

Some aspects of Hooded Plover behaviour and ecology based on a colour-banding study on Kangaroo Island

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Abstract

Between May 1986 and May 1991 on Kangaroo Island, 284 Hooded Plovers were captured at night and fitted with coloured PVC bands for individual recognition. Of these, 221 were subsequently recorded a total of 2133 times, with the last re-sight record in 2006.

*Considerable mobility was recorded among the population, including a small number of movements to the mainland, with the furthest distance travelled from place of banding being ~145 km. Flocks of >20 birds were common in autumn and early winter, often occurring at near-coastal saline lakes where the mollusc *Coxiella striata* was abundant, or on beach habitats with heavy seagrass accumulations. Flock size and composition were dynamic and included paired birds temporarily absent from breeding beaches. The high proportion of unbanded adults among autumn-winter flocks suggests either a previously overlooked sub-population of non-territorial adults on Kangaroo Island; or a seasonal immigration of birds from elsewhere.*

When last recorded, eight colour-banded birds were aged 10 years or more, with the oldest aged 15.5 years. Eleven known age young were in adult plumage when aged <1 year (mean 329.1 ± 16.7 days; range 303-352) some of which were paired and fecund (mean age of 346.3 ± 15.4 days; range 336-364). A total of 27 pairs remained together at the same location for consecutive breeding seasons; 16 of these were with the same partner on the same territory over multiple seasons (range 3-6).

In addition to known beach breeding habitats, the Hooded Plover flock foraging locations identified in this study appear to be important to sustain the population through the non-breeding season, and therefore need to be considered in habitat management strategies.

INTRODUCTION

The Hooded Plover, *Thinornis rubricollis* is a rare endemic shorebird of southern Australia found mainly in coastal habitats, with most breeding in the east of its range occurring on broad sandy high-energy beaches. The spread of urbanisation in coastal areas in the south-east of the continent has been exponential through the latter part of the 20th century (Hamilton and Cocks 1996), with the consequent increase in recreational activity directly impacting on many beach-dwelling bird species resulting in population decline of several species, including the Hooded Plover (Dowling and Weston 1999; Baird and Dann 2003; Dennis and Masters 2006; Maguire 2008).

In the mid-1980s there was growing concern at the plight of the Hooded Plover population in South Australia, including on Kangaroo Island where more than a third of the population was known to occur (Bransbury 1987). That concern initiated this study, largely emanating from the work of the late Allen Lashmar (e.g. Lashmar 1984) who sadly did not live to see the end-point of his pioneering conservation initiatives. It was his fore-sight and active contribution to studying the plight of the species which provided the motivation for the project described here. His unpublished data from eastern Kangaroo Island contributed greatly to modelling trends in the Hooded Plover population reported by Dennis and Masters (2006), who found that coincident with the rapid growth in tourism and coastal recreation, a substantial population decline (24%) had occurred on the Island between 1985 and 2004. Since that data was published, more recent surveys indicate an increase in the overall numbers of Hooded Plovers on Kangaroo Island;

i.e. from an estimated population of 110 in 2004 (Dennis and Masters 2006) to 129 in 2006; 180 in 2008 and 2010 (Ewers *et al.* 2011) and 186 in 2012 (Jane Renwick, *in litt.*). These numbers should be treated with some caution however, as the amount of habitat surveyed varied between years, with later surveys being the most comprehensive.

Initially, the underlying aim of the banding effort was to provide the basis for others to conduct a comprehensive study of the species and the issues surrounding its conservation. However, this failed to materialise and, while the project data continued to accumulate, its analysis and promulgation languished. As a consequence, the scope and therefore the outcomes of the project remained limited by being conducted through volunteer effort, with time inputs never systematic and data collection remaining largely opportunistic.

The colour-marking aspect of the project generated considerable community interest, with many local people assisting with the capture and banding effort and subsequently continuing to contribute independent sightings of marked birds.

A study of colour-banded Hooded Plovers conducted in central Victoria found varying levels of mobility and dispersal among the population, including among paired adults from established territories, outside of the breeding season (Weston, Ehmke and Maguire 2009). While Dennis and Masters (2006) have reported some aspects derived from the long-term study on Kangaroo Island (e.g. population distribution and trends) the aim of this paper is to add to what is known of the species behaviour and population dynamics. It provides observation data on aspects of: individual mobility (within and beyond Kangaroo Island) including post fledging dispersal; seasonal behaviour e.g. autumn-winter flocking; pair and territory fidelity; age at maturity and first breeding; and individual longevity.

METHODS

Study area

Kangaroo Island is situated ~15 km southwest of the Fleurieu Peninsula in South Australia. The Island is ~150 km in length (east-west) and ~55 km wide, with a coastline of ~500 km in total length, ~112 km of which is sandy beaches (Schulz 1995). The western and southern coastlines are exposed to Southern Ocean swell and prevailing weather patterns (Schwerdtfeger 2002) while the northern and eastern aspects are generally more sheltered and consist of moderate to low energy coastlines (Thomas and Edmonds 2002). Hooded Plovers are distributed on sandy beach habitat all around the Island (Schulz 1995; Dennis and Masters 2006).

Individual colour-marking scheme

Between 1981 and 1985 several Hooded Plovers were experimentally captured and banded on Kangaroo Island using metal bands supplied by the Australian Bird and Bat Banding Scheme (ABBBS). Commencing in mid-May 1986, a colour-marking scheme was approved by the ABBBS enabling individual Hooded Plovers to be re-identified in the field without the stress of recapture. In addition to sequentially numbered ABBBS stainless steel bands, three coloured Darvic PVC bands were applied in a combination unique to each bird. Bands were applied to the metatarsus on each leg, i.e. two colour bands on the left and one colour band above the ABBBS metal band on the right. Seven colours were allocated to the project by the ABBBS and a single alpha code assigned to each; i.e. red = r, mid-blue = b, yellow = y, orange = o, light green = p, black = n, white = w. Metal bands were assigned the alpha code 'm'. When bands were subsequently 'read' in the field these were recorded from left to right, with each bird retaining the individual identity (Id.) code throughout the life of the project, e.g. red over green (left leg), with black over metal (right leg) was assigned the Id. code of 'rpnm'.

