

A review of Osprey distribution and population stability in South Australia

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Abstract

Comprehensive surveys of Osprey habitat across all coastal regions of South Australia were undertaken in 2008–10 and in 2015–17. Comparison of results from the two surveys has revealed a significant decline in the population. In 2008–10, 58 occupied territories were found; in 2015–17 only 43 were identified. This represents an overall decline of 26% in the breeding population over the period between surveys. The steepest declines were in the west of the state where the number of occupied territories decreased from 33 in 2010 to 22 in 2017, a decline of 33%; and on Kangaroo Island where 14 occupied territories in 2010 declined to eight in 2015 and 2016, a 43% decline. When recent survey results from the quasi-mainland habitat of Kangaroo Island are combined with mainland data, a decline of 39% is revealed in the number of occupied territories across mainland coastal areas in South Australia; i.e. a combined total of 49 (of 58) territories were found on the mainland in 2008–10 and only 30 (of 43) territories were identified in these habitats in 2015–17 surveys.

In addition to the number of abandoned territories we found an underlying level of instability in the contemporary population evidenced by: a) the high number of nest relocations ($n = 16$ of 43; 37%) that had occurred within occupied territories over the period since 2010; and b) the number of probable ‘refugee’ pairs ($n = 6$; 14% of the breeding population) apparently having moved to start new territories. Although the causes for this population instability and rapid decline are not immediately apparent, because it has occurred widely across the extreme

southern edge of the Australasian sub-species’ continental distribution, there are likely multiple contributing factors that require further investigation. From these compelling survey results we contend that species and habitat conservation measures are required in the short term to prevent further decline among the remaining Osprey population in South Australia.

INTRODUCTION

The taxonomy of the Australasian Osprey has been subject to debate in Australia. Here we use the most widely accepted sub-species designation *Pandion haliaetus cristatus* (vide Horton, Blaylock and Black 2013; Monti *et al.* 2015).

The Australasian Osprey occurs over a broad tropical region between New Caledonia and New Guinea to central Indonesia and north to the southern Philippines (Prevost 1983; Poole 1989, 1994; Coates and Bishop 1997). In Australia the majority of the Osprey population is found in coastal and estuarine habitats across northern temperate and subtropical regions of the continent where high population densities occur in remote areas (Johnstone and Storr 1998; Dennis and Clancy 2014).

On southern coastlines, the species is more sparsely distributed, and there is a broad geographical gap in the breeding distribution in the southeast corner of the continent below

latitude 35°30'S. The apparent adaptation to tropical regions by the Australasian sub-species implies that the small isolated population in South Australia is likely to be on the extreme southern edge of the species' preferred bioclimatic range (Dennis and Clancy 2014).

In stark contrast to the forested coastal and estuarine Osprey habitat in the tropical north and warm temperate regions of the eastern and northern states (Figure 5), Osprey breeding habitat in South Australia is limited to mostly semi-arid open coastal landscapes with low coastal heath vegetation cover (Dennis *et al.* 2011). In these settings, tree nests are non-existent and typical nest sites are on an exposed cliff feature or associated broken terrain with little or no visual screening, or on near-shore sea-stacks and vulnerable to damage from storm-surge and severe weather events (Figure 2). While unique in Australia as Osprey habitat, these coastal landscape characteristics found across the southern extent of the species' continental range are remarkably similar to *P. haliaetus* habitat in the Cape Verde and Canary Islands off northwest Africa and on the island of Corsica west of Italy. Here nest sites are also on cliffs in open terrain and subjected to frequent disturbance from human activity or approach, resulting in breeding failures (Palma *et al.* 2004; Siverio and Rodriguez 2005; Thibault, Bretagnolle and Domonici 1995).

The South Australian Osprey population was estimated at 52 breeding pairs in 2005 (Dennis 2007a) and was formally up-listed to Endangered species status in South Australia in 2008 (*National Parks and Wildlife Act* 1972). Subsequent data from a comprehensive series of targeted breeding season surveys in 2008–10 confirmed a total of 58 occupied territories across the state, with most of these found on western and southern Eyre Peninsula (Dennis *et al.* 2011). A concurrent habitat threat assessment concluded that some breeding sites on Eyre Peninsula, Yorke Peninsula and Kangaroo Island were vulnerable to failure and displacement to sub-optimal

habitat because of ongoing human disturbance (e.g. Figure 3). These surveys and associated research also provided evidence that a substantial decline in the Osprey population, coincident with a contraction in the species' breeding range, had occurred in the 20th century (Dennis *et al.* 2011).

The Osprey is acknowledged world-wide as a sentinel species by which to measure the health and stability of coastal and wetland ecosystems (Poole 1994, 2009; Henny *et al.* 2008; Grove, Henny and Kaiser 2009). In recognition of this, and that results from previous surveys had clearly highlighted the species' apparent tenuous existence in South Australia, another comprehensive multi-year survey project began in 2015. Primarily this project aimed to:

- re-assess the status of Osprey populations in each coastal region of SA (including offshore island habitats) to measure population stability or trend against the available baseline data from previous surveys (2008–10); and
- identify threats likely to adversely impact the quality of the breeding refuge habitat.

