Oriental Bird Club Conservation Grant 2012 (No. P956) Final report

Southward migration phenology and impacts of aquaculture on shorebirds at the Dandong Yalu Jiang Estuarine Wetland National Nature Reserve, Liaoning, China

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Cover photo taken by Xiao-Yang LIU

Waders fly over Roost Site A1 watched by a group of local visitors. The cranes in the background are at Da dong Port, an area of former tidal flats that has been successively reclaimed since 1980s.

SUMMARY

Twelve surveys were conducted between June and December 2012 at the Yalu Jiang coastal wetland between China and North Korea border, to understand the importance of the study area to shorebirds during southward migration. We found that southward migration began in mid June and finished in mid November; it is estimated that around 60,000 shorebirds used the study area. The highest number of shorebirds (38,133) was recorded in mid August. During our surveys, 13 shorebird species occurred in numbers exceeding 1% of their flyway population estimates: Bar-tailed Godwit *Limosa lapponica*, Whimbrel *Numenius phaeopus*, Eurasian Curlew *Numenius arquata*, Far Eastern Curlew *Numenius madagascariensis*, Spotted Redshank *Tringa erythropus*, Common Greenshank *Tringa nebularia*, Nordmann's Greenshank *Tringa guttifer*, Terek Sandpiper *Xenus cinereus*, Dunlin *Calidris alpina*, Far Eastern Oystercatcher *Haematopus [ostralegus] osculans*, Grey Plover *Pluvialis squatarola*, Kentish Plover *Charadrius alexandrinus* and Lesser Sand Plover *Charadrius mongolus*. The peak number of Far Eastern Curlew at the Yalu Jiang coastal wetlands was 7,486 individuals, equivalent to 23.4% of the total flyway population. We adopted a modelling approach to estimate the passage times and total numbers of birds passing through the site for 15 shorebird species. Some shorebird species such as the Bar-tailed Godwit, Great Knot and Nordmann's Greenshank, showed different peaks between adults and juvenile birds during southward migration, with adults preceding juvenile birds. We also found that at least 13 shorebird species were in active primary wing moult while staging at Yalu Jiang coastal wetland. These results indicate that Yalu Jiang coastal wetland is used as both a refuelling and moulting site by shorebirds during southward migration along the East Asian-Australasian Flyway.

INTRODUCTION

Shorebird populations along the East Asian-Australasian Flyway (hereafter EAAF) are among the most poorly known of the different flyways (Stroud et al. 2006). Many are declining (MacKinnon et al. 2012), one of the main drivers being wetland habitat loss through reclamation (Moores et al. 2008; Amano et al. 2010; Rogers et al. 2011) and *Spartina* invasion (Gan et al. 2009). The Yellow Sea in northeast Asia is located at the heart of the EAAF, providing crucial stopover sites for migratory shorebirds to rest and refuel, thus playing a critical role in shorebird migration along the EAAF (Barter 2002). However, the Yellow Sea is also home for approximately 600 million people (10% of the world population), who rely heavily on the Yellow Sea for food and economic development, putting enormous pressure on local ecosystems (UNDP/GEF 2007) especially the intertidal wetlands that the shorebirds rely heavily on.

The Yalu Jiang estuary is located in the north of Yellow Sea, being the border between China and North Korea. The Chinese side of the Yalu Jiang coastal wetland (here after YLJCW) has been identified as an important stopover site for migratory shorebirds along the EAAF during northward migration (Barter 2002; Bamford et al. 2008), supporting significant number of shorebirds, such as Bar-tailed Godwit *Limosa lapponica*, Great Knot *Calidris tenuirostris* (IUCN category Vulnerable), Far Eastern Curlew *Numenius madagascariensis* (IUCN category Vulnerable), Eurasian Curlew *Numenius arquata* (IUCN category Near Threatened), Far Eastern Oystercatcher *Haematopus [ostralegus] osculans* and Dunlin *Calidris alpina* (Barter et al. 2004; IUCN 2012; Riegen et al. 2013; Choi et al. in press; Melville et al. in press). Part of this coastal wetland was designated as the Dandong Yalu Jiang Estuarine Wetland National Nature Reserve (39°40'–39°58'N, 123°28'–124°09'E, **Figure 1**) in 1997 to conserve the coastal wetland ecosystem and wildlife (Yan 2008).