Standard morphometric measurements (i.e. weight, and length of head + bill, culmen, wing

and tarsus) were recorded from all birds at time of initial capture and banding, and during subsequent recapture events, with the data routinely reported to the ABBBS.

Band replacement

Some colours among the PVC bands were known to fade more rapidly than others (e.g. red) and glued joints to fail resulting in band losses, which required that these birds be recaptured and their bands replaced.

Capture methods

The nocturnal technique of using strong light to capture wildlife has been widely used for many decades around the world, including in many terrestrial bird species research projects (Labisky 1959; Campbell 1968; Benitez-Lopez *et al.* 2010). Its potential as a method to capture Hooded Plovers was discovered prior to this project by a local ornithologist; while walking a beach at night he found that a powerful hand torch successfully transixed two adult Hooded Plovers, enabling them to be approached to within a few metres (C. Baxter, pers comm.). Subsequently, a foot-based stalking and capture technique was developed and refined to confidently capture adult and fledged immature Hooded Plovers (and other shorebird and wader species) using a modified spotlight and hand-net.

Nocturnal capture method

For freedom of movement the 'catcher' carried only the spotlight (including battery backpack) and hand-net. To avoid the risk of prematurely spooking the target species, care was taken not to project the beam further than an ~100 m search area ahead, or to 'flash' the light beam onto capture team participants. The catcher wore dark clothing and would lead, keeping the concentrated beam lowered in a search pattern and when a bird was detected, move on >25 m ahead (usually barefoot to minimise footfall noise) keeping the light on one bird and holding it forward at arm's length to minimise light backwash, quickly closing the distance to ~20 m. The final approach involved a slower and quieter

pace, keeping the net high out of the light wash, bringing it down over the bird in one smooth action at the very last moment.

With multiple target birds in one location, it was important to extinguish the spotlight and work with minimal light (one headlamp) and noise, and to quickly transfer the first captured bird to a holding box or 'bird bag', before attempting to scan for others.

A shortcoming of this capture method occurs on beaches where resident birds become accustomed to other sources of light such as street lights and vehicle headlights, resulting in them becoming extremely difficult to approach. Also, attempts to use this capture method on inland saline lagoons or on shell-grit beaches were ineffective, as the substrate 'crunched' underfoot, precluding close approach.

Equipment

A hand-held hunting spotlight fitted with a 50 watt halogen globe and powered by a small wet-cell (motorcycle) battery carried in a sealed backpack was effective and reliable for 60–90 minutes of semi-continuous use (LED lighting devices were not then available). The spotlight reflector was adjusted to concentrate the beam width and was fitted with an 80 mm shroud. Shrouding of the beam was found to be essential to eliminate light wash reflection off the operator. A simple 550 mm diameter hand-net with a 1400 mm blackened handle was used for catching, fitted with a soft synthetic dark-coloured 12 mm mesh cone.

Ambient conditions

Prevailing weather and swell conditions, as well as tide and moon-phase cycles, were critical considerations affecting the efficacy and outcomes of the capture method. Optimum conditions were moonless nights with full cloud cover and light to moderate winds to muffle footfall and other noise (Benitez-Lopez *et al.* 2010) coupled with low swell conditions during low to mid-tide (when the maximum area of firm sand would be exposed).

Handling and minimal impact protocols

Typically, an entire beach was sweep-searched and captured birds held in a lined and compartmented bird-box (carried by an assistant). Banding and morphometric data collection procedures were conducted subsequently in one session. On longer beaches with more than one Hooded Plover territory, presumed paired adults and young were released synchronously within the territorial boundaries.

To avoid the stress of capture and handling during the breeding season, the nocturnal capture method was limited to beaches where pairs had been previously assessed as not currently engaged with incubation or young aged <25 days.

Diurnal capture method

Daytime captures were only attempted with pre-fledged young aged >15 days, by which time they were more robust and feather development advanced (Dowling and Weston 1999). These captures were opportunistic on remote beaches, or based on prior observation of the stage of breeding activity in more accessible locations. Capture was by hand (or hand-net) and followed careful observation on approach to pre-determine cryptic concealment locations (behaviour typically exhibited by species with nidifugous young) and by following fresh tracks.

Re-sighting of banded individuals

For this study the term 're-sight' includes both the visual re-identification of an individual in the field from a record of its colour band sequence, or by physical recapture, using the nocturnal trapping method.

A standardised observation record form was widely distributed among local bird-watchers, National Park staff and project volunteers. The resulting records were carefully scrutinised and evaluated against known or apparent skill levels of the observer and the geographical probability of the record before acceptance and entry into the project database. Follow-up surveys were

conducted when a sighting record was in doubt or incomplete. The substantial re-sight records collected by visiting ornithologists in 1989 and 1990 (J. Bransbury, *in litt.*) and in 1994 (M. Schulz, *in litt.*) were also incorporated into the project.

As colour bands were found to deteriorate with fading and glued joint failure (typically after two to three summers), only a small number of valid observation records were collected after 1995. These were invariably of birds that had colour bands replaced at least once or, as with one bird (pnwm) with one colour band missing, its ABBBS band numeral sequence was read by spotting scope at close range.