METHODS

Typically, raptor population size is determined from an assessment of the number of territorial or breeding pairs (Newton 1979). As is usual for large raptors, the Osprey is known to form long-term pair bonds and to use the same nesting locations over long time periods, with favoured nest sites used by successive generations (Poole 1989; Clancy 2006; Dennis 2007b). The earlier baseline coastal raptor population surveys in South Australia (2008–10) and the recent surveys reported here were based on these precepts. Therefore, relative stability of territories was assumed. Surveys were targeted to previously determined territory locations and to areas where abandoned or vacant nest sites had been identified previously (Dennis 2005; Dennis *et al.* 2011).

Survey scope and planning

With the advantage of known nest site locations from previous research, strategic surveys were conducted over three breeding seasons between May 2015 and December 2017. These were in areas with known and potential Osprey breeding habitat from the Bunda Cliffs in the Great Australian Bight to Kangaroo Island in the south, including offshore islands off both Yorke and Eyre Peninsulas.

Permits and project approvals

Annual Scientific Permits No(s) M26377 1-3; Marine Parks Scientific Permit No(s) MR00048 1-3; and Wildlife Ethics Committee Approvals No(s) 4/2015 and 16/2017 were obtained from the South Australian Department for Environment and Water (DEW). The associated Permit Conditions were followed throughout.

Ground surveys

Ground surveys were conducted by a combination of vehicle and foot traverse, with the latter employed on remote coastlines where vehicle access to survey sites was not possible or ethical, e.g. Venus Bay peninsula on western Eyre Peninsula.

Disturbance minimisation protocols developed in earlier coastal raptor surveys (Dennis *et al.* 2011) were again observed, including avoidance of sensitive phases of the breeding cycle. Therefore, surveys were invariably undertaken by one of us or a suitably trained volunteer, and mostly confined to the period extending from late October through to mid-December, when pairs in active territories were settled into daily patterns of nest provisioning forays and territory defence. Depending on terrain, nest observations were made at distances >500 m using high-resolution binoculars and / or a tripod-mounted spotting scope, with observation time kept to an absolute minimum. Several near-shore island and sea-stack nest sites could be visually surveyed satisfactorily by spotting scope from the nearest mainland vantage point.

In territories where Ospreys were not seen at the nest or nearby in the core territory, the nest was examined visually for evidence of recent activity (e.g. prey remains, scat spray, nest repair or nest lining activity) and images taken of the nest platform for further detailed scrutiny. This enabled confident classification of territories as: *occupied* – where there was evidence of nest preparation activity or use; or as *abandoned* – where nests showed no signs of activity after repeat surveys over two breeding seasons (including territories with unrepaired storm damaged nests). Known alternative and abandoned nest sites were similarly checked and additional searches carried out to determine if a new site had been established.

Sea-based surveys

Typical Osprey nest placements in South Australia are either surrounded by or overlook the sea. Even in remote locations such as islands, pairs are at least partly pre-conditioned to the presence and movement of boats and largely ignore an approaching or slowly passing vessel at distances >150 m. Appropriately timed sea-based surveys were used wherever possible as they are by far the most effective and time-efficient survey method for remote coastlines and island-based habitats, and can be undertaken with minimal or no disturbance to the birds. A dinghy or canoe was used for prospecting surveys in some tidal creeks in mangrove forest areas.

Data processing and storage

A standardised survey datasheet was developed and used for each survey site throughout the project. All location data and observation notes were subsequently transcribed from these to an electronic spreadsheet. Images of surrounding terrain characteristics were obtained at all sites and archived for future reference.

Threats

Actual and potential threats at occupied and some abandoned territories with potential for re-occupation were recorded using the standardised

survey datasheet. Likely threats assessed during surveys included: the level of disturbance from recreation pursuits occurring within or near the core territory; landscape scale habitat degradation, such as vegetation clearance or damage from fire or overgrazing; change of land-use, e.g. from open range grazing to sub-division development; proximity to dwellings and other buildings, tourism destinations, roads, tracks or walking trails; recreational and commercial use of drones; and proximity to land-based or marine industry likely to cause disturbance or affect the availability of prey.

Horizontal distance measurements between nest sites and physical features associated with disturbance in the landscape were measured using mapping programs including NatureMaps, Google Earth and ArcMap.

Community contact and participation

With a view to developing greater community awareness concerning threatened coastal raptor conservation issues in South Australia, considerable effort was made to liaise with and involve regional Department for Environment and Water staff, and through them, their respective community networks. In addition, to update local knowledge and garner information on recent observations, contact was made with key community members in coastal regions, including: members of the coastal raptor volunteer network established during the 2008–10 surveys; regional Birds SA members; the executive and members of the Abalone Industry Association of South Australia; and coastal land owners where access permission was required.

Terminology

Key terms used throughout are defined as follows.

Occupied territory: where an adult pair is observed together during the breeding season in the vicinity of the nest(s) with nest repair or territory defence behaviours observed.

Active nest or territory: where incubation behaviour is observed, or where young are recorded.

Successful nest or territory: where young are fledged.

Failed nest or territory: where eggs fail to hatch, or where eggs or young are lost.

Abandoned territory: a territory found unoccupied over two or more consecutive seasons and where nest structures have fallen into disrepair.