The YLJCW is composed of mainly of bare intertidal mudflats and sometimes *Phragmites*-dominated saltmarsh on the seaward side of the seawall, with aquaculture ponds and farmland on the landward side (**Figure 1**); a typical coastal landscape of much of the Chinese Yellow Sea coasts. The bare intertidal mudflats provide important foraging and resting habitats for migratory shorebirds during their stopover, but also are used for shellfish farming and other fishing activities. Aquaculture ponds have been used to cultivate prawns since the early 1980s, but shellfish became more common by the late 90s due to disease problems with prawns (Yu 1994; Chang et al. 2008). Subsequently this was followed by polyculture of shellfish and jellyfish. Sea cucumbers have become increasingly popular since the late 2000s due to their high market value. Shorebirds use aquaculture ponds mainly for roosting during high tide, when they usually roost on the bunds when the ponds are filled with water. However, when the water level in the ponds dropped for management purposes, shorebirds often prefer to roost in the middle of a pond on the wet substrate and sometimes even foraged when the opportunity arises.

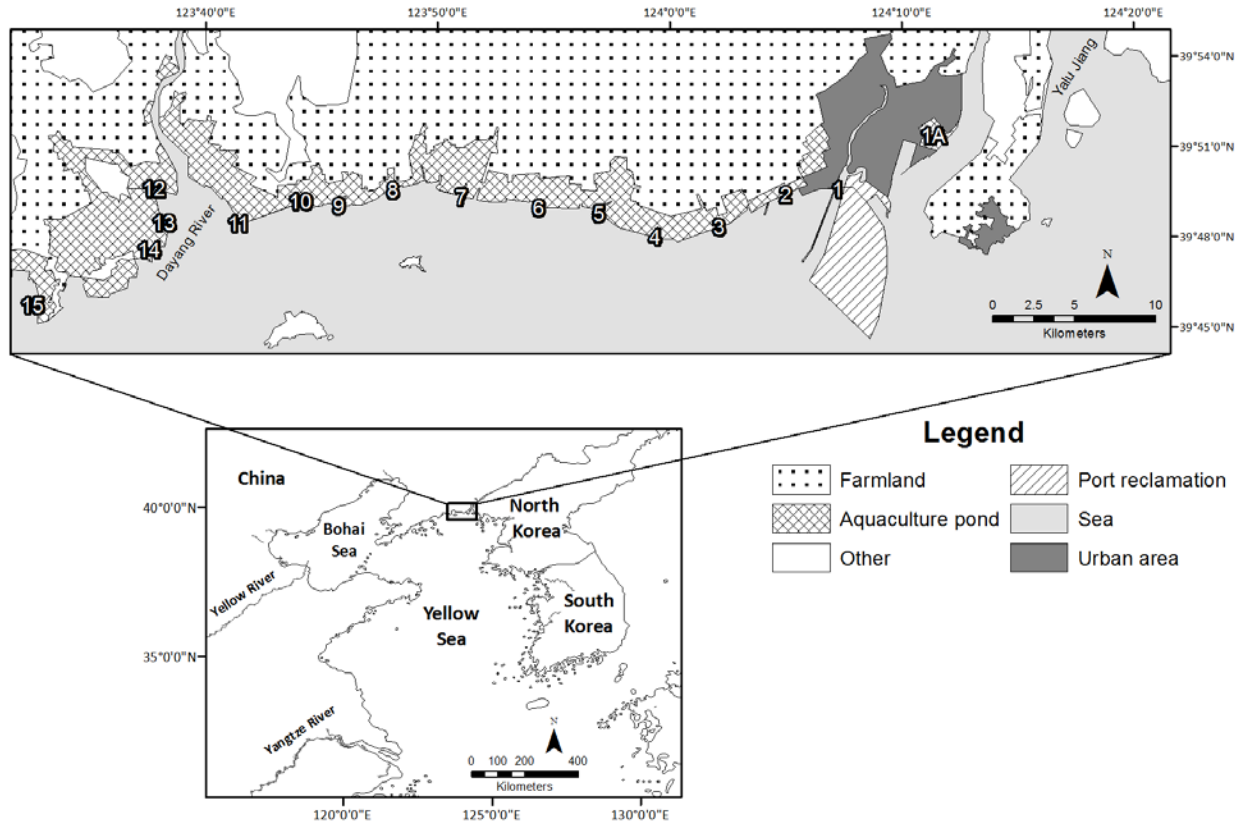

Figure 1. Map of Yalu Jiang coastal wetland, showing some of the pre-roosts counted during this study. The inset shows the location of Yalu Jiang coastal wetland within the Yellow Sea region. Note that the eastern and western boundaries of the Dandong Yalu Jiang Estuarine Wetland National Nature Reserve were adjusted in 2012 to exclude pre-roosts 1 and 15. The channel east of the pre-roost 1A is the western branch of Yalu Jiang, which marks the boundary between China and North Korea.

PROJECT OBJECTIVES

Despite the known importance of the Yalu Jiang coastal wetland to shorebirds during northward migration, it was one of the two important Chinese shorebird sites in the Yellow Sea (ten in total) identified by Barter (2002) that lacked southward migration data . In this project, we aimed to fill in this knowledge gap by conducting periodic shorebird surveys during southward migration. We also adopted a modelling approach (Thompson 1993; Rogers et al. 2010; Choi et al. in press) to estimate the passage time and total number of birds passing through the site for some common species, thereby improving our understanding of the southward migration of shorebirds along the EAAF. Finally, we recorded age ratio and moult information that could improve our understanding on the role of YLJCW to shorebirds during southward migration.