Equipment

Visual re-identification of individual birds involved use of high-resolution binoculars and/or a tripod-mounted spotting scope. Similar optical equipment was used by volunteers involved with the project.

Age and sex classes

An age-class based on plumage characteristics was assigned on initial capture and subsequently, to re-sighted birds using the following definitions:

- *runners* – pre-fledged young (aged <35 days; *vide* Baird and Dann 2003);
- *juvenile* – fledged and near adult size but with pale grey crown and upper mantle;
- *sub-adult* – when moult to adult plumage had commenced or progressed, i.e. emergent black feathers visually evident in crown or mantle;
- *adult* – crown and mantle all black.

Hatchling age data was determined from monitored incubation events and considered accurate to ± 3 days. Additional data on moult progression with age was obtained from Adelaide Zoo records for a small number of captive Hooded Plovers which had been hand-reared following artificial incubation, or were bred in captivity (M. Craig and B. Backhouse, *in litt.*).

Being strongly monomorphic, Hooded Plovers cannot be accurately sexed in the field and in this study only a small number were classified from observed behavioural cues.

Breeding season

The Hooded Plover breeding season in South Australia is annual and extends from August to the following March, which is similar to elsewhere in south-eastern Australia (Maguire 2008). Many pairs bond for consecutive seasons, often using the same area of beach (Dennis and Masters 2006; Weston, Ehmke and Maguire 2009).

Data storage and analysis

From project commencement in 1985, all banding and re-sight data was systematically recorded in dedicated project field notebooks. From 1992 these data were transcribed to an electronic spreadsheet, which thereafter formed the project database. This subsequently provided some ability to interrogate the copious life-history notes and observation data accumulated over the life of the project and enabled determination of some aspects of the species' life history. Much of the data has been summarised as means with standard deviations.

RESULTS

Number of birds banded and re-sighted

Between November 1981 and May 1991 a total of 338 Hooded Plovers were captured and banded with ABBBS bands on Kangaroo Island. Commencing in mid-May 1985, 284 of these (31 of which were previously ABBBS banded) were also fitted with coloured PVC bands enabling easy individual recognition in the field. Most (84%) were banded in the first four years of the project. Two hundred and twenty one (69.7%) of the colour-banded birds were subsequently re-sighted (visually or physically recaptured) on a total of 2133 occasions: 21 individuals were re-sighted 20 or more times (up to 54 re-sights); 42 were re-sighted 11-20 times; 62 were re-sighted 5-10 times; with the remainder (96) re-sighted <5 times.

Among the individually colour marked birds, 116 were in adult plumage at time of first capture, 122 were either juvenile or sub-adult, and 46 were runners aged >15 days.

Mobility and post-breeding season dispersal

Of the movements recorded on Kangaroo Island, 316 were of distances >10 km (range 10-98 km). Considerable mobility was recorded among the sub-adult age group (mean distance 28.4 ± 27.4 km; range 5-145 km) and among unpaired adults (mean distance 32.7 ± 18.9 km; range 9-105 km) and included a small number of movements to the mainland (Table 1). Details of these movements follow:

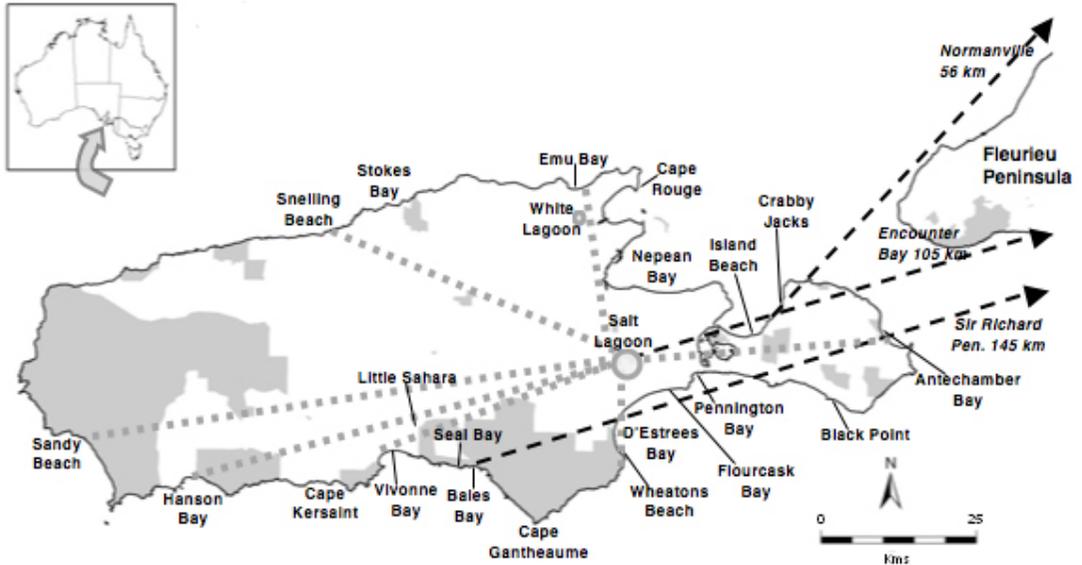
Id. nyrm: banded as a juvenile at Bales Bay on 28 February 1987, then recorded 99 days later on 7 June in a mixed-age flock of six birds ~3 km north of the Murray River mouth on the Sir Richard Peninsula, ~145 km from the last sighting on Kangaroo Island (TD pers obs.).

Id. ypom: banded as an adult at Browns Beach on 17 December 1987, then observed on 5 July 1989, 2.7 years (930 days) later, paired and breeding on Normanville Beach (L. Montagus, pers comm.), ~56 km from the last sighting on Kangaroo Island. Several subsequent sightings reported it as paired and at the same location until 26 December 1991, when it was found dead at nearby Carackalinga Beach and the band retrieved (ABBBS, *in litt.*).

