FINAL REPORT ON PROJECT D13-0379 – DARWIN – EAST ARM PORT PROJECT

REPORT TO THE NORTHERN TERRITORY GOVERNMENT

30 JUNE 2015

Amanda Lilleyman, Michael J. Lawes and Stephen T. Garnett

Research Institute for the Environment and Livelihoods, Charles Darwin University, Darwin 0909, Northern Territory

Lilleyman, A., Lawes, M.J. and Garnett, S.T. 2015. Final report on Project D13-0379 – Darwin – East Arm Port Project. Report to the Department of Business, Northern Territory Government

29 March 2017

Front cover: A flock of Eastern Curlew (*Numenius madagascariensis*) roosting in Pond K at East Arm Wharf.

Image credit: Amanda Lilleyman

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EXECUTIVE SUMMARY

Ten species of migratory shorebird, all listed in the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) under 'Matters of National Environmental Significance', have been recorded roosting at East Arm Wharf (EAW) in sufficient numbers for the land holder (the Northern Territory Government) to be obligated to protect and maintain part of the site for shorebirds in perpetuity. Targeted monitoring of migratory shorebirds has been performed at EAW since 2009 by Conservation Volunteers Australia and as part of a PhD research project. Initial monitoring suggested that species abundance thresholds were crossed rarely. More recent monitoring has demonstrated that nationally significant numbers of multiple species are now using the site, indicating that the site is becoming more important with time. During six years of targeted surveys, EAW has also supported 15 or more species of migratory shorebird, another trigger for significance under the EPBC Act.

The migratory shorebirds using EAW breed in northern Russia, China and Alaska. They reach Australian shores via stop-over sites in east Asia, principally the Yellow Sea, which is bounded by China and North and South Korea. Many species are known to use direct flights to reach these sites so that they arrive with depleted fat stores that they then replenish. These stop-over sites are rapidly being lost to development or pollution and are subjected to disturbance and hunting. For shorebirds to survive after reaching compromised stop-over sites they depend on their fat stores. Thus high quality non-breeding sites are important to persistence of shorebird species. This is especially true of the Eastern Curlew (*Numenius madagascariensis*), recently uplisted under the EPBC Act to Critically Endangered on the basis of an 80% decline in abundance over the last three generation times.

Based on the tracking component of this study, all tagged migratory shorebirds preferred to roost at EAW over all other known major roost sites between East Arm and Lee Point. Furthermore, EAW is now as important as the other major roost sites monitored in the network of surveyed sites in the Darwin Harbour region. While this is a new site, since the area was probably not suitable for roosting before EAW was constructed, it is evidently superior to other sites in the region. This may mean either that fewer birds used the surrounding mudflats than before, that they had to travel further to find a suitable roost site or had to use sites where they were more likely to face disturbance or predation. Given evidence that quality of non-breeding sites is now likely to be of greater importance than previously, conservation of a roost site on or near EAW is most likely to be consistent with compliance with the EPBC Act. Thus any reclamation of EAW that prevents its use as a roost site should be offset by creation and protection of an equivalent roost site in the vicinity.

BACKGROUND

Extensive monitoring of migratory shorebirds at known roost sites in Darwin Harbour has revealed the species composition and abundances at a local Darwin scale. This project provides the first information on the connectivity of sites and how important the sites are relative to one another, allowing a coarse classification of site importance. This report identifies the work that has been done to date; including preliminary results of the 2014-15 shorebird tracking program.

This project assesses the importance of EAW for 36 species of migratory shorebird (listed in Table 1) protected under the EPBC Act. The EPBC Act operationalizes responsibilities under the following international agreements to which Australia is a signatory: the Convention on the Conservation of Migratory Species of Wild Animals, Japan-Australia Migratory Bird Agreement, China-Australia Migratory Bird Agreement and Republic of Korea-Australia Migratory Bird Agreement. These agreements recognise the need to protect shorebirds by co-operating across jurisdictions, obligating Australia to protect migratory shorebird habitat and maintain sustainable populations when birds are in Australia (Department of the Environment Water Heritage and the Arts 2009).

The Northern Territory Government is obligated to protect migratory shorebirds that use EAW under conditions set out by the Australian Government in the Consolidated Approval Notice (Department of the Environment 2014), and the Migratory Birds Management Plan (Garnett 2013), following the EPBC Act Policy Statement 3.21 (Department of the Environment Water Heritage and the Arts 2009). The Migratory Birds Management Plan was submitted to the Commonwealth Minister for Sustainability, Environment, Water, Population, and Communities as part of fulfilling Approval 2010/5304 condition 36 of the EPBC Act. The purpose of this condition is to provide appropriate (and commensurate) offsets for the residual and consequential impact of the East Arm Wharf Expansion Works upon migratory shorebirds. Broadly, the condition provides for:

- the protection and maintenance of ‘Pond D’ as a suitable high tide roost habitat;
- capture of data to enhance the understanding of migratory shorebirds and their use of this location; and
- the use of adaptive management to optimise outcomes.

Table 1. Migratory shorebird species monitored at East Arm Wharf. Species conservation status shown for EPBC listing, migratory species listing, Territory Parks and Wildlife Conservation Act 2006, bilateral agreements, and IUCN Red List status. Species listed in taxonomic order following Christidis and Boles (2008).

Shorebird	Scientific name	EPBC Act	EPBC Mig sp list	NT	Bonn	CAMBA	JAMBA	ROKAMBA	IUCN
Pacific Golden Plover	*Pluvialis fulva*		protected		A2H	listed	listed	listed	LC
Grey Plover	*Pluvialis squatarola*		protected		A2H	listed	listed	listed	LC
Little Ringed Plover	*Charadrius dubius*		protected			listed			LC
Lesser Sand Plover	*Charadrius mongolus*		protected	V	A2H	listed	listed	listed	LC
Greater Sand Plover	*Charadrius leschenaulltii*		protected	V	A2H	listed	listed	listed	LC
Oriental Plover	*Charadrius veredus*		protected		A2H		listed	listed	LC
Black-tailed Godwit	*Limosa limosa*		protected		A2H	listed	listed	listed	NT
Bar-tailed Godwit	*Limosa lapponica*		protected	V	A2H	listed	listed	listed	LC
Whimbrel	*Numenius phaeopus*		protected		A2H	listed	listed	listed	LC
Eastern Curlew	*Numenius madagascariensis*	CR	protected	V	A1	listed	listed	listed	V
Terek Sandpiper	*Xenus cinereus*		protected		A2H	listed	listed	listed	LC
Common Sandpiper	*Actitus hypoleucos*		protected		A2H	listed	listed	listed	LC
Grey-tailed Tattler	*Tringa brevipes*		protected		A2H	listed	listed	listed	NT
Common Greenshank	*Tringa nebularia*		protected		A2H	listed	listed	listed	LC
Marsh Sandpiper	*Tringa stagnatilis*		protected		A2H	listed	listed	listed	LC
Wood Sandpiper	*Tringa glareola*		protected		A2H	listed	listed	listed	LC
Ruddy Turnstone	*Arenaria interpres*		protected		A2H	listed	listed	listed	LC
Asian Dowitcher	*Limnodromus semipalmatus*		protected	V	A2H	listed	listed	listed	NT
Great Knot	*Calidris tenuirostris*		protected	V	A2H	listed	listed	listed	V
Red Knot	*Calidris canutus*		protected	V	A2H	listed	listed	listed	LC
Sanderling	*Calidris alba*		protected		A2H	listed	listed	listed	LC
Red-necked Stint	*Calidris ruficollis*		protected		A2H	listed	listed	listed	LC
Sharp-tailed Sandpiper	*Calidris acuminata*		protected		A2H	listed	listed	listed	LC
Curlew Sandpiper	*Calidris ferruginea*	CR	protected	V	A2H	listed	listed	listed	LC
Broad-billed Sandpiper	*Calidris falcinellus*		protected		A2H	listed	listed	listed	LC

Key: A2H: species is member of a family listed in Appendix 2 of the Bonn Convention, CR: Critically Endangered, LC: Least Concern, NT: Near Threatened, V: Vulnerable

Under the EPBC Act Policy Statement 3.21, sites for migratory shorebirds can be classified as nationally important if they meet any of the criteria listed in Box 1.

