

# Flagged and colour-banded Bar-tailed Godwit in the Hunter Estuary

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Regular systematic observation of flagged and colour-banded Bar-tailed Godwit *Limosa lapponica* in the Hunter Estuary during two non-breeding seasons (September 2011 to March 2012 and September 2012 to March 2013) identified birds that had been caught previously in New South Wales, Victoria, New Zealand, China and Alaska. The majority of flagged birds (14 in 2011/12 and 18 in 2012/13) were passage birds, staying only for short periods (minimum of 1 to 17 days) before continuing their southward migration. Approximately 2% of the Bar-tailed Godwit in the Hunter Estuary were individually marked with uniquely notched or alphanumeric-engraved leg flags. Bar-tailed Godwit returning to their non-breeding sites in Victoria dominated the passage birds in 2011. However, in 2012 approximately equal proportions of flagged passage birds were destined for Victoria and New Zealand. One colour-banded and three flagged birds stayed in the estuary for both the 2011/12 and 2012/13 non-breeding seasons. These birds had been caught in the Hunter Estuary in 2004 and displayed strong site-fidelity. No mature flagged godwits appeared in the Hunter Estuary during the northward migration period (March - April).

## INTRODUCTION

The foundations of modern scientific bird banding were laid in Denmark in 1899 when Christian Mortensen placed aluminium bands, stamped with numbers, on the legs of 162 young starlings (Purchase 1969). The technique was rapidly adopted elsewhere. In Australia the first bands stamped with unique series of numbers were used in 1912 (Purchase 1969). Recovery of band numbers both in Australia and overseas has greatly assisted in clarifying migration routes. However, birds had to be re-caught or found dead for the bands to be read. Since 1990, coloured leg flags have been used on migratory shorebirds in Australia, in addition to metal bands (Australasian Wader Studies Group website 2012). Leg flags are small plastic bands with a tab on the end making them readily visible in the field by observers using binoculars or telescopes. The flagging program is international with different coloured flags or combinations of flags unique to particular countries or banding sites. This has revolutionised shorebird migration studies as it is not necessary for birds to be caught to work out where the birds have been banded. More recently, leg flags engraved with an alpha-numeric code have been used to individually mark birds.

Australian sightings of colour-banded or flagged shorebirds are reported to the Australasian Wader

Study Group (AWSG), which maintains a database and regularly publishes summaries of flag sightings, indicating general migration routes throughout the East Asian-Australasian Flyway (EAAF) (e.g. Minton *et al.* 2006). Similarly, the New Zealand Wader Study Group (NZWSG) maintains a database of banded and flagged birds. Based on this data, Riegen (1999) proposed two southward migration routes for Bar-tailed Godwit *Limosa lapponica* from Alaska to New Zealand: one directly across the Pacific Ocean, the other via Kamchatka Peninsula, the Yellow Sea and the Gulf of Carpentaria. Subsequently, satellite tracking of several Bar-tailed Godwit from New Zealand and several from Alaska provided amazing details of their migration routes (Battley *et al.* 2012, Gill *et al.* 2009). It is now known that Bar-tailed Godwit coming to eastern Australia and New Zealand are mainly the subspecies *Limosa lapponica baueri*, that breed in Alaska between late May and early August (Woodley 2009). After breeding, the birds fly south, non-stop, directly across the Pacific to eastern Australia and New Zealand (Battley *et al.* 2012), where they spend the non-breeding season (from September to March). Towards the end of March and into April, the birds fly north to stage in the Yellow Sea for about a month before flying on to their breeding grounds in May.

During the non-breeding season, mature Bar-tailed Godwit are known to be site-faithful, whereas

immature Bar-tailed Godwit are known to wander between non-breeding areas, only becoming site-faithful after making their first breeding migration (C.D.T. Minton pers. comm.; Battley *et al.* 2011). First-year Bar-tailed Godwit do not breed and spend the entire year in the southern hemisphere. During their second year, partial northward migration (April to May) may take place, but it is not until their third year that migration to the breeding grounds occurs (C.D.T. Minton pers. comm.). Consequently, Bar-tailed Godwit spending the months from April to August in the Hunter Estuary will be predominantly immature birds that are yet to make a complete northward migration. Some, however, may be old or injured birds that are no longer capable of the endurance required to complete the >20,000km round trip to and from the breeding grounds (Riegen 2013).

During May 2004, 15 Bar-tailed Godwit were caught and colour-banded in the Hunter Estuary to study the behaviour and movements of what were considered to be over-wintering immature birds (Richardson 2004). These birds were colour-banded with orange-over-green bands. During November 2004, another 15 Bar-tailed Godwit were caught in the estuary and *flagged* with individually notched orange-over-green flags (Foate 2005). These were mostly mature birds recently arrived after breeding. Radio transmitters were glued to the backs of these birds so that their behaviour and movement throughout the estuary could be studied. Five of the transmitters were preened off within 65 days (Foate 2005) and the others would have been shed when the birds moulted.

For many years, flagged and colour-banded birds were noted occasionally in the Hunter Estuary, but systematic searches for flagged or colour-banded birds were not carried out. We commenced regular monitoring in September 2011 and continued through the non-breeding season until April 2012. Monitoring was repeated during the 2012/13 non-breeding season. It revealed that most flagged Bar-tailed Godwit passed through the estuary on southward migration between late September and late October, while a few flagged birds stayed for the whole non-breeding season. Because some birds were individually marked, it was possible to estimate the time they spent in the estuary before moving on.