Id. rywmm: banded as a juvenile at Wheatons Beach on 6 February 1991. After several re-sightings among winter flocks at Salt Lagoon (Figure 1) in 1991, it was subsequently recorded on several occasions during April and May 1994, among a small mixed age flock in the Inman River estuary at Encounter Bay. For example, 5 April, >3 years (1153 days), and 14 May (1192 days) after initial capture and banding, ~105 km from the last sighting on Kangaroo Island (R. Sharpe, *in litt.*).

In addition, during the winter of 1989 several sightings of "one, sometimes two" unidentified

Figure 1. Examples of Hooded Plover mobility on Kangaroo Island, between breeding beaches and the autumn-winter flocking sites at Salt and White Lagoons (dotted lines), mainland dispersals (dashed arrows) and habitat locations mentioned in the text. Shaded areas denote conservation reserves.



colour-banded Hooded Plovers were reported among small flocks at Basham Beach and between Middleton and Goolwa in Encounter Bay (L. Montagus pers. comm.). These were assumed to be from Kangaroo Island, as colour-banded birds from elsewhere (e.g. Victoria) had not been recorded in South Australia.

When re-sightings are grouped by age-class and by season (i.e. breeding and non-breeding) Hooded Plover movements within Kangaroo Island indicate that sub-adults (with 68.0% of movements) and non-paired adults (with 56.2% of movements) are more mobile across all habitats in the non-breeding season (Table 2).

Two nocturnal movements were recorded on the same night, both of adults recaptured <2 hours later at localities ~5 km and 12 km distant respectively.

Age at maturity (based on adult plumage) and first breeding

Re-sight records from a small number of known-age birds provided an estimated mean of 134.6 ± 12.2 days (range 119–149; $n = 7$) for the average

age at which moult into sub-adult plumage commenced; and 329.1 ± 16.7 days (range 303–352; $n = 11$) for when the moult into full adult plumage appeared complete (Table 3).

In addition, some hatchling to maturity data was made available from captive-bred Hooded Plovers at the Adelaide Zoo (M. Craig and B. Backhouse, *in litt.*). When these are collated with field data, the average age for moult commencement was 138.1 ± 17.3 days (range 111–163; $n = 13$); and for moult completion was 327.1 ± 16.2 days (range 311–352; $n = 13$) (Table 3).

Inclusive of two captive birds, five known-age individuals were paired (territory defence behaviour and copulations observed) aged <12 months (mean 334.2 ± 20.2 days; range 311–364). One of these, a female (rbwm) was recorded incubating at Black Point beach when aged 336 days (Table 3). In addition, among the young birds colour-banded when juveniles of imprecise age, 11 were later recorded as paired and breeding aged <18 months.

Table 1. Examples of mobility among sub-adult ($n = 13$) and unpaired adult ($n = 4$) Hooded Plovers (age-class at time of banding) on Kangaroo Island and dispersal to nearby mainland locations ($n = 3$). All movements are given as straight-line distances from previous re-sight location.

Individual id. code	Total re-sights	Movements (kms)		Years unpaired	Behaviour notes
		as sub-adult	when adult		
Sub-adults					
rbpm	25	46, 44	54, 15	3.5	with small winter flocks on north coast
rpnm	15	18, 14, 6, 6	24, 22, 25, 26, 24, 26	>5	with winter flocks at Salt Lagoon '89-91
boym	5	42	90, 52, 42	<1.5	with winter flocks at Salt Lagoon '91
nbom	7	49, 10, 30	nd	nd	mobile on eastern beaches as sub-adult
nbrm	52	80, 45	nd	2.5	80 km flight aged <3 months (~89 days)
pynm	14	36, 42, 12	38, 45	3	with winter flocks at Salt Lagoon '89-91
bnbm	10	21, 22, 22	25, 8, 25, 18	4.5	mobile with small flocks on south coast
obrm	18	24, 24	9, 16, 16	4	with winter flocks at Salt Lagoon '89-91
yrrm	6	10	43, 67	nd	'disappeared' for >5 years
prrm	12	10, 45, 45	26, 26, 18	4	with winter flocks at Salt Lagoon '91
oprmm	15	5, 9	10, 35, 35, 13, 33	2.5	with small flocks on south coast
obom	13	22, 21	12, 21	1.5	with winter flocks at Salt Lagoon '89
boom	15	5, 5, 5	31, 34, 30, 30	4	with winter flocks at Salt Lagoon '91
Means		25.0 ± 18.2 km (range 5-80)	29.5 ± 16.8 km (range 9-90)		
Unpaired adults					
rnwm	9	-	46, 52, 52, 28, 28	4.5	aged >5 years at first pairing; briefly with winter flocks
yrbm	6	-	43, 43, 42, 37, 62	2.5	adult when banded
poom	11	-	26, 34, 12, 24, 11, 11	2.5	with winter flocks at Salt Lagoon '89
onym	8	-	24, 31	3	with winter flocks at Salt Lagoon '91
Means			33.7 ± 14.7 km (range 11-62)		
Mainland records					
ypom	2	-	57	nd	adult when banded; paired at Normanville Beach '89-91
nyrm	2	145	-	nd	with flock of sub-adults on Sir Richard Peninsula, June '87
rywm	5	18	105	nd	with flocks at Salt Lagoon '91; with small flock at Encounter Bay April-May '94
Means (combined)		28.4 ± 27.4 km (range 5-145)	32.7 ± 18.9 km (range 9-105)		

Table 2. Examples of mobility among sub-adult Hooded Plovers (prior to entering the breeding population) and a small number of unpaired adults, with movements (<100 days apart; *vide* Weston *et al.* 2009) grouped by season. Movements are given as straight-line distances from previous re-sight locations.