Box 1. Criteria under the EPBC Act Policy Statement 3.21 for classification of a site as nationally important for migratory shorebirds (Department of the Environment Water Heritage and the Arts 2009).

A site is nationally important habitat if it:

- is identified as internationally important under Ramsar;
- supports at least 0.1% of the flyway population of a single migratory shorebird species;
- sustains 2,000 or more migratory shorebirds; or
- sustains 15 or more shorebird species.

Protection of habitat at other ports in Australia

A number of ports around Australia meet environmental obligations to protect migratory shorebirds that use port facilities by conserving appropriate habitat or by creating compensatory habitat as part of a sustainable offset solution to development. Major ports in Australia that support ongoing monitoring and research of shorebirds include Gladstone Port Corportation in Queensland, Port Botany and the Port of Newcastle in New South Wales, Broome Port in Western Australia, and the Port of Brisbane in Queensland. The Darwin Port Corporation has been funding the monitoring of shorebirds at EAW since 2010 and continues to engage with Conservation Volunteers Australia on a monthly basis.

Two major projects in NSW have resulted in a net increase in habitat availability for migratory shorebirds and other waterbirds as an offset for the expansion of ports. The design and construction of roosting and feeding habitat has allowed for nocturnal roosting, a low maintenance and fully functioning ecosystem, while considering climate change and sea level rise (Avifauna Research and Services Pty Ltd 2010).

SHOREBIRD ROOSTING SITES IN DARWIN HARBOUR

Shorebird ecology in Australia

Most shorebirds in Australia are long-distance migrants that breed in Siberia, Alaska or China, and visit Australian shores in their thousands in the austral summer. Their annual migration is determined by the phenology of food availability, reproduction and individual survival (Geering 2007). On arrival in Australia, shorebirds spend the duration of the austral summer seeking out high-quality food resources. Tidal cycles dictate foraging and roosting times for most coastal shorebirds that feed on benthic macroinvertebrates on exposed mudflats during low tide. At high tide, when the foraging grounds are submerged, shorebirds retreat to roosts on sandy beaches and rocky reefs where they typically loaf.

Shorebird ecology in Darwin Harbour

Monitoring of migratory shorebirds in the Darwin Harbour region has primarily focused on the northern beaches for which a large database of shorebird counts is owned by the Shorebirds 2020 program, under the direction of Birdlife Australia. Monitoring of the East Arm Wharf dredge ponds for migratory shorebirds began in 2010. As part of this PhD study, AL has been monitoring seven sites in the region, East Arm Wharf (Ponds E, D, K, B), Lee Point (LP), Sandy Creek (SC), Nightcliff Rocks (NR), East Point (EP), Ludmilla Bay (LB) and Spot on Marine (SOM) (Figure 1).

Migratory shorebirds in Darwin Harbour are forced to move off mudflats as the tide height increases and often move to supratidal saltpans immediately behind the mangroves that fringe the coastline. Once the saltpans are inundated the birds fly to the EAW ponds to roost for the duration of the high tide, and move to mudflats and creek beds once they are exposed to recommence feeding (AL pers. obs.). For a series of spring high tides from January to March in 2015, the time of arrival was recorded for birds at the EAW roost. Arrival times were correlated with tide height (obtained from the National Tidal Centre) to demonstrate the critical tide height range for shorebirds that feed on Darwin Harbour mudflats and roost nearby (Figure 2).

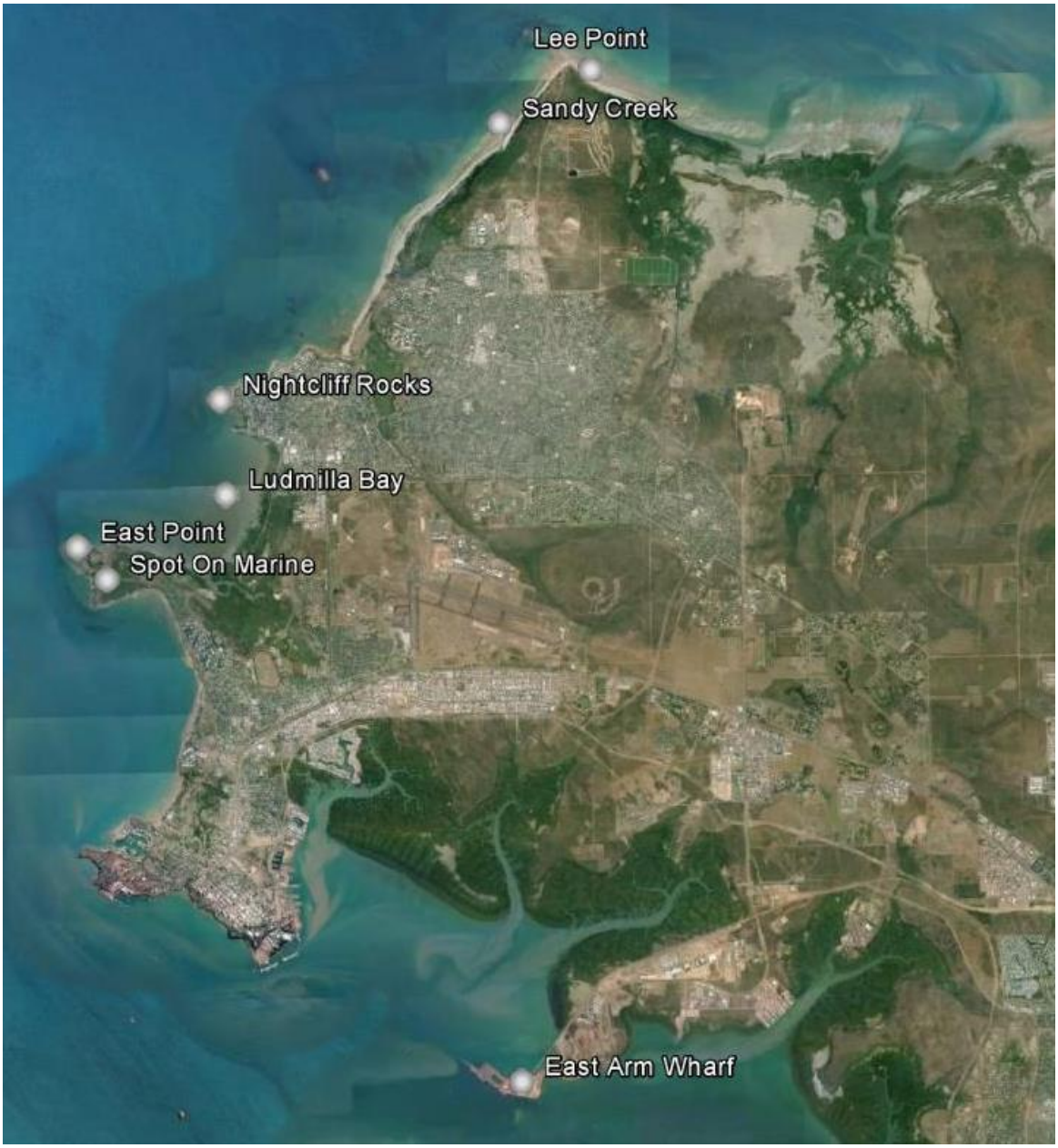


Figure 1. Migratory shorebird monitoring sites around Darwin Harbour, Northern Territory. Image credit: Google Inc (2015).

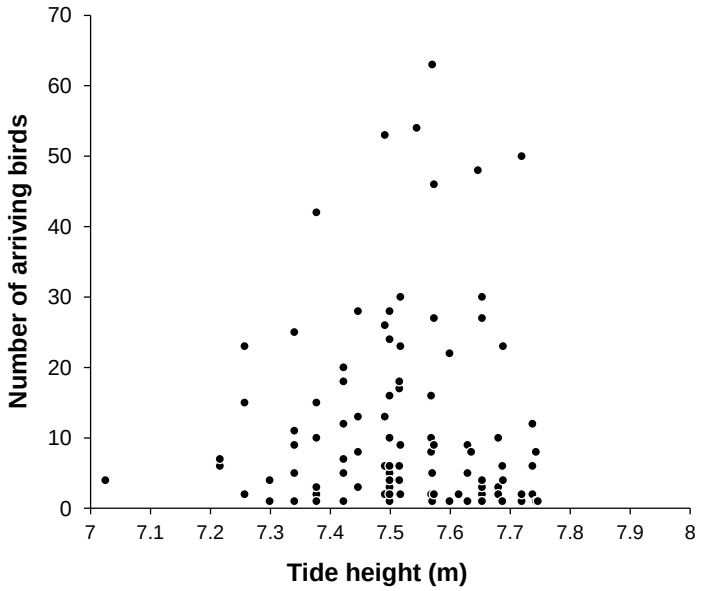


Figure 2. The critical tide height range for migratory shorebirds that arrive at East Arm Wharf from the mudflats and saltpans of Darwin Harbour.