Vacant territory: where no birds were seen nearby for one season and the nest structure was intact but no evidence of recent repair or occupation was apparent.

Primary nest: the most frequently used nest within a territory.

Alternative nest: one of sometimes several nest structures within a territory.

Core territory: the defended area around a primary nest site.

Guard-roosts: nest defence vantage points within the core territory.

RESULTS

Initial surveys in 2015 found an unexpectedly high number of vacant and abandoned territories in most regions. Follow-up surveys in 2016 were frustrated by adverse weather through July and September, with persistent strong winds, above average heavy rainfall and record cold temperatures, making both ground and sea-based surveys impractical and unethical. These weather conditions culminated in a severe storm event over the period 28 September to 5 October, which resulted in several localised tornados, heavy rains and widespread flooding, extreme gale-force winds and large ocean swells in coastal areas (Bureau of Meteorology 2016). At least eight

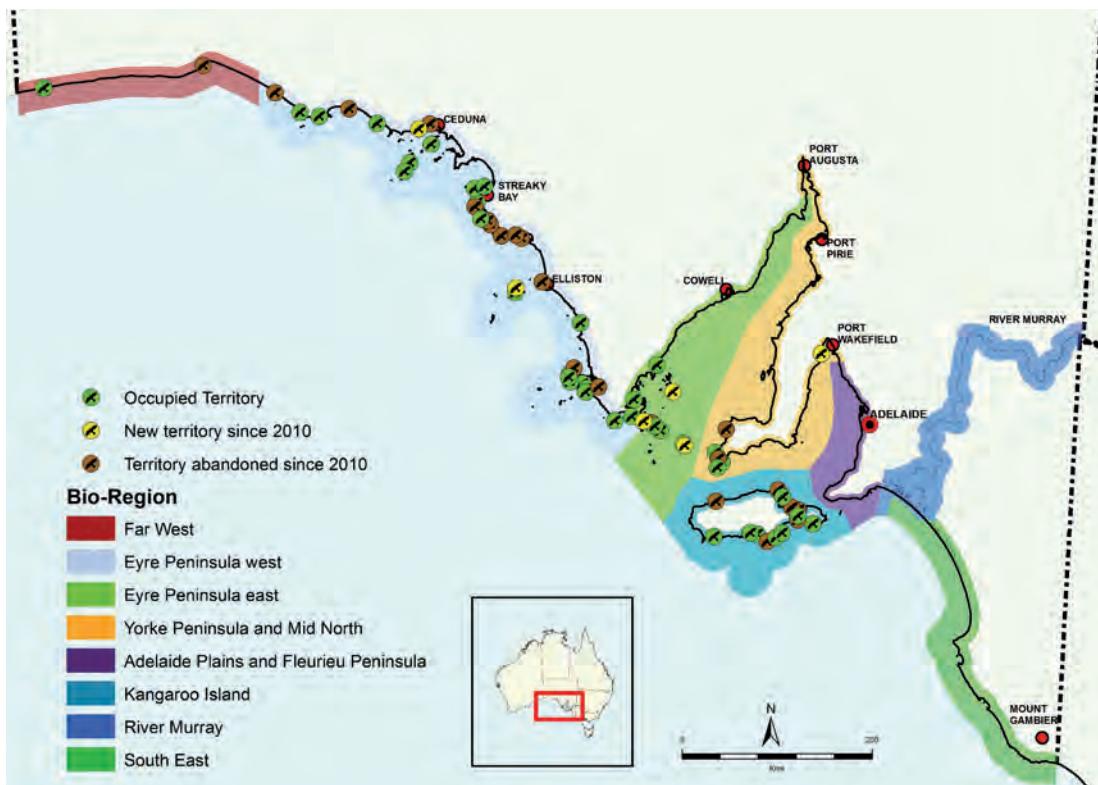


Figure 1. Map of the South Australian coast showing the current distribution of Osprey territories, including new territories since 2010 and the location of territories that have been abandoned since 2010.

nests on western Eyre Peninsula and southern Kangaroo Island were severely damaged or completely destroyed. Six of these were located on near-shore sea-stacks and therefore particularly vulnerable in large swell and severe wind conditions; and an artificial nest platform at an oyster farm and a nest in mangroves were swept away. Subsequently, strategic surveys were repeated in 2017 to test the adverse findings from 2015 and 2016 and to increase confidence levels in the survey data overall.

Survey results

Between May 2015 and December 2017 the known and potential Osprey breeding habitat west of the River Murray mouth (including Kangaroo Island) was surveyed at least twice in each coastal bio-region (Figure 1) over three breeding seasons, with offshore islands surveyed at least once. A total of 43 occupied Osprey territories were confirmed across all regions

(including islands), with the majority on western Eyre Peninsula (Table 1 and Figure 1). When compared with data from the 2008–10 surveys when 58 occupied territories were identified, an apparent overall decline of 26% has occurred in the breeding population (Table 1).

The steepest declines have occurred in the west of the state where the number of occupied territories has decreased from 33 in 2010 to 22 in recent surveys, a decline of 33%; and on Kangaroo Island where there were 14 occupied territories in 2010 and only 8 in recent surveys, a decline of 43% (Table 1).