Id. code	Total re-sights	No. of movements represented by distance from last re-sight (km)				No. years unpaired
		as sub-adult		when adult		
Sub-adults		breeding season	non-breeding season	breeding season	non-breeding season	
rbpm	25	-	46, 44	54, 15	-	3.5
rpnm	15	6	18, 14, 6	24, 22	25, 26, 24, 26	>5
boym	5	-	42	-	90, 52, 42	<1.5
pynm	14	36, 12	42	38	45	3
bnbm	10	22, 22	22	21, 22, 22, 25, 8, 25, 18	-	4
obrm	18	-	24, 24	9	16, 16	4
prrm	12	45, 45	10	26	26, 18	4
oprm	15	-	5, 9	13	10, 35, 35, 33	2.5
obom	13	22	21	15, 22	22, 12, 21, 21, 12	1.5
boom	15	-	5, 5, 5	5, 5, 5, 24	31, 34, 6, 30	4
Unpaired adults						
rnwm	9	-	-	52, 52	46, 28, 28	4.5
yrbm	6	-	-	43	43, 42, 37, 62	2.5
poom	11	-	-	34, 11, 11	26, 12, 25	2.5
onym	8	-	-	31	24	3
Total movements		8	17	28	36	
% of movements			68.0%		56.2%	

Pair and site fidelity

Many individually marked birds were identified as paired and sedentary on apparent breeding territories over multiple seasons, i.e. 27 pairs remained together at the same location for at least one consecutive breeding season, with 16 of these recorded with the same partner on the same territory over multiple seasons (Table 4). Two of these pairs had been previously captured (nest-trapped) and banded (ABBBS bands) as breeding pairs in 1981 (A. Lashmar, *in litt.*), and both were recaptured on the same territory five years later (Table 4).

Flocking behaviour on Kangaroo Island

In addition to favoured beach foraging locations,

flocks formed in autumn on a small number of inland saline lakes (e.g. White Lagoon and Salt Lagoon; Figure 1) and remained there through early winter before apparent dispersal in July. At these, the Salt-lake Snail, *Coxiella striata*, a minute mollusc known to be an important over-wintering food source for migratory waders (Dittmann *et al.* 2006) was abundant, and likely provided the foraging attraction for the Hooded Plover and other over-wintering migratory wader species.

In 1989, flocks were present at Salt Lagoon from late-March through to mid-July with the largest aggregations being recorded in June (A. Lashmar, *in litt.*). On the 22nd of June a flock of 34 was

Table 3. Age estimates (in days) of sub-adult and adult Hooded Plovers based on plumage phase in re-sighted and captive-bred birds and when first recorded as paired or breeding.

Id. code (sex)	Hatch date	No. re-sights	Moult commencement*	Full adult plumage	Paired/breeding
Resighted birds					
npbm	26-1-87	3	-	325	-
oprm	20-2-87	15	119	313	-
bbom	4-10-87	6	126	-	-
rbom	4-10-87	14	125	-	-
obom (f)	5-11-87	13	149	314	(eggs at 505**)
rnom	7-1-88	9	-	348	-
rbnm	25-1-88	14	131	303	-
ypwm (f)	12-11-89	5	-	350	364
wpwm	12-11-89	3	-	352	-
opwm	12-12-89	1	-	328	-
rbwm (f)	23-10-90	9	144	336	336 (eggs)
bbwm	23-10-90	12	148	336	339
nbwm	12-1-91	1	-	315	-
Means (days)			134.6 ± 12.2	329.1 ± 16.7	346.3 ± 15.4
Captive-bred birds					
AdZ930561 (f)	22-11-93	na	141	311	311 (eggs)
AdZ930562 (f)	21-12-93	na	155	-	-
AdZ930563 (m)	21-12-93	na	163	-	-
AdZ930564 (f)	21-12-93	na	163	-	-
AdZa10111 (m)	16-1-01	na	120	321	321
AdZa40665 (m)	5-11-04	na	111	-	-
Means (days)			142.2 ± 22.4	316.0 ± 7.1	316.0 ± 7.1
Combined (days)			138.1 ± 17.3 (range 111 - 163)	327.1 ± 16.2 (range 303 - 352)	334.2 ± 20.2 (range 311 - 364)

* some black adult feathers (i.e. <20% cover) appearing on crown and mantle

** not included in age at first breeding estimates as it may have been a second clutch event i.e. late in breeding season

present, of which 12 were adult (four colour-banded) and 22 were juvenile or sub-adult age birds (six colour-banded). On the 29th a flock of 49 was present, of which 33 were adult (10 colour-banded) and 16 were juvenile or sub-adult age birds (two colour-banded). The mean proportion of colour-banded Hooded Plovers in these two flocks was 27%.

In 1990, flooding rains in late March filled Salt Lagoon to peak-flood level precluding observer access for the autumn-winter period of that year.

In 1991, Salt Lagoon was monitored weekly from April to mid-July. The largest aggregations were recorded in April and May (Figure 2), when the mean flock size was 33.4 ± 3.0 (range 12–55) and

Table 4. Examples of Hooded Plover pair fidelity and adherence to territory locations on Kangaroo Island spanning multiple breeding seasons.