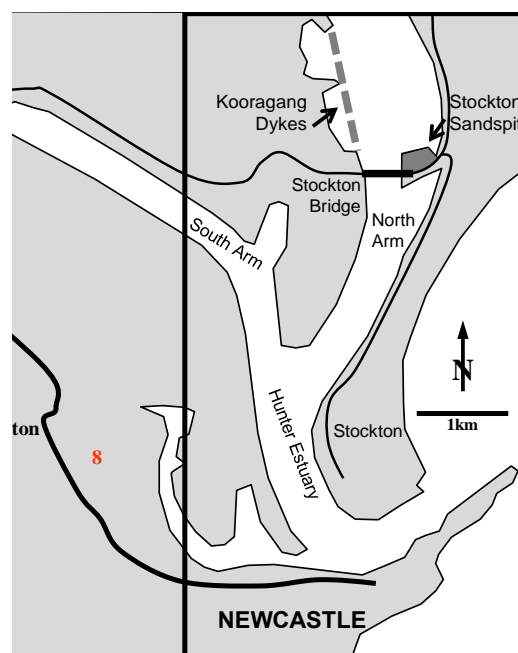
Although the advent of satellite tracking has recently confirmed migration routes for nine Bar-tailed Godwit from New Zealand and eight from Alaska (Battley *et al.* 2012), there is still much to

be learnt from observations of flagged and colour-banded birds: Are they always site-faithful? How long do they spend at stop-over sites during southward migration? Do they regularly use the same stop-over sites? Where is their final non-breeding season destination? Do they stop-over in the Hunter Estuary on northward migration? Where do they stop-over on northward migration? Where do the Hunter Estuary site-faithful godwits breed?

Observations of Bar-tailed Godwit bearing coloured flags or bands in the Hunter Estuary during the 2011/12 and 2012/13 non-breeding seasons provide answers to some of these questions.

## METHODS

During high-tide periods, most shorebirds in the Hunter Estuary roost on the Kooragang Dykes (32°52'30" S 151°46'00" E) and Stockton Sandspit (32°53'56" S 151°47'26" E) (**Figure 1**). Kooragang Dykes is accessible only by boat, but Stockton Sandspit is easily monitored on foot. Roosting flocks on the Kooragang Dykes were scanned using binoculars (Swarovski 10x42) from a small motorboat and photographed with a digital camera (Canon 550D, 400mm lens) to confirm or clarify leg-flag sightings. With care, birds could be approached to within approximately 10 metres while observers remained in the boat. At Stockton Sandspit roosting and foraging birds were scanned using a telescope (Swarovski HD 80mm x30) from distances of approximately 20 to 70 metres and photographed to confirm or clarify observations.



**Figure 1.** Shorebird roost sites at Kooragang Dykes and Stockton Sandspit (arrows) where band and flag searches were conducted.

It was difficult to detect flagged birds among roosting shorebirds because they often stood on one leg and crowded together. Although the front row was readily visible, those behind were largely obscured. However, as the tide fell, birds began to move about to preen, bathe and begin foraging, particularly at Stockton Sandspit where the falling tide exposed mudflats adjacent to the roost site. The optimum time for scanning shorebirds at Stockton Sandspit, when the birds were resting on the beach on the northern side of the Sandspit, was about two to four hours after high-tide. Disturbance by raptors or fishermen moving close to the roost sites also provided opportunities for leg-flag observations as the birds lowered their tucked-up legs and moved in response to the intrusion. Repeated scanning of the flock was necessary to find all the flagged birds present.

Observations of roosting shorebirds at Stockton Sandspit commenced on 1 September 2011 and were carried out every week during September, every two to three days during October and weekly from November 2011 to early April 2012. Similar observations were made from 1 September 2012 until 13 March 2013. No observations were made from 14 March to mid April 2013 during the main period of northward migration due to the authors' absence. Less frequent weekly observations were made at Kooragang Dykes owing to the difficulty of access. Fortunately, most Bar-tailed Godwit present in the estuary were visible at Stockton Sandspit, as those roosting on Kooragang Dykes would often fly to Stockton Sandspit as the tide fell and mudflats were exposed.

Leg-flag observations were reported to AWSG, which supplied banding locations and dates. In previous years, searches for flagged and colour-banded birds were less systematic. However, a number of valuable observations were recorded and drawn on where appropriate for an understanding of the 2011/12 and 2012/13 sightings. Plain-coloured flags indicate where shorebirds were caught and banded. International protocol determines colour combinations for each region: orange flags were placed on birds caught in Victoria; orange-over-green flags in NSW; white or red flags in New Zealand; green-over-orange flags in China; and black flags in Alaska.

Although plain-coloured flags do not identify individual birds, frequent thorough observations of flocks revealed discrete periods when one, two or three of the same plain-colour-flagged birds were present in the estuary and periods when they were absent. Consistent numbers of plain-colour-flagged birds over a particular time period were assumed to be the same birds. A change in numbers indicated that new birds arrived or that birds departed from the estuary. In addition, individual birds were identified by notches cut into the flags, by alphanumeric codes engraved on the flags, or by additional coloured leg bands in unique combinations (**Figure 2**).



(a)



(b)



(c)

**Figure 2.** (a) Bar-tailed Godwit with orange-over-green flags, both notched underneath (caught and flagged at Stockton Sandspit, Hunter Estuary, NSW); (b) Bar-tailed Godwit with orange flag with a notch (caught and flagged at Stockton Sandspit, Hunter Estuary, NSW and originally flagged with orange-over-green flags; green flag lost before October 2009); and (c) Bar-tailed Godwit with orange flag engraved KS (caught and flagged at Corner Inlet, Victoria). Photos by Chris Herbert.

## RESULTS

Sightings revealed three categories of birds: first, passage birds that stage for a short time in the Hunter Estuary during southward migration (September to December); secondly, birds which had reached their final destination and stayed throughout the entire non-breeding period (September to March); and thirdly, a young bird on partial northward migration (March to April). We observed 18 flagged and colour-banded birds in 2011/12 and 23 in 2012/13 (**Figure 3**). Of these, 14 were passage birds in 2011/12 and 18 in 2012/13 (**Tables 1** and **2**). Also, four flagged birds stayed for the entire non-breeding season – the same four birds in 2011/12 and 2012/13. One young bird (less than one year old) arrived in the Hunter from Victoria in March 2013 on what was likely to be partial northward migration.