Core territory locations

In the 2008–10 surveys the majority of Osprey territories (60%) had primary nest sites on the mainland or on near-shore sea-stacks and islets <1 km offshore ($n = 35$ of 58), with the remainder on offshore islands. However, if the quasi-

Table 1. The number of occupied Osprey territories identified for each coastal bio-region* in South Australia (see map, Figure 1) from surveys over three breeding seasons (2015–17) compared with data from earlier (2008–10) surveys (Dennis *et al.* 2011).

Coastal bio-region, South Australia	General locality and number of occupied territories identified in 2015–17 (2008–10)	No. of territories 2008–10	No. of territories 2015–17	% Change
Far West (Wilson Bluff to Wahgunyah CP)	Bunda Cliffs 1 (2); Head of Bight to Wahgunyah 0 (0)	2	1	-50.0
Eyre Peninsula west (Wahgunyah CP (western boundary) to Cape Catastrophe)	Mainland 17 (29); Nuyts Archipelago 3 (3); Investigator Group 2 (1); Whidbey Group 0 (0); other islands 0 (0)	33	22	-33.3
Eyre Peninsula east (Cape Catastrophe to Two Hummocks Point, upper Spencer Gulf)	Mainland 2 (1); Thorny Passage Islands 2 (2); Sir Joseph Banks Group 1 (0); Gambier Group 2 (1); other islands 1 (1)	5	8	+60.0
Yorke Peninsula and Mid North	Mainland 1 (2); Islands 3 (2)	4	4	0.0
Adelaide Plains and Fleurieu Peninsula	Transient and vagrant records only	-	-	-
Kangaroo Island	Kangaroo Island 8 (14)	14	8	-42.8
Murray River (flood plain and wetlands)	Historical and vagrant records only	-	-	-
South East	Vagrant records only	-	-	-
Cooper Basin	Vagrant records only	-	-	-
	Total	58	43	Av. -25.9%

* broadly based on Natural Resource Management Board regions and Birds SA regional boundaries (*vide* Blaylock *et al.* 2017).

mainland Kangaroo Island data are added, the overall proportion of mainland-based territories increases to 84% ($n = 49$ of 58); compared with 70% ($n = 30$ of 43) in recent surveys. Therefore a decline of 39% (i.e. from 49 in 2010 to 30 in 2017) in the number of mainland-based territories has occurred over the period between surveys.

Nest sites

In contrast to what is widely understood of Osprey long-term and often multi-generational attachment to favoured primary nest sites (Poole 1989; Marchant and Higgins 1993; Dennis 2007b), we found that among the 43 occupied territories identified, 16 nests (37%) had been relocated since the previous surveys were completed in

2010. Added to this unexpected dynamic, five new territory locations were established, possibly by ‘refugee’ pairs, accentuating the probability of an underlying level of instability in the population.

Consistent with previous surveys, most nests were on broken sections of coastal cliff and near-shore sea-stacks, often on highly exposed sections of coastline vulnerable to storm events and extreme weather (e.g. Figure 2). Whereas in 2010 six nests were on specially constructed artificial platforms (e.g. Figure 4) only two of these were occupied in 2017, and at one of these the pair was presumed to have relocated <1 km to another purpose-built platform on a disused barge.

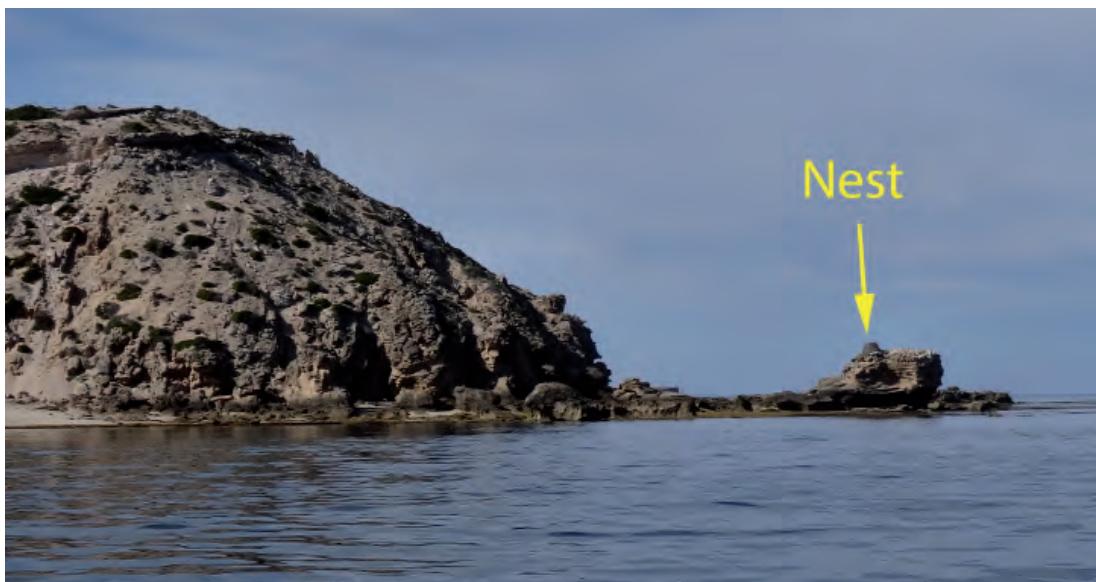


Figure 2. A typical Osprey nest placement in South Australia's open coastal landscapes. The nest, although 'protected' in a National Park, is vulnerable to climatic events (e.g. storm surge) and to disturbance from recreational activities above nest-level. It also can be readily accessed by people and predators (e.g. foxes) at low tide.

