

Endangered Species Research

Manuscript:	ENSR-2020-09-008/R3 RESUBMISSION
Title:	Social facilitation for conservation planning: understanding Fairy Tern behaviour and site selection in response to conspecific cues
Authors(s):	Claire Greenwell (Corresponding Author), Kate Born (Co-author), Ryan Admiraal (Co-author), Amanda Hodgson (Co-author), James Dunlop (Co-author), Neil Loneragan (Co-author)
Keywords:	Conservation behaviour, Laridae, managed site, seabird restoration, sensory ecology
Type:	Research Article

Social facilitation for conservation planning: Understanding Fairy Tern behavior and site selection in response to conspecific audio-visual cues

Greenwell, C.N.^{1,2†}, Born, K.S.³, Admiraal, R.⁴, Hodgson, A.^{1,2}, Dunlop, J.N.^{1,3} & Loneragan, N.R.^{1,2}

¹Conservation and Environmental Sciences, College of SHEE, Murdoch University, 90 South Street, Murdoch, Western Australia, 6150, Australia

²Centre for Sustainable Aquatic Ecosystems, Harry Butler Institute, Murdoch University, 90 South Street, Murdoch, Western Australia, 6150, Australia

³Conservation Council of Western Australia, Lotteries West House, 2 Delhi Street, West Perth, Western Australia, 6150, Australia.

⁴Victoria University of Wellington, School of Mathematics and Statistics, Kelburn Parade, Wellington, 6012, New Zealand.

† Corresponding author: c.greenwell@murdoch.edu.au

ABSTRACT

Simulated social facilitation techniques (e.g. decoys and call playbacks) are commonly used to attract seabirds to restored and artificially created nesting habitats. However, a lack of social stimuli and conspecific cueing at these habitats may limit the use of these sites, at least in the short term. Therefore, testing the effectiveness of simulated audio-visual cues for attracting gregarious birds is important for conservation planning. In this study we: 1) assessed whether call playback and decoys were associated with an increased likelihood of Australian Fairy Terns, *Sternula nereis nereis*, visiting potentially suitable nesting habitats; 2) tested their behavioural response to different cues; and 3) documented whether social facilitation had the potential to encourage colony establishment. A full cross-over study design consisting of all possible pairings of decoy and call playback treatments (control [no attractants], decoys, call playback, decoys and playback), allocated as part of a random block design, was undertaken at two sites. Linear modelling suggested that call playback was important in explaining the time spent aerial prospecting as well as the maximum number of Fairy Terns aerial prospecting, although this only appeared to be the case for one of the two sites. Decoys, on the other hand, did not appear to have any effect on time spent aerial prospecting. The results from this study

1 suggest that audio cues have the potential to encourage site selection by increasing social
2 stimuli, but attractants may be required over several breeding seasons before colonies are
3 established.

4
5 **Keywords:** Conservation behaviour; Laridae; managed site; seabird restoration; sensory
6 ecology
7

8 1. INTRODUCTION

9 Coastal systems, with their complex mosaic of shallow water habitats and shorelines of
10 varying geomorphology, support rich floral and faunal communities worldwide and are
11 important breeding and feeding sites for an array of birds. Despite the importance of these
12 environments, growing human populations and the associated demand for housing, ports and
13 marinas, and recreational amenities has led to significant reductions in habitat and resource
14 availability, driving population declines among coastal bird communities (Yasué et al. 2007,
15 Pakanen et al. 2014).

16 The threats to coastal birds during the breeding season are numerous and include both
17 climate and anthropogenic-driven pressures. Managed sites, where interventions, such as
18 habitat enhancement and predator control, are undertaken to improve breeding success
19 (Greenwell et al. 2019a, 2020), may become increasingly important within urban environments
20 (e.g. Jenniges & Plettner 2008; Fujita et al. 2009). However, remedial works and site
21 engineering can be costly (Hecht & Melvin 2009) and restored or artificially created sites may
22 not be immediately utilized because of an absence of social stimuli and conspecific cueing
23 (Boulinier et al. 1996).

24 Given the potential for colony- and nest-site selection to affect individual fitness, birds
25 use complex strategies to select breeding sites, including environmental and social cues (Cody
26 1985). Among gregarious birds, social facilitation, i.e. where the behaviour of one individual

1 increases the probability of other animals engaging in that same behavior, at colony sites is
2 often used to assess habitat quality and an individual's chance of reproductive success –
3 proximate cues for nest site selection (Gochfeld 1980, Boulinier et al. 1996, Kress 1997,
4 Danchin et al. 1998). Social facilitation behavior may be especially important among coastal
5 gulls and terns, who are known to periodically shift colony sites between breeding attempts
6 (Dunlop 1987, Gochfeld & Burger 1992, Dunlop & Greenwell 2020).

7 Simulated social facilitation techniques, such as the use of conspecific audio-visual cues
8 (e.g. call playback and decoys), offer a powerful opportunity to influence animal behavior,
9 including occupancy at restored or created habitats (James et al. 2015, Friesen et al. 2017),
10 particularly among species, like seabirds, that have behavioral and life-history traits that rely
11 on strong sensory signaling (Kress & Nettleship 1988, Kress 1997, Friesen et al. 2017). A study
12 by James et al. (2015) showed that call playback could be used to manipulate the distribution
13 of amphibians within previously unoccupied ponds, offering a habitat restoration tool for
14 threatened species conservation. Conspecific cues have also been used to successfully restore
15 numerous seabird colonies (e.g. Roseate Terns, *Sterna dougallii*, Arctic Terns, *Sterna*
16 *paradisaea*, and Common Terns, *Sterna hirundo*, [Kress 1983, 1997]). When combined with
17 appropriate habitat management and predator controls, they offer great potential to improve
18 long-term conservation outcomes. However, the effectiveness of simulated audio-visual stimuli
19 can vary between species (reviewed by Friesen et al. 2017). Therefore, understanding the
20 drivers of site selection for the target species and assessing the efficacy of simulated social
21 facilitation techniques is an important step for conservation planning.

22 The Fairy Tern, *Sternula nereis*, is listed as threatened (Vulnerable), because of
23 decreasing population trends over much of its breeding range in recent decades (BirdLife
24 International 2018, Commonwealth of Australia 2019). Fairy Terns typically nest on sheltered
25 bays, coastal lagoons, sand spits or lacustrine islands (Higgins & Davies 1996, Johnstone &

Storr 1998, Dunlop 2018), habitats that are also highly valued for human use. To overcome a lack of natural nesting sites and to reduce disturbance at breeding colonies, managed sites, combined with social facilitation techniques, may be an effective strategy for improving nesting success (Dunlop 2018, Greenwell et al. 2020). Social facilitation to encourage site selection at secure or managed nesting sites has been identified as a possible ‘local conservation strategy’ to improve population trends under the *Draft National Recovery Plan for the Australian Fairy Tern, *Sternula nereis nereis** (Commonwealth of Australia 2019).