The fortnightly 'spring-neap' cycle of tides and their macrotidal nature (tide range up to 8.2 m over a year) means that shorebirds using mudflats in Darwin Harbour require roost sites when tides reach >7.0 m. In addition, the roost site must meet several ecological criteria to suit the range of migratory shorebird species that use the area. Several factors influence shorebird choice of roosting site and individuals must assess the distance to tall cover, visibility, microclimate, distance from feeding sites and disturbance rates (Rogers 2003, Rogers et al. 2006a, Rogers et al. 2006b). The EAW dredge ponds provide a range of habitats for roosting shorebirds (Table 2), with Pond D (Table 3) having been set aside as a reserve in perpetuity. In total 27 species of migratory shorebird have been recorded roosting at EAW, nearly double the threshold required for the area to be considered a site of national significance (15 species). For 10 species the national threshold of 0.1% of the flyway population has been met. This includes 39 occasions when the threshold has been exceeded for the Critically Endangered Eastern Curlew, out of 101 occasions when the birds were recorded roosting there and 41.56% of all counts undertaken at the site.

Table 2. Maximum count, occurrence of species during study period, and threshold exceedances for 37 species of migratory shorebird at East Arm Wharf, Darwin, for the period of 2010 – 2015 (243 counts). Species that have exceeded the EPBC threshold are in boldface.

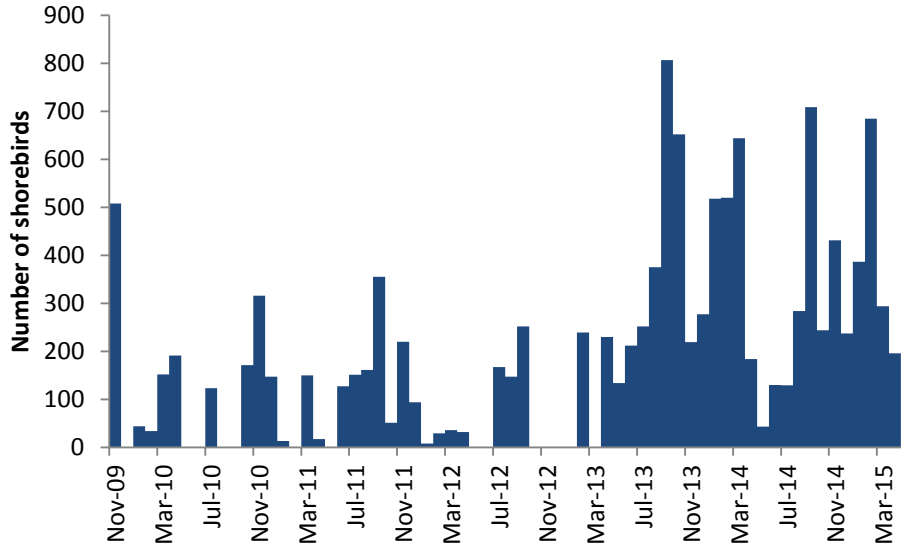
Shorebird	Maximum count	Number of counts species present	% present in counts	No. counts > EPBC (0.1%) threshold	Threshold (DEWHA 2009)
Latham's Snipe	0	0	0.00	0	18
Pin-tailed Snipe	0	0	0.00	0	n/a
Swinhoe's Snipe	1	2	0.82	0	n/a
Black-tailed Godwit	40	19	7.82	0	160
Bar-tailed Godwit	60	70	28.81	0	325
Little Curlew	44	1	0.41	0	180
Whimbrel	**289**	**94**	**38.68**	**17**	**55**
Eastern Curlew	**235**	**101**	**41.56**	**39**	**38**
Common Redshank	0	0	0.00	0	75
Marsh Sandpiper	259	87	35.80	0	1000
Common Greenshank	**112**	**186**	**76.54**	**4**	**100**
Wood Sandpiper	47	17	7.00	0	100
Terek Sandpiper	**142**	**45**	**18.52**	**9**	**50**
Common Sandpiper	6	65	26.75	0	50
Grey-tailed Tattler	**218**	**52**	**21.40**	**14**	**40**
Wandering Tattler	0	0	0.00	0	n/a
Ruddy Turnstone	5	6	2.47	0	35
Asian Dowitcher	3	10	4.12	0	24
Great Knot	125	75	30.86	0	380
Red Knot	**253**	**14**	**5.76**	**1**	**220**
Sanderling	8	3	1.23	0	320
Red-necked Stint	129	139	57.20	0	160
Long-toed Stint	0	0	0.00	0	25
Pectoral Sandpiper	0	0	0.00	0	n/a
Sharp-tailed Sandpiper	**200**	**98**	**40.33**	**1**	**180**
Curlew Sandpiper	23	61	25.10	0	180
Broad-billed Sandpiper	18	18	7.41	0	25
Ruff	0	0	0.00	0	n/a
Red-necked Phalarope	0	0	0.00	0	100
Pacific Golden Plover	**145**	**37**	**15.23**	**2**	**100**
Grey Plover	19	55	22.63	0	125
Double-banded Plover	0	0	0.00	0	50
Lesser Sand Plover	**300**	**74**	**30.45**	**4**	**140**
Greater Sand Plover	**483**	**91**	**37.45**	**23**	**100**
Oriental Plover	27	10	4.12	0	70
Oriental Pratincole	0	0	0.00	0	2880
Little Ringed Plover	3	1	0.41	0	25
Unidentified	70	1	0.41	0	n/a

Table 3. Maximum count, occurrence of species during study period, and threshold exceedances for 37 species of migratory shorebird at Pond D, East Arm Wharf, Darwin, for the period of 2010 – 2015 (243 counts). Species that have exceeded the EPBC threshold are in boldface.

Shorebird	Maximum count	Number of counts species present	% present in counts	No. counts > EPBC (0.1%) threshold	Threshold (DEWHA 2009)
Latham's snipe	0	0	0	0	18
Pin-tailed snipe	0	0	0	0	n/a
Swinhoe's snipe	0	0	0	0	n/a
Black-tailed godwit	3	8	11	0	160
Bar-tailed godwit	55	37	50	0	325
Little curlew	0	0	0	0	180
Whimbrel	**289**	**59**	**80**	**12**	**55**
Eastern curlew	**157**	**42**	**57**	**11**	**38**
Common redshank	35	1	1	0	75
Marsh sandpiper	13	52	70	0	1000
Common greenshank	**112**	**94**	**127**	**6**	**100**
Wood sandpiper	18	11	15	0	100
Terek sandpiper	**73**	**17**	**23**	**3**	**50**
Common sandpiper	6	31	42	0	50
Grey-tailed tattler	10	15	20	0	40
Wandering tattler	0	0	0	0	n/a
Ruddy turnstone	0	0	0	0	35
Asian dowitcher	3	15	20	0	24
Great knot	125	47	64	0	380
Red knot	6	6	8	0	220
Sanderling	0	0	0	0	320
Red-necked stint	68	78	105	0	160
Long-toed stint	0	0	0	0	25
Pectoral sandpiper	0	0	0	0	n/a
Sharp-tailed sandpiper	110	49	66	0	180
Curlew sandpiper	8	42	57	0	180
Broad-billed sandpiper	18	22	30	0	25
Ruff	0	0	0	0	n/a
Red-necked phalarope	0	0	0	0	100
Golden plover	72	14	19	0	100
Grey plover	19	25	34	0	125
Double-banded plover	0	0	0	0	50
Lesser sand plover	17	24	32	0	140
Greater sand plover	40	24	32	0	100
Oriental plover	0	0	0	0	70
Oriental pratincole	0	0	0	0	2880
Little Ringed Plover	0	0	0	0	0

The total number of migratory shorebirds using EAW has increased since the monitoring of this site commenced in 2009 (Figure 3a) a pattern matched by the trend in Critically Endangered Eastern Curlew (Figure 3b).