Image Sharie Detmar



Figure 3. An example of a highly disturbed Osprey nest, near Elliston on western Eyre Peninsula. Situated next to a popular surfing location, the nest is in full view from a recently upgraded carpark (210 m distant) and lookout. Added to this, some surfers use the headland as an access/egress point to the surf-break just offshore. This territory was occupied during the 2008-10 surveys but has been abandoned since.

Image Sharie Detmar



Figure 4. The resident Osprey pair immediately adopted this up-graded nest platform built by local oyster farmers at Denial Bay in 2013. The original platform, which had been in place since 1991, had been re-built twice after collapsing under the weight of nesting material or from storm damage.

Image Andrew Brooks

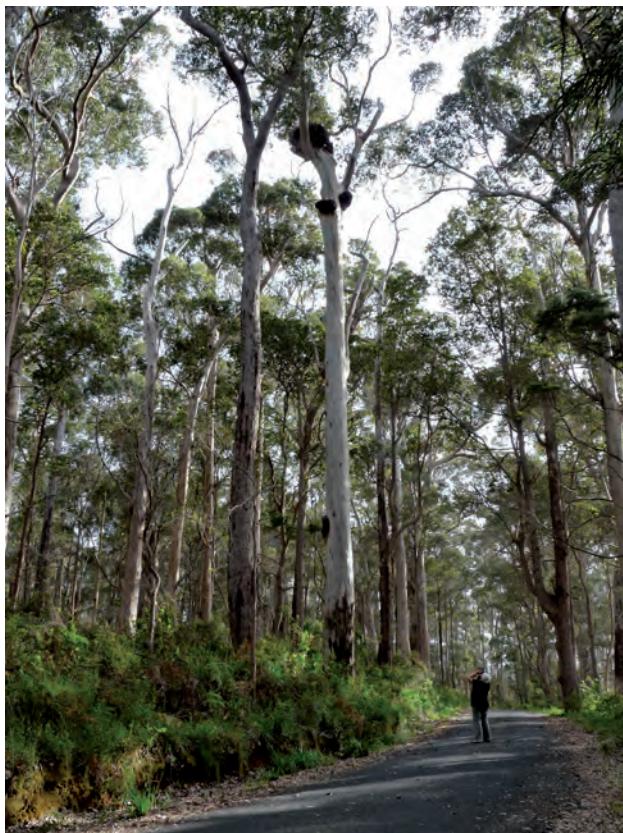


Figure 5. In warm-temperate to tropical climes in Australia most Osprey nest placements are in coastal or estuarine forests, often in similar settings to this interstate example. At this nest, in contrast to behaviours near typically exposed nest sites in South Australia, the parents continued feeding the young while vehicle and foot traffic on the road below were totally ignored!

Image Terry Dennis

Across all regions only two tree-nests were found. One of these was first located in 2013 situated in Grey Mangrove, *Avicennia marina*, forest flanking a tidal creek complex on western Eyre Peninsula (Dennis and Brooks 2014). The nest was set <3 m above average high-tide level and was subsequently destroyed during peak-tide and storm events in the spring of 2016, but rebuilt nearby and found to be active again in 2017. The other was perched on top of the dense canopy of a Swamp Paperbark, *Melaleuca halmaturorum*, ~3 m in height on a prominence overlooking a sheltered embayment.

Two nesting attempts were made on navigation markers over the survey period. One of these was in Coffin Bay on Eyre Peninsula and the other in Gulf St Vincent: both failed.

Far West region

In 2010 there were two occupied territories on the ~200 km long Bunda Cliffs, ~163 km apart between the Head of Bight and Wilson Bluff on the Western Australian border (Figure 1). Only one territory was occupied in recent surveys on the western end of the cliffs, with several other known nest structures to the east having deteriorated or disappeared since 2010. The coastline east of the Head of Bight through the Yalata Indigenous Protected Area to Wahgunyah Conservation Park (CP) is composed of mainly long sandy beaches backed by large dune-fields with few low rocky headlands and near-shore reefs and is devoid of Osprey breeding habitat and activity.

Eyre Peninsula west region

Including those on offshore islands, there were 33 occupied Osprey territories recorded in this region in 2010, whereas in recent surveys 22 were recorded, a decline of 33% (Table 1). This region also had the highest density of territories on mainland habitats in previous surveys, with 29 territories found between Wahgunyah in the west to Cape Catastrophe on southern Eyre Peninsula, whereas just 17 occupied territories were found over the same coastline in recent surveys, a

decline of 41%. In addition, between Streaky Bay and Elliston there were 11 occupied territories in 2010 and just 4 were found occupied in recent surveys, a decline of 64%.