The first objective of this study was to determine whether audio-visual cues would increase the likelihood of attracting Australian Fairy Terns, *Sternula nereis nereis* (hereafter Fairy Terns) to an area of potentially suitable nesting habitat, and if so, which cue would attract the strongest behavioral response. It was hypothesized that a combination of auditory and visual cues would elicit the strongest response compared to either visual or audio cues used in isolation and control treatments. Call playback was expected to provide a strong initial cue and draw attention to the site, while decoys were likely to encourage settlement through visual cueing. The second objective was to determine whether social facilitation had the potential to encourage Fairy Tern colony establishment and egg-laying at two managed sites (Mandurah and Garden Island) in temperate south-western Australia (Fig. 1), historically important nesting sites for the species.

2. METHODS

2.1 Study sites

The first study site was located in Mandurah (32° 31'14.24" S, 115° 43'0.26" E) and is managed by the local government authority, the City of Mandurah. Fairy Terns have a long-known history of nesting in the lower reaches of the Peel-Harvey Estuary, Mandurah, likely because of the abundance of potential fish prey in the system and adjacent coastal waters. For

1 many years, Fairy Terns nested at the mouth of the estuary, but this land has since been
2 developed as part of the Mandurah Ocean Marina precinct (Dunlop 2016). Over the past decade,
3 Fairy Terns have attempted to nest on a number of estuarine islands (Boundary, Channel,
4 Creery, Len Howard and Mandurah Quay Islands) and at Nairns beach, near the mouth of the
5 Serpentine River (Fig. 1). However, these nesting attempts have failed, primarily because of
6 increased high-tide levels and summer storm surge events (Dunlop 2016). In 2015/16 and
7 2016/17, nesting attempts were made on vacant development blocks within the Mandurah
8 Marina Precinct. However, few chicks fledged, possibly as a result of high disturbance levels
9 or predation (Dunlop 2018, Greenwell et al. 2019a; Corker, C, pers. comm.)

10 In 2017, the Mandurah Fairy Tern breeding site was established to overcome a lack of
11 secure, flood-free breeding sites available to Fairy Terns in the region. The site (~ 1,500 m²)
12 has a uniform elevation of ~ 3.0 m above sea-level and is separated from the adjoining beach
13 by a ~ 1.5 m high limestone rock sea wall. The perimeter of the site is fully enclosed with chain-
14 wire fencing, lined with shade-cloth. A layer of shell material was added to the ground surface
15 by land managers to enhance its attractiveness to Fairy Terns. Black Rats, *Rattus rattus*, were
16 not detected in the area prior to the commencement of breeding but baits were deployed along
17 the adjoining sea wall as a precautionary measure. During the 2017/18 breeding season
18 (October to January), decoys were deployed at the site in an attempt to attract mature breeding
19 adults. *Ad-hoc* observations indicated that the birds were not interested in the site, despite the
20 presence of the decoys. On 2 October 2018, prior to the start of our study, adult Fairy Terns in
21 advanced nuptial breeding plumage (i.e. solid black head cap and bright orange bills and legs,
22 indicating a readiness for breeding), were observed landing on the seawall and beach adjacent
23 to the Fairy Tern site.

24 The second site is located at Garden Island (32° 14' 31.92" S 115° 41' 36.3372" E), a
25 listed place on the Commonwealth Heritage List and a Commonwealth military base (HMAS

1 Stirling) managed by the Department of Defense. Garden Island is a historically important
2 breeding site for Fairy Terns with records of colonies at various sites across the island, including
3 the Causeway, a traffic bridge that provides access to the island from the mainland (Higgins &
4 Davies 1996, Dunlop 2016). Reproductive success varies greatly from year to year.
5 Occasionally, entire colonies are lost through colony inundation and egg burial during summer
6 storms, and mortality arising from vehicle strike has been recorded when birds nest on the edge
7 of the Causeway (Dunlop 2016; Davies, G., Department of Defence, pers. comm.). Garden
8 Island has also been identified as an important pre-breeding night roost location for Fairy Terns
9 (see Dunlop & Greenwell 2020).

10 In 2018, a managed site was established on Garden Island for Fairy Terns in an attempt
11 to improve breeding outcomes and discourage nesting on the Causeway. The site (~ 3,500 m²)
12 has a uniform elevation of ~ 3.0 m above sea-level and is separated from the adjoining beach
13 by a ~ 1.5 m high, vegetated sand dune. A limestone rock wall, which adjoins a road, runs
14 parallel to the dune, along the entire length of the site on the opposite side. A layer of shell
15 material was added to the ground surface by land managers to enhance its attractiveness to Fairy
16 Terns. A baiting program was undertaken in 2019 after Black Rats were detected in the area, to
17 reduce the potential for egg depredation. During the 2018/19 breeding season (October to
18 January), before this study commenced, decoys were deployed on the site, however, *ad-hoc*
19 observations indicate that no interest was shown by the terns.

21 2.2 Study design

22 Conspecific call playback (audio cues) and decoys (visual cues) were used at Mandurah
23 and Garden Island to determine whether these sensory-based cues increase the likelihood of
24 attracting Fairy Terns to an area of potential nesting habitat. A cross-over study design was

adopted in order to measure the behavioral response of terns to different cues. This design consisted of all possible pairings of decoy and call playback treatments (control [no attractants], decoys only, call playback only, decoys and call playback), allocated as part of a random block design (Table 1).

The study was carried out between 06:15 and 08:15 on 5 – 19 October 2018 and 7 – 30 October 2019 at Mandurah and Garden Island, respectively, corresponding with the typical prospecting and early egg laying period of Fairy Terns. Six, four-day blocks were planned for each site, but on 19 October 2018, a Fairy Tern was observed incubating an egg at the Mandurah site. As a result, the social facilitation treatment was stopped due to the need for the egg to be incubated, which would bias further observations. As a consequence, the behavioral response of Fairy Terns at Mandurah was limited to three full blocks.

The length of time that any individual from a group of terns spent (1) flying above the site, or (2) on the ground was measured using two stop watches to produce separate timing intervals for each activity. Timing commenced when terns either flew over or landed on the site. Stop watches were left running for as long as any individual remained either over the site or on the ground, allowing the time interval of each landing and aerial-prospecting event to be recorded separately. Observations on the maximum number of birds present and the duration of each landing or aerial prospecting event were made over a continuous 120 min observation period on consecutive days from a vantage point outside the study area. Note that a lack of distinguishing features between birds precluded individuals being counted. The cumulative time that Fairy Terns spent on the ground (landing events), or in the air over the site (aerial prospecting events) each day, was calculated for the two sites and is used as the sampling unit in this study.