3a.



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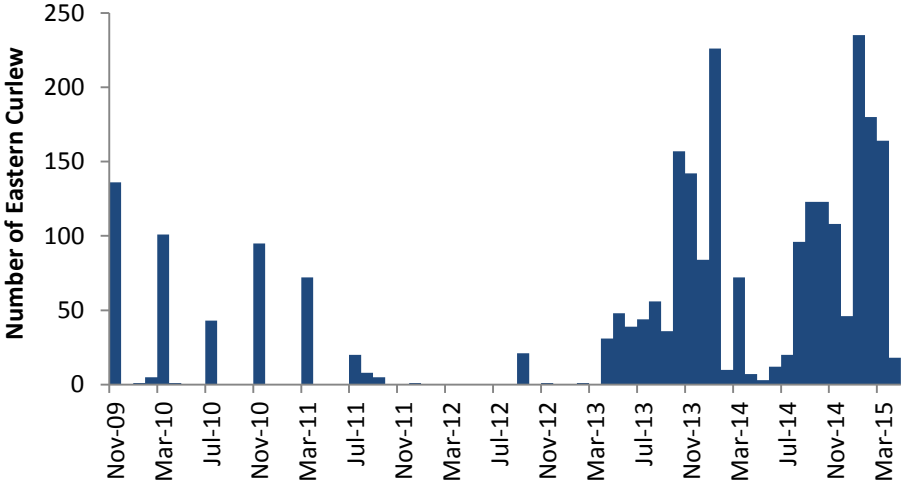


Figure 3. The monthly maximum number of migratory shorebirds (a) and Eastern Curlew (b) counted at East Arm Wharf from November 2009 to April 2015.

The number of birds using EAW and other roost sites peaks during September and November with smaller numbers during the wet season and an even smaller number during the middle of the year when all but immature birds have migrated north to breed (Figure 4).

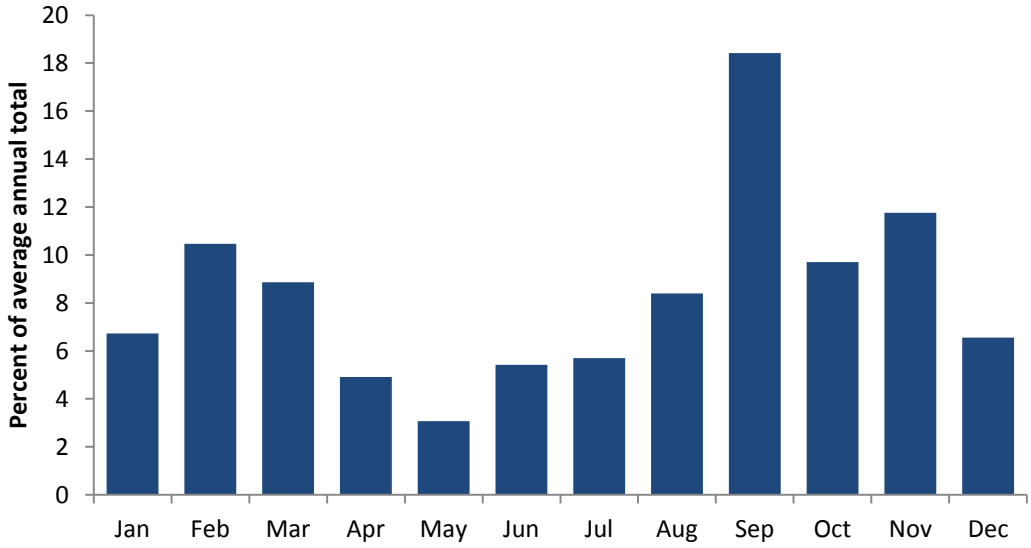


Figure 4. Monthly percentage of annual total of shorebirds at East Arm Wharf, Darwin Harbour, showing peak of birds on passage in September, when the area is critical for birds refuelling after flying from East Asia, and, to a lesser extent, during northward passage in February/March.

SHOREBIRD FEEDING SITES NEAR DARWIN

The extensive low tide mudflats of Darwin Harbour provide feeding grounds for migratory shorebirds that roost at the EAW ponds. Throughout the 2014-15 austral summer season, migratory shorebirds were observed moving directly from their roost at the EAW ponds to the mudflat immediately north-west of the rail line on ≤3 m tides. In addition to these direct observations, boat surveys (Figure 5-6) around Darwin Harbour confirmed the use of habitat at low tides, with flagged birds recorded on these trips (see next section for more detail).

Table 4. Details of low tide counts conducted during boat-based surveys around Darwin Harbour and from a vantage point at EAW.

Date	Site/track	Number of shorebird species	Total count of shorebirds
3/9/2014	EAW mud	4	47
7/10/2014	Dinah Beach - East Arm - Inpex Point - Woods Inlet - Myilly Point Sandbar - Doctors Gully - East Arm - Dinah Beach	8	129
11/12/2014	Dinah Beach - EAW mud - return	7	25
17/12/2014	EAW mud	11	158
23/12/2014	EAW mud	8	69

Migratory shorebirds were also observed feeding at other sites in the Darwin Harbour region during low tide. The main feeding sites north of Darwin Harbour are located at Ludmilla Bay, Sandy Creek and Buffalo Creek. Shorebird site use varied across these sites according to the time of the season and amount of food available. A monthly monitoring program of the intertidal invertebrates was conducted alongside the roost surveys and foraging observations (data still being analysed).

Figure 5. Boat track from 7/10/2014 from 8:30-13:02 with principal feeding sites at EAW in mustard and roosting sites in blue.

Figure 6. Boat track from 11/12/2014 from 13:00-16:40 with principal feeding sites at EAW in mustard and roosting sites in blue.

SHOREBIRD CAPTURE IN DARWIN

In September 2014 a team of volunteers from the Australasian Wader Studies Group caught 432 migratory shorebirds with cannon-nets at EAW and Lee Point beach (LP). Of those, 38 individuals were from EAW and the remaining 394 individuals were from LP (Table 5). All birds were marked with a metal identification ring provided by the Commonwealth Government's Australian Bird and Bat Banding Scheme, and then had a yellow and a blue flag applied to the right leg in accordance with East Asian-Australasian Flyway marking protocol (Figure 7). Each yellow flag has a unique code on it that can be read using a telescope or a camera with a telephoto lens.

Table 5. Breakdown of migratory shorebird species caught at Pond E, East Arm Wharf and Lee Point, Darwin.

Species	EAW E	LP	Total
Greater Sand Plover	-	189	**189**
Great Knot	1	97	**98**
Red-necked Stint	-	71	**71**
Terek Sandpiper	16	13	**29**
Common Greenshank	14	-	**14**
Grey-tailed Tattler	5	5	**10**
Ruddy Turnstone	-	11	**11**
Lesser sand Plover	-	6	**6**
Bar-tailed Godwit	2	-	**2**
Red Knot	-	2	**2**
Total	**38**	**394**	**432**

Figure 7. Migratory shorebirds marked with a metal ring and yellow over blue leg flags. Image credit: Gavin O'Brien.

Age demographics of shorebirds

The migratory shorebirds caught during September 2014 were a mix of juvenile, sub-adult and adult birds (Table 6) with most classified as adults (aged in their second year of life or older) (Figure 8). The skew towards adults was expected given that most adult birds arrive on their non-breeding grounds in August and September, whereas most juvenile birds do not arrive until November.

Table 6. Breakdown of shorebird species by age. Age key: U: undetermined, 1: first year, 2: second year, 2+: second year or older, 3+: third year of life or older.