### Passage birds

An increase above the usual number of over-wintering Bar-tailed Godwit in the Hunter Estuary was recorded on 15 September 2011 and 15 September 2012, indicating the first arrivals on southward migration for the non-breeding seasons 2011/12 and 2012/13 respectively (**Table 3**). However, *flagged* Bar-tailed Godwits were not seen in the estuary until 27 September 2011 and 26 September 2012. In 2011 ten Bar-tailed Godwit flagged in Victoria (orange flags), two flagged in New Zealand (white or red flags), one flagged in Alaska (black flag) and one flagged in China (green-over-orange flags) passed through the Hunter Estuary (**Table 1**). In 2012 eight Bar-tailed Godwit flagged in Victoria (orange flags), eight flagged in New Zealand (white flags) and two flagged in China (green-over-orange flags) passed through the Hunter Estuary on southward migration (**Table 2**).

Three individually marked birds have made repeat visits to the Hunter Estuary while on southward migration (**Table 4**). One consistently staged in the first half of October (orange flag engraved 59) while the timing of the other has been less consistent (orange flag engraved SS). The third bird (white flag engraved BLN) was first recorded in the estuary in October 2009 while on southward migration. However, in 2012 it arrived much later, on 23 December, with only one foot. It stayed until 2 January 2013 before moving on.

Passage of flagged Bar-tailed Godwits ended on or shortly after 1 November 2011 and 31 October 2012 respectively, except for the disabled godwit (white flag engraved BLN) that arrived on 23 December 2012.

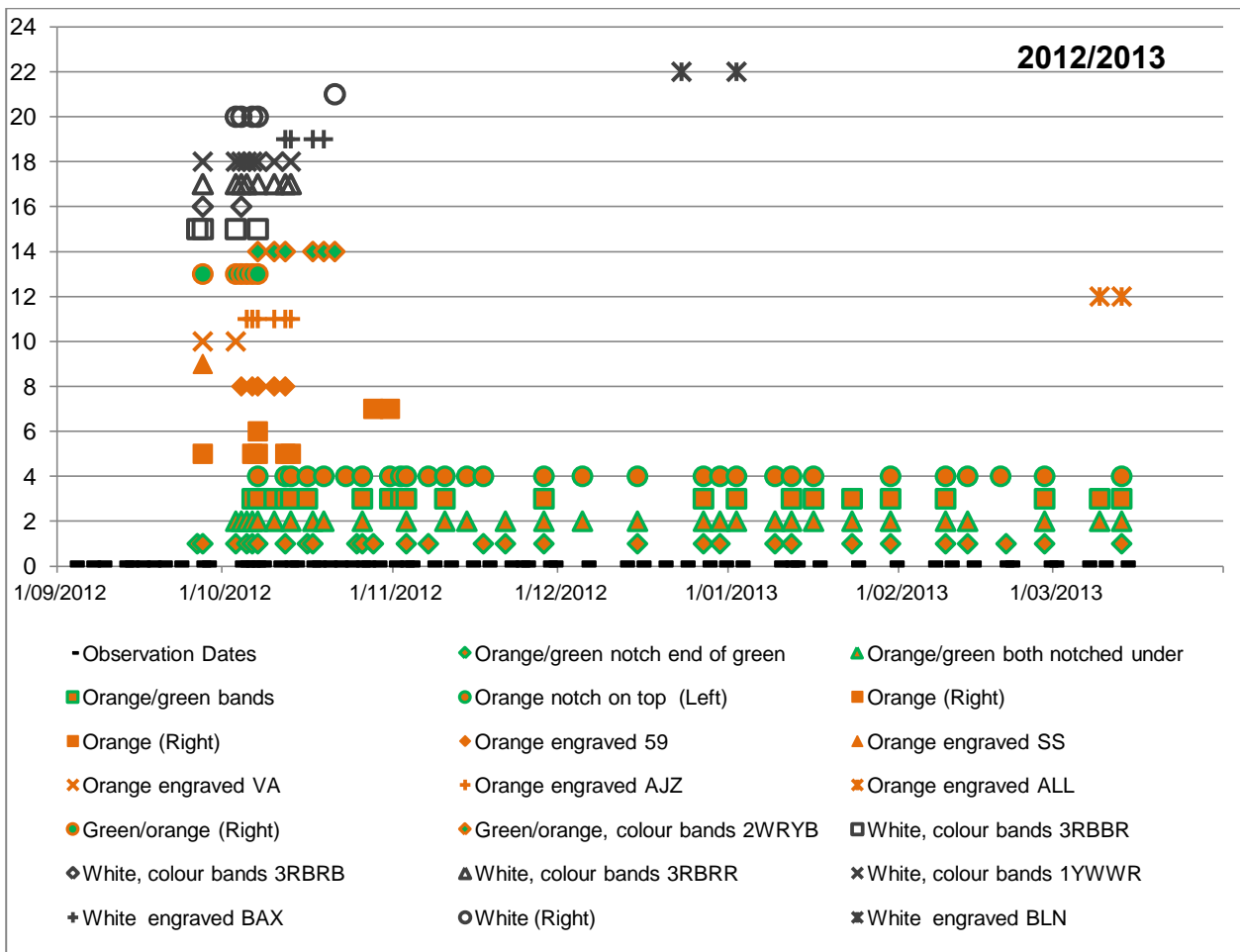
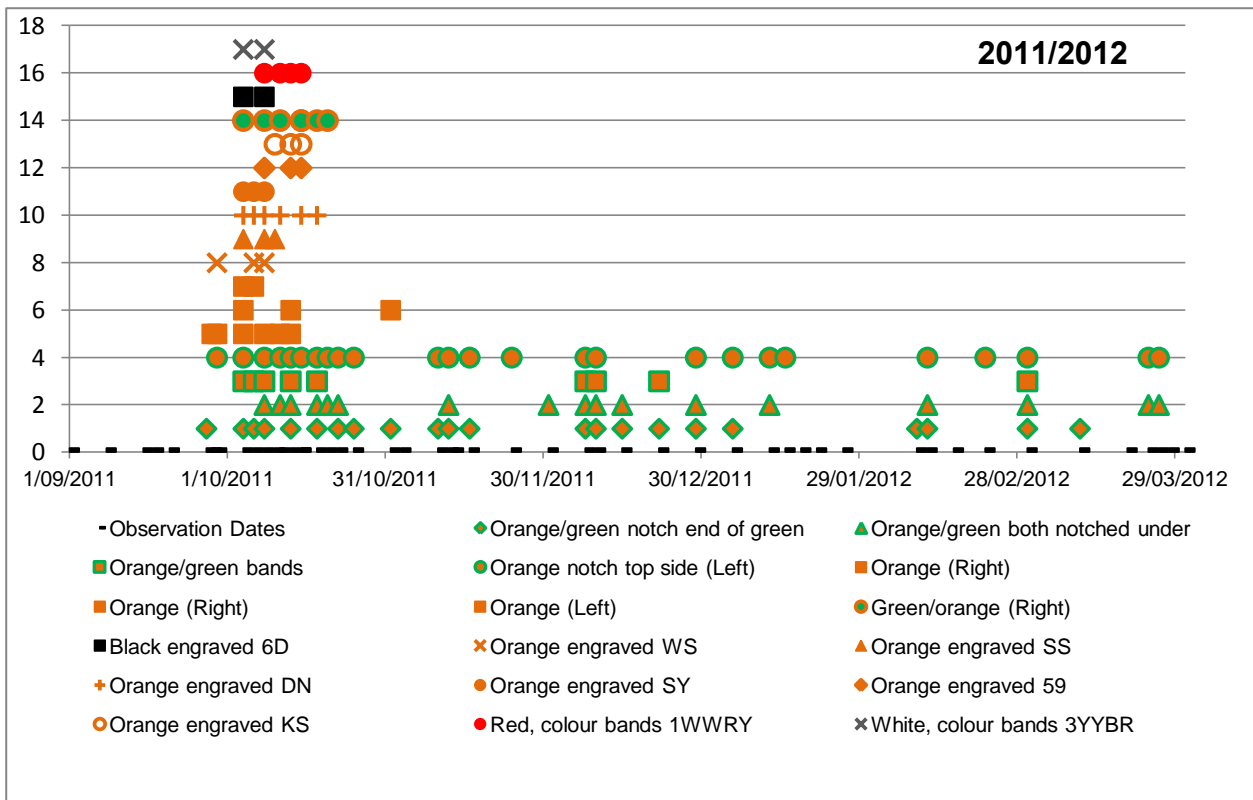
### Birds that stayed in the Hunter Estuary for the non-breeding season