METHODS

Tides at YLJCW are semi-diurnal, with spring high tides inundating all of the intertidal flats. As the tide rises and approaches the seawall, birds concentrate at pre-roosts – upper intertidal flats that are last to be covered by the tide – before flying towards aquaculture or abandoned ponds on the landward side of the seawall to roost (Barter et al. 2004), or in more recent years flying to roost on port reclamation sites. Our survey methodology followed that of Barter and Riegen (2004), however we restricted our counts to 10 of their 15 identified fixed pre-roosts. We also conducted counts at the western branch of Yalu Jiang Estuary (pre-roost 1A) (**Figure 1**, **Figure 2**), which is further east than any of the other pre-roosts but holds significant numbers of birds (Riegen et al. 2013, Choi et al. in press).

The western branch of the Yalu Jiang Estuary (pre-roost 1A) was the only surveyed location that is not part of the reserve, however, this area was the most important roost site during 2012 southward migration. Unlike most other pre-roosts, this site had three large abandoned and non-flooded ponds (one reclamation pond and two ponds for power station fly ash disposal) that were at least 1,000 m long, creating relatively less disturbed and favourable roosting conditions for shorebirds (**Figure 2, Table 1**). Birds were often concentrated in the reclamation and ash ponds during spring high tide when the intertidal mudflat was submerged. This area was most suitable for survey during spring high tide, especially when tidal level reached a predicted 680 cm (National Marine Data and Information Service 2011), submerging most of the intertidal mudflat including those on the North Korean side of the river, forcing more shorebirds to roost in the ponds. Although the number of birds using this area has dropped in the last few years as the port development sites further south created temporarily suitable roosting habitat to shorebirds (QQB, unpublished), the western branch continued to hold a significant number of shorebirds.

Table 1. Main habitat type at different pre-roosts surveyed in this study.

