance (Owen, 1990; 1991; Smith, 1990; Murray & Reside, 1995; DSE, 2003). Flagging has also been used to discourage nesting at sites where management actions are difficult to implement (Owen, 1991). However, as the birds become progressively more threatened (i.e. continued declines in local population numbers), management effort should not necessarily dictate measures as drastic as this, rather effort should be directed at understanding the site dynamics and understanding how to effectively mitigate the site-specific threats.

- **Quantity:** dependent on the size of the site (see below).

- **Placement:** parallel lines 8 m apart placed on sections of the beach where nesting is to be discouraged (Reside et al., 1989). Flagging should occur from the high tide mark up to the foredunes (Reside et al., 1989). Placement should occur prior to the breeding season beginning (Owen, 1990).

- **Materials:** bunting or rope with long strips of coloured flagging tape attached to wooden stakes (Reside et al., 1989; Smith, 1990). The bunting is tied loose enough to allow it to drag across the sand when blown by the wind which discourages birds from nesting between the lines (Reside et al., 1989).

Decoys

- **Purpose:** to attract breeding birds during the site prospecting phase to a particular site which is thought to be optimal for breeding and free from threats.

- **Quantity:** partly dependent on size of site. Two to three breeding pairs with at least two birds mimicking incubation (e.g. head angled down and tail up; Smith, 1990). Avoid having too many decoys on the ground as lots of decoys may deter prospective breeding birds (Smith, 1990).

- **Placement:** central to where you want the colony to establish within the site.

- **Materials:** initial decoys were made from dense polystyrene, however this does not weather well. More recently, decoys have been 3D printed using PLA (Polylactide) plastic which is biodegradable and made from renewable resources and which produces more durable and realistic models (S. Lee, pers. comm.). Decoys are mounted on a large spike which can be pushed into the ground. This enables the decoy to pivot on the spike (like a wind vane) resulting in the bird always facing into the wind, mimicking real incubating/roosting birds (S. Lee, pers. comm.). Alternatively, decoys can be cemented into a bucket and buried in the sand to prevent being blown away. All decoys are hand painted to match real birds. Call playback can be used at the site in association with decoys to enhance attraction of birds to the site. Calls used should be from previously recorded breeding birds from that region due to potential differences in vocalisations between regions.

Fairy Tern decoys used at the artificially created Rous Head Fairy Tern Sanctuary to attract prospecting birds to the site (photo: Freemantle Ports).

Decision-making trigger

Methods influencing site selection by prospecting birds should only be implemented after thorough research of the breeding site has been conducted to ensure a comprehensive knowledge of site selection is gained.

Methods to deter breeding birds from a site are employed when the site is regarded as being sub-optimal for nesting and breeding success. These sites often have a history of tidal inundation, predation or high disturbance levels and these threats are perceived to still be relevant for the upcoming breeding season and unable to be mitigated (Owen, 1990; 1991; Smith, 1990; Murray & Reside, 1995).

Methods to attract breeding birds to a site are employed when the site is regarded as having optimal nesting habitat conducive to achieving high breeding success compared to other potential sites which birds could nest at. In these instances, managers do not want to leave it to chance for prospecting birds to settle at the desired site (Smith, 1990). Often these sites have been subject to management works such as vegetation and predator control prior to the breeding season and are considered safe from tidal inundation as well as from human-related disturbance events.

Timing and suggested frequency

Methods to attract or deter breeding birds to/from a desired site should be implemented prior to the expected arrival of breeding birds in the area and ideally before any clutches are laid (Owen, 1990).

Evaluation of sites to determine if avoidance/attraction methods are required should be conducted on an annual basis prior to the expected arrival of breeding birds.

Advantages

- A potential simple and effective management tool to attract breeding birds to nesting habitats which are perceived as being safer and have a higher probability of breeding success.
- Can be easier to manage nesting colonies if they establish at desired locations already subject to management.

Disadvantages

- If nests/eggs have been made/laid prior to the placement of flagging at sites considered undesirable, these are destroyed (Owen, 1990).
- Methods attracting breeding birds to a site can result in a high density of birds which can lead to increased adult attacks on chicks when nearby chicks are left unattended and come in close proximity to their chicks.
- The degree of resemblance of decoys to real birds, the type of calls used in call playback and the posture of decoys require further investigation to ensure their effectiveness (Jefferies & Brunton, 2001).

Case studies

Western Australia:

The Mandurah marina Fairy Tern Sanctuary is a historically important breeding site which has been developed into a marina and housing estate (C. Greenwell, pers. comm.). Post-development, Fairy Terns have nested on empty blocks of land within the housing estate (C. Greenwell, pers. comm.). However, breeding success has been low, likely contributed to high levels of disturbance. Specially designed nesting habitat was created to overcome the lack of suitable nesting habitat within this important breeding area (C. Greenwell, pers. comm.). In 2018, the entire colony was abandoned due to the presence of a cat (Greenwell et al., 2019). Since then, vegetation clearing has not occurred in an effort to reduce the attractiveness of the site to prospecting birds. This decision was based on the perception that it would be too difficult to control cats at this site due to the close proximity to residential housing (C. Greenwell, pers. comm.).

Victoria:

Little Terns were successfully discouraged from nesting on the Lake Entrance beach for two seasons in the late 1980s by flagging the sections of beach where the birds were beginning to make scrapes. Within a week, the birds were beginning to nest on the preferred Rigby Island (Reside et al., 1989). The Rigby Island site went on to become highly successful in terms of breeding success (Reside et al., 1989; DSE, 2003).

Flagging was also implemented at Lake Tyers in Gippsland in an effort to get the Little Terns that were trying to nest there to move to the preferred nesting site on Rigby Island (Owen, 1991). However, flagging in this instance was not effective at moving the birds away from the site. The flagging was eventually removed due to concerns that the birds would be discouraged from nesting altogether for the season (Owen, 1991). Almost immediately after removal, the breeding birds began landing on the spit and nests were established within three days. The colony went on to produce at least 36 fledglings (Owen, 1991).

In the 1990s, Little Tern nests and eggs were destroyed on Little and Albifrons Islands in Gippsland to prevent the site from becoming a second colony as managers wanted all of the Little Tern colonies to be located on Crescent Island (Schipper & Mitchell, 1999).

New Zealand:

A controlled experimental trial consisting of four experimental plots (120 x 55 m) was implemented in New Zealand during the non-breeding season on a sand and shell beach to determine if call playback and decoys could successfully attract Fairy Terns to safe nesting habitat with the aim of re-establishing nesting colonies in protected habitat (Jeffries & Brunton, 2001). Fairy Terns were no more likely to land in one of the four experimental plots when call playback was being used, compared to when calls were not being played (Jeffries & Brunton, 2001). However, Fairy Terns were significantly more likely to land in experimental plots which had decoy models in them compared with control plots (Jeffries & Brunton, 2001). The behaviour of the Fairy Terns towards the decoys paralleled live tern interactions (e.g. aggressive response, erect posture; Jeffries & Brunton, 2001). Following this experiment, Forest and Bird used the decoys and taped vocalisations to attract Fairy Terns to restored shell habitat within a historic breeding site on the Kaipara Harbour.

Recommendations

- Under **NO** circumstances should any Fairy or Little Tern nests be destroyed.

- Dissuading terns from using a site through the use of flagging for example, should only be considered an option for sites subject to tidal inundation, and for sites with high risk of predation and/or human use. All other options for reducing predators and disturbance at the site should fully be explored first before making the decision of discouraging site use.

- Attraction to a site should be done based on knowledge of the suitability of that particular location for the birds, at the macro- and micro-habitat scale, and taking into account the factors which birds are selective of to maximise proximity to feeding areas, minimise risk of predation and minimise thermal stresses. Further research should be undertaken to better inform human selection of sites for terns.