The same three orange-over-green flagged and one colour-banded Bar-tailed Godwit stayed in the Hunter Estuary for both the 2011/12 and 2012/13 non-breeding seasons, with observed durations ranging from 148 to 178 days in 2011/12 and 158 to 169 days in 2012/13 (**Tables 1** and **2**, **Figure 3**). One of these godwit was caught and colour-banded in the estuary as an immature bird in May 2004 (Richardson 2004); and three were flagged in the estuary as adult birds in November 2004 (Foate 2005).

At the end of the 2011/12 non-breeding season, Bar-tailed Godwit departed from the Hunter Estuary on northward migration from early March to 5 April 2012, when an over-wintering flock of 171 birds remained (**Table 3**). On 26 March 2012, the last observations of flagged Bar-tailed Godwit were made in the Hunter Estuary - by 28 March 2012 no flagged birds remained. Departure of birds on northward migration at the end of the 2012/13 non-breeding season was not observed owing to the absence of the authors from the estuary.

### Birds on partial northwards migration

One Victorian-flagged bird arrived on 9 March 2013, probably on partial northward migration as it was less than one year old (orange flag engraved ALL - see **Table 2**). This bird stayed in the Hunter Estuary for the entire winter of 2013 and was still in the estuary in September 2013 when birds arrived on southward migration from the breeding grounds.



**Figure 3.** Flagged and colour-banded Bar-tailed Godwit sighted in the Hunter Estuary during the 2011/12 and 2012/13 non-breeding seasons. The y-axis shows cumulative total of flagged and colour-banded godwit. See footnote 4 on **Table 1** for explanation of colour-band naming convention.

**Table 1.** Flagged and colour-banded Bar-tailed Godwit in the Hunter Estuary during the 2011/12 non-breeding season

Flags (unless stated otherwise)	Flag Position on Leg	Banding Location	Date Banded	Metal Band No.	Age at banding	Age in April 2012	First Observation	Last Observation	Minimum Days in Estuary
Orange-over-green BANDS <sup>1</sup>	Right upper	Hunter Estuary, NSW	2/05/2004		1+	9+	4/10/2011	1/03/2012	148
Orange-over-green (notch in end of green flag) <sup>2</sup>	Left upper	Hunter Estuary, NSW	14/11/2004				27/09/2011	11/03/2012	165
Orange-over-green (both flags notched underside) <sup>2</sup>	Right upper	Hunter Estuary, NSW	14/11/2004				8/10/2011	26/03/2012	169
Orange (notch on top edge) <sup>3</sup> (originally banded with orange-over-green flags)	Left upper	Hunter Estuary, NSW	14/11/2004	072-69361	2+	9+	29/09/2011	26/03/2012	178
Orange	Right upper	Victoria	since 1990				28/09/2011	13/10/2011	16
Orange	Right upper	Victoria	since 1990				4/10/2011	13/10/2011	10
Orange	Right upper	Victoria	since 1990				1/11/2011	1/11/2011	1
Orange	Left upper	Victoria	since 1990				4/10/2011	6/10/2011	3
Orange engraved WS	Right upper	Corner Inlet, Vic	1/02/2011	07363792	3+	3+	29/09/2011	8/10/2011	10
Orange engraved DN	Right upper	Corner Inlet, Vic	26/06/2010	07359576	1+	2+	4/10/2011	18/10/2011	15
Orange engraved SS	Right upper	Barwon Heads, Vic	18/01/2011	07363762	3+	3+	4/10/2011	10/10/2011	7
Orange engraved SY	Right upper	Barwon Heads, Vic	18/01/2011	07324195	3+	3+	4/10/2011	8/10/2011	5
Orange engraved 59	Right upper	Corner Inlet, Vic	7/02/2009	07336876	2+	5+	8/10/2011	15/10/2011	8
Orange engraved KS	Right upper	Corner Inlet, Vic	26/06/2010	07363809	1+	2+	10/10/2011	15/10/2011	6
Green-over-orange	Right upper	Yalu Jiang, China	24 - 28/04/2002		2+	12+	4/10/2011	20/10/2011	17
Black engraved 6D	Right upper	Colville River, North Slope, Alaska	4/07/2009	86403735	2+	5+	4/10/2011	8/10/2011	5
Red with coloured bands R1WWR <sup>Y</sup> <sup>4</sup>	Left upper	Waimea Estuary, South Is, NZ	20/10/2009	Y12324	3+	5+	8/10/2011	15/10/2011	8
White with coloured bands W3YYBR <sup>4</sup>	Left lower	Farewell Spit, South Is, NZ	2/02/2006	Y12406	3+	5+	4/10/2011	8/10/2011	5