Species	U	1	2	2+	3+
Bar-tailed Godwit				1	1
Common Greenshank			4	2	7
Great Knot		2	12		85
Greater Sand Plover	1	3	15		170
Grey-tailed Tattler			1	1	9
Lesser Sand Plover			1		5
Red Knot					2
Red-necked Stint			3		70
Ruddy Turnstone			2		9
Terek Sandpiper		2	3	19	5

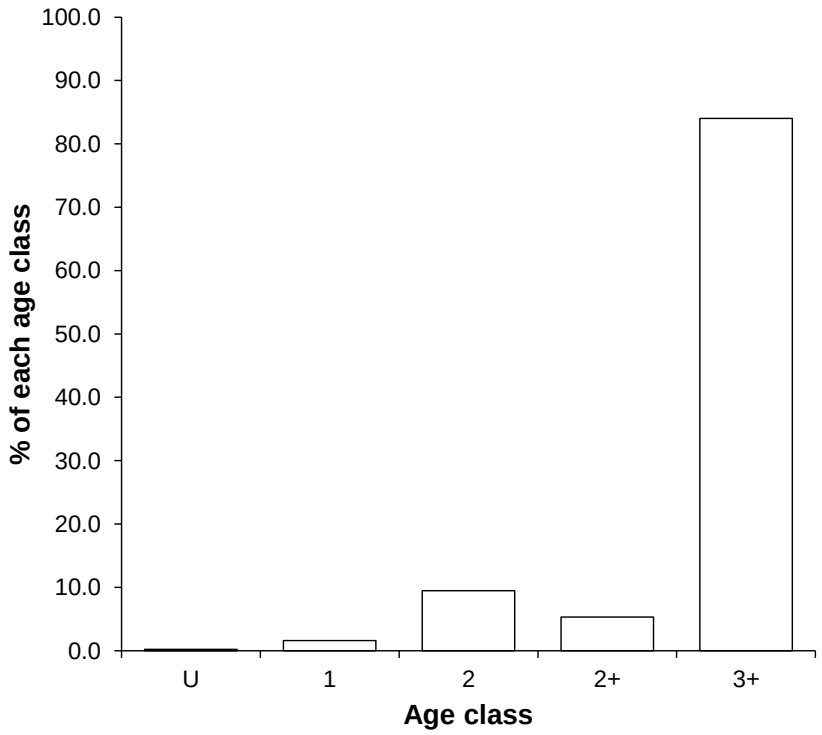


Figure 8. Breakdown by age class for migratory shorebirds caught in Darwin in September 2014.

We applied 44 radio tags on selected individual shorebirds across the two capture sites (Table 7; see Figure 9 for radio-tagged shorebird).

Table 7. Breakdown of shorebird species selected for radio tracking at Pond E, East Arm Wharf, Darwin.

Species	EAW E
Bar-tailed Godwit	2
Common Greenshank	13
Great Knot	1
Grey-tailed Tattler	3
Terek Sandpiper	1
Total	**20**

Figure 9. Greater Sand Plover with radio tag applied to rump.

MOVEMENTS AROUND DARWIN HARBOUR OF SHOREBIRDS ROOSTING AT EAST ARM WHARF

Summary of flagged shorebirds in the Darwin Harbour region

Migratory shorebird habitat use and site connectivity was analysed from resightings of flagged birds. The 38 birds caught at EAW were marked with yellow over blue leg flags with a unique code on the yellow flag allowing resighted birds to be identified individually (Table 8).

Table 8. Details of shorebirds flagged at East Arm Wharf and subsequently resighted in the Darwin region. Key to sites: EAW: East Arm Wharf, EP: East Point, DBG: Darwin Botanic Gardens, DH: Darwin Harbour, BC: Buffalo Creek, NR: Nightcliff Rocks, LB: Ludmilla Bay, SC: Sandy Creek.

Species	Engraved leg-flag	Number of resighting records	Frequency (day records) of occurrence at sites
Common Greenshank	00	1	1 DBG
Common Greenshank	03	3	3 EAW
Common Greenshank	04	4	4 EAW
Common Greenshank	07	1	1 EAW
Common Greenshank	09	2	2 EAW
Common Greenshank	10	2	2 EAW
Common Greenshank	11	3	2 EAW, 1 DH
Grey-tailed Tattler	47	1	1 DH
Great Knot	57	8	6 EP, 1 NR, 1 SC
Bar-tailed Godwit	AA	12	6 EP, 1 DH, 2 LB, 2 NR, 1 BC
Bar-tailed Godwit	AB	5	5 EP

The resighting rate of individual shorebirds was high, with returns of 80-100 % for six of the ten species caught and flagged (Table 9). This implies that, having reached Darwin Harbour, most marked birds remained until departing on their northward migration although at least one species is likely to have flown to other sites (see below). The resighting rate for Red-necked Stint is not available as this species was flagged with plain yellow over blue leg flags, thus the true number of marked individuals within the region cannot be estimated.

Table 9. The resighting rate for flagged birds as a percent of the total pool of flagged birds for the Darwin Harbour region.

Species	% resighted of total flagged
Greater Sand Plover	83.6
Great Knot	95.9
Red-necked Stint	n/a
Terek Sandpiper	0
Common Greenshank	42.9
Grey-tailed Tattler	50
Ruddy Turnstone	100
Lesser sand Plover	83.3
Bar-tailed Godwit	100
Red Knot	100

Of the 432 individual shorebirds caught and flagged from this study, there were 1,294 resighting records over eight months across six monitoring sites in the Darwin Harbour region (Figure 10).

Most resightings of flagged shorebirds in the Darwin region were at Lee Point and Sandy Creek because more of the species most abundant at these sites (Greater Sand Plover and Great Knot) had been flagged.

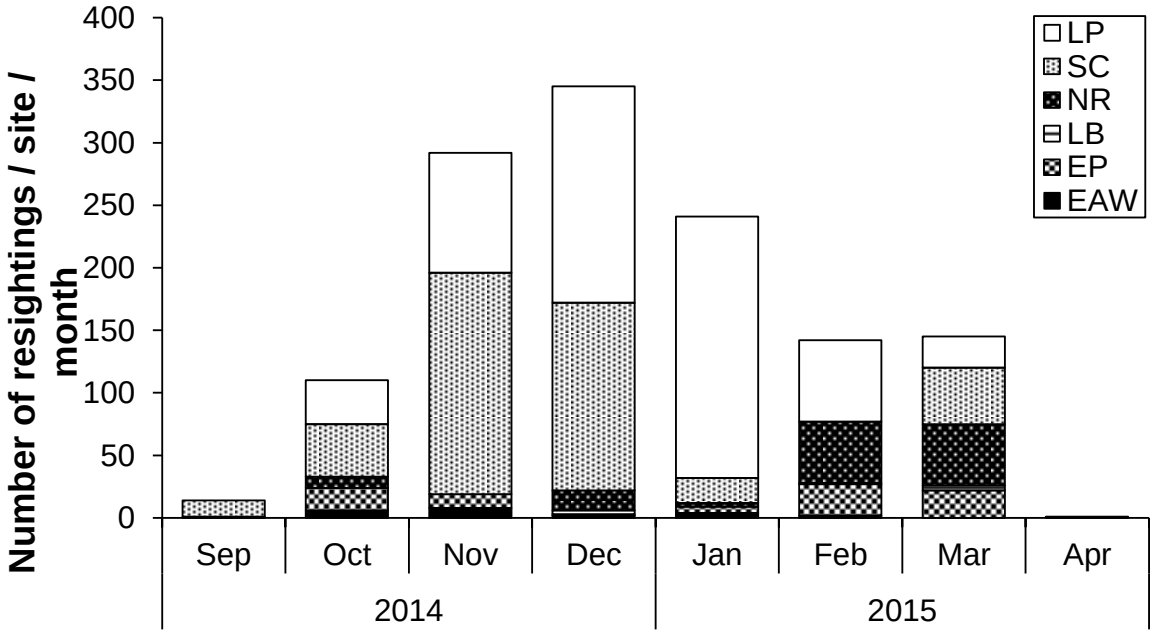


Figure 10. The number of resighting records for flagged migratory shorebirds at six sites in Darwin Harbour from 2014 – 2015 (LP: Lee Point, SC: Sandy Creek, NR: Nightcliff Rocks, LB: Ludmilla Bay, EP: East Point, EAW: East Arm Wharf).