Site Wardens

The breeding season of terns, like other beach-nesting bird species, peaks during the summer months coinciding with peak recreational use of coastal areas. This can result in increased disturbance to nesting colonies, resulting in colony failure and/or site abandonment. One key component of ensuring success of management actions and maximising breeding success at sites is the regular wardening of nesting colonies (Smith, 1990). Site wardens serve two purposes: 1) to attempt to protect the nesting site and/or mobile chicks by directing people past the sensitive nesting area, and 2) to educate beach visitors. Wardens typically will not have the authority to enforce regulations at the site unless they are also an authorised officer and regulations are gazetted for the site. Site wardening may also be required at some sites as a condition for work activities which are being undertaken near an active nesting colony (K. Bartley, pers. comm.).

Implementation

Wardens can either be paid staff or volunteers when there is insufficient staffing or budgeting resources. If wardens are volunteers, they will require the support and guidance from the land manager. Volunteers can also help assist site wardens with their duties. While on duty, wardens should always wear an identification badge. In some instances, land managers supply wardens with t-shirts which identify the program.

Duties of site wardens include (Owen, 1990; Smith, 1990; Schipper & Mitchell, 1999; Keating & Jarman, 2004; Brooks et al., 2011):

- Maintaining a daily presence where possible at nesting sites to help inform beach users, dog walkers, horse riders and/or vehicles of the presence of the colony and ask that they avoid approaching the nesting area in an effort to protect the colony. When an unleashed dog is observed racing ahead of its owner into a nesting area, the warden should attempt to call the dog over to them, and try to keep it out of the area until the owner arrives but should not try to restrain the dog themselves to avoid potential injury (Maguire, 2008). Wardens should carry spare dog leads to give to owners in the event they do not have a lead with them (Maguire, 2008).

- Monitoring, or the organisation of monitoring, the breeding activity and progress of nesting colonies.

- Protection of nests including installing and maintaining temporary signage and fences around nesting sites.
- Implementation of chick protection measures if required, such as placement of shelters.
- Conducting threat assessments at time of monitoring and implementation of predator control if required (including use of remote cameras).
- Recording details about egg and chick failures.
- Training and supervision of volunteers.
- Public education and raising awareness about Fairy and Little Terns and the conservation efforts being implemented. Wardens should carry educational resources, such as brochures, for distribution as well as laminated photos of the birds to help with interpretation. It can be beneficial to have a scope set up for those interested to view the birds from a safe distance under the guidance of the warden/s.

Not all duties will be required at all nesting sites.

At all times, wardens must ensure that their behaviour does not disturb the nesting birds (Smith, 1990). The success of wardens, particularly those who are volunteers, will be dependent on the level of feedback and support that they receive from the land manager or coordinator of the program. This should occur on a regular basis throughout the breeding season (Smith, 1990). At the end of the breeding season, a debrief should be held between wardens, volunteers and land managers to thank the wardens for their time and commitment and to seek their opinion on how management at sites can be improved (Smith, 1990). They will have important insights into the temporal use of sites by recreationists and can assist with identifying key user groups for further targeted education.

Decision-making trigger

Site wardens are best located at nesting sites that get very busy, particularly sites that experience a large volume of holidaymakers or dog walkers. Their presence will help to communicate site restrictions and increase public awareness and education (C. Schipper, pers. comm.). Where resources are limited, first priority should be given to sites which are highly vulnerable to disturbance (Smith, 1990). Safety considerations of the site should also be considered and where a particular community of beach users is predicted to be hostile or aggressive, wardening by volunteers may not be an option. Instead, a site such as this may require a range of educational activities to build connection among community members, coupled with the presence of authorised officers at the site to reinforce site restrictions. Site wardens can also be employed at sites to gather fine-scale temporal resolution about what disturbance events the colony faces and timing of these events and to help determine if additional real-time management responses are required (D. Rogers, pers. comm.).

Timing and suggested frequency

It may be that a site only experiences high human use at particular times of day, of the week or year, and the wardening roster should be formed around these peak times of use. The best timing for wardens is typically on weekends, public holidays and over the summer holiday period so that they can interact with large

numbers of visitors at once and protect the nesting site during peak visitation (Smith, 1990). Where possible, it is also good to have a warden on a few early morning or evenings during the week to interact with regular, local beach users, in particular people walking their dog before or after work hours. In some instances (i.e. those sites with high recreational use), wardens will be present daily at the nesting site once breeding activity has been observed and will be present until the colony has departed the area (Smith, 1990). It is important to consider warden burn out and adjust the amount of wardening hours, or number of wardens available to call upon, to improve the well-being of volunteers if required. Wardens can be implemented at nesting sites anytime throughout the active nesting period if disturbance levels begin to adversely impact the colony.

Advantages

- Wardening of colonies can have a significant positive impact on breeding success. For example, the breeding success rate of Little Terns increased from 0.1 fledgling/pair prior to sites having wardens to 1.1 fledgling/pair after wardens were instated (Lloyd et al., 1975).

- Wardens can engage with more members of the public to raise awareness of the species and educate beach users and answer their questions on site which can lead to the creation of a groundswell of local community interest (D. Rogers, pers. comm.).

- Presence of wardens can increase compliance regarding dog restrictions and prohibited areas around nesting colonies (K. O'Brien, pers. comm.).

- Potential to collect more data for the nesting colony and site including breeding success, threats present and causes of nesting failure.

- Potential to collect information about peak times of beach use and then adapt the wardening roster (and management methods) to reflect this.

- Full-time wardens enable a timely response to disturbance events and mitigation of threats in real time (Brooks et al., 2011).

Disadvantages

- Requires funding to employ someone, otherwise is reliant on dedicated volunteers to be present throughout the breeding season. Volunteers would still require support or coordination and this should not be underestimated.

- Wardening can involve potentially negative interactions with beach users and this can take its toll on the well-being of volunteers and can require substantial investment in training in communications and conflict resolution techniques.

- Usually wardens don't hold the relevant authority to enforce compliance thus require law enforcement officials to issue penalties (Brooks et al., 2011).

- Daily monitoring by wardens has caused instances of nest predation (Murray & Reside, 1995).

- Wardening may not prevent nest failures despite increased vigilance (D. Rogers, pers. comm.).

- Untrained wardens with poor communication styles can polarise the community and damage future education efforts with beach users that have been interacted with (G. Maguire, pers. comm.).

Case studies

South Australia:

An attempt was made to use volunteer-based site wardens at the Murray Mouth Fairy Tern colonies during the initial breeding attempt who were logistically supported by the SA NPWS (e.g. boat use) and were coordinated by a NPWS Ranger Ecologist (D. Rogers, pers. comm.). Wardens were scheduled to visit the site at least once a day however, this was limited by volunteer availability and did not always occur (D. Rogers, pers. comm.). A fox-related nesting failure was detected by wardens within 12 hours of the event occurring (D. Rogers, pers. comm).

In February 2023, site wardens were used at the Murray Mouth Fairy Tern nesting site during works to remove 15 decommissioned dredging pipes. Wardens were tasked with monitoring the breeding colony including the recently hatched chicks while machinery entered the site to safely remove the pipes (K. Bartley, pers. comm.). This included checking the pipes for chicks prior to removal and ensuring no birds were in the way of the operational machinery. An onsite information session was provided to the staff from Maritime Constructions who were undertaking the works and who provided transport for the volunteer site wardens (K. Bartley, pers. comm.).

Checking the decommissioned pipes for Fairy Tern chicks at the Murray Mouth breeding site prior to their removal from the area (photo: K. Bartley).