Pair Id. codes	Territory location	No. br. seasons paired	Period	No. re-sights		Pair bond behaviour notes
				paired	off-terr.	
nnrm + onrm	Crabby Jacks	6	Nov 81 - Dec 86	7	0	paired when first banded in 81-82 breeding season
oppm + ppm	Black Point Beach	5	Dec 81 - Jul 86	3	0	paired when first banded in 81-82 breeding season
rypm + nypm	Island Beach	4	Jun 86 - Jun 90	2	1	pair together in small flock <4 km distant during winter high tide event
rybm + orbm	Emu Bay (east)	4	Aug 86 - May 90	12	0	rybm (m) not recorded away from Emu Bay over 9.5 yrs (23 re-caps.)
rybm + oywm	Emu Bay (east)	5	Mar 91 - Nov 95	9	0	second long-term pairing for rybm on same territory
rpym + bpym	Hanson Bay (mid)	6	Jan 87 - Jan 92	14	0	only recorded together and on territory
porm + bprm	Bales Bay (mid)	5	Feb 87 - Aug 90	4	1	bprm 22 km E in small flock post 88-89 breeding season
wowm + bpbm	Emu Bay (mid)	3	Aug 87 - May 90	19	1	both briefly 38 km W from highly disturbed terr. during 87-88 br. season
rbpm + nrom	Snellings Beach	5	Sep 87 - Jan 92	16	0	both highly mobile before pairing, then only rec. together on territory
nnpm + nrrm	Antechamber Bay	4	Nov 87 - Aug 90	8	1	both briefly 30 km distant in winter
brm + rbrm	Pennington Bay	3	Jan 88 - Sep 91	8	1	both briefly 20 km from highly disturbed terr. during 87-88 br. season
oorm + rnrn	D'Estrees Bay (south)	5	Mar 88 - Mar 92	27	1	with winter flocks at nearby beach
rrbm + onbm	Stokes Bay	5	Jan 89 - Nov 92	15	0	only recorded together and on territory
nbrm + yrom	D'Estrees Bay (south)	4	Aug 89 - Apr 93	26	1	with winter flocks at nearby beach
pybm + bnnm	Emu Bay (east)	4	Aug 89 - Nov 93	18	2	both in small winter flock on nearby saline lagoon (5 km distant) in 90; bnnm (f) with flocks at Salt Lagoon (28 km distant) May - Jun 91
wowm + prwm	Emu Bay (mid)	3	Mar 91 - Feb 93	10	0	only recorded together and on territory

Table 5. Hooded Plover flock numbers and composition i.e. age-class and percentage of colour-banded (c-b) birds present at Salt Lagoon at weekly intervals during autumn and early winter in 1991.

	April				May			
	Flock size	No. ad. (c-b)	No. s-ad. (c-b)	% c-b ad. & s-ad.	Flock size	No. ad. (c-b)	No. s-ad. (c-b)	% c-b ad. & s-ad.
Week 1	25	14 (4)	11 (4)	28.6 & 36.4	12	10 (1)	2 (0)	10.0 & 0.0
Week 2	28	18 (6)	10 (4)	33.3 & 40.0	55	42 (12)	13 (4)	28.6 & 30.8
Week 3	40	30 (13)	10 (3)	43.3 & 30.0	43	33 (8)	10 (3)	24.2 & 30.0
Week 4	32	21 (7)	11 (1)	33.3 & 9.1	32	22 (10)	10 (0)	45.4 & 0.0
Means	31.3	20.8	10.5	ad. 34.6 ± 6.2% s-ad. 28.9 ± 13.8%	35.5	26.8	8.8	ad. 27.0 ± 14.6% s-ad. 15.2 ± 17.6%
June								
	Flock size	No. ad. (c-b)	No. s-ad. (c-b)	% c-b ad. & s-ad.				
Week 1	13	10 (6)	3 (2)	60.0 & 66.7				
Week 2	16	14 (3)	2 (0)	21.4 & 0.0				
Week 3	18	18 (4)	0	22.2 & 0.0				
Week 4	5	4 (0)	1 (1)	0.0 & 20.0				
Means	13.0	11.5	1.5	ad. 25.9 ± 24.9% s-ad. 21.7 ± 31.5%				

Combined (12 weeks)

Mean flock size 26.6 ± 11.9 (range 5 - 55); mean c-b component $29.1 \pm 13.2\%$

Flock composition (means): ads 19.7 ± 7.7 (c-b $29.2 \pm 4.7\%$) and s-ad. 6.9 ± 4.7 (c-b $28.5 \pm 13.3\%$)

the mean proportion of colour-banded birds was $28.4 \pm 9.5\%$. The mean flock size over the autumn-winter period was 26.6 ± 11.9 birds (range 5-55) and the mean proportion of colour-banded birds among them was $29.1 \pm 13.2\%$ (Table 5).

Fourteen of the colour-banded adults among these flocks were known to be paired, and were later recorded as having returned to their respective territorial beaches during the following breeding season. Seven of these were recorded on multiple occasions during the autumn-winter of 1991, with the average (minimum) period spent at Salt Lagoon being 20.4 ± 19.7 days (range 7-64; Table 6). Among these: pobm was recorded seven times over a period of 64 days in April-June; obom and bnm were both recorded three times over 16 days in

May-June; and bnom was recorded twice over 20 days in April (Table 6).

Similarly, unpaired adults and sub-adult Hooded Plovers were also recorded on multiple occasions at Salt Lagoon in 1991, with minimum periods of time spent there averaging 32.4 ± 21.3 days (range 7-66) for unpaired adults; and 52.0 ± 24.5 days (range 7-71) for sub-adults (Table 7).

Breeding records away from beach habitat

In early December 2001 a single adult was observed attending a nest with two eggs ~3.5 km inland at the Little Sahara Geological Monument site (a landlocked sand dune complex inland from Vivonne Bay). In November 2010 a pair with two small runners (aged <5 days) was recorded at an un-named hyper-saline lake ~1.5 km inland from Flour Cask Bay (C. Baxter, *in litt.*).