Summary of radio-tagged shorebirds in the Darwin Harbour region

Shorebirds with radio tags were tracked from September through to December 2014. They were tracked using a hand-held yagi antenna and automatic receiver stations with either an omnidirectional antenna or a yagi antenna, or a combination of the two. Eight automatic receiver tracking stations were set up at the following sites: EAW Pond E, EAW Pond D, Lee Point, Sandy Creek, Nightcliff Rocks, East Point, Spot on Marine, and Ludmilla Bay (Figure 11).

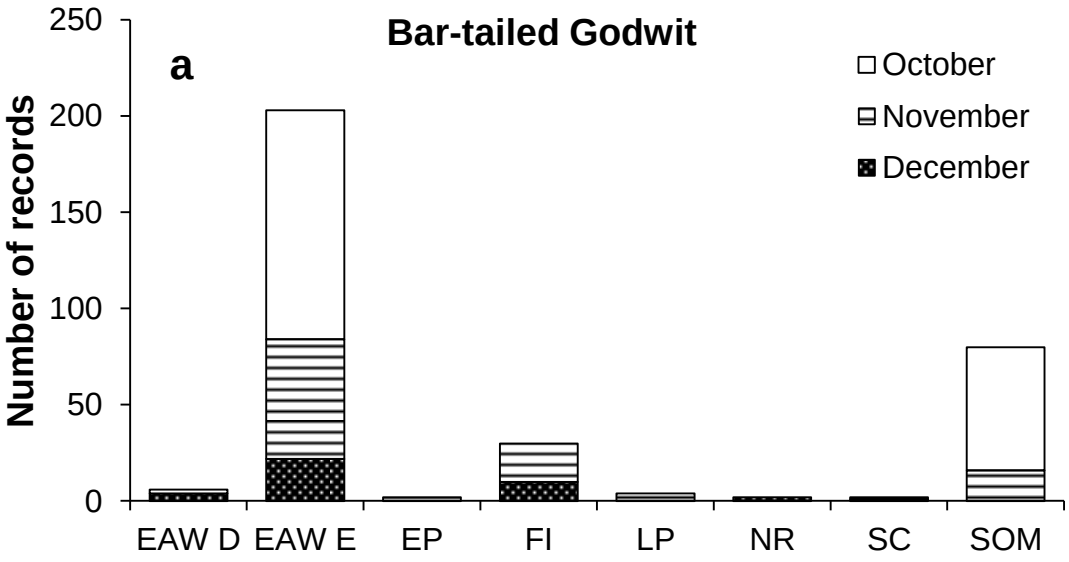
Figure 11. Six of the eight automatic receiver radio-tracking towers in the Darwin Harbour region.

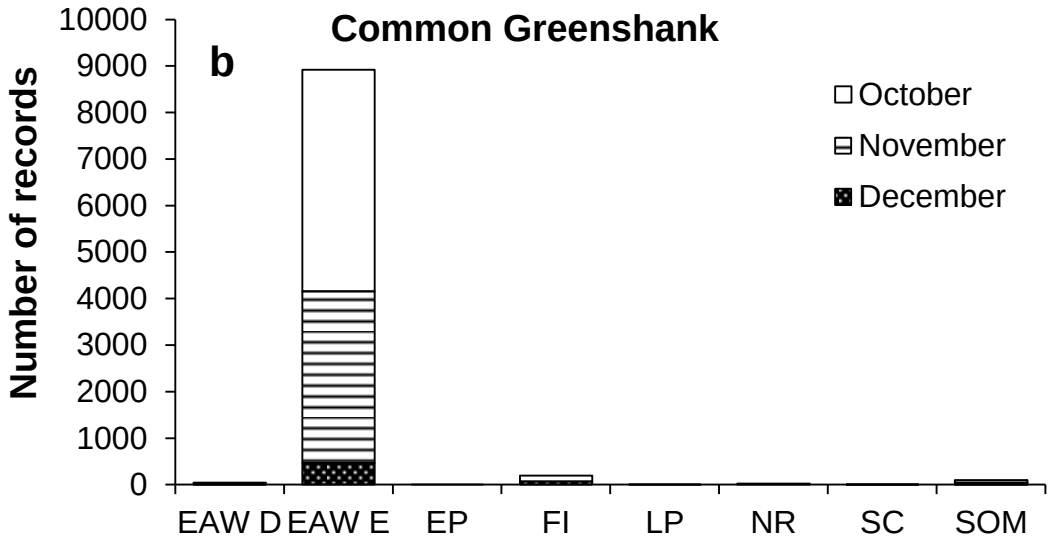
Each radio tag was programmed to a different frequency which was captured by a datalogger attached to the automatic receiver that scanned through frequencies sequentially and continuously. The tracking stations ran continuously for the duration of the tracking study period and were powered by a deep cycle battery connected to a solar panel (Figure 11).

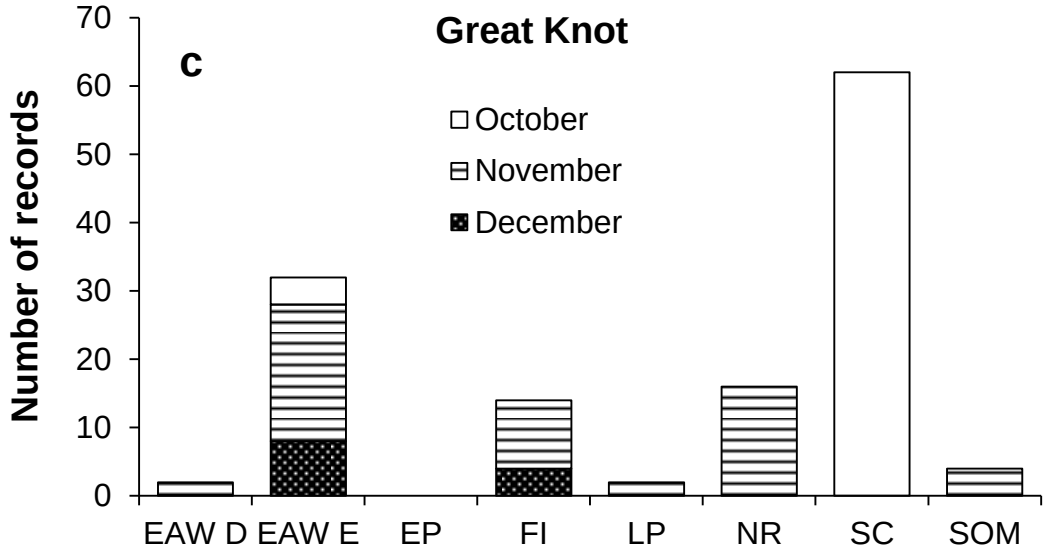
All tagged birds were recorded at stations away from where they were caught and marked. All individuals were first detected at EAW Pond E. Shorebirds that were tagged at EAW used a range of sites, and each tracking tower recorded all of the tagged birds. On average, the tagged birds used 5.25 of the 8 sites with tracking towers. Occupancy of tagged birds was highest at EAW Pond E, SOM, LB, and EAW Pond D, respectively. Birds were detected

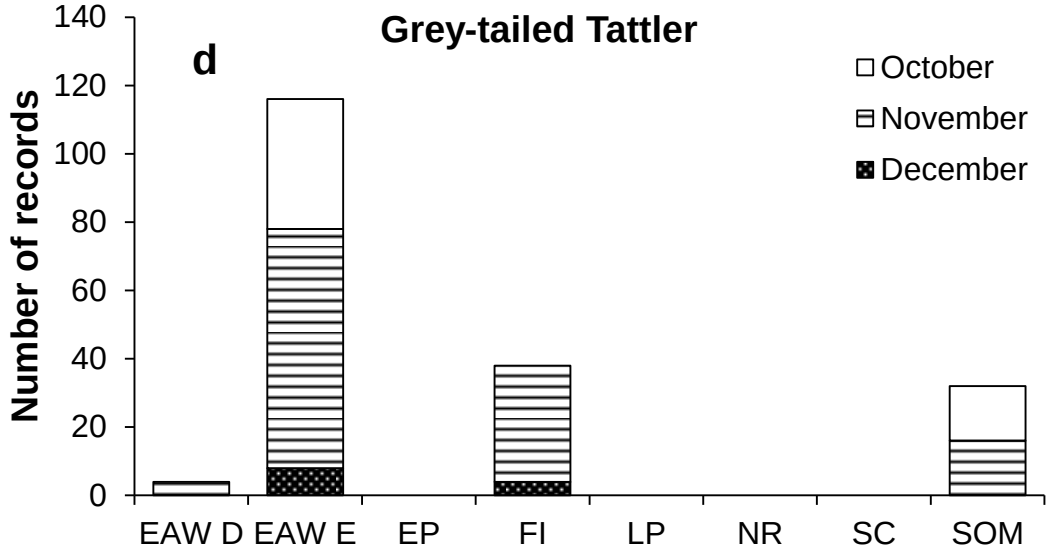
many times on any given day if they were within range of the datalogger and antenna. Thus, while the average number of total days of detection was 61, the average number of days that birds were detected (therefore recorded by the datalogger) was 31. Detectability records of tagged birds ranged from 60 – 3,962 occasions, with a median of 114 occasions during the duration of this study.