Eyre Peninsula east region

Despite apparently suitable habitat, there is an inexplicable dearth of Osprey breeding territories throughout Spencer Gulf. Previous surveys reported only five occupied territories in this region (as defined in Table 1 and Figure 1), with all but one of those found on offshore islands. Recent surveys identified eight territories with two of these as mainland territories, one being on a near-shore artificial platform and the other, a new territory in a remote area of Lincoln National Park, found by sea-based survey in 2015. In addition, an apparent Osprey pair was recorded in the vast mangrove and tidal creek complex in Franklin Harbor during 2016 surveys, but a nest could not be found to confirm what may yet prove to be a previously unrecorded territory.

Yorke Peninsula and Mid North region

Only four occupied territories were recorded in this central coastal region of the state in both the previous and recent series of surveys (Table 1). Three were on islands and the other, a nesting attempt on a near-shore navigation marker in Gulf St Vincent in 2017. The latter is significant as there are no known contemporary or historical Osprey breeding records for Gulf St Vincent. Two highly disturbed mainland nest sites on southern Yorke Peninsula (including one in Innes National Park) have been abandoned since 2010, resulting in the entire mainland coastline of Yorke Peninsula being now devoid of occupied Osprey territories.

Kangaroo Island region

A total of 14 occupied Osprey territories were found on Kangaroo Island during surveys in 2008-10; however a series of thorough boat-based and land surveys in 2015 and 2016 found only 8, a decline of ~43% over the intervening period (Table 1).

Osprey foraging habitats

Single Ospreys, including sub-adults, were recorded in several areas distant from known breeding territories that are likely important foraging locations. These included: remote coastal areas in the far west of the state; Baird Bay and Franklin Harbour on Eyre Peninsula; upper Spencer Gulf; near Port Broughton and Port Victoria; and Gulf St Vincent, including the eastern coastline of Yorke Peninsula and the Torrens Island–Barker Inlet complex. Single Osprey sightings are also occasionally reported in the Port River channel and over Adelaide metropolitan beaches and further south in the Onkaparinga and Myponga River estuaries.

Other coastal regions, inland rivers and lakes

No evidence was found during recent surveys to indicate that Ospreys breed in other coastal regions (e.g. the Fleurieu Peninsula or the South East region), or on inland rivers and lakes in South Australia. Along the River Murray, there were reports during the survey period of single vagrant Ospreys and of two which lingered together through the autumn and early-winter period in 2013 near the Old Customs House on the Victorian border (F. Malor *in litt.*); and for a similar period in 2015 (G. Norman pers. comm.). These eluded detection during subsequent surveys, which included the adjacent Chowilla wetland complex in July and September 2015 and in May 2016. Further upstream on the Murray, a single Osprey was reported as being a new ‘resident’ at Curlwaa in the Mildura Weekly newspaper on 20 April 2016.

Other inland records during the survey period came from the far northeast of the state, where exceptional rainfall events in central and southwest Queensland had sent floodwaters down Cooper Creek into South Australia, and a single Osprey was observed over several days at Policemans Waterhole near Innamincka in late May 2016 (B. Johnson *in litt.*). At the same time, ~45 km upstream from Innamincka at Bulloo Waterhole near the Dig Tree in southwest Queensland, an Osprey was present over several

weeks and was observed carrying sticks to a nest. Although the outcome of this behaviour was not followed-up, at least one Osprey was still present in early August 2016 (Colin Mate, Queensland National Park Service Ranger pers. comm.).

DISCUSSION

Population decline

These survey results indicate that the Osprey breeding population in South Australia in 2017 had declined significantly (~26%) since the previous state-wide surveys were completed in 2010, when 58 occupied territories were identified (Dennis *et al.* 2011). This was similar to an earlier estimate of 52 breeding pairs compiled from surveys in 2003 and 2005 (Dennis 2004, 2007a). While the causes of this rapid recent decline are not immediately apparent, it is likely that multiple contributing factors need to be considered. These include, but are not limited to: increasing levels of anthropogenic disturbance; behaviour; and environment.

Increasing levels of anthropogenic disturbance

Osprey productivity is adversely affected at nest sites subject to disturbance and frequent disturbance may result in nest desertions (Levenson and Koplin 1984; Poole 1989; Dennis 2004, 2007b). Many breeding sites, even in remote mainland areas, continue to be subjected to varying levels of direct (human activities) and indirect (habitat degradation) disturbances during the breeding season (Figure 3). These factors combined adversely contribute to the incidence of nest failure, resulting in a fall in population recruitment levels, and inevitably, to a reduction in the number of breeding pairs.

Behaviour

Not all Osprey pairs breed every year. A long-term study of Osprey breeding biology on Kangaroo Island (Dennis 2007b) and a nest-monitoring program in northern New South Wales (Bischoff 2001) found a considerable proportion of pairs (averaging 29% and 26% respectively) were inactive (i.e. failed to produce

eggs) each year. Therefore, with surveys conducted toward the end of the breeding season, pairs in some occupied but inactive territories may be absent from the core territory precinct and have escaped detection.