<sup>1</sup> Bar-tailed Godwits with orange-over-green bands were banded in the Hunter Estuary as part of a Bachelor of Environmental Science Honours Thesis (Richardson 2004).

<sup>2</sup> Bar-tailed Godwits fitted with radio transmitters at the time of banding, as part of a Bachelor of Environmental Science Honours Thesis (Foate 2005). Various notches cut in the orange and/or green flags allowed identification of individuals. Unfortunately, there is no record of metal band numbers corresponding to the notched flags.

<sup>3</sup> The metal band on this Bar-tailed Godwit was read from digital photographs of the bird in the wild. The bird was flagged in the Hunter Estuary originally with orange-over-green flags. The green flag was lost sometime between March 2005 and October 2009.

<sup>4</sup> Convention for describing colour flags and bands. R = Red, W = White, Y = Yellow and B = Blue. The first letter is the flag colour, followed by a numeral giving the position of the flag relative to the colour bands and legs. The next two letters describe the colour bands on the left leg, followed by two letters describing the colour bands on the right leg. The flag position is given the numeral 1 when the flag is above the colour bands on the left leg; 2 when the flag is above the colour bands on the right leg; 3 when the flag is between the colour bands on the left leg; and 4 when the flag is between the colour bands on the right leg.

**Table 2.** Flagged and colour-banded Bar-tailed Godwit in the Hunter Estuary during the 2012/13 non-breeding season

Flags (unless stated otherwise)	Flag Position on Leg	Banding Location	Date Banded	Metal Band No.	Age at banding	Age in April 2013	First Observation	Last Observation	Minimum Days in Estuary
Orange-over-green BANDS	Right upper	Hunter Estuary, NSW	2/05/2004		1+	10+	6/10/2012	13/03/2013 <sup>1</sup>	159
Orange-over-green (notch in end of green flag)	Left upper	Hunter Estuary, NSW	14/11/2004				26/09/2012	13/03/2013 <sup>1</sup>	169
Orange-over-green (both flags notched underside)	Right upper	Hunter Estuary, NSW	14/11/2004				3/10/2012	13/03/2013 <sup>1</sup>	162
Orange (notch on top edge) (originally banded with orange-over-green flags)	Left upper	Hunter Estuary, NSW	14/11/2004	072-69361	2+	10+	7/10/2012	13/03/2013 <sup>1</sup>	158
Orange	Right upper	Victoria	since 1990				27/09/2012	27/09/2012	1
Orange	Right upper	Victoria	since 1990				6/10/2012	13/10/2012	8
Orange	Right upper	Victoria	since 1990				7/10/2012	7/10/2012	1
Orange	Right upper	Victoria	since 1990				28/10/2012	31/10/2012	4
Orange engraved SS	Right upper	Barwon Heads, Vic	18/01/2011	07363762	3+	4+	27/09/2012	27/09/2012	1
Orange engraved VA	Right upper	Barwon Heads, Vic	18/01/2011	07301642	3+	4+	27/09/2012	3/10/2012	7
Orange engraved 59	Right upper	Corner Inlet, Vic	7/02/2009	07336876	2+	6+	4/10/2012	12/10/2012	9
Orange engraved AJZ	Right upper	Rhyll, Phillip Is, Victoria	11/02/2012	07364151	3+	4+	5/10/2012	13/10/2012	9
Orange engraved ALL <sup>2</sup>	Right upper	Barwon Heads, Victoria	18/12/2012	07370305	1	1	9/03/2013	11/05/2013	64
Green over orange	Right upper	Yalu Jiang, China	24 - 28/04/2002		2+	13+	27/09/2012	7/10/2012	11
Green-over-orange with coloured bands GO2WRYB	Right upper	Yalu Jiang, China	2/04/2012	G09-4641	NR		7/10/2012	21/10/2012	15
White with coloured bands W3RBBR	Lower left	Christchurch, New Zealand	20/11/2009	Y12354	3+		26/09/2012	7/10/2012	12
White with coloured bands W3RBRB	Lower left	Christchurch, New Zealand	20/11/2009	Y12348	3+		27/09/2012	4/10/2012	8
White with coloured bands W3RBRR	Lower left	Christchurch, New Zealand	20/11/2009	Y12347	2+		27/09/2012	13/10/2012	17
White with coloured bands W1YWWR	Upper left	Golden Bay, New Zealand	13/12/2004	Y11257	1		27/09/2012	13/10/2012	17
White engraved BAX	Right upper	Miranda, Firth of Thames, NZ	21/11/2009	Y6640	3+	6+	12/10/2012	19/10/2012	8
White	Right upper	New Zealand	since Dec 1991				3/10/2012	7/10/2012	5
White	Right upper	New Zealand	since Dec 1991				21/10/2012	21/10/2012	1
White engraved BLN <sup>3</sup>	Right upper	Miranda, Firth of Thames, NZ	14/02/2009	Y8698	3+	7+	23/12/2012	2/01/2013	11

<sup>1</sup> The last observation on 13 March 2013 was prior to departure of these birds on northward migration, so residence time in the Hunter Estuary may have been longer.