Based on the tracking component of this study, all tagged migratory shorebirds preferred the EAW E roost site over other major monitored roost sites in the Darwin Harbour region (Figure 12, a-e). Tagged birds from EAW did not show a preference for the northern beaches of Darwin (Sandy Creek and Lee Point), further supported by the lack of leg-flag resightings made of these birds from these sites. Most records of EAW-tagged birds at Sandy Creek belong to Great Knot '57'; while records for other individuals were much lower. Great Knot (and Red Knot, also common in the Darwin region) prefer sheltered coastal habitat and use intertidal sandflats and mudflats to feed on bivalves and other invertebrates along the tide edge (Higgins 1996). In Darwin, Great and Red Knots primarily feed on a small bivalve (*Paphies* sp.) that lives in the top 5 cm of sandflats along the intertidal zone of Sandy Creek and Lee Point – Buffalo Creek beach (AL, unpublished data). As this bivalve does not occur on mudflats, it is likely that its availability drives the habitat choice of shorebird species such as Great Knot, hence the movement of bird '57' away from EAW/Darwin Harbour.


Bar-tailed Godwit
a
Number of records
250
200
150
100
50
0
October
November
December
EAW D
EAW E
EP
FI
LP
NR
SC
SOM


Common Greenshank
b
Number of records
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
October
November
December
EAW D
EAW E
EP
FI
LP
NR
SC
SOM


c
Great Knot
Number of records
70
60
50
40
30
20
10
0
October
November
December
EAW D
EAW E
EP
FI
LP
NR
SC
SOM


d
Grey-tailed Tattler
Number of records
140
120
100
80
60
40
20
0
October
November
December
EAW D
EAW E
EP
FI
LP
NR
SC
SOM

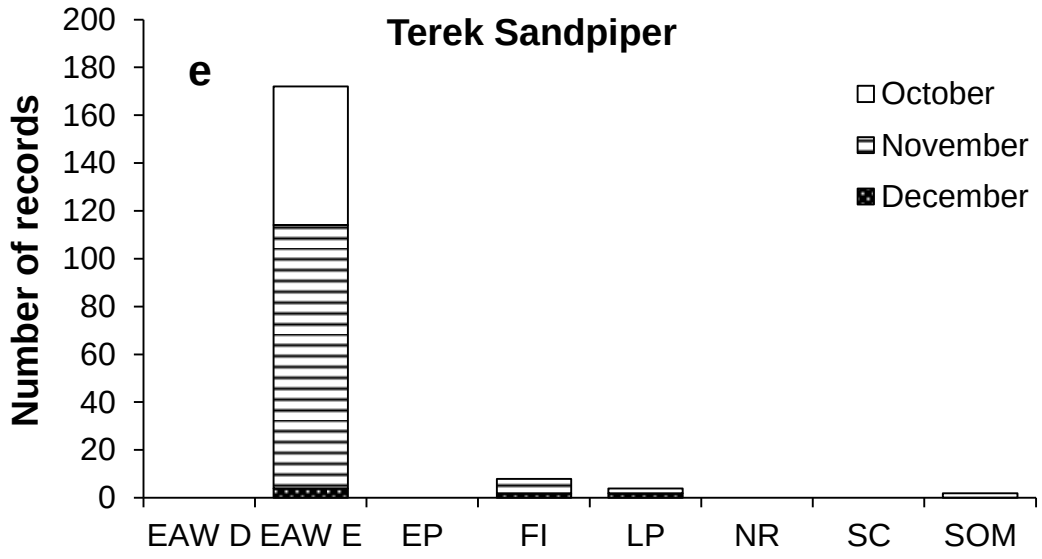


Figure 12. The number of records across 8 sites where automated radio-tracking towers were deployed from October through to December 2014 for a. Bar-tailed Godwit, b. Common Greenshank, c. Great Knot, d. Grey-tailed Tattler, e. Terek Sandpiper.

Shorebird subpopulations in north-east Darwin Harbour

Based on leg-flag resightings and radio tracking of shorebirds, there are two subpopulations of migratory shorebirds in the Darwin Harbour region (Figure 13); one focussed around the Buffalo Creek/Shoal Bay area and the other centred around the East Arm area and Darwin Harbour. These two subpopulations mix around East Point, Spot on Marine, Ludmilla Bay and Nightcliff Rocks, however not all individuals used all of the available sites in each subpopulation area. Subpopulation assemblages differed based on the substrate type and food availability in these different habitat types. Some species of shorebird prefer soft sediment, typical of Darwin Harbour, whereas other species prefer sandy substrate, which supports a different invertebrate assemblage to that of soft mud.

Figure 13. Proposed subpopulations of migratory shorebirds in the Darwin Harbour region. Red polygon: Buffalo Creek/Shoal Bay region subpopulation; and blue polygon: East Arm area and Darwin Harbour. Image credit: Google Inc (2015).

Movements of Darwin Harbour shorebirds away from Australia

Migratory shorebirds flagged in Darwin in 2014 have been resighted at stop-over sites along the East Asian-Australasian Flyway (Table 10). The average distance between their non-breeding grounds in Darwin (where birds were flagged) and their stop-over sites was 5235 km. The days since last resighting in Australia and first resighting in the Yellow Sea region of China and in Taiwan ranged from 10 – 187 days with a median of 30 days. The two outliers (Greater Sand Plover '06' at 147 days and Great Knot '96' at 187 days) were not seen in Darwin after their capture in September 2014, indicating that they continued further south in their migration to their non-breeding site/s in Australia. This is typical of some individuals for a range of species that use Darwin Harbour, and explains why species richness is highest at East Arm Wharf in September each year during the southward passage of birds.

Table 10. Records of Darwin-flagged migratory shorebirds away from Australia, at other sites in the East Asian-Australasian Flyway. Distance measurements are estimates assuming a straight line of flight. Key: ELF: engraved leg flag.

Species	ELF	Resighted at	Country	Date resighted	Distance (km) from Darwin, NT	Days since resightings between Aust. and overseas
Greater Sand Plover	AC	Yangkou-Fengli coast, Rudong	China	9/04/2015	5077	21
Great Knot	77	Yalujiang National Nature Reserve, Liaoning	China	17/04/2015	5821	33
Greater Sand Plover	06	Han-pao wetland, Changhua County	Taiwan	2/04/2015	4188	147
Great Knot	16	Han-pao wetland, Changhua County	Taiwan	6/04/2015	4188	22
Great Knot	96	Han-pao wetland, Changhua County	Taiwan	2/04/2015	4188	187
Great Knot	65	Han-pao wetland, Changhua County	Taiwan	2/04/2015	4188	10
Great Knot	63	Han-pao wetland, Changhua County	Taiwan	2/04/2015	4188	23
Red Knot	EY	Nanpu, Bohai Bay	China	26/04/2015	5855	34
Great Knot	AD	Nanpu, Bohai Bay	China	1/05/2015	5855	52
Red Knot	EZ	Nanpu, Bohai Bay	China	13/05/2015	5855	27

DISCUSSION

The aerial and ground surveys of migratory shorebirds conducted by Chatto (2003), which forms the baseline data for migratory shorebirds in the region and further afield in the Top End, did not detect many shorebirds using EAW and the nearby mudflats. The Department of Lands and Planning subsequently concluded that alternative foraging and roosting grounds in the Darwin Harbour region must support the apparently large numbers of shorebirds observed in the region (Department of Natural Resources Environment the Arts and Sport 2011). Similarly the risk of impact on migratory shorebirds from habitat removal and reclamation of the dredge ponds at EAW was considered 'low' (Department of Natural Resources Environment the Arts and Sport 2011). In contrast, the ground-based surveys described here suggest that EAW is now at least as important as the natural roost sites in the north-eastern part of Darwin Harbour. EAW commonly supports shorebird numbers exceeding the national threshold for 10 of the 36 shorebird species listed under the EPBC Act. It is particularly important for the Critically Endangered Eastern Curlew.