Victoria:

From 1979 until 2005, a site warden was employed full time from October/November to March to protect Little Tern breeding colonies in Gippsland and implement the East Gippsland Little Tern management strategy and was at times assisted by volunteers (Reside et al., 1989; Owen, 1990; DSE, 2003). The warden regularly visited all of the known breeding sites with particular focus to those sites with the largest and most vulnerable colonies (Owen, 1990). The duties of the warden including maintenance of signs and fencing, public liaison and distribution of educational pamphlets, supervision of volunteers and colony monitoring (Owen, 1990). Volunteers who were assisting the site warden to help protect breeding colonies from disturbance and raise awareness through public education were typically present at all of the major nesting sites from 8 am to 8 pm each day (Owen, 1990). The presence of a warden at nesting sites early in the breeding season was considered

critical to ensure breeding success. In 1991, employed wardens were appointed as authorised officers under Section 83 of the Conservation, Forests and Lands Act 1987 and the Wildlife Act 1975 to enable indemnity when they were exercising their powers and functions under the relevant Acts (Owen, 1991). A volunteer community group, The Little Tern Taskforce, was formed and active from the late 1980s to 2005 to assist the wardens in the management and monitoring of Little Tern nesting sites (Reside et al., 1989; Owen, 1990; DSE, 2003). During the 1990s, volunteer wardens were also recruited from Ballarat University to help warden sites in East Gippsland for 2 week periods (Schipper & Mitchell, 1999).

New South Wales:

The majority of Little Tern nesting sites have established volunteer warden programs in conjunction with community education campaigns aiming to raise public awareness around the conservation status, biology and recovery efforts of the Little Tern (Keating & Jarman, 2004). The site wardens are generally volunteers with support from Department staff (Smith, 1990; Keating & Jarman, 2004). Volunteer wardens have previously utilised a roster system to ensure colonies are watched all-day during the summer holiday period (Smith, 1990).

New Zealand:

During the breeding season, both full-time paid and volunteer site wardens have been utilised to help protect all of the Fairy Tern nesting sites in an attempt to protect breeding birds from predators and human disturbance (Brooks et al., 2011). Wardens are generally present at sites between late-September to mid-February (Brooks et al., 2011). The Department of Conservation (DOC) funds the contract wardens typically for five days a week (including the weekends), while volunteers (who are under the direction of DOC) are present on the remaining two days (Brooks et al., 2011). Wardens in conjunction with the management program are important to the success of chicks fledging (Brooks et al., 2011).

Recommendations

- Site wardens are valuable commodities to have at sites which get very busy and are prone to high levels of disturbance.

- It is important to consider the social dynamics of the community for the site to be wardened. If the community has already been polarised around the issue, or there is an element of anger about the presence of the birds, use of volunteer wardens should be avoided and investment in community education plus patrols by authorised officers should be carried out to improve community connectedness to the issue. Only if volunteer wardens can be supported by paid wardens and safety assurances, should their involvement be considered.

- Site wardens must be adequately supported to ensure their well-being and effectiveness in the role. This means ongoing support from a coordinator and access to training in communications and conflict resolution.

Site Closures

Beach use by the general public peaks at the same time as the breeding season for threatened beach-nesting birds, including Fairy and Little Terns. As previously mentioned, repeated human-related disturbance events at beaches and other coastal sites can cause nesting terns to abandon a nesting site. In some instances, it may be essential to temporarily close a nesting site to the public to protect a vulnerable nesting colony in an effort to increase breeding success (DECC, 2008). Cove beaches, estuaries, small islands and small peninsulas benefit the most from temporary site closures, as these sites correspond to sites where human recreation pressures are the most heavily concentrated and where nesting birds have the least amount of room to adapt to disturbance and pedestrian traffic. They are also more logistically feasible for closure implementation.

Implementation

Site closures are often a controversial management option, requiring consultation and the full support of the land manager. Closures should be seasonal and dependent on the presence of a nesting colony. All efforts need to be made to inform beach users about the reason for the temporary closure and signs should be installed at the site explaining the reason for the closure (DECC, 2008). Site wardens or volunteers can help reinforce the site closure by communicating with the public the reasoning behind the closure and can report breaches to the relevant authority in real-time. The public should also be made aware when the site re-opens.

Decision-making trigger

Temporary closure of a site to the public is determined by the presence of a nesting colony at a site which experiences high levels of human-related disturbance, where the level of disturbance is likely to cause nesting failure and site abandonment. Consequently, the closure of the site is expected to contribute to a greater probability of breeding success.

Timing and suggested frequency

During the breeding season in response to the establishment of a nesting colony at a priority or heavily disturbed site. Closed sites should re-open once nesting has concluded.

Advantages

- Minimises human-related disturbance to the nesting colony increasing breeding success.
- Can also reduce disturbance to other beach-nesting birds present at the site, as well as other waterbirds that utilise the site for roosting and/or feeding.
- Can assist with limiting avian predator opportunities for predation, as often Silver Gulls for example can take the opportunity of human disturbance to predate the nest.
- Can be easier to implement when there is a single point of access such as for a peninsula.
- Social acceptance of the site closure can be improved when there is a nearby, alternative area for their desired recreational activities.

Disadvantages

- Excluding people from public land is often hard to police and enforce.
- Can be challenging to physically close off if the site morphology has multiple access points.
- Can be controversial and politically contentious.
- Requires regular patrols to ensure compliance thus is labour-intensive and expensive.

Case studies

Western Australia:

Point Walter has been used as a nesting site for Fairy Terns each breeding season since 2015 and is a well established 'hotspot' for breeding birds (C. Greenwell, pers. comm.). The site is co-managed by Parks and Wildlife (DBCA) and the City of Melville which manages the vegetation on the islet (C. Greenwell, pers. comm.). Due to the importance of this site to breeding Fairy Terns, it is pre-emptively closed around October each year, accompanied by temporary signage and fencing, to prevent disturbance of breeding Fairy Terns (C. Greenwell, pers. comm.). The closed section of the sandbar is approximately 200 m in length. The fencing is installed across the islet, extending into the water, to act as a barrier to walkers coming along the sandbar (C. Greenwell, pers. comm.). Along with temporary signage installed at the beginning of the sandbar and at the fence, floating marker buoys are also installed to prevent boats and kayaks from landing on the islet (C. Greenwell, pers. comm.). Compliance has improved greatly over time, with members of the community having been observed calling out to people when they go beyond the fence (C. Greenwell, pers. comm.). Closure of the site is promoted through the City of Melville's social media accounts and in their newsletter (C. Greenwell, pers. comm.).

Pre-emptive site closures occur on Carnac Island, Green Islets and Wedge Island if Fairy Terns are observed above the high tide mark (C. Greenwell, pers. comm.). This pre-emptive closure has not always occurred, but Parks and Wildlife staff have suggested that this measure has increased the breeding at these sites, potentially due to reduced disturbance in the early site selection/egg-laying period (C. Greenwell, pers. comm.). Parks and Wildlife install 'NO ACCESS' and 'Fairy Tern' signs advising people that DBCA has closed the site under regulation 44. At Green Islets, additional floating marker buoys are installed to prevent people landing on the beach (C. Greenwell, pers. comm.). Compliance can be difficult to police due to accessibility (only accessible by boat and staff resources are limited; C. Greenwell, pers. comm.). Successful colonies in some years at these sites indicate that these measures are effective (C. Greenwell, pers. comm.).

South Australia:

On the Younghusband Peninsula, it was found that 81% of artificial Hooded Plover (*Thinornis cucullatus*) nests were run over by off-road recreational vehicles. Furthermore, chicks shelter in the wheel ruts with up to 30% of chicks likely to be crushed (Buick & Paton, 1989). Consequently, an annual beach closure occurs from 24 October to 24 December primarily to protect breeding Hooded Plover. However, all shorebirds, including breeding Fairy Terns have benefited from this management action (Baker-Gabb & Manning, 2011; DENR,

2011). Site closure is advertised through signage at landing points and compliance is enforced by the Coorong NPWS Park Rangers through regular patrols (K. Bartley, pers. comm.). Site closures have resulted in the hatching of Fairy Tern eggs (K. Bartley, pers. comm.).

Queensland:

Purtaboi Island is an important seabird breeding site, including for small terns. Since 1996, the site is closed annually from 1st October through to 31st March to protect the tern breeding grounds due to the growing number of visitors to the island and associated disturbance caused to nesting colonies (Stokes et al., 1996).