<sup>2</sup> This Bar-tailed Godwit (orange engraved ALL) may be wandering between non-breeding sites before making its first migration to the northern hemisphere breeding grounds in 2014.

<sup>3</sup> This Bar-tailed Godwit (white engraved BLN) arrived much later than the usual influx of birds on southward migration. However, it had lost a foot and this disability may have delayed its migration.

**Table 3.** Counts of Bar-tailed Godwit flock and coincident numbers of flagged and colour-banded Bar-tailed Godwit at Stockton Sandspit, Hunter Estuary during the 2011/12 non-breeding season.

Survey Date	Southward migration (September to December)												Northward migration (March-April)				
	1/09/2011	15/09/2011	29/09/2011	4/10/2011	8/10/2011	11/10/2011	15/10/2011	20/10/2011	22/10/2011	25/10/2011	1/11/2011	3/11/2011	12/11/2011	26/03/2012	28/03/2012	31/03/2012	5/04/2012
No. of Flagged Bar-tailed Godwits	0	0	4	12	14	10	9	5	4	4	5	4	4	2	0	0	0
Bar-tailed Godwit Count	201 <sup>1</sup>	269	342	-500	475	846	909	546	750	714	779	674	785	538	507	337	171 <sup>2</sup>
% Flagged of count	0	0	1.2	2.6	3.2	1.2	1.0	0.9	0.5	0.6	0.6	0.6	0.5	0.4	0	0	0

Note: <sup>1</sup> Average of over-wintering counts (May to August 2011) for Bar-tailed Godwit in the Hunter Estuary.

<sup>2</sup> Over-wintering population of Bar-tailed Godwit.

**Table 4.** Repeat sightings of individually flagged Bar-tailed Godwit in the Hunter Estuary.

Flag	Date & Place Flagged	Sightings in Hunter Estuary			
		2009/10	2010/11 <sup>1</sup>	2011/12	2012/13
Orange engraved 59	7/02/2009 Victoria	9 to 17/10/2009		8 to 15/10/2011	4 to 12/10/2012
Orange engraved SS	18/01/2011 Victoria			4 to 10/10/2011	27/09/2012
White engraved BLN	14/02/2009 New Zealand	2/10/2009			23/12/2012 - 2/01/2013 <sup>2</sup>

Note: <sup>1</sup> No observations were made from late September to mid-October 2010, the period of southward migration.

<sup>2</sup> This bird lost its left foot sometime since October 2009.

## DISCUSSION

Flagging and banding studies of shorebirds in Australia and New Zealand indicate a range of possible behaviours for Bar-tailed Godwit that can be related to the observations presented above:

- *Immature* birds banded in the Hunter Estuary during winter *may or may not be site faithful*;
- *Adult* birds banded in the Hunter Estuary after their first breeding attempt and subsequent southward migration *are likely to be site faithful* to the Hunter Estuary and remain throughout the non-breeding season (October to March);
- *Immature* birds banded in Victoria or New Zealand are not necessarily site faithful and therefore may or may not return to their banding sites after their first migration north to breed;
- *Adult* birds banded in Victoria or New Zealand are likely to be faithful to those banding locations and will only be observed in the Hunter Estuary for short periods as they pass through during southward migration. These birds will not visit the Hunter Estuary during northward migration; and
- *Adult* birds banded in the northern hemisphere that are seen in the Hunter Estuary are most likely to be passage birds because the population in the Hunter in the non-breeding season is a very small proportion of the total population occurring in the East Asian-Australasian Flyway [less than 1% of Bar-tailed Godwit stay in the Hunter Estuary - approximately 800 birds out of 155,000 Bar-tailed Godwit that spend the non-breeding season in southeast Australia and New Zealand (Bamford *et al.* 2008; Woodley 2009)].



In the following discussion we examine our results for evidence of these behaviours.

### Peak passage of Bar-tailed Godwit through the Hunter Estuary

As indicated in **Tables 1** and **2** and **Figure 3**, the number of flagged Bar-tailed Godwit observed was highest in early October. Fourteen of the 18 flagged and colour-banded birds present in September-October 2011 and 18 of the 22 flagged and colour-banded birds present in September-October 2012 were passage birds, suggesting that the number of godwits passing through the estuary also peaked at that time. Higgins & Davies (1996, p.87) noted that Bar-tailed Godwit arrive in eastern Queensland by early August, with temporary influxes on the east coast till November, suggesting birds move south down the coast; numbers at most sites in south-eastern Australia increase in late September. The observations of flagged birds present in the Hunter Estuary during September/October support this assessment.

An interesting exception to this pattern was a Bar-tailed Godwit flagged in New Zealand in February 2009 with a white flag engraved BLN. This bird had staged in the Hunter Estuary in October 2009, during the usual peak passage time. However in 2012 it arrived very late - on 23 December - and stayed for at least 11 days before moving on, presumably to New Zealand. Unfortunately, the bird had lost its left foot. This disability may have reduced its foraging success and consequently delayed its departure on southward migration.

### Site infidelity of immature Bar-tailed Godwit

In a study of Bar-tailed Godwit movements in New Zealand, Battley *et al.* (2011, p. 35) found that young godwits "... may wander widely around New Zealand before settling on a non-breeding site (which may or may not be where the bird was caught and banded)." Bar-tailed Godwits usually make their first migration to the northern hemisphere breeding grounds when they are more than two years old (C.D.T. Minton pers. comm.).