This temporal bias in the survey method may draw a presumption of abandonment and thereby negatively skew survey data. This bias is largely discounted however, as the Australasian Osprey is sedentary and continues to use the nest platform throughout the year as a roost and feeding platform, even when breeding has failed (Bischoff 2001; Clancy 2006; Dennis 2007b). Also, routine thorough examination of the nest platform during ground surveys in apparently unoccupied territories, to detect evidence of recent activity (see Methods section), enabled confident determination of territory status.

Environment

The possibility of a perturbation in the near-shore marine environment affecting the availability or quality of prey, causing pairs to fail to reach optimal condition and therefore to forego breeding for one or more seasons cannot be easily ruled out (see Henny *et al.* 2008). Moreover, there may be a previously undetected behavioural dynamic in the southern ecotype, which in response to disturbance or cyclic extreme weather events at a critical phase, triggers an over-riding primary survival response with territorial attachment discontinued or aborted more readily than occurs elsewhere.

Each of these factors, or a combination of them, may have diminished the habitat quality for the small Osprey population in South Australia, thereby adversely affecting territory productivity, and over time, contributing to population decline.

Population distribution and isolation

The pattern of sparse distribution and rarity of breeding territories in South Australia continues westward through southern Western Australia, with the nearest known territory to

the most westerly one in South Australia being ~700 km distant in the Recherche Archipelago near Esperance (Johnstone and Storr 1998; Dennis 2007a). To the east there is a broad gap in the species' historical breeding range, i.e. from Kangaroo Island to about 180 km south of Sydney in New South Wales at latitude 35°30'S (Clancy 2009). Ospreys are known only as rare vagrants in Victoria and Tasmania (Barrett *et al.* 2003; Dennis and Clancy 2014; DEE 2017).

Historical distribution

Recent surveys also confirmed the continued absence of Osprey from former breeding areas in upper Spencer Gulf and along the River Murray (Dennis 2007a; Dennis *et al.* 2011), and again draw attention to the inexplicable relative rarity of breeding activity over apparently suitable habitat in both Spencer Gulf and Gulf St. Vincent. While there is no ready explanation for their disappearance from upper Spencer Gulf, their demise as a breeding species along the River Murray appears to have coincided with the spread of feral European Carp, *Cyprinus carpio*, in the early 1970s (Scott, Glover and Southcott 1980; Dennis 2007a). Carp actively sluice through mud substrates when feeding and are thought responsible for an increase in turbidity in the waterways and swamps along the Murray (King 1995), which may have adversely affected the ability of Ospreys to locate and catch prey. The last reliable breeding record from the River Murray in South Australia was from near Nildottie in 1980 (Robinson 1980).

Threats

In remote coastal areas on Eyre Peninsula and in the Far West of South Australia (where many abandoned territories were found), the long-standing practice of gaining access to every beach and coastal feature by 4WD vehicles has resulted in vegetation damage and serious erosion. Many of these tracks closely follow the cliff-edge in direct line-of-sight to nests and guard roosts, inevitably causing disturbance and increasing the risk of nest failures. Human disturbance at critical times near nesting sites can be a cause of

desertion, particularly at exposed and accessible nests (Palma *et al.* 2004).

In South Australia's open coastal landscapes, Osprey nest sites are particularly vulnerable to disturbance from human activity or approach, as this invariably occurs in line-of-sight at long distance from the nest or nest guard-roost location and typically above nest level. In Ospreys and other large raptor species, an elevated approach in open landscapes triggers an earlier and stronger response than would occur from below nest-level in forested terrain, invariably causing the pair to loft sooner (Olsen 1998; Romin and Muck 2002). This leaves nest contents exposed to ambient conditions for longer and also to scavengers and nest predators, such as the Pacific Gull, *Larus pacificus*, and Australian Raven, *Corvus coronoides*, in South Australia (Dennis 2007b).

Paradoxically, in some areas (e.g. Kangaroo Island) inter-species kleptoparasitism and spatial conflict with the state-listed (endangered) White-bellied Sea Eagle, *Haliaeetus leucogaster*, may cause breeding disruption and territory displacement (Dennis and Baxter 2006; Dennis 2007b).

Other threats identified in this study potentially increasing the frequency of disturbance incidents at nest sites or degrading habitat quality, included:

- the increase and expansion of recreational activity in coastal areas, such as surfing and fishing;
- poorly sited tourism developments channelling people into remote locations;
- coastal land division resulting in the spread of residential development;
- ill-timed research projects and land management activities coincident with the breeding season on Reserves and other

remote areas including islands, e.g. biological surveys and marine mammal research, pest plant control and fuel reduction burn-offs;

- the rapidly increasing recreational, scientific and commercial use of drones as camera platforms etc. over-flying coastal features and islands;
- an increasing use of digital cameras with powerful zoom capabilities by irresponsible or naive enthusiasts to 'collect' bird images of even endangered species (the scale of this activity has caused both Birdlife Australia and Birds SA to update their respective Ethical Birding policies and guidelines for members, in an effort to raise awareness of potential impacts); and
- sea level rise, climate change and associated increase in extreme weather events.

Collectively, these habitat degrading processes and disturbance threats have reduced the breeding refuge quality for the Osprey population in South Australia, thereby contributing to population decline.