Recommendations

- Closures should be implemented with a full communication plan in place including providing advanced notice of closure to the public if known (i.e. if the site is used annually for breeding) and its purpose. This should include awareness of alternative nearby locations that beach users can use for recreation.

- Invest in monitoring of compliance with the site closure and adapt communications and strategies where needed. This is likely to include the need for patrols of the site by authorised officers, particularly in the first year/s of the site closure implementation.

Public Education

The breeding season of Fairy and Little Terns coincides with peak coastal use throughout summer. Unless previously exposed to terns, the majority of beach users are unlikely to be aware of their threatened status and the fact that they breed on beaches/coastal areas. Furthermore, they may not be aware of how their behaviour can negatively impact the breeding success of these colonies.

Educating the public about beach-nesting birds is fundamental to bringing about positive social change and to maximising the effectiveness of protective management actions implemented at nesting sites (Maguire, 2008). Public education around the conservation of beach-nesting birds, including terns, should focus on promoting the sharing of the shore – that is co-existence between recreationists and the breeding requirements of the birds. This message encourages positive, low impact beach usage allowing people to continue to enjoy coastal areas while reducing disturbance to nesting birds (DECC, 2008; BirdLife Australia Beach-nesting Birds Program).

Implementation

All management plans should feature a communication strategy to maximise the likelihood of breeding success at a site which requires community education to elicit behavioural changes (Baker-Gabb & Manning,

2011). This strategy should identify target audiences (e.g. the general community, tourists, school/community/coastal groups, land managers), the target message/s (i.e. issues needing to be addressed to minimise the threats to the nesting colony) and the most suitable communication method to convey the desired message (Baker-Gabb & Manning, 2011). Often a combination of communication methods are used throughout the breeding season to communicate these messages and to enhance the audience reach. It is important to ensure that all communication and messages are positive to maximise compliance and that they don't come across as imposing.

Numerous methods can be used to educate the public about the conservation status, breeding requirements and management activities of Fairy and Little Terns. Written information includes pamphlets, stickers, posters, newspaper or newsletter articles, website content and social media posts. Pamphlets can be handed out at nesting sites by site wardens or volunteers or at workshops or local events such as festivals. Local businesses near nesting sites, such as caravan parks, bait shops, information centres and council offices, can stock pamphlets or other written resources. Posters can be placed on community noticeboards or in windows of local businesses. Community awareness of conservation and management activities can be enhanced through radio and television interviews, which has the potential to reach a broader audience (Keating & Jarman, 2004). Targeted workshops, school visits and public talks can further promote local awareness of nesting terns. A presence at local community events such as festivals and farmers markets, with a stall offering tern-related craft activities (e.g. colouring in sheets, badge making, bag painting) can assist in reaching a broader audience.

Decision-making trigger

Public education should accompany any management activities occurring at breeding sites to ensure beach users are aware of the plight of the species and of any local management activities being implemented (Smith, 1990). The cooperation and support of the public is crucial to the success of these management activities.

Timing and suggested frequency

Public awareness and education is best conducted just prior to the breeding season (in areas where the terns consistently breed) to prepare the community for their arrival, as well as during the breeding season when the public are more likely to encounter breeding birds during their outings or at least come across the signage.

Public awareness events such as workshops, as well as the production/distribution of educational resources, should be conducted annually in areas where Fairy and Little Terns nest to ensure continued community awareness of the presence of nesting threatened species and reminders of best-practice behaviours around nesting colonies.

Advantages

- Raises awareness of threatened species and the threats they face and can encourage volunteer participation in monitoring (Baker-Gabb & Manning, 2011; C. Greenwell, pers. comm.; K. Bartley, pers. comm.).

- Can bring about positive social changes by changing change people's behaviour and perception, reducing disturbance to nesting birds and interference with nests (Keating & Jarman, 2004; Maguire, 2008; Baker-Gabb & Manning, 2011).

- Enhances the explanation of on-ground managements and increases familiarity with these and knowledge of desired behaviours.

- Increases community stewardship and stakeholder engagement (C. Greenwell, pers. comm.; R. Andrews, pers. comm.).

Disadvantages

- Resources can be time-consuming to create and costly to produce (C. Greenwell, pers. comm.).

- Despite the clear messages and restrictions portrayed to beach users, including information about dog restrictions, members of the public may not comply with the instructions (Baker-Gabb & Manning, 2011). In other words, education alone is not enough to produce compliance results and needs to be coupled with a range of methods to result in behavioural change.

Case studies

Western Australia:

During the breeding season, the City of Mandurah conducted a letterbox drop in the community near an active Fairy Tern colony with the aim of informing the public of the colony and listing instructions on how to keep the colony safe (e.g. keep your dogs away from the colony, keep your cats inside) which helped to increase community awareness of the local colony (C. Greenwell, pers. comm.).

An educational event was run in association with the Port Bouvard Surf Lifesaving Club to engage kids during a surf carnival. Kids were able to learn how to use scopes and binoculars while looking for and learning about Fairy Terns. This resulted in several kids becoming unofficial wardens for the breeding colony. In one instance, these kids were observed informing a local researcher that she shouldn't be inside the fenced area due to the presence of threatened Fairy Terns (C. Greenwell, pers. comm.).

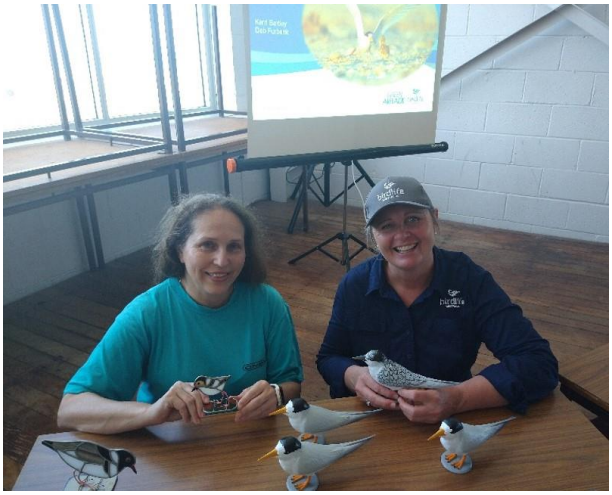
South Australia:

In the Coorong, tour operators are provided monthly updates regarding nesting Fairy Tern colonies which has increased support for the implemented management actions from this sector with some tour operators even wanting to assist with monitoring (Baker-Gabb & Manning, 2011; DENR, 2011).

In November 2022, a series of six Fairy Tern breeding interpretive signs were installed on Bird Island, Outer

Installing interpretative signage at Fairy Tern breeding sites to engage and inform boaters and fishers (photo: K. Bartley).

Harbor to engage and inform boaters and fishers to keep out of the breeding area in an effort to reduce disturbance to the nesting colony (K. Bartley, pers. comm.). In January 2023, National Parks and Wildlife and Limestone Coast Board staff met onsite at the Murray Mouth Fairy Tern breeding site to install temporary signage and exclusion fencing to engage and inform beach users and boaters visiting the area.



Using life-sized models of Fairy Terns at community presentations to enhance community awareness and assist with identification (photo: K. Bartley).

A Fairy Tern presentation including information about their ecology and distribution in South Australia was held at the Henley Sailing Club in November 2022. The aim of the information session was to raise awareness, engage the local community and encourage new volunteers to join the Fairy Tern monitoring program on Bird Island (K. Bartley, pers. comm.). A beach-nesting birds presentation including the Bird Island Fairy Tern monitoring program was also given to the 2022-23 Coastal Ambassadors participants in November 2022 resulting in one new volunteer signing up to join the volunteer monitoring team on Bird Island (K. Bartley, pers. comm.). Life-sized models of Fairy Terns in various plumages (breeding, non-breeding, juvenile) were used to enhance community awareness of these birds and assist with identification.