Pre-roost	Latitude	Longitude	Main shorebird habitat type
1A	39°51′	124°11′	Reclamation pond, ash pond, saltmarsh, bare intertidal mudflat
1	39°50′	124°07′	Reclamation pond
2	39°50′	124°05′	Bare intertidal mudflat, aquaculture pond
3	39°48′	124°02′	Bare intertidal mudflat, aquaculture pond
4	39°48′	123°59′	Bare intertidal mudflat, aquaculture pond
5	39°49′	123°57′	Bare intertidal mudflat, aquaculture pond
6	39°49′	123°54′	Bare intertidal mudflat, aquaculture pond
8	39°50′	123°48′	Bare intertidal mudflat, aquaculture pond
9	39°49′	123°46′	Bare intertidal mudflat, aquaculture pond
10	39°49′	123°44′	Bare intertidal mudflat, aquaculture pond
11	39°49′	123°41′	Bare intertidal mudflat, aquaculture pond
11A	39°50′	123°40′	Bare intertidal mudflat, aquaculture pond
12	39°50′	123°38′	Bare intertidal mudflat, saltmarsh

Twelve shorebird surveys were conducted between June and December 2012 (**Table 2**). All surveys were conducted during spring tide periods. The main survey period was between mid-July and mid-October, when 7 surveys were conducted. These surveys were conducted roughly once every two weeks, covering most of the shorebird pre-roosts. Surveys conducted before mid-July only covered a few pre-roosts while surveys in November and December covered most of the pre-roosts. Details of the main habitat types in each pre-roosts can be found in **Table 1**.

Table 2. Date, duration and number of pre-roosts covered for each survey.

Survey period	9 Jun	22 Jun	7-8 Jul	19-23 Jul	2-5 Aug	15-18 Aug	1-3 Sep	14-17 Sep	29-30 Sep	14-15 Oct	17-18 Nov	15 Dec
Duration (days)	1	1	2	5	4	4	3	4	2	2	2	1
Number of pre-roosts	2	1	2	8	6	10	9	8	6	9	10	8

Figure 2. The western branch of the Yalu Jiang estuary showing roost sites and pre-roost at 1A.

Survey methods

Based on prior observations, most of the birds found in pre-roosts 7, 8 and 9 tended to fly towards the west and concentrated at pre-roost 10 during the flood tide. Meanwhile, birds at pre-roosts 3, 4 and 5 tended to fly towards the east and concentrated at pre-roost 2. Birds at pre-roost 6 could go either way. Such a tendency was due to the relatively higher beach elevation at pre-roosts 2 and 10, which were inundated later than other pre-roosts. For the birds in pre-roost 1A, they often flew into the reclamation and ash ponds when the intertidal mudflat was inundated. Therefore, it took at least two days to survey the study area, with one day covering the eastern half (pre-roosts between 1A and 6), and another day covering the western half (pre-roosts between 8 and 11). Due to the importance of pre-roost 2 and 10, counts were conducted during both flood and ebb tides at these two locations, but only during ebb tide for pre-roost 3 to 9. Counts at pre-roost 1A and 11 were only conducted during very high tide. To minimize the chance of double counting, the sum of the counts of either flood tide or ebb tide (depends on which gives the higher total for each species), but not both, were used as the total number of birds between pre-roost 2 and 11. This number was then added to the counts at pre-roost 1A to give the total. Any suspected double-counting records were excluded in analysis. For any pre-roost that was surveyed more than once in one time period, the larger count data was used.

It is important to note that although pre-roost 1A and 2 were approximately 9 km apart, it is thought unlikely that birds travel between these roosts within a single high tide period. This is supported by the different species composition in these roosts. Throughout our survey period, there were 9 species that reached 1% of the EAAF estimate at pre-roost 1A, while there were 5 at pre-roost 2, however, only three species (Far Eastern Curlew, Nordmann's Greenshank and Grey Plover) reached 1% of the EAAF estimate at both roosts. As the numbers of these 3 species were high at one roost, the numbers on the other roost became relatively small. In addition, our observations indicated that most of the birds seen at pre-roost 2 often landed and probably roosted in the port development sites, while those roosting at the ash ponds in pre-roost 1A often flew from the intertidal mudflat on the North Korean side. Therefore, numbers counted at these two pre-roosts could be added with little or no double-counting.