Table 6. Utilisation of saline lake habitat at Salt Lagoon by paired adult Hooded Plovers during the autumn and early winter of 1989 and 1991, with examples of multi-year use ($n = 2$) and of extended use in 1991 ($n = 7$).

Id. code (sex)	Territory location	Total re-sights	No. br. seas. paired	Distance (km) to Salt Lagoon	No. re-sights at Salt Lagoon	No. days at Salt Lagoon	Period
Extended use records							
pobm (f)	Browns Beach	15	5	22	7	64	Apr-Jun 91
bnom	D'Estrees Bay	13	2	15	2	20	Apr 91
obom	Stanleys Beach	13	3	14	1 3	1 16	Jun 89 May-Jun 91
bnnm (f)	Emu Bay	24	4	28	3	16	May-Jun 91
yrom	Wheatons Beach	37	4	18	2	10	Apr 91
yobm (f)	Pelican Lagoon	7	2	14	2	10	Jun 91
borm	Bales Bay	22	5	30	2	7	May 91
Mean period at Salt Lagoon in 91						20.4 ± 19.7 days	
Single day records							
ppom (m)	Browns Beach	12	2	22	1	1	Jun 91
opom (m)	Browns Beach	5	3	22	1	1	Jun 89
ynpm (f)	Sandy Beach	11	3	92	1	1	Jun 89
rnwm	Emu Bay	9	2	28	1	1	Apr 91
boym	Rocky River	5	2	90	1 1	1	Jun 89 Apr 91
ppom (m)	Browns Beach	12	2	22	1	1	Jun 91
rpbm (m)	Nepean Bay	12	4	11	1	1	May 91

Longevity

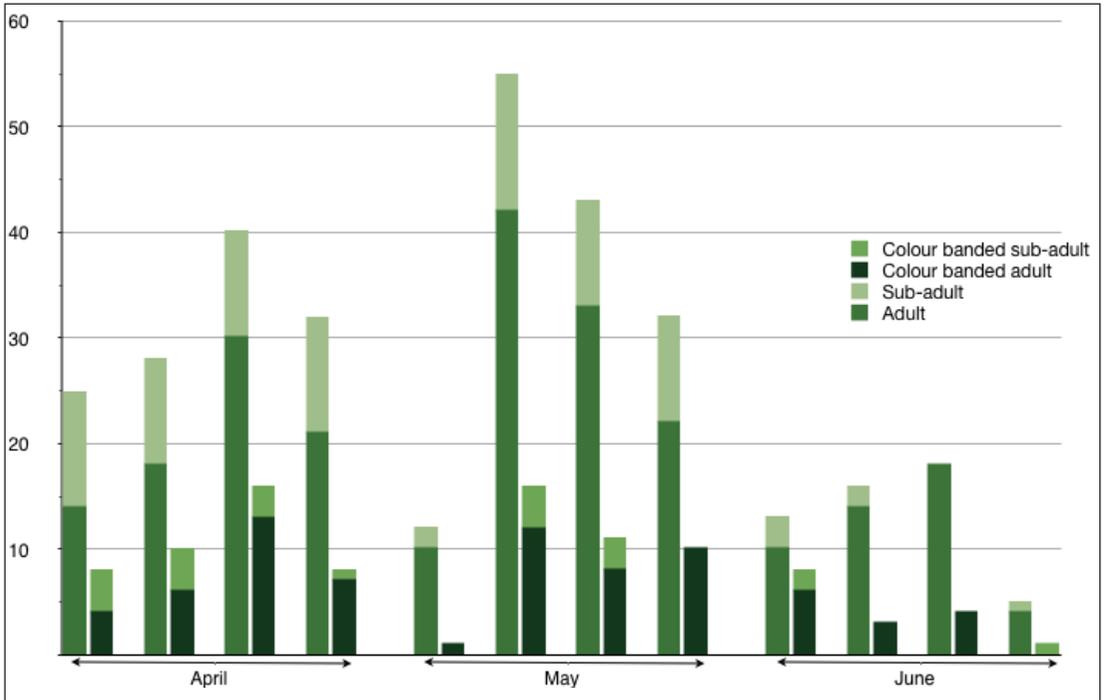
A total of 63 colour marked birds were aged >5 years when last recorded. Among these, 24 were aged >7 years, and eight were aged 10 years or more. Some life-history details for the three oldest follow.

Id. pnpnm: banded as an adult at Wheatons Beach on the south coast in August 1986; subsequently

recorded nine times between 1988–94, 17 km distant (paired and on territory) at Cape Gantheaume; last re-sight record was late-October 1998 (on territory), when aged >13 years.

Id. pnpwm: banded as sub-adult at Vivonne Bay in mid-June 1990; subsequently recorded three times (paired and on territory) 3.5 km distant near Cape Kersaint; the last re-sight record was

Figure 2. Hooded Plover flock composition (i.e. age-class and proportion of colour-banded to unbanded birds) at Salt Lagoon, recorded weekly during autumn and early winter in 1991.



DISCUSSION

Age at maturity (adult plumage) and at first breeding

It is possible that field observations, which relied on visually determining moult completion, may have been subjective or inaccurate due to prevailing ambient conditions or observer error. Even if this had occurred in some cases, the number of individuals ($n = 13$) re-sighted on multiple occasions in this study, and the evidence provided for age at first pairing and egg-laying at less than 12 months (Table 3) confirms the early maturity of some individuals and widens the understanding of reproductive parameters for the species.