Victoria:

As part of the community education program in Gippsland in the late 1980s to mid-1990s, the local newspaper featured a *Ternwatch* column providing information each breeding season on the Little Tern colonies in the area (Owen, 1990; Murray & Reside, 1995; Schipper & Mitchell, 1999). Pamphlets and posters were also distributed at local milk bars and caravan parks to help inform and raise awareness of the tern colonies amongst the general public (Schipper & Mitchell, 1999). A '*Shorebirds on the beach*' diorama was also created and put on display at several locations around the Gippsland region during the summer months which was a huge hit with the community, garnering a lot of attention (Reside et al., 1994).

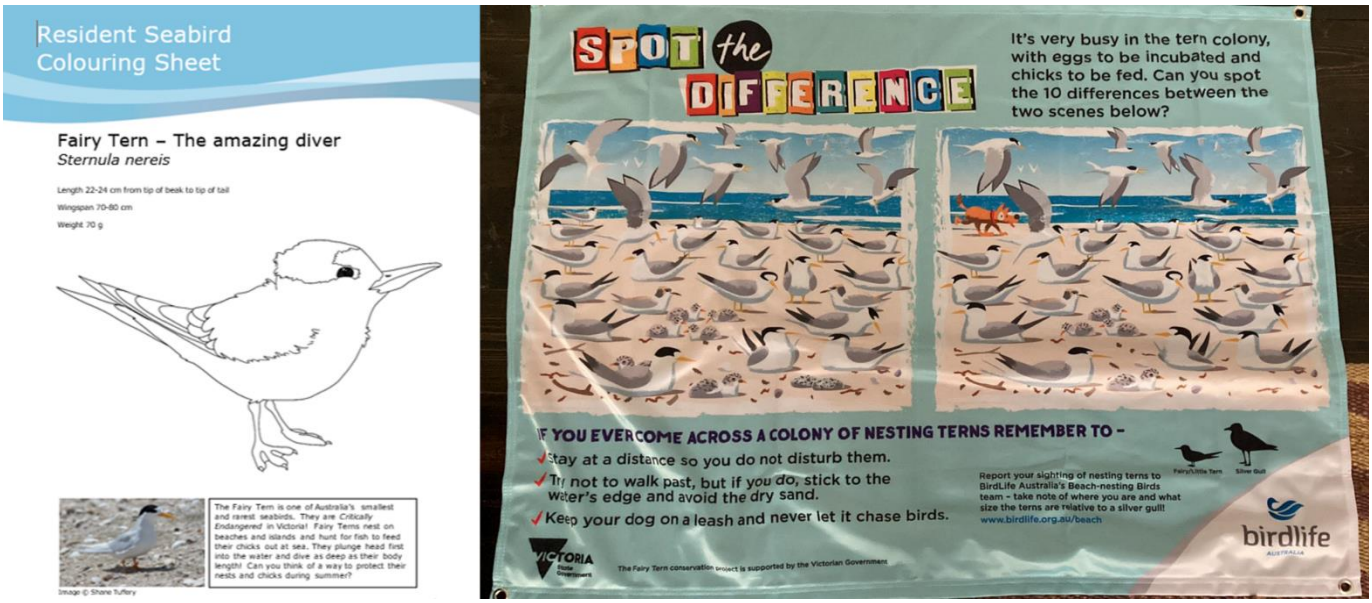
As part of the Victorian Fairy Tern project, several educational resources have been developed to engage different stakeholders and community groups. An identification guide '*MyTern: A pocket guide to the terns of Australia*' has been developed and distributed widely throughout Australia to aid with the identification of Australia's tern species. These pocket guides are distributed at workshops and presentations as well as provided to various organisations for further circulation among community groups including Friends groups, Parks Victoria branches and local environmental clubs.

A waterproof '*Boating, fishing and birding*' flip guide has been developed to engage recreational boat users and fishers aiming to enhance awareness, identification and reporting of Fairy and Little Tern sightings during the breeding season as well as providing advice on how they can implement safe boating practices around nesting seabirds. This key community group was targeted as they have the potential to greatly aide conservation efforts in real-time through the regularity of being out on the water more so than volunteers and project staff thus reporting sightings that may otherwise be missed. The flip guides have been distributed at boat ramps as well as stocked at several local bait shops located near known nesting sites, and at several public events and festivals throughout the breeding season (e.g. Sea Days Festival, Women in Recreational Fishing event days). Electronic versions of the flip guide are available through the Beach-nesting Birds Hub (https://beachvol.birdlife.org.au) or by request to the Beach-nesting Birds team and feature on the websites of several marine-based Victorian organisations (e.g. Boating Vic, Maritime Safety Victoria). A tern educational sticker has also been produced and handed out at events in association with the flip guide with the aim to help with tern identification and increase reporting rates.

The front cover of the waterproof flip guide targeted at recreational boaters and fishers (photo: A. Adams).

The educational sticker distributed at public events to aide in Fairy and Little Tern identification (photo: A. Adams).

Another resource that has been developed for the educational toolkit are '*Spot the Difference*' tern fabric banners (measuring 0.9 m x 1.2 m). Based on the traditional 'spot 10 differences' between two pictures game, these banners depict two beach scenes with 10 differences between the two pictures. This has been a fun way to engage (and educate) both kids and adults alike at public events, with many a competition being had between family members and friends. Colouring sheets consisting of an outline of a cartoon Fairy Tern accompanied with some Fairy Tern facts are also available to help engage and educate children at events.



The colouring sheet and '*Spot the Difference*' tern banner used at public events (photo: G. Maguire).

Several 3D-printed and hand painted life-sized models of adult and juvenile Fairy Terns also accompany project staff at workshops and public events to further assist with Fairy Tern identification and to demonstrate how small these birds are (as the majority of public members that engage with project staff or volunteers at events commonly mis-identify Fairy Terns as Crested Terns as do not realise how small Fairy Terns are).

Life-sized 3D printed and hand painted adult and juvenile Fairy Tern models used at public events and workshops (photo: S. Lee).

Recommendations

- An active community education program should exist at all locations where breeding occurs as the public's support for the conservation of different bird species is directly related to their knowledge of that species' existence and status (Maguire, 2008).

- Educational materials should take on several forms and be specifically tailored to the target audience. Messages contained in these resources should be clear and written in a friendly, easy to read style and be attention grabbing and engaging.

- Any face-to-face public events should be well advertised to ensure community turnout on the day and be well stocked with resources to distribute.

References

Adams, A. (2020). *BirdLife Australia's guidelines for monitoring nesting success of Fairy Terns*. BirdLife Australia, Carlton, Victoria.

Alluvium. (2020). *Sand renourishment effectiveness for small tern habitat in the Gippsland Lakes.* Unpublished report by Alluvium for the East Gippsland Catchment Management Authority, Victoria.

Andrews, J. (2020). *EG1617.1.330: Managing threatened terns in the Gippsland Lakes. Project tern 07/02/18 to 30/06/2020. End of project report*. Unpublished report for the Department of Environment, Land, Water and Planning, Victoria.

Babcock, M. & Booth, V. (2020). *Tern conservation best practice. Habitat creation and restoration*. Roseate Tern Life Project, U.K.

Baker-Gabb, D. & Manning, C. (2011). *Local action plan for the Coorong Fairy Tern Sternula nereis South Australia*. Final Plan for the Department of Environmental and Natural Resources, South Australia.

Barrett, G. (2022). Fairy Terns on Boundary Island. *Bushland News*, **123**: 5.

Baxter, C.I. (2003). Banded Stilt *Cladorynchus leucocephalus* breeding at Lake Eyre north in year 2000. *South Australian Ornithologist,* **34**: 33-56.

Beveridge, N. (2018). *New Zealand fairy tern (tara-iti) project*. Media release available from https://www.forestandbird.org.nz/projects/new-zealand-fairy-tern-tara-iti-project-0 (accessed 7.10.22).