One Bar-tailed Godwit with orange-over-green bands stayed in the Hunter Estuary for both the 2011/12 and 2012/13 non-breeding seasons. This bird was one of fifteen caught in the Hunter Estuary in May 2004 from an over-wintering flock of immature Bar-tailed Godwit (Richardson 2004). In the summer of 2004/05 immediately following banding, one orange-over-green banded Bar-tailed

Godwit was seen in the North Island of New Zealand (AWSG database) and one was seen in the Hunter Estuary. In the summer of 2007/08 up to two birds were seen in New Zealand and one was seen in the Hunter Estuary. In the summer of 2009/10 one bird was seen in New Zealand and two in the Hunter Estuary, where one stayed for the entire non-breeding season while the other bird passed through, being seen only in October 2009. Only one orange-over-green banded bird has been seen in the Hunter Estuary since October 2011. This bird appears to be atypical of other birds in the banded cohort that have not returned. It is likely that several of these birds have adopted New Zealand as their preferred non-breeding area. Indeed, it appears that all but one godwit from the fifteen immature birds caught in the estuary in 2004 have either died or relocated elsewhere. This is consistent with Battley *et al.*'s (2011) observation that immature Bar-tailed Godwits wander widely from site to site before settling on a non-breeding area when mature.

### Site fidelity of mature Bar-tailed Godwit flagged in the Hunter Estuary

Mature Bar-tailed Godwits are known to be highly site-faithful. Battley *et al.* (2011, p.35) found that: "Overall, adult godwits can be characterised as highly site-faithful birds that apparently only infrequently venture far from their 'usual' non-breeding site. They are highly likely to return to the same non-breeding site year after year." Passage through the Hunter Estuary of all Victorian-flagged and all New Zealand-flagged godwits on southward migration supports this, particularly when subsequent sightings of these birds were made at their original flagging sites.

On 14 November 2004, 15 presumed mature Bar-tailed Godwit were caught and flagged in the Hunter Estuary. Uniquely notched flags were placed on each bird so that they could be individually identified in the field using a telescope (Foate 2005) (**Figure 2**). Three of these birds spent both the 2011/12 and 2012/13 non-breeding seasons in the Hunter Estuary, demonstrating their site fidelity.

Six orange-over-green flagged birds (presumably mature when flagged in November 2004) returned to the estuary in the following 2005/06 non-breeding season and again in the 2007/08 non-breeding season, indicating continued site fidelity (no specific flag searches were conducted in 2006/07). Only four birds were present in the 2008/09 and 2009/10 non-breeding seasons, but

during the 2011/12 and 2012/13 non-breeding seasons, only three were present. Assuming these birds were site-faithful, it is possible that we have been recording natural attrition over the nine-year period since the birds were flagged.

It is interesting to note that in the year following the catching and flagging, two orange-over-green flagged Bar-tailed Godwit were seen in New Zealand in the 2005/06 non-breeding season (one in the North Island and one in the South Island) and two were recorded together in the North Island in the 2010/11 non-breeding season. These birds may not have been full adults as presumed when caught in the Hunter Estuary and may have made their first breeding migration after being flagged in November 2004 and then subsequently relocated to New Zealand as mature birds in the 2005/06 non-breeding season.

In addition, a single orange-over-green flagged Bar-tailed Godwit was sighted in Queensland on 10 October 2006 and 16 November 2006 (AWSG database). As flagged Bar-tailed Godwit were observed to pass through the Hunter Estuary before the end of October, it is likely that movement of Bar-tailed Godwit down the coast from Queensland would have been completed earlier than mid-November. Thus it seems likely that this bird had adopted Queensland as its non-breeding site for 2006/07.

### Staging and breeding sites

Single orange-over-green *banded* birds have been recorded on northward migration in South Korea (2 May 2005) and Japan (21 April 2008 and 10 April 2009) and on the Alaskan breeding grounds (18 June 2010) (AWSG database). Single orange-over-green *flagged* birds have also been sighted on northward migration in South Korea (April 2006, May 2007, May 2008 and April 2012) and have been recorded in Alaska at the end of the breeding season (13 August 2005 and 20 August 2006) (AWSG database). These sightings confirm that Bar-tailed Godwit from the Hunter Estuary use the Yellow Sea area as a stop-over site during northward migration and also that they breed in Alaska. A Bar-tailed Godwit with a black leg flag engraved 6D, caught on the breeding ground in Alaska in 2009, stayed for a minimum of five days in the Hunter Estuary in October 2011 before moving on (**Table 1**). This is direct confirmation that Bar-tailed Godwit staging in the Hunter Estuary breed in Alaska.

Further evidence of birds staging in the Yellow Sea on northward migration comes from observations of a Bar-tailed Godwit with green-over-orange flags, which had been caught in Yalu Jiang, China, on northward migration in April 2002. This bird subsequently staged in the Hunter Estuary from 4 to 20 October 2011 on southward migration. A similarly flagged bird staged in the Hunter Estuary from 27 September to 7 October 2012 before moving on. A Yalu Jiang-flagged godwit had also been seen previously on 19 September 2008 (M. Roderick pers. comm.). Without individual identification marks, it is not possible to know whether these are repeat visits by the same bird or visits by three different birds. However, an individually marked godwit caught at Yalu Jiang on 2 April 2012 staged in the Hunter Estuary from 7 to 24 October 2012 (green-over-orange flags with colour bands - see **Table 2**). We will be searching for this bird in October 2013 to determine if it habitually stages in the Hunter Estuary.

Lack of sightings in Asia during southward migration correlates with the results of satellite-tracking, which showed Bar-tailed Godwit were migrating directly across the Pacific Ocean to southeast Australia and New Zealand from their Alaskan breeding grounds (Battley *et al.* 2012).

### Bar-tailed Godwit flagged in Victoria

All Victorian-flagged birds (10 in the 2011/12 and 8 in the 2012/13 non-breeding seasons) passed through the Hunter Estuary during southward migration, spending up to 17 days in the estuary before presumably continuing their southward migration to Victoria.

One individually marked bird (orange flag engraved 59) has been seen in the Hunter Estuary in the first half of October in 2009, 2011 and 2012 (**Table 4**), suggesting that it regularly stages in the Hunter Estuary on southward migration.