It can be argued that, before EAW was constructed, the shorebirds now roosting there did so elsewhere and thus removal of protection of the site, or its conversion into habitat unsuitable for roosting, would mean the birds would simply return to their previous roost sites. There are two potential reasons why this argument may no longer be relevant to protection of the site. First, the increasing numbers using the site suggest that either more birds are now using the vicinity of EAW to feed and roost than previously, because a safe roost site is available nearby. Second, roost sites to which they used to retreat at high tide, particularly the very high tides when saline mudflats and other commonly-used roost sites are not available, are suboptimal. This could be because these roost site are distant from the feeding grounds, are subject to higher levels of disturbance or predation, or are more difficult and energy-expensive to use. Thus there are observations of shorebirds roosting in the tops of mangrove trees at the peak of very high tides. Such sites are obviously not preferred or they would be used at lower tides, suggesting they incur a cost to the shorebirds that is reduced by access to EAW. The research undertaken here cannot answer which of these answers is more likely.

It could further be argued that having to roost at less suitable sites at very high tides is part of the natural selective environment within which the shorebirds have evolved. However there are two novel pressures on the migratory shorebirds reaching Australia that combine to make EAW of increasing importance. First is the rise in global sea level, particularly along the north coast of Australia. Sea level has risen 130 mm since 1950 globally (Church et al. 2013) and is rising faster in northern Australia because of heating of the large relatively shallow Arafura Sea to the north (CSIRO 2014). The consequence of this is that mud flats are exposed for shorter periods and that the time needed for roosting at relatively unsuitable sites has increased. Secondly, the loss of habitat at staging posts in the Yellow Sea (Zhijun Ma et al. 2014, Murray et al. 2015) means that those birds most likely to survive migration have either maximised their fat stores immediately before migration north, or have ready access to food for minimal extra energy expenditure immediately after they arrive on their southward migration. Individuals are known to return to specific sites on their non-breeding grounds and at staging sites during their migration (Warnock and Takekawa 1996, Rehfisch et al. 2003, Leyrer et al. 2006, Conklin et al. 2007). However, when they reach stop-over sites in China they are likely to have to find alternative habitat because the mudflats have been converted to non-suitable habitat, to evade hunting or cope with lower food densities because of pollution. Thus the condition of non-breeding sites needs not only to be as good as it was previously but even better as compensation for reductions in habitat quality elsewhere along the migration pathway. EAW provides a roost site of enhanced quality.

As it is, the main threats to migratory shorebirds on non-breeding grounds in Australia are habitat destruction or loss and disturbance to birds which depletes fat stores crucial for successful migration, breeding and survival (Harding 2007). Shorebirds preparing for their northward migration to breeding grounds undergo dramatic physiological changes to satisfy the demands of their migration, including increasing their total fat mass by 40% or more (Zwarts 1990) and models suggest that the quality of non-breeding sites is critical to successful migration and breeding (Aharon-Rotman 2015). Also, in other sites, displacement as a result of loss of habitat following industrial development has been shown to increase competition for resources at nearby roosting and feeding sites, increasing mortality (Burton et al. 2006). In Darwin, disturbance at roost sites by dogs and people is a common occurrence

(Lilleyman 2012) but the birds may not be able to recover from the resulting energy loss, particularly if they have to travel a long way to an undisturbed roost site (Rogers et al. 2006a).

That said, the fact that EAW was constructed only recently and then adopted as a roost site by shorebirds suggests that the site is not irreplaceable. Should all areas at EAW be required for activities incompatible with shorebird roosting, alternative safe roost sites could be created just as EAW was created. Such an approach has been followed by other harbours around Australia. Done cleverly, a new roost site could be incorporated into a bird tourism strategy while still providing a site where the birds feel safe.

An alternative to creating a new roosting site is to manage dredge spoil in a manner that always ensures that roosting habitat will be available. Within EAW there are times when Pond D, the site set aside in perpetuity as a reserve, is not suitable because of natural fluctuations in water level. Either the water is too high, in which case only a narrow fringe is suitable, or it is dry when few if any birds roost there. When Pond K was available many birds roosted beside the water there, but few do so now it is usually dry. Instead large numbers are being recorded on the edge of the water in Pond E. Pond E is used for overflow from Pond K and to contain stormwater. The water level within Pond E rises and falls with the tide but the edge of the fresh dredge spoil provides a roosting site that is in many ways superior to Pond D. This is because it always has both water at the prevailing temperature of the harbour and a wide open fringe, regardless of rain or tide; it is just as well protected from disturbance as Pond D because it is subject to the same access restrictions, and; it may be better protected from predators because the freshness of the dredge spoil means there is no vegetation within which predators can find cover while the softness of the substrate inhibts approach across land.

Pond E is part of an active system and current management appears to be ideal for roosting shorebirds. The long terms plans for East Arm Wharf are for there always to be at least one storm water retention pond into which dredge spoil will be deposited. While there are plans for Pond E to be filled in the medum to long term, new ponds will need to be built to serve

the same purpose. Given the attractivenss of Pond E, it should be relatively easy to construct replacement ponds in a way that is also suitable for shorebirds.

CONCLUSIONS

EAW provides important roosting habitat to migratory shorebirds that use the Darwin Harbour region as their non-breeding grounds during the austral summer, and as a staging site on their passage to more southerly sites. The EAW dredge ponds provide a range of habitats for roosting shorebirds and the site has become more appealing over time, with the total number of migratory shorebirds using EAW increasing since 2009. Shorebirds tracked during this study used EAW and several roosting and feeding sites in the greater Darwin area, where two subpopulations appear to exist. Shorebirds were faithful to the EAW site and the tracking and flagging of individuals confirmed that birds routinely use the site to roost. Site use was influenced by the availability of food resources nearby and tide height, with greatest use during the highest spring tides of every month. The site is particularly important for the Critically Endangered Eastern Curlew. This species has been recorded 39 times at EAW at 0.1% of its total flyway population. Given the other pressures on this and other migratory shorebirds using EAW, continued protection is recommended unless an equally secure alternative site can be created.

RECOMMENDATIONS

- Continue to maintain EAW Pond D as suitable habitat for migratory shorebirds and supplement water level in the pond prior to the wet season, and on an annual basis, unless an equally secure and suitable roosting habitat can be created.
- Continue to restrict access by the public and animals (wild and domestic) to EAW.
- Consider the cumulative impact of development in Darwin Harbour and how the (future) loss of EAW in the network of sites may lead to negative impacts on shorebird survival at a flyway level.
- Consider adaptive management of the dredge spoil and stormwater retention ponds at EAW so that they are always suitable for roosting shorebirds..

ACKNOWLEDGEMENTS

Thank you to the Northern Territory Government for funding this important project on shorebirds in the region. Special thanks to Clive Minton from the Australasian Wader Studies Group and all of the volunteers (international, national and Darwin locals) that helped catch shorebirds for this tracking project during the Darwin wader expedition in September 2014. Additional thanks to the NT Parks and Wildlife team for their assistance during shorebird catching, for loaning gate keys to AL for fieldwork purposes, and for approving the installation of a tracking tower to go on Parks Reserve land. Thanks to Darwin City Council for approving the use of East Point and Nightcliff parks as tracking tower sites and for loaning a key to AL. Many thanks go to Gavin and Meg O'Brien who helped with catching and counting shorebirds and leg-flag resightings in Darwin. A big thank you to Fiona Douglas, who welcomed the opportunity of having a tracking tower positioned on her balcony overlooking Ludmilla Bay and for having me visit almost fortnightly to download from the datalogger. Thanks also to Coen van Tuijl for assisting with installing tracking towers, tracking, counting, and recording behaviours of shorebirds.

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