Bishop, J.J., Ross, G.A. & Ryall, S. (2009). *Management of Little Tern, Sterna albifrons, at Towra Spit Island, Botany Bay, N.S.W. Season 2008/2009*. Unpublished report for the NSW National Parks and Wildlife Service, Hurstville, New South Wales.

Brooks, J., Davis, A., Baird, K., Bellingham, M. & Zimmerman, R. (2011). *Issues and options for the conservation and recovery of the critically endangered New Zealand Fairy Tern*. Technical Report for the Royal Forest and Bird Protection Society of New Zealand, New Zealand.

Buick, A.M. & Paton, D.C. (1989). Impacts of off-road vehicles on the nesting of Hooded Plovers *Charadrius rubricollis* in the Coorong region of South Australia. *Emu*, **89**: 159-172.

Burness, G.P. & Morris, R.D. (1992). Shelters decrease gull predation on chicks at a Common Tern colony. *Journal of Field Ornithology*, **63**: 186-189.

Campbell, J. & Christie, M. (2009). *Population status of the Little Tern Sterna albifrons and the Fairy Tern S. nereis in the lower South East of South Australia.* Unpublished report for the Department of Environment and Heritage volunteer support grants programme, South Australia.

Catry, T., Ramos, J.A., Catry, I., Allen-Revez, M. & Grade, N. (2004). Are salinas a suitable alternative breeding habitat for Little Terns *Sterna albifrons*? *Ibis*, **146**: 247-257.

Christens, E. Blokpeal, H., Rason, G. & Jarvie, S.W.D. (1995). Spraying white mineral oil on Canada Goose eggs to prevent hatching. *Wildlife Society Bulletin*, **23**: 228-230.

Cullen, M., Wilson, C., Mead, R. & Maguire, G. (2020). *Seven seasons of monitoring Hooded Plover breeding success on the Fleurieu Peninsula, South Australia 2009/2010 – 2015/16*. BirdLife Australia report, Carlton, Victoria.

Dann, P. & Baird, B. (1997). An experiment: a study of egg loss in Hooded Plovers on Phillip Island. *Stilt*, **31**: 54.

Department of Agriculture, Water and the Environment (DAWE) (2020). *National Recovery Plan for the Australian Fairy Tern (Sternula nereis nereis)*. Department of Agriculture, Water and the Environment, Canberra. Available from http://www.dcceew.gov.au/environment/biodiversity/threatened/publications/recovery/fairy-tern-2022.

Department of Conservation (DoC). (2020). *New nests for New Zealand's most endangered bird*. Media release available from https://www.doc.govt.nz/news/media-releases/2020-media-releases/new-nests-for-new-zealands-most-endangered-bird/ (accessed 7.10.22).

Department of Environment and Natural Resources (DENR) (2011). *Murray Mouth bird nesting habitat rescue final report 2010-2011*. Unpublished report for the Department of Environment and Natural Resources, Adelaide.

Department of Sustainability and Environment (DSE) (2003). *Action statement 51 – Little Tern Sterna albifrons sinensis*. Available from: https://www.environment.vic.gov.au/__data/assets/pdf_file/0024/32874/Little_Tern_Sterna_albifrons_sinensis.pdf.

Dunlop, N. (2018). *Fairy Tern (Sternula nereis) conservation in south-western Australia*. Second Edition. Conservation Council (WA): Perth.

Dunn, J. & Jorgensen, A. (2007). *South Coast Shorebird recovery newsletter - Sharing the Shoreline*. National Parks and Wildlife Service, New South Wales.

Dunn, J. & Jorgensen, A. (2008). *South Coast Shorebird recovery newsletter - Sharing the Shoreline 2007/08 season*. National Parks and Wildlife Service, New South Wales.

Erwin, R.M., Allen, D.H. & Jenkins, D. (2003). Created versus natural coastal islands: Atlantic waterbird populations, habitat choices, and management implications. *Estuaries*, **26**: 949-955.

France, T. (2006). Use of predator exclusion cages (PEC) at Hooded Plovers' nests at Yalgorup Lakes 2005/2006. *Western Australia Bird Notes*, **117**: 11-12.

France, T. (2007). Use of predator exclusion cages (PEC) with Hooded Plovers' nests at Yalgorup Lakes 2005/2006. *Western Australia Bird Notes*, **122**: 11-14.

Fraser, N. (2017). Observations of Little Tern nesting at Winda Woppa, Port Stephens, 2016-2017. *The Whistler*, **11**: 15-25.

Fremantle Ports. (2019). *Fairy Tern sanctuary ready for breeding season*. Available from https://www.fremantleports.com.au/news/fairy-tern-sanctuary-ready-for-breeding-season (accessed 20.01.23).

Fremantle Ports. (2022). *Fairy Terns*. Available from https://www.fremantleports.com.au/environment-safety/supporting-wildlife-research/fairy-terns (accessed 20.01.23).

Fujita, G., Totsu, K., Shibata, E., Matsuoka, Y., Morita, H., Kitamura, W., Kuramoto, N., Masuda, N. & Higuchi, H. (2009). Habitat management of Little Terns in Japan's highly developed landscape. *Biological Conservation*, **142**: 1891-1898.

Golder, W., Allen, D., Cameron, S. & Wilder, T. (2008). *Dredged material as a tool for management of tern and skimmer nesting habitats*. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Greenwell, C., Calver, M.C. & Loneragan, N.R. (2019). Cat gets it tern: A case study of predation on a threatened coastal seabird. *Animals*, **9**: 445.

Guilfoyle, M.P., Fischer, R.A., Pashley, D.N. & Lott, C.A. (2006). *Summary of first regional workshop on dredging, beach nourishment and birds on the south Atlantic coast*. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Haddon, P.C. & Knight, R.C. (1983). *A guide to Little Tern conservation*. World Wildlife Fund, Royal Society for the protection of birds, Bedfordshire, UK.

Harrison, S.J. (2010). *Interactions between Silver Gulls (Larus novaehollandiae) and Southern Bluefin Tuna (Thunnus maccoyii) aquaculture in the Port Lincoln area*. PhD thesis, Flinders University, South Australia.

Higgins, P.J. & Davies, S.J.J.F. (Eds.) (1996). *Handbook of Australian, New Zealand and Antarctic Birds. Volume 3: Snipe to Pigeons*. Oxford University Press, Melbourne.

Hill, R. (1990). *A strategy for the conservation of the Little Tern in Australia*. Australian National Parks and Wildlife Service.

Hill, R. & Montague, D. (1985). *A report on the management of the Little Tern (Sterna albifrons placens) in East Gippsland, Victoria, during 1984/85*. Unpublished report for the Department of Conservation, Forests and Lands, Bairnsdale, Victoria.

Hill, R., Bamford, M., Rounsevell, D. & Vincent, J. (1988). *Little Terns and Fairy Terns in Australia*. An RAOU Conservation Statement. RAOU Report no 53, Melbourne.

Jarman, M. (2006). *South Coast Shorebird recovery newsletter - Sharing the Shoreline*. National Parks and Wildlife Service, New South Wales.

Jeffries, D. & Brunton, D.H. (2001). Attracting endangered species to safe habitats: responses of Fairy Terns to decoys. *Animal Conservation*, **4**: 301-305.

Jenkins-Jay, N. (1982). Chick shelters decrease avian predation in Least Tern colonies on Nantucket Island, Massachusetts. *Journal of Field Ornithology*, **53**: 58-60.

Johnston, G.R. (2018). *Colony breeding birds of Bird Island and the northern revetment at Outer Harbour, South Australia, July 2015-June 2018*. South Australian Department of the Environment and Water; Adelaide, South Australia.

Keating, J. & Jarman, M.R. (2002). *South Coast shorebird recovery program breeding season 2001-2002*. Unpublished report, NSW National Parks and Wildlife Service, Narooma and Ulladulla New South Wales.

Keating, J. & Jarman, M.R. (2003). *South Coast shorebird recovery program breeding season 2002/2003*. Unpublished report, NSW National Parks and Wildlife Service, Narooma and Ulladulla New South Wales.