2.3 Decoys and audio recordings

1 Models of Least Tern (Mad River Decoys, Audubon Society) were hand-painted to
2 replicate the nuptial plumage of breeding adult Fairy Terns (Fig. 2). A conspecific-vocalization
3 recording, obtained from a Fairy Tern colony in Bunbury (~ 120 km south of Mandurah, Fig. 1)
4 during the 2017/18 breeding season, was edited using Wavepad software to increase its
5 amplitude, remove Silver Gull, *Chroicocephalus novaehollandiae*, vocalizations and remove the
6 first and last segment of the recording to ensure that only settled colony call playbacks were
7 used. The recording (~ 50 min long) was then loaded onto an MP3 player (Apple iPod) and set
8 to loop.

9 Conspecific call playback was played using a 15-watt Toa broadcast megaphone
10 modified with input socket for MP3 attachment. The megaphone was positioned at the edge of
11 the study site in the surrounding vegetation and call playbacks were projected up and over the
12 site. On the days that decoys were deployed, 10 were spaced 1.5 m apart in a combination of
13 singles (8) and pairs (2), to reflect natural conditions observed within a colony (Burger 1988,
14 Fig. 3). A social experiment on the closely related Least Tern, *Sternula antillarum*, showed that
15 terns were attracted to larger groups and preferred to land where decoys were more spaced out
16 (1.5 m vs. 0.5 m), landing in the center of the group rather than the edge (Burger 1988). Singular
17 decoys may provide a cue for single birds to settle and acquire mates, while established decoy
18 pairs may provide a cue for nest site-selection and colony stability (Burger 1988, Arnold et al.
19 2011).

20 In 2018, the removal of the decoys was hampered when Fairy Terns remained on the
21 ground of the Mandurah site at the conclusion of the observation period. To minimize
22 disturbance to birds prospecting the site, decoys were left in place until early the following
23 morning and removed prior to the commencement of the observation period, when decoy
24 treatments were not scheduled. At Garden Island in 2019, the process of removing decoys early
25 the following morning was repeated for consistency between the two sites. Wind speed and

direction data, at 30-minute intervals, were obtained from Bureau of Meteorology, and both average and maximum wind speed over the two-hour sampling period were calculated. In addition, the physical behavior of terns towards call playbacks and decoys was recorded in an *ad hoc* manner.

2.4 Statistical analyses

All statistical analyses were performed using R version 4.0.2 (R Core Team 2020). We investigated the relationship between (1) the time spent aerial prospecting and the two treatments (decoys and call playback) and (2) the maximum number of birds aerial prospecting and the two treatments in separate analyses. In both cases we fitted multiple linear regression models which included the two treatments and site as dummy variables and average wind speed and maximum wind speed as continuous explanatory variables. These models considered all possible interactions between the two treatment variables and site as well as interactions between site and wind speed variables. Residual plots highlighted the need to transform the time spent aerial prospecting (square root transformation, as identified using the “boxcox” function in the MASS package for R [Venables and Ripley 2002]) to produce greater compliance with the assumptions of linear regression. No transformation was required for the maximum number of birds aerial prospecting. Using the previously described explanatory variables and interactions, we performed an exhaustive model search to find the models minimizing second order Akaike information criterion (AIC_C , Akaike 1974, Hurvich and Tsai 1989) for each response variable (i.e. time spent aerial prospecting, maximum number of birds aerial prospecting). The “AICcmodavg” package for R was used in calculating AIC_C (Mazerolle 2020).

Birds landed on the site at Garden Island on only one day during the observation period, and only 12 days were recorded for landing time at Mandurah before a Fairy Tern was observed

1 incubating an egg. Considering the small number of days for which there was any (non-zero)
2 landing time data, our analysis of (1) landing time data and (2) maximum number of Fairy Terns
3 observed on the ground and the relationship between these outcomes and the treatments is
4 purely descriptive.

5 **3. RESULTS**

6 On average, the time Fairy Terns spent aerial prospecting or on landing events in
7 treatments with call playbacks (either with or without the decoys) was greater than in the control
8 and decoy-only treatments (Figs. 4, 5). However, there was substantially greater variability in
9 time spent aerial prospecting at Mandurah relative to Garden Island, particularly in the call
10 playback only treatment. Fairy Terns began aerial prospecting at both sites within 20 minutes
11 of the first call playback treatments and at Mandurah, terns began landing within 60 minutes.

12 An exhaustive model search based on minimising AIC_C was carried out for the response
13 of square root transformed aerial prospecting time using, as explanatory variables, the two
14 treatment variables (decoys, call playback), site, average wind speed, maximum wind speed, all
15 possible interactions between the treatment variables and site, and interactions between the
16 wind speed variables. The model minimising AIC_C included the call playback treatment, site,
17 maximum wind speed, a call playback treatment × site interaction, and a site × maximum wind
18 speed interaction (Table 2, adjusted $R^2 = 0.827$), and all of these terms, except the call playback
19 treatment × site interaction were in the top five models in terms of minimising AIC_C (Tables
20 S1 and S2). For this model, there was an estimated increase of 3.00 (95% CI = (0.58, 7.29))
21 minutes in time spent aerial prospecting when call playback was used on Garden Island,
22 controlling for maximum wind speed. No real call playback effect was evident for Mandurah,
23 however, with an estimated call playback effect of -0.57 (95% CI = (-10.85, 9.70)) on the square

1 root scale due to the call playback treatment $\times$ site interaction essentially negating the single
2 term call playback effect.

3 A similar exhaustive model search based on minimizing AIC_C but using the maximum
4 number of Fairy Terns prospecting as the response variable, led to selection of a model that
5 included single terms for the call playback treatment, site, and average wind speed variables, a
6 call playback treatment $\times$ site interaction, and a site $\times$ average wind speed (Table 3, adjusted
7 $R^2 = 0.848$). Site, average wind speed variables, and a site $\times$ average wind speed were in each
8 of the top five models based on minimizing AIC_C with the call playback treatment appearing in
9 three of these (Tables S3 and S4). For the model minimizing AIC_C (Table 3), there was an
10 estimated increase of 2.41 (95% CI = 0.31, 4.51) birds aerial prospecting when call playback
11 was used on Garden Island, controlling for average wind speed. Again, however, there does not
12 appear to be a real call playback effect for Mandurah (estimated decrease of -1.04 birds with
13 95% CI = (-4.03, 1.94)), with the call playback treatment $\times$ site interaction again essentially
14 negating the single term call playback effect.

15 **3.1 Mandurah**

16 The time spent aerial prospecting over Mandurah increased between the first and second
17 treatment blocks for all treatments (Fig. 5a). During the third treatment block, this increase was
18 followed by a sharp decline. The decline in aerial prospecting coincided with a cold front
19 producing ~ 32 km/h winds and rainy conditions on 14 October (call playback), and there was
20 an increase in the time spent on the ground on 16 October (playbacks and decoys).

21 Fairy Terns spent an average (± 1 SE) of 65.9 (± 6.6) min and 42.8 (± 21.6) min on the
22 ground in response to the call playback plus decoy treatment and call playback treatment,
23 respectively (Fig. 4b, 5c). In comparison, terns spent an average of 31.0 (± 13.9) min and 6.9
24 (± 1.5) min on the ground in response to decoy and control treatments, respectively (Fig. 4b).