Habitat protection

South Australia has a Reserve system whereby land is proclaimed under various legislation (e.g. *National Parks and Wildlife Act 1972*, *Wilderness Protection Act 1992*, *Crown Land Management Act 2009*) for various purposes, including biodiversity conservation and to protect threatened species habitat. Within the Reserve system (eg. National Park, Conservation Park or Wilderness Protection Area) fewer Osprey territories were found abandoned (11%) than outside of Reserves where the decline has been considerably greater, i.e. from 30 territories in 2008-10 to 18 in 2015-17 (or 40%; Table 2), indicating that the Reserve system may provide a reasonable level of habitat protection.

In 2009, 19 Marine Parks were established in South Australian waters with four zones or

Table 2. The number of occupied Osprey territories found in 2008–10 and 2015–17 surveys categorised as either located outside the (terrestrial) Reserve system (i.e. National or Conservation Park, or Wilderness Protected Area); or within Reserves. The increase or decrease (change) is calculated for each habitat category over the period between surveys.

Coastal bio-region	Territories outside Reserves		Territories within Reserves	
	(2008-10) 2015-17	% Change	(2008-10) 2015-17	% Change
Far West	(1) 0	-100	(1) 1	0
Eyre Peninsula west	(16) 9	-44	(17) 13	-24
Eyre Peninsula east	(4) 6	+50	(1) 2	+100
Yorke Peninsula and Mid North	(1) 0	-100	(3) 4	+33
Kangaroo Island	(8) 3	-63	(6) 5	-17
Totals	(30) 18	Av. -40%	(28) 25	Av. -11%

levels of protection designated within them, with Restricted Access and Sanctuary zones having the highest level of species and habitat protection. The decline of occupied Osprey territories recorded in Marine Parks over the period between surveys was found to be 24%, i.e. from 46 territories in 2008-10 to 35 in 2015-17 (Table 3), which is similar to the overall state-wide decline of 26% (Table 1). Significantly, the number of territories located within the Sanctuary and Restricted Access Zones ($n = 9$) remained stable over the period, affirming the importance of the higher level of habitat protection provided by these zones in species conservation.

Threat abatement and recovery

To address the recent rapid population decline, a Species Management Plan or Recovery Plan is required for the Osprey in South Australia. This should define species and habitat protection and conservation strategies, including:

- specific habitat management prescriptions for remaining breeding and foraging habitats, which include breeding refuge protection zones of 1000 m radius (*vide* Dennis 2015; Coast Protection Board 2016) around nest sites;
- systematic population and productivity monitoring programs in key areas;

Table 3: The number of occupied Osprey territories found in 2008–10 and 2015–17 surveys categorised as either located within or immediately adjacent to a Marine Protected Area (MPA) and those within Sanctuary or Restricted Access Zones within the MPA. The increase or decrease (change) is calculated for each habitat category over the period between surveys.

Coastal Bio-region	Territories within or adjacent to Marine Protected Areas (MPA)		Territories within MPA Sanctuary or Restricted Access Zones	
	(2008-10) 2015-17	% Change	(2008-10) 2015-17	% Change
Far West	(2) 1	-50	(2) 1	-50
Eyre Peninsula west	(28) 19	-32	(3) 4	+33
Eyre Peninsula east	(2) 5	+150	(0) 0	0
Yorke Peninsula and Mid North	(4) 4	0	(1) 1	0
Kangaroo Island	(10) 6	-40	(3) 3	0
Totals	(46) 35	Av. -24%	(9) 9	Av. 0%

- pursuit of sponsorship sources (e.g. corporate or industry) to fund further research and for the strategic placement of appropriately designed artificial nest platforms in key areas;
- identification and protection of key foraging locations;
- the development of community awareness and recovery participation programs;
- guidelines for land-owner and land-management agencies to avoid disturbance during sensitive phases of the breeding cycle; and
- prioritise future research directions for the recovery of the South Australian Osprey population.

In addition, formal recognition is required at all levels of Government to ensure that land-use planning, development assessment processes and land management decisions in coastal areas include consideration of impacts to threatened species habitat. In the case of Osprey habitat, this requires formal adoption of the breeding refuge protection zone concept around known primary nest sites (Richardson and Miller 1997; Romm and Muck 2002; Dennis 2015), including for those found abandoned with re-occupation potential. Without this level of habitat protection it is likely that the negative outcomes from disturbance and disruption during breeding will continue to contribute to territory abandonment and further population decline.

CONCLUSIONS

The comparative survey data presented indicate a recent, irrefutable population decline in the Osprey population in South Australia. When considered together with the evidence of an earlier reduction in range (Dennis 2007a; Dennis *et al.* 2011), these data confirm that significant

broad-scale declines have occurred over time, with an apparent radical decline over the period 2010 to 2017.

Because the Australasian sub-species of Osprey may be subsisting somewhat tenuously on the edge of its preferred continental range in South Australia, it may be doubly susceptible to adverse exogenous threats and/or shifts in bioclimatic dynamics. Further research and more frequent site monitoring data are needed to determine whether these declines are an outcome of habitat degradation and/or disturbance, or other, as yet undetected, phenomena.

Regardless of cause, to mitigate further decline in the South Australian Osprey population, decisive and immediate action is required to protect and manage remaining breeding habitat to ensure maximal population recruitment occurs.

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