Keating, J. & Jarman, M.R. (2004). *Little Terns in New South Wales, a six year review, breeding seasons 1998/99 to 2003/04*. Unpublished report for the Department of the Environment and Conservation, New South Wales.

Keating, J. & Jarman, M.R. (2006). *South Coast shorebird recovery program: breeding season 2005/2006*. Unpublished report for the NSW National Parks and Wildlife Service, Narooma and Ulladulla New South Wales.

Knight, R.C. & Haddon, P.C. (1982). Little Tern (*Sterna albifrons*) in England and Wales 1977-79, with details of conservation work carried out at Rye Harbour local nature reserve. *Seabird Report*, **6**: 71-85.

Kress, S.W. (1983). The use of decoys, sound recordings, and gull control for re-establishing a tern colony in Maine. *Colonial Waterbirds*, **6**: 185-196.

Lane, B.A. (1981). The Hooded Plover survey, October 1980. *Victorian Wader Study Group Bulletin*, **3**: 6-8.

Liebezeit, J.R. & George, T.L. (2002). *A summary of predation by corvids on threatened and endangered species in California and management recommendations to reduce corvid predation*. Species Conservation and Recovery Program Report 2002-02, California Department Fish and Game, Sacramento, California.

Lloyd, C.S., Bibby, C.J. & Everett, M.J. (1975). Breeding terns in Britain and Ireland in 1969-74. *British Birds*, **68**: 221-237.

Maguire, G. (2008). *A practical guide for managing beach-nesting birds in Australia*. Birds Australia, Melbourne.

Maguire, G.S., Duivenvoorden, A.K., Weston, M.A. & Adams, R. (2011). Provision of artificial shelter on beaches is associated with improved shorebird fledgling success. *Bird Conservation International*, **21**: 172-185.

Maguire, G., Ekanayake, K., Cullen, M., Mead, R. & Rhodes, L. (2018). *Ten years of Hooded Plover recovery on the Bellarine Peninsula and Surf Coast: An overview and future recommendations*. BirdLife Australia report, Carlton, Victoria.

Martin, J.M., French, K. & Major, R.E. (2007). The pest status of Australian White Ibis (*Threskiornis molucca*) in urban situations and the effectiveness of egg-oil in reproductive control. *Wildlife Research*, **34**: 319-324.

Melvin, S.M., McIvor, L.H. & Griffin, C.R. (1992). Predator enclosures: a technique to reduce predation at Piping Plover nests. *Wildlife Society Bulletin*, **20**: 143-148.

Minton, C. (1988). Terns. *Victorian Wader Study Group Bulletin*, **12**: 29.

Montague, D. (1984). *Report on Little Tern Sterna albifrons management in East Gippsland 1983/84*. Unpublished report for the Fisheries and Wildlife Division, Victoria.

Morris, A.K. (1979). The declining status of the Little Tern in New South Wales. *Corella*, **3**: 105-110.

Murphy, R.K., Michaud, I.M.G., Prescott, D.R.C., Ivan, J.S., Anderson, B.J. & French-Pombier, M.L. (2003). Predation on adult Piping Plovers at predator exclosure cages. *Waterbirds*, **26**: 150-155.

Murray, A. (2000). *DRAFT - A five year strategy for the management of Little Tern, Sterna albifrons sinensis in far East Gippsland, Victoria 2000/2001 – 2004/2005*. Unpublished report, Victoria.

Murray, A.J. & Reside, J. (1995). *Management of the Little Tern (Sterna albifrons) in Victoria 1994/95.* Unpublished report for the Department of Conservation and Natural Resources, Bairnsdale, Victoria.

National Parks and Wildlife Service (NPWS) (2019*). Shorebird recovery newsletter South Coast. Sharing the Shoreline 2018/19 season*. National Parks and Wildlife Service, New South Wales.

Newnham, R. & Murray, A. (1994). *Little Tern (Sterna albifrons sinensis) habitat enhancement project on Goodwin Sands*. Unpublished funding proposal, Victoria.

Northern Advocate. (2015). *Protection put on beaches for tern*. Available from: https://www.nzherald.co.nz/northern-advocate/news/protection-put-on-beaches-for-tern/EFZ4ICWM6C5XBSXKTTY6IX3LZY/ (accessed 3/10/2022).

NSW National Parks and Wildlife Service (NSW NPWS) (2003). *Little Tern (Sterna albifrons) Recovery Plan*. NSW National Parks and Wildlife Service, Hurstville.

Owen, R. (1990). *A report on the management of Little Terns (Sterna albifrons) in the Bairnsdale region during the 1989/90 breeding season*. Unpublished report for the Department of Conservation and Environment, Bairnsdale, Victoria.

Owen, R. (1991). *A report on the management of Little Terns (Sterna albifrons) in the Bairnsdale region during the 1990/91 breeding season*. Unpublished report for the Department of Conservation and Environment, Bairnsdale, Victoria.

Pakanen, V-M., Hongell, H., Aikio, S. & Koivula, K. (2014). Little tern breeding success in artificial and natural habitats: modelling population growth under uncertain vital rates. *Population Ecology*, **56**: 581-591.

Pauliny, A., Larsson, M. & Blomqvist, D. (2008). Nest predation management: effects on reproductive success in endangered shorebirds. *Journal of Wildlife Management*, **72**: 1579-1583.

Priddel, D. & Ross, G.A. (1996). *Monitoring of Little Terns Sterna albifrons in Botany Bay: Seasons 1993/94 to 1995/96*. Unpublished report for the NSW National Parks and Wildlife Service, Hurstville, New South Wales.

Ratcliffe, N., Pickerel, G. & Brindley, E. (2000). Population trends of Little and Sandwich Terns *Sterna albifrons* and *S. sandvicensis* in Britain and Ireland from 1969 to 1998. *Atlantic Seabirds*, **2**: 211-226.

Ratcliffe, N., Schmitt, S., Ayo, A., Tratalos, J. & Drewitt, A. (2008). Colony habitat selection by Little Terns *Sternula albifrons* in East Anglia: implications for coastal management. *Seabird*, **21**: 55-63.

Reside, J., Willoughby, L. & Whillance, L. (1989). *A report on the management of Little Terns (Sterna albifrons) in East Gippsland during the 1988/89 breeding season*. Unpublished report for the Department of Conservation, Forests and Lands, Bairnsdale, Victoria.

Reside, J., Newnham, R. & Murray, A. (1994). *Little Tern (Sterna albifrons) management during the 1993/94 breeding season in Gippsland, Victoria*. Unpublished report for the Department of Conservation and Natural Resources, Bairnsdale, Victoria.

Ross, G.A. & Jarman, M.R. (2001). *Monitoring of Little Terns Sterna albifrons at Towra Spit Island, Botany Bay, NSW: Season 2000/2001*. Unpublished report for the NSW National Parks and Wildlife Service, Kurnell, New South Wales.

Schipper, C. & Mitchell, P. (1999). *The breeding activity of the Little Tern, Sterna albifrons sinensis, and other shorebirds at managed sites in East Gippsland during summer 1997-8 and 1998-9*. Unpublished report for the Department of Natural Resources and Environment, Bairnsdale, Victoria.

Skira, I.J. & Wapstra, J.E. (1990). Control of Silver Gulls in Tasmania. *Corella*, **14**: 124-129.

Smith, P. (1990). *The biology and management of Little Tern (Sterna albifrons) in NSW*. Species Management Report No 1. NSW National Parks and Wildlife Service, Hurstville, New South Wales.

Smith, J. & Smith, H. (2001). *Report on the Little Tern (Sterna albifrons) breeding season 2000/2001 Glenelg River Estuary Nelson*. Unpublished report, Victoria.

Stokes, T., Hulsman, K., Ogilvie, P. & O'Neill, P. (1996). Management of human visitation to seabird islands of the Great Barrier Reef Marine Park region. *Corella*, **20**: 1-13.