When decoys were *in situ*, Fairy Terns were observed interacting with the models (Fig. 2), and terns were regularly observed walking towards or flying above the speaker when call playbacks were broadcast.

On 19 October 2018, a Fairy Tern was observed incubating an egg on the Mandurah site. The colony grew steadily in size over several weeks, and the site went on to support a colony that peaked at ~ 110 nests in late November 2018 (Greenwell et al. 2019a). While decoys remained *in situ*, no further call playback was used following the laying of the first egg. A second colony of terns was established on a beach ~ 50 m away from the managed site on 30 October and peaked at ~ 40 nests in late November 2018 (Greenwell et al. 2019a).

3.2 Garden Island

On average, terns spent more time aerial prospecting over the site when call playback was used than the control or decoy-only treatments at Garden Island (Figs. 4a, 5b). Unlike Mandurah, Fairy Terns only landed on the Garden Island site on a single day – birds landed amongst the decoys during the playback plus decoy treatment on 20 October 2019, when two or three birds landed on three occasions for 15, 21, and 40 seconds. However, terns landed on the adjacent beach on six days (14, 16, 18, 19, 24, and 29 October) when call playbacks were used, and this location was in close proximity to the speaker. No landing events were recorded on control or decoy treatment days. Terns regularly hovered over the speaker projecting the call playback and were observed making low flights over the decoys when *in situ*.

Terns spent an average ($\pm$ SE) of 10.2 ($\pm$ 2.32) and 6.9 ($\pm$ 1.8) min flying over the site when call playback plus decoy and call playback-only treatments were used, respectively (Fig. 4a). In contrast, terns spent an average of 1.5 ($\pm$ 0.8) and 1.3 ($\pm$ 0.8) min over the site on decoy-only and control days, respectively (Fig. 4a). There was a general increasing trend in the time spent prospecting over the study period, except in block five when strong winds (33 km/h)

1 were recorded on 24 October (call playback plus decoy) and on 25 October during the call
2 playback-only treatment. A decrease in the time spent at the site was also observed in block 6
3 during the decoy treatment (Fig. 4).

4 Fairy Terns did not establish a colony at the Garden Island managed site during or after
5 the study period. Instead the birds selected an alternative and historically important breeding
6 site on Parkin Point, an expansive sandbar ~ 800 m away from the managed site. The first
7 colony on Parkin Point failed, likely due to egg depredation by Black Rats, *Rattus rattus*, and
8 possibly Ghost Crabs, *Ocypode* sp., with animal tracks of these species found around Fairy Tern
9 nests. However, Fairy Terns formed a second colony on an alternative part of the sandbar,
10 protected by coastal vegetation, and following rodenticide baiting, the site went on to support a
11 breeding colony of an estimated ~ 145 pairs that peaked in mid-late January 2020.

12 **4. DISCUSSION**

13 While settling decisions by prospecting Australian Fairy Terns varied between the two
14 study sites, the audio-visual cues elicited a strong behavioral response at previously unused
15 areas and resulted in egg laying at Mandurah. Overall, treatments with call playbacks stimulated
16 a stronger behavioral response than decoy-only or control treatments. Active colonies provide
17 information to prospecting birds about habitat suitability and the potential for individual
18 breeding success (Reed & Dobson 1993, Boulinier et al. 1996, Danchin et al. 1998). Therefore,
19 the use of audio-visual cues, particularly call-playbacks, which mimicked active breeding
20 colony sounds, provided an opportunity to influence Fairy Tern behavior (Friesen et al. 2017).
21 For species that breed in relatively ephemeral habitats, exhibit low site tenacity and have a
22 tendency to periodically shift colony sites, such as Fairy Terns (Dunlop & Greenwell 2020,
23 Greenwell et al. 2020), social cues may be strong drivers of site selection (Burger 1984,
24 Medeiros et al. 2012).

1 The results of this study, while limited in extent, appear consistent with those of Arnold
2 et al. (2011) who also highlight the importance of call-playbacks, compared to decoys for
3 attracting Common Terns, *Sterna hirundo*, in Massachusetts, USA. They suggested that ‘decoys
4 are likely to be a secondary cue signaling the presence of breeding conspecifics only in the
5 presence of sound’ (Arnold et al 2011). Decoys deployed at Mandurah and Garden Island in
6 the years prior to this study failed to attract prospecting Fairy Terns (see Methods), yet birds
7 began actively prospecting these sites within 20 minutes of call playbacks being used,
8 supporting the premise that call-playbacks are the primary cues needed to attract terns.

9 The results of the current study contrast with those of Jeffries & Brunton (2001), who
10 found that decoys attracted a significant behavioral response from New Zealand Fairy Terns,
11 *Sternula nereis davisae*, with or without playbacks. The reasons for the observed behavioral
12 differences between the two subspecies remain unclear, although decoy design and the origin
13 and type of conspecific call recordings used in the experiments may be important (see
14 ‘Management implications’ below). The differences in responses to artificial social facilitation
15 between subspecies highlight the importance of assessing species-specific responses when
16 efforts to improve reproductive success are required (reviewed by Friesen et al. 2017).

17 Marked differences in the time spent prospecting, settling behavior and colony site selection
18 were observed between the two sites at Mandurah and Garden Island. We propose four possible
19 factors that may have contributed to these differences, including reproductive phase, habitat
20 availability and past breeding experience at other suitable sites, and the influence of group
21 adherence behavior. During the pre-breeding period, attachment to potential colony sites is low
22 and prospecting bouts may be limited to a few birds visiting for brief periods before dispersing
23 (Greenwell et al. 2020). Over time, terns may begin alighting and engaging in site attachment
24 activities such as territory establishment and scraping (Dunlop 1987, Kress 1997, Greenwell et
25 al. 2020), but the timing of breeding likely coincides with a peak in prey availability (Monaghan

et al. 1989, Zuria & Mellink 2005, Paillisson et al. 2007). The rapid settling behavior at Mandurah, while unusual, may have been driven by individuals in an advanced reproductive stage, who were already utilizing a beach for courtship within close proximity (~ 50 m) of the site just prior to the study period (CNG, pers. obs.).

Conversely, at Garden Island, it is possible that terns were less advanced in their reproductive condition than those observed in Mandurah one year earlier or that their fish prey was not sufficiently abundant. At Garden Island in 2019, the number of breeding pairs peaked in mid-late January 2020 compared to a peak in late November in Mandurah in 2018. The timing of breeding varies widely between individuals and food availability in the lead up to the breeding period has the potential to affect the timing and success of reproduction (Regehr & Rodway 1999, Zuria & Mellink 2005, Kitaysky et al. 2007).

At Mandurah, the managed site is located within a historically important breeding area that has since been developed into a marina and terns have periodically nested on empty blocks, adjacent to the managed site. Therefore, strong area knowledge and historical use, and social stimuli and conspecific cueing associated with previous experience may have contributed to a stronger response by Fairy Terns already prospecting in the area (Boulinier et al. 1996), outweighing the simulated cues. On Garden Island, alternative habitat, i.e. a large sandbar (Parkin Point), located ~ 800 m away that is also used as a night roost, may have contributed to the terns on the island ultimately selecting this alternative site and birds showing less interest in the prepared managed site.