On Phillip Island, Victoria, two known-age Hooded Plovers were first recorded breeding (incubating) aged 23.5 and 20.5 months (± 0.25 months) respectively (Baird and Dann 2003). The South Australian Recovery Plan for the Hooded Plover recognises that some breed much earlier, i.e. 'when aged a little over 12 months' (Baker-Gabb and Weston 2006). Results from this study

confirm the potential for early-age breeding, but with wide variability for the timing of pairing and breeding (Table 3). However, the apparent Hooded Plover population increases recorded since 2004, together with the known density of pairs (1.69/km) over available habitat on Kangaroo Island (Ewers *et al.* 2011; Jane Renwick, *in litt.*) may limit the opportunity for unpaired adults to enter the breeding population spatially, as much as by age.

Pair and site fidelity

Many individually marked birds were identified as paired and sedentary on apparent breeding territories over multiple seasons. Other than short distance (<5 km) movements, paired birds in multi-season partnerships were rarely recorded away from their territory during the breeding season (Table 4). Such movements may have occurred in response to disturbance, as in each case given in Table 4, the birds involved emanated from beaches with high levels of recreation use, including vehicle usage (Dennis and Masters 2006).

It cannot be assumed however, that the examples of pair and site fidelity provided (Table 4) are the blissful norm on Kangaroo Island, as there are examples of short-term (single or part-season) pairings (see Bransbury 1991), and unverified polygamous relationships in the data accumulated over the life of the project. However, it was beyond the scope of this study to explore these particular behavioural aspects in depth.

Seasonal movements and flocking behaviour

Winter aggregations of Hooded Plovers on inland lakes and estuaries have been recorded throughout the species' range in south-eastern Australia, often coincident with beach habitats being deserted due to prevailing storm conditions (Schulz 1987; Baker-Gabb and Weston 2006). Prior to this study, post breeding season flocking was known to occur on Kangaroo Island: e.g. "15 Hooded Plovers in a tight huddle ... during a south-westerly storm" at Vivonne Bay in early August 1982 (Baxter 1995); 28 birds at D'Estrees Bay (including 13 sub-adults) in late April 1983 (TD pers obs.); and 46 birds on Salt Lagoon in May 1984 (A Lashmar, *in litt.*).

Over the course of this study, flocks of ten or more birds (of mixed age) were recorded in all seasons at apparently favoured coastal foraging locations and often included pairs from nearby beaches when not actively breeding. Flocking typically occurred at beaches with heavy accumulations of seagrass (*Posidonia* sp.), where prey such as sandhoppers (*Talorchestia* sp.) and other invertebrate detritivores were abundant (often super-abundant nocturnally) in the supra-littoral zone (Currey and Poulin 2006). These locations included Emu Bay and Cape Rouge on the north coast of the Island, and at D'Estrees, Bales and Vivonne Bays on the south coast (Figure 1). Other shorebird species, such as migratory waders and gulls, were also attracted to these foraging locations with spectacular flocks of >100 birds of several species being common.

Among the flocks recorded at Salt Lagoon in 1991, fourteen colour-banded adults were known to be paired, and were recorded as having returned to their respective territorial beaches in the following breeding season. Seven of these were recorded on multiple occasions spanning from seven to 64 days during the autumn-winter survey period (Table 6). These behaviours indicate that extended (or multiple short-term) periods of absence off-territory during the non-breeding season may be a social norm for the species, which aligns generally with the findings from the central regions of Victoria, where the majority of movements across all age-classes occurred during the non-breeding season (Weston, Ehmke and Maguire 2009).

Because paired and non-paired adults as well as sub-adults were regularly present among the flocks at Salt Lagoon, many for extended periods (Tables 5, 6 and 7), it can be assumed that there may be a level of seasonal reliance on some saline lakes as foraging habitat.

Population estimates

Following extensive surveys during the early phase of this study, the Kangaroo Island Hooded Plover population was estimated at ~150 birds, i.e. 143 in 1987 (Bransbury 1987) and 151 in 1994 (Schulz 1995). However, given the proportion of unbanded adults (>60%) recorded among the autumn-winter flocks during this period (Table 5), these estimates now appear flawed. Between May 1986 and the autumn of 1991, 221 (of 284) colour-banded Hooded Plovers were re-sighted on multiple occasions. Even assuming that only 50% of these were extant in 1991, the level of dilution among the autumn-winter flocks at Salt Lagoon would indicate either:

- a previously overlooked 'floating' sub-population of non-territorial adults on Kangaroo Island; or more likely,
- a possible seasonal influx of Hooded Plovers from mainland habitats where there is an absence of saline lakes with the mollusc *Coxiella* sp. available.

Habitat management implications

Although the exogenous factors driving individual Hooded Plover mobility and flocking behaviour are not well understood, the foraging locations on Kangaroo Island and associated dependence behaviours identified in this study, appear to answer some aspects of the species' overall habitat requirements; e.g. saline lakes appear important as refuge and seasonal foraging habitat. These may be crucial to survival outcomes for cohorts of young each breeding season and may also sustain birds from nearby mainland habitats.

In a recent study in Victoria, Weston, Ehmke and Maguire (2009) identified the need for further research into the characteristics and significance of flock foraging sites to overall population stability. Future research involving individual identification and satellite tracking technology could be usefully directed toward unravelling this aspect of the species' behaviour and habitat dependence on Kangaroo Island and elsewhere. Additionally, in accord with the Primary Recovery Actions recommended in the South Australian Hooded Plover Recovery Plan (Baker-Gabb and Weston 2006), a comprehensive phenological assessment of all habitat types frequented by the Hooded Plover is required, including saline lakes. These appear important to sustain at least some elements of the population through the non-breeding season and therefore have implications for the adequacy of habitat management on Kangaroo Island and indirectly, for conservation outcomes across the species range in South Australia.

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