In March 2013, during northward migration, a Bar-tailed Godwit flagged in Victoria in December 2012 (orange flag engraved ALL) as a first-year bird, arrived in the Hunter Estuary (**Table 2**). This young bird lacked breeding plumage and had not laid on fat reserves in preparation for migration (Woodley 2009). It was still present in the Hunter Estuary on 11 May 2013, as part of the overwintering godwit flock. It appeared to be an example of an immature bird wandering between sites before making its first full migration to the breeding grounds.

## Bar-tailed Godwit flagged in New Zealand

Only 2 of the 18 flagged Bar-tailed Godwit (11%) observed in the Hunter Estuary in 2011/12 were caught previously in New Zealand; however, 8 out of the 23 flagged birds (35%) observed in the Hunter Estuary in 2012/13 had been caught previously in New Zealand (**Tables 1 and 2**). Five of these birds (two from 2011 and three from 2012) with distinctive colour-band combinations were subsequently seen at their original banding sites in New Zealand, confirming that they had completed their southward migration to their non-breeding sites (**Table 5**).

Satellite-tracking of Bar-tailed Godwit from New Zealand showed that these birds flew north to stage in the Yellow Sea, then flew to Alaskan breeding grounds and, after breeding, flew back to New Zealand directly across the Pacific Ocean (Gill *et al.* 2009; Battley *et al.* 2012). So it is not surpris-

ing that relatively few godwits flagged in New Zealand appear in New South Wales, as was the case in 2011/12. However, it has been suggested that if the birds encounter adverse weather conditions on their southward flight from the breeding grounds, they may divert to eastern Australia (Gill *et al.* 2009). It is possible that adverse weather conditions affected a significant number of migrating godwits in late September 2012, resulting in the arrival of four New Zealand-flagged birds on or about 26 September 2012. However, weather maps around the time of southward migration did not display particularly adverse winds prior to 26 September and it may be that, due to the prevailing strong south-easterly trade winds north of New Zealand, the birds simply drift off course to the west during migration and stage in the Hunter Estuary for a relatively short time before making the final flight across the Tasman Sea to New Zealand.

**Table 5.** Re-sighting records for New Zealand-flagged birds seen in the Hunter Estuary (NZWSG database)

NZ Flag and Colour bands	Banding Date	Banding Location in New Zealand	Sighted in Hunter Estuary	Sighted in New Zealand	Sighting Location in New Zealand
White flag W3YYBR <sup>1</sup>	2/02/2006	Farewell Spit, South Island	4/10/2011 - 8/10/2011	10/01/2012	Golden Bay
Red flag R1WWRY	20/10/2009	Waimea Estuary, South Island	8/10/2011 - 15/10/2011	29/11/2011; 14/03/2012	Waimea Estuary
White flag W3RBBR	20/11/2009	Christchurch	26/09/2012 - 7/10/2012	17/10/2012	Christchurch
White flag W3RBRB	20/11/2009	Christchurch	27/09/2012 - 4/10/2012	18/10/2012	Christchurch
White flag W3RBRR	20/11/2009	Christchurch	27/09/2012 - 13/10/2012	18/10/2012	Christchurch

Note: <sup>1</sup> W = White; Y = Yellow; B = Blue; R = Red. The first letter is the flag colour; the first numeral is the position of the flag relative to the colour bands and legs; the next two letters are the colour bands on the left leg; the last two letters are the colour bands on the right leg.

## CONCLUSIONS

Flagged and colour-banded Bar-tailed Godwit observed in the Hunter Estuary during the 2011/12 and 2012/13 non-breeding seasons show that Bar-tailed Godwit on southward migration stage in the Hunter Estuary for periods ranging from a minimum of 1 to 17 days. Staging occurs mainly from late September to late October, when hundreds of Bar-tailed Godwit may use the estuary as an important re-fuelling site on southward migration. Repeat visits indicate that some godwits en route to Victoria regularly use the Hunter Estuary as a staging site on southward migration. Bar-tailed Godwit destined for New Zealand may be diverted to the east coast of Australia by adverse weather conditions during

their trans-Pacific flight from the Alaskan breeding grounds, or they may simply drift off-course due to the persistent southeast trade winds north of New Zealand. After staging, these birds depart the Hunter Estuary to continue their migration to New Zealand.

The estuary is also an important site for Bar-tailed Godwit to stay for the non-breeding season, with approximately 780 birds in 2011/12 and 800 birds in 2012/13. The same three flagged and one colour-banded godwit demonstrated site-fidelity to the Hunter Estuary over both non-breeding seasons.

Most Bar-tailed Godwit colour-banded as immature birds in the Hunter Estuary adopted

other sites for the non-breeding season following their initial migrations. The propensity of immature Bar-tailed Godwit to wander between sites until their first breeding migration has been demonstrated by an individually marked bird flagged in Victoria in December 2012, in its first year. It appeared in the Hunter Estuary during the northward migration period in March 2013 and has joined the over-wintering group of around 210 Bar-tailed Godwit still present at the end of April 2013.

Birds preparing for northward migration from southern parts of Australia lay on fat stores that make them capable of long-distance migration, with the Yellow Sea the most likely first landfall (Battley *et al.* 2011). Our observations confirm that mature birds migrating from further south have no need to stage in the Hunter Estuary on northward migration.

## ACKNOWLEDGEMENTS

We are indebted to Heather Gibbs, former custodian of the AWSG database, for prompt acknowledgement of our flag sightings and helpful provision of banding and sighting histories for birds seen in the Hunter Estuary. We thank Rob Schuckard for providing re-sighting details of Bar-tailed Godwits in New Zealand. Adrian Riegen and Rob Schuckard greatly encouraged and enhanced our flag-searching skills. Clive Minton also encouraged our research. We thank Mike Newman and Harold Tarrant for constructive comments on an early draft of this manuscript and Peter Driscoll, Adrian Riegen and an unknown reviewer for helpful comments on a later draft.

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