Finally, the origin of call playbacks obtained for this study may have contributed to the terns ultimately selecting an alternative site at Garden Island. Group adherence and the maintenance of strong alliances between groups of birds is, potentially, an important behavioral trait among Fairy Terns (Dunlop & Greenwell 2020), as has been shown for Least Terns and Common Terns (Austin 1951, Atwood & Massey 1988). Playback experiments performed in a

1 Least Tern colony in North Carolina showed that the temporal and spectral characteristics of
2 calls varied significantly between individuals, enabling the identification of mates (Moseley
3 1979). The individual recognition of associates and group adherence behavior may, therefore,
4 be an important cue in encouraging site selection, particularly during the early stages of colony
5 formation. Further research is required to elucidate whether the behavioral response of small
6 terns varies according to the origin of the playback call. That is, can the calls of birds from one
7 region be used to successfully encourage settlement of birds from another region or state, and
8 do locally sourced colony calls lead to increased settlement. It's also possible that different
9 decoy designs, such as recently developed, 3D-printed Fairy Tern models (shaunlee.co.nz), and
10 model eggs (visual cues) may influence the behavior of terns, topics for future research.
11 Anecdotal observations of early colony formation in Fairy Terns indicate that the presence of
12 eggs may provide a strong stimulus for prospecting individuals (C.N Greenwell, pers. obs.).

13 Social facilitation and the stimuli acting on gregarious species, such as the Fairy Tern,
14 have the potential to influence colony establishment, but may be dependent on a range of
15 interacting factors. While Fairy Terns did not select the Garden Island managed site for nesting,
16 this site has potential to be occupied in subsequent breeding seasons with further artificial social
17 facilitation. It is important to note that call playback was only utilized on two days within a
18 four-day block and was limited to a two-hour period in the morning over 24 days at this site. In
19 a restoration project involving Arctic Terns, *Sterna paradisaea*, and Common Terns, call
20 playbacks were broadcast for three years before a colony was formed (Kress 1983). Sightings
21 of terns increased two-fold within the first year of using call playbacks and decoys, and despite
22 not actively nesting on the site, terns were seen interacting with decoys and made nest scrapes
23 in the area of the decoys (Kress 1983). By the third year of using these attractants, a mixed
24 colony of Arctic and Common Terns formed (80 pairs) around the decoys and speaker, with
25 some of the early colonizers establishing nests < 10 cm from decoys (Kress 1983).

4.1 Management Implications

The behavioral response of Fairy Terns to artificial social facilitation over a relatively short period highlights the potential for call playback and, to a lesser extent, decoys to be used as a tool to encourage site selection by increasing social stimuli (Kress 1983). However, due to an absence of past experience at newly created sites, social facilitation may be required over several breeding seasons before colonies are established (Kress 1983, 1997). This may include the use of decoys and broadcasting call playbacks for at least several hours per day, particularly in the mornings when site prospecting activity is high (Dunlop 1987, Greenwell et al. 2020). Site-selection and the associated site threat profiles should be given careful consideration before social facilitation is undertaken to reduce the potential for terns to be attracted into ecological traps or sub-optimal habitats (Battin 2004, Ward et al. 2011). While habitats may provide the fundamental conditions necessary to encourage site selection, the inability of land managers to adequately mitigate the external influences that limit reproductive success may lead to reproductive failure (Ward et al. 2011, Greenwell et al. 2019b).

Increased anthropogenic pressures, including coastal development have the potential to fundamentally change coastal processes and the habitats that support birdlife. In some locations, dedicated managed sites may offer long-term solutions for coastal birds, like Fairy Terns. Managed sites e.g. North Fremantle (see Greenwell et al. 2019b), show the potential of dedicated nesting areas to maintain breeding aggregations and support reproductive success by overcoming a lack of natural habitat. However, the regular monitoring and management of site threat profiles to support the target species remains critical (Commonwealth of Australia 2019).

The maintenance and establishment of multiple sites, whether they are natural or artificially created, in areas of high human activity, is important. The availability of multiple sites will allow for the periodic shifting of colony locations over the years in response to changes in site suitability (e.g. food availability, habitat stability, disturbance, predation), an

important behavioral characteristic of Fairy Terns (Dunlop & Greenwell 2020, Greenwell et al. 2020).

Acknowledgements

We acknowledge the traditional owners of the Binjareb and Whadjuk Noongar country, upon whose lands we have had the great privilege of conducting this research. We extend our sincere thanks to members of the Western Australian Fairy Tern Conservation Network, including Alanna Smith, Alanna Wonders, Barbara Manson, Barbara Sing, Bel Matthews, Brett Newmarch, Caitlan Davis, Cherilyn Corker, Clara Obregon Lafuente, Elly Bentley, Jo Drew, Jorja Claybrook, Julie Knight, Kara Price, Kathleen Broderick, Maggie Duggan, Mal Beeton, Mary-Ann Rath, Peter Moore, Phil Auty, Phillip Moll, Robyn Bickell, Serin Sabaraj, Susie Stockwell and Tahlia Jones, who generously gave their time to assist with this research. We thank Rebecca Cassells and the City of Mandurah for their support and championing Fairy Tern management in the Mandurah region. To Georgia Davies, Kara Price, Mark Sweetman and Department of Defence staff at HMAS Stirling, thank you for your efforts to improve breeding outcomes for Fairy Terns on Garden Island. Thank you to Mike Calver for advice on the experimental design. Financial support for this project was provided by Stuart Leslie Bird Award & BirdLife Australia and the Holsworth Wildlife Research Endowment & Ecological Society of Australia. We are extremely grateful to the reviewers and handling editor, who provided constructive feedback to improve this manuscript. This research was conducted in accordance with Murdoch University Animal Ethics approval (Permit R3077/18).

References

- Akaike H (1974) A new look at statistical model identification. *IEEE Transactions on Automatic Control* 19(6):716-723.
- Arnold JM, Nisbet ICT, Veit R (2011) Assessing aural and visual cueing as tools for seabird management. *J Wildl Manage* 75:495–500.
- Atwood JL, Massey BW (1988) Site fidelity of Least Terns in California. *Condor* 90:389–94.
- Austin OL (1951) Group adherence in the Common Tern. *Bird-Banding* 22:1–15.