Sullivan, D. (2019). *Gippsland Lakes tern monitoring 2018-19*. Unpublished report by BirdLife Australia, Carlton, Victoria.

Sullivan, D. (2020). *Gippsland Lakes tern monitoring 2019-20*. Unpublished report by BirdLife Australia, Carlton, Victoria.

Swan, A. (1977). Tern nesting at Rams Island – A conservation problem. *The Bird Observer*, **544**: 19.

Treadgold, S.J. (2000). *Behavioural ecology of the endangered New Zealand Fairy Tern (Tara-iti) Sterna nereis davisae: implications for management*. Unpublished Masters thesis, Massey University, Palmerston North. Available from: https://mro.massey.ac.nz/handle/10179/7614.

Urquhart, M. & Teoh, V. (2001). *Strategies for the management of the Hooded Plover in Victoria*. Unpublished report for Parks Victoria, Melbourne.

Von Holle, B., Irish, J.L., Spivy, A., Weishampel, J.F., Meylan, A., Godfrey, M.H., Dodd, M., Schweitzer, S.A., Keyes, T., Sanders, F., Chaplin, M.K. & Taylor, N.R. (2019). Effects of future sea level rise on coastal habitat. *The Journal of Wildlife Management*, **83**: 694-704.

Waldegrave-Knight, L., Moss, B., Rolland, T., Mitchell, P., Murray, A., Taylor, S. & Turner, L. (1997). *Report on the Little Tern (Sterna albifrons) breeding season 1996/7 – East Gippsland*. Unpublished report for the Department of Conservation and Environment, Bairnsdale, Victoria.

Weston, M.A. & Morrow, F. (2000). *Managing the Hooded Plover in western Victoria*. Threatened Bird Network report to Parks Victoria, Melbourne.

Willig, R. (1981). *A preliminary assessment of the status and distribution of terns in Victoria*. Unpublished report for the Fisheries and Wildlife Division, Victoria.

A breeding Fairy Tern with fish (photo: C. Greenwell).

Appendix A: Protocols for remote-sensing camera use at tern colonies

Rules of use

- Only use **one** camera per colony per season. This is because if a predator finds one nest, then sees another camera and finds another nest by it, then you have created a reward associated with the presence of cameras.

- If a raven/magpie takes a nest/s within the colony, do not use a camera at this site for at least a year (to avoid training predators to associate cameras with food).

- Cameras should not be installed during adverse weather conditions (i.e. high to gale force winds, temperatures exceeding 30°C, heavy rain).

- Prior to installation, you should monitor the nesting site to ensure that you are aware of any potential nests and make note of these locations to avoid accidental crushing of any eggs that may be present when you enter the site.

- The camera should ideally be installed when the colony is beginning to form and prior to egg-laying. The camera should be set up in the general locality of the colony, aiming for where the edge of the colony may occur. This also enables nests to be built around the camera. If nesting colonies are discovered post egg-laying, a camera can be installed on the edge of the colony to avoid accidental crushing of eggs/chicks and can face a particular nest/s as long as the view of the incubating adult/s is not obstructed and disturbance is kept to a minimum. If adults are extremely agitated, cease installation and move away from the nesting site.

- Do not place the camera within the middle of a nesting colony (this will prevent camera checks as you should not be walking within an active colony). If nests are built around the camera after it has been installed, you should not perform camera checks.

- After installation, make sure the colony returns to the nesting site, and if there are active nests, ensure that these birds return to incubate their nests to ensure that there isn't abandonment related to camera placement. If birds do not return to the nest after 20 minutes, you should remove the camera.

- Do not have the camera too high or on a stake that sticks up high – you do not want to create a predator perch immediate to the vicinity of any nests.

- Camera checks should only occur every 3-4 weeks and can include a SD card and battery swap. Please act as though there may be chicks about by walking super carefully and be aware that new nests may have been constructed since your previous visit. It is recommended to view the colony from a distance prior to approaching the area to visualise the birds on their nests and once confident all nest locations are known

to then slowly approach. SD card and battery changes must be made within the same approach and ideally take no more than 10 minutes.

- It is recommended to use at least a 16GB storage card due to the potential number of trigger events associated with a colony (i.e. multiple birds and nests).

- A small waterproof label should be stuck on the camera including the permit number and contact phone number.

Scout Guard cameras

The Scout Guard SG560K has a rear opening door, which holds a 5cm LCD screen, from which you can view your practice shots and configure the settings using the navigation buttons. It uses eight AA batteries to make sure the camera can last for an extended period of time in the field. It is recommended to use at least a 16GB SD card, to ensure the camera can hold as many photos as possible, and limits the number of times the camera is approached *in situ*. Cameras can only be approached a maximum of 3-4 weekly for battery and SD card changes.

Camera installation process using Scout Guard cameras:

Camera installation

1. Set up the camera when the colony is beginning to form or after egg-laying (if the colony was discovered during the egg-laying phase) and adults are incubating.

2. Ensure no predators are nearby when installing a camera.

3. Choose an appropriate location: if the colony is only beginning to form, this can be in the general locality of where the birds are prospecting/nest-scrape making; if the colony has eggs, the camera should be placed within 2 metres of the outer most nest of the colony. Be careful not to create too many footprints leading up to the nesting area and brush over your footprints after deployment.

4. If possible, place the camera close to natural vegetation, debris, rocks etc which is within 2 metres of the nest. This is to limit visibility of the camera to the public and predators. Also, if possible, face the camera North or South, but not directly to the West or East as photos will be over-exposed by the sunlight.

5. If there is no vegetation, driftwood etc that you can attach the camera to, you will need to use a stake.

6. Prior to approaching the colony area, ensure the camera has the batteries and SD card loaded.

7. Ensure that mounting strap/bracket and stake or mounting device are available prior to going onsite.

8. Load the SD card and batteries prior to approaching the colony.

9. If using a stake, hammer it in BEFORE strapping the camera on. Make sure the camera is as close to the ground as possible – we do not want the stake to become a predator perch.

10. Strap the camera onto the stake.

Camera settings

11. Open the camera, turn the switch to SETUP.

12. Wait for the screen to load, then press the MENU button.

13. The "left/right" arrow keys allow you to move from one setting parameter to another. Use the "up/down" arrows to select alternative settings and when completed hit "OK" to save and continue to systematically scroll to different menus by using the "left/right" until all parameters are set. Check all the settings are correct (see table below).

    Our settings:

Parameter	**Setting**
Image size	5M
Capture number	3 images
Interval	1 second (lowest number available)
Sense level	High
Time stamp	On
Timer switch	Off
Set mode	Save

14. Any parameters which do not appear above, press the RIGHT ARROW to skip and move to the next parameter.

15. When setting timestamp, make sure to set the time by pressing OK and changing time/date using the "up/down" arrow keys.

16. DO NOT FORMAT THE CARD unless instructed to do so.

17. Once all settings are loaded, close the camera.

18. Take a preview image to ensure the camera is capturing the focal area.

19. TURN THE CAMERA ON. Wave a stick or your hand at the level of the nest to make sure that the sensors are triggering when there is movement.

20. Open the camera, and change to SETUP. Press OK and the up/down arrows to preview the images taken making sure images have been taken and the camera is working.

21. Close the camera up and TURN THE CAMERA ON.

22. Hold up a piece of paper for 20 seconds in front of the camera that displays the date, time and colony location plus START (use a dark texta if possible).

23. When changing the SD card or batteries, turn the camera OFF and then back ON once the swap has been completed.

Camera retrieval

24. When you collect the camera, hold up a piece of paper for 20 seconds in front of the camera that says the date, time and colony location plus END.

25. Open the camera and turn it OFF.

26. Take camera off stake, vegetation or natural debris. If attached to a stake, ensure stake is collected.

27. Once offsite, download the photos into a folder that is labelled by date and location.

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Thank you

Photos: Top: I. Forsyth; bottom: S. Tuffery.

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