- 1 Battin J (2004) When good animals love bad habitats: ecological traps and the conservation of
2 animal populations. *Conserv Biol* 18:1482–1491.
- 3 BirdLife International (2018) Fairy Tern, *Sternula nereis*.
4 <http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22694691A132568135.en>.
5 (accessed 6 August 2019)
- 6 Boulinier T, Danchin E, Monnat J-Y, Doutrelant C, Cadiou B (1996) Timing of prospecting
7 and the value of information in a colonial breeding bird. *J Avian Biol* 27:252–256.
- 8 Burger J (1984) Colony stability in Least Terns. *Condor* 86:61–67.
- 9 Burger J (1988) Social attraction in nesting Least Terns: Effects of numbers, spacing, and pair
10 bonds. *Condor* 90:575–582.
- 11 Cody ML (1985) Habitat selection in birds. Academic Press.
- 12 Commonwealth of Australia (2019) Draft National Recovery Plan for the Australian Fairy
13 Tern (*Sternula nereis nereis*).
14 [https://www.environment.gov.au/biodiversity/threatened/recovery-plans/comment/draft-](https://www.environment.gov.au/biodiversity/threatened/recovery-plans/comment/draft-recovery-plan-australian-fairy-tern)
15 [recovery-plan-australian-fairy-tern](https://www.environment.gov.au/biodiversity/threatened/recovery-plans/comment/draft-recovery-plan-australian-fairy-tern)
- 16 Danchin E, Boulinier T, Massot M (1998) Conspecific reproductive success and breeding
17 habitat selection: Implications for the study of coloniality. *Ecology* 79:2415–2428.
- 18 Dunlop J (1987) Social behavior and colony formation in a population of Crested Terns,
19 *Sterna bergii*, in southwestern Australia. *Wildl Res* 14:529.
- 20 Dunlop JN (2018) Fairy Tern (*Sternula nereis*) conservation in south-western Australia, 2nd
21 ed. Conservation Council of Western Australia, Perth, Western Australia.
- 22 Dunlop JN (2016) Local Fairy Tern conservation strategy for the south west coastal region.
23 Perth, Western Australia.
- 24 Dunlop JN, Greenwell CN (2020) Seasonal movements and meta-population structure of the
25 Australian Fairy Tern in Western Australia. *Pacific Conserv Biol*.
- 26 Friesen MR, Beggs JR, Gaskett AC (2017) Sensory-based conservation of seabirds: a review
27 of management strategies and animal behaviours that facilitate success. *Biol Rev*
28 92:1769–1784.
- 29 Fujita G, Totsu K, Shibata E, Matsuoka Y, Morita H, Kitamura W, Kuramoto N, Masuda N,
30 Higuchi H (2009) Habitat management of little terns in Japan’s highly developed
31 landscape. *Biol Conserv* 142:1891–1898.
- 32 Gochfeld M (1980) Mechanisms and adaptive value of reproductive synchrony in colonial
33 seabirds. In: *Behavior of Marine Animals*. Burger J, Olla BL, Winn HE (eds) Springer
34 US, Boston, MA, p 207–270
- 35 Gochfeld M, Burger J (1992) Family Sternidae (Terns). In: *Handbook of the birds of the*
36 *world*. Hoyo J del, Elliott A, Sargatal J, Cabot J (eds) Lynx Edicions, Barcelona, p 624–
37 667
- 38 Greenwell CN, Calver MC, Loneragan NR (2019a) Cat gets its tern: A case study of predation
39 on a threatened coastal seabird. *Animals* 9:445.
- 40 Greenwell CN, Calver MC, Loneragan NR (2019b) Cat gets its tern: A case study of
41 predation on a threatened coastal seabird. *Animals* 9.
- 42 Greenwell CN, Dunlop JN, Admiraal R, Loneragan NR (2020) The secret life of Fairy Terns:
43 Breeding chronology and life history observations of *Sternula nereis nereis* in south-
44 western Australia. *Pacific Conserv Biol*.
- 45 Greenwell CN, Dunlop JN, Loneragan NR (2019c) Nest desertion: an anti-predator strategy
46 of the Australian Fairy Tern, *Sternula nereis nereis*. *Mar Ornithol* 47:197–201.
- 47 Hecht A, Melvin SM (2009) Expenditures and effort associated with recovery of breeding
48 Atlantic coast Piping Plovers. *J Wildl Manage*.
- 49 Higgins P, Davies SJJF (1996) Handbook of Australian, New Zealand and Antarctic birds.
50 Volume 3: snipe to pigeons. Oxford University Press, Melbourne, VIC; Auckland, NZ.
- 51 Hurvich CM, Tsai C-L (1989) Regression and time series model selection in small samples.
52 *Biometrika* 76(2):297–307.
- 53 James MS, Stockwell MP, Clulow J, Clulow S, Mahony MJ (2015) Investigating behaviour
54 for conservation goals: Conspecific call playback can be used to alter amphibian
55 distributions within ponds. *Biol Conserv* 192:287–293.
- 56 Jeffries DS, Brunton DH (2001) Attracting endangered species to ‘safe’ habitats: Responses
57 of fairy terns to decoys. *Anim Conserv* 4:301–305.

- 1 Jenniges JJ, Plettner RG (2008) Least Tern nesting at human created habitats in central
2 Nebraska. *Waterbirds* 31:274–282.
- 3 Johnstone RE, Storr GE (1998) Handbook of Western Australian Birds. Volume 1- non
4 passerines, Emu to Dollarbird. Taylor DL (ed) Western Australian Museum, Perth,
5 Western Australia.
- 6 Kitaysky AS, Piatt JF, Wingfield JC (2007) Stress hormones link food availability and
7 population processes in seabirds. *Mar Ecol Prog Ser* 352:245–258.
- 8 Kress SW (1983) The use of decoys, sound recordings, and gull control for a tern colony in
9 Maine. *Colon Waterbirds* 6:185–196.
- 10 Kress SW (1997) Using animal behavior for conservation: case studies in seabird restoration
11 from The Maine Coast, USA. *J Yamashina Inst Ornithol* 29:1–26.
- 12 Kress SW, Nettleship DN (1988) Re-establishment of Atlantic Puffins (*Fratercula arctica*) at
13 a former breeding site in the Gulf of Maine. *J F Ornithol* 59:161–170.
- 14 Mazerolle MJ (2020) AICcmodavg: Model selection and multimodel inference based on
15 (Q)AIC(c). R package version 2.3-1. <https://cran.r-project.org/package=AICcmodavg>.
- 16 Medeiros R, Ramos JA, Pedro P, Thomas RJ (2012) Reproductive consequences of nest site
17 selection by little terns breeding on sandy beaches. *Waterbirds* 35:512–524.
- 18 Monaghan P, Uttley JD, Burns MD, Thaine C, Blackwood J (1989) The relationship between
19 food supply , reproductive effort and breeding success in Arctic Terns *Sterna*
20 *paradisaea*. *J Anim Ecol* 1:261–274.
- 21 Moseley LJ (1979) Individual auditory recognition in the Least Tern (*Sterna albifrons*). *Auk*
22 96:31–39.
- 23 Paillisson JM, Reeber S, Carpentier A, Marion L (2007) Reproductive parameters in relation
24 to food supply in the Whiskered Tern (*Chlidonias hybrida*). *J Ornithol* 148:69–77.
- 25 Pakanen VM, Hongell H, Aikio S, Koivula K (2014) Little Tern breeding success in artificial
26 and natural habitats: modelling population growth under uncertain vital rates. *Popul Ecol*
27 56:581–591.
- 28 R Core Team (2020) R: A Language and environment for statistical computing. [http://www.r-](http://www.r-project.org/)
29 [project.org/](http://www.r-project.org/)
- 30 Reed JM, Dobson AP (1993) Behavioural constraints and conservation biology: Conspecific
31 attraction and recruitment. *Trends Ecol Evol* 8:253–256.
- 32 Regehr HM, Rodway MS (1999) Seabird breeding performance during two years of delayed
33 Capelin arrival in the northwest Atlantic: A multi-species comparison. *Waterbirds Int J*
34 *Waterbird Biol* 22:60–67.
- 35 Venables WN, Ripley BD (2002) Modern Applied Statistics with S. Fourth Edition. Springer,
36 New York.
- 37 Ward MP, Semel B, Jablonski C, Deutsch C, Giammaria V, Miller SB, McGuire BM (2011)
38 Consequences of using conspecific attraction in avian conservation: A case study of
39 endangered colonial waterbirds. *Waterbirds* 1:476–480.
- 40 Yasué M, Patterson A, Dearden P (2007) Are saltflats suitable supplementary nesting habitats
41 for Malaysian Plovers *Charadrius peronii* threatened by beach habitat loss in Thailand?
42 *Bird Conserv Int* 17:211–23.
- 43 Zuria I, Mellink E (2005) Fish abundance and the 1995 nesting season of the Least Tern at
44 Bahía de San Jorge, Northern Gulf of California, México. *Waterbirds* 28:172–180.
- 45

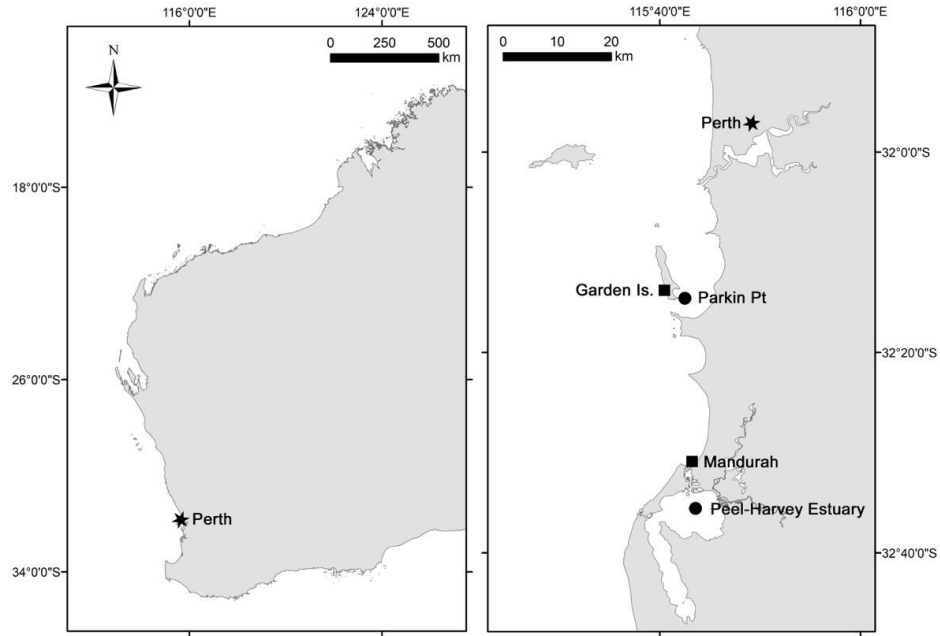


Figure 1. Locations of study (■) and historically important breeding (●) sites for Australian Fairy Tern, *Sternula nereis nereis*, studied along the south-western Australian coastline between 2018 and 2020.



Figure 2. Australian Fairy Terns, *Sternula nereis nereis*, interacting with “incubating” decoys (painted plastic models) at the Mandurah managed breeding site, south-western Australia in 2018.

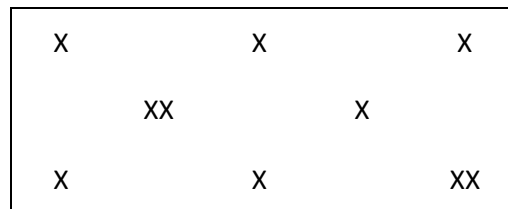
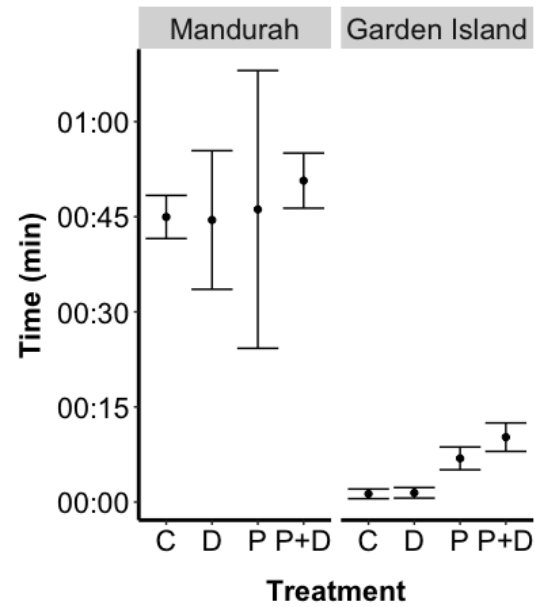


Figure 3. Arrangement of decoys shown by X with a 1.5 m spacing, at Mandurah and Garden Island managed Australian Fairy Tern, *Sternula nereis nereis*, breeding sites.

(a)



(b)

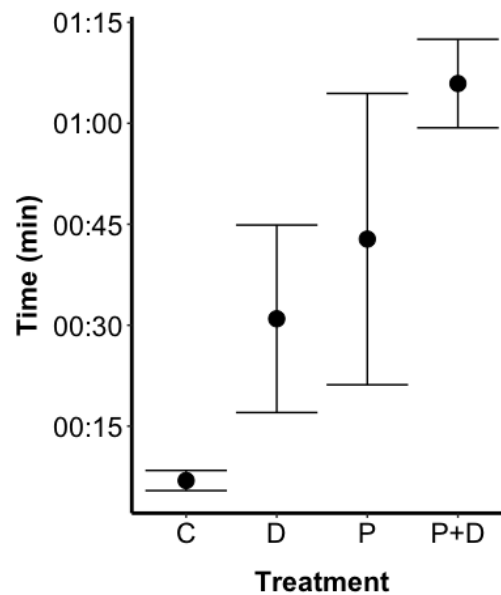


Figure 4. Behavioral response of the Australian Fairy Tern, *Sternula nereis nereis*, to conspecific audio-visual cues at a potentially suitable nesting site at Mandurah (2018) and Garden Island (2019) in different treatments. (a) mean cumulative time (± 1 standard error) spent aerial prospecting; and (b) mean cumulative time (± 1 standard error) spent on the ground at Mandurah. Treatments are: C = control, D = decoys, P = call playback, P + D = call playback and decoys.

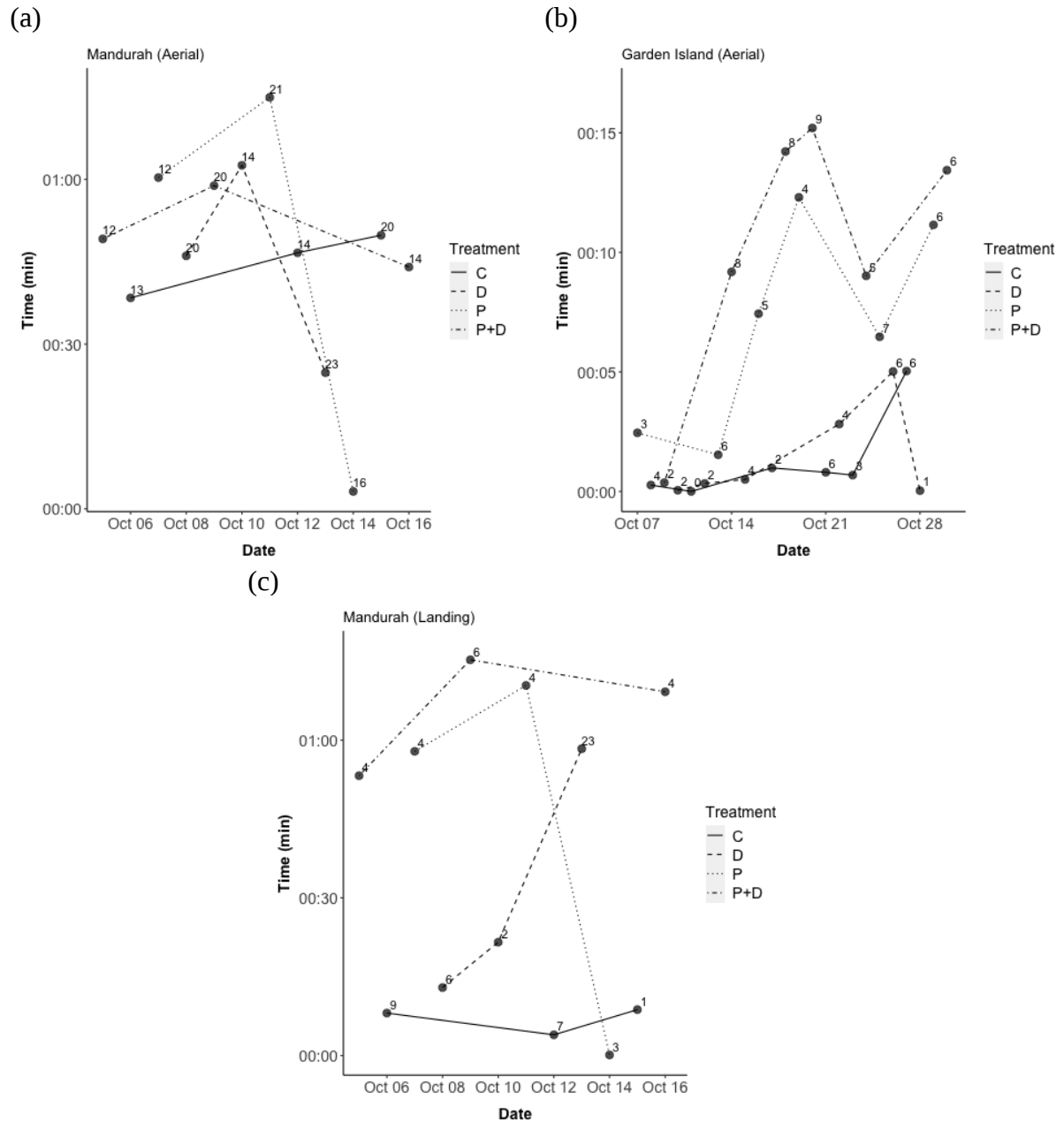


Figure 5. Behavioral response of the Australian Fairy Tern, *Sternula nereis nereis*, to conspecific audio-visual cues. Points represent the total time (mins) spent (a) aerial prospecting at Mandurah; (b) aerial prospecting at Garden Island; and (c) on the ground at Mandurah, during a two-hour observation period in response to one of four different treatments (C = control, D = decoys, P = call playback, P + D = call playback and decoys). Labels above points represent the maximum number of birds present at any one time during the observation period.

Table 1. Cross over study design to test the effectiveness of conspecific audio-visual cues (decoys and call playback) in attracting the Australian Fairy Tern, *Sternula nereis nereis*, to areas of potential nesting habitat in south-western Australia. Treatment groups (C = control, D = decoys, P = call playback, P + D = decoys and call playback) were allocated as part of a random block design. Start dates are provided for each 4-day block encompassing the four treatment groups.

Day	Mandurah			Garden Island					
	5/10/18	9/10/18	13/10/18	7/10/19	11/10/19	15/10/19	19/10/19	23/10/19	27/10/19
1	P + D	P	D	P	C	D	P	C	C
2	C	D	P	C	D	P	P + D	P + D	D
3	P	P	C	P + D	P	C	C	P	P
4	D	C	P + D	D	P + D	P + D	D	D	P + D

Table 2. Model fit for a multiple linear regression of time spent aerial prospecting (square root transformed) on the treatments of call playback, site, maximum wind speed, an interaction ($\times$) between the call playback and site variables, and an interaction between the maximum wind speed and site variables. ($n = 36$).

Variable	Estimate	SE	t-value	p-value
Intercept	14.108	9.886	1.427	0.164
Call playback	13.417	3.672	3.654	0.001
Site (Mandurah)	1.387	14.743	0.094	0.926
Max Wind Speed	-0.118	0.162	-0.728	0.473
Interactions				
Call playback $\times$ Site (Mandurah)	-13.990	6.228	-2.246	0.032
Max Wind Speed $\times$ Site (Mandurah)	0.777	0.250	3.108	0.004

Adjusted R²: 0.8271

Table 3. Model fit for a multiple linear regression of maximum number of birds aerial prospecting on the treatment of call playback, site, average wind speed, an interaction ($\times$) between the call playback and site variables, and an interaction between the average wind speed and site variables. ($n = 36$).

Variable	Estimate	SE	t-value	p-value
Intercept	0.445	5.522	0.081	0.936
Call playback	2.415	1.029	2.348	0.026
Site (Mandurah)	30.508	7.048	4.328	<0.001
Ave. Wind Speed	0.156	0.295	0.528	0.602
Interactions				
Call playback $\times$ Site (Mandurah)	-3.458	1.787	-1.935	0.062
Ave. Wind Speed $\times$ Site (Mandurah)	-1.324	0.470	-2.819	0.008

Adjusted R²: 0.8477