The shortcomings of our survey approach included 1) overlooking individuals that roosted in the aquaculture ponds between pre-roost 3 and 9; 2) some birds might not return to the intertidal mudflat until the tide dropped too far away from the observer for accurate identification and counting. Both of these led to an underestimate of the total number of birds using the study area, thus our final result is likely to be a conservative estimate. Although most of the bird-rich pre-roosts were included in the survey, several pre-roosts used by Barter and Riegen (2004) such as 7, and 12-15 were not surveyed due to the limited number of observers available and poor accessibility. This again led to a conservative estimate of the number of birds using the study area.

There were occasions when differentiating the two curlew species was difficult. The most common solution was to record the total number of identifiable curlews in the same flock, and use that ratio to estimate the total numbers for each curlew species. In the most extreme cases, the ratio was derived from the most recent count data, but such occasion was very rare and only several hundred curlews were estimated in this way. In every survey, effort was made to keep the number of unidentified curlews as low as possible. The reclamation pond and ash ponds at pre-roost 1A were the most important roost where large numbers of curlews were recorded (**Table 3**). These ponds were used as a high tide roost and curlews often gathered at accessible places, allowing detailed observation to determine species identification and assessment of the age ratio. The counting conditions at two other favourable curlew roosts (pre-roost 2 and 10) also allowed good records to be made. Therefore, most of the Eurasian and Far Eastern Curlews during our surveys were counted accurately, and the number of unidentified curlews was a small proportion of the total.

Table 3. The total of Far Eastern Curlew recorded in the whole study area related to the numbers present at pre-roost 1A during different surveys.

	9-Jun	22-Jun	7-8 Jul	19-23 Jul	2-5 Aug	15-18 Aug	1-3 Sep
Total	990	1332	3930	7486	5681	5147	3952
Pre-roost 1A	990	1332	3230	4534	4130	1971	1940
% Pre-roost 1A	100	100	82.2	60.6	72.7	38.3	49.1

The ratios between adults and juvenile birds of some species were recorded based on plumage differences between ‘adults’ and ‘juveniles’ (Prater et al. 1977). Such information was collected from as many different pre-roosts as possible. The entire flock was sampled if the flock size was small and time was available. Otherwise, 100 individuals were sampled randomly in the flock by taking 30 individuals from the left, 40 from the middle and 30 from the right to record the age ratio. This ratio was then incorporated to the total numbers counted to obtain the number of adults and juvenile birds.

All observation was made using a Leica APO77 telescope and photos were taken using a Canon 7D and 400mm lens.

Modelling transiting population and passage times

Many surveys along the Chinese coast have used peak counts to represent the total number of birds transiting an area, which may be applicable at non-breeding sites, but not at stopover sites where where population turnover means that some individuals may depart before all have arrived (Moser et al. 1983; Ma et al. 2013). The use of peak counts to represent the total number of birds transiting a site would likely to be an underestimate (Thompson 1993; Ma et al. 2013). Here we followed the approach of Thompson (1993) (developed in Rogers et al. 2010) to model the numbers of birds and passage times, using repeated within-season counts data and assuming normally distributed arrival and departure times (see Choi et al. in press for detailed methods). We applied the model to species commonly occurring in the study area during southward migration, with the emphasis on species that exceeded 1% of the flyway population estimate (Wetlands International 2013). Such an approach was taken because the 1% criterion is important for identifying internationally important shorebird sites (Ramsar Convention Secretariat 2013).

RESULTS

Overall pattern

Twelve surveys were conducted during southward migration in 2012, with around 60,000 shorebirds of 35 species recorded (**Table 5, Appendix 1**). The number of shorebirds increased from late June, stabilized between mid-July and mid-October, then decreased in mid-November (**Figure 3**). The number of species that reached 1% of the EAAF population changed in a similar way as the total number of birds. Few species met the 1% criterion before mid-July and then it increased and stabilized between mid-July and mid-October before decreased sharply in mid November (**Figure 3**). The whole migration period lasted for almost 5 months, which was almost twice as long as the northward migration (Riegen et al. 2013, Choi et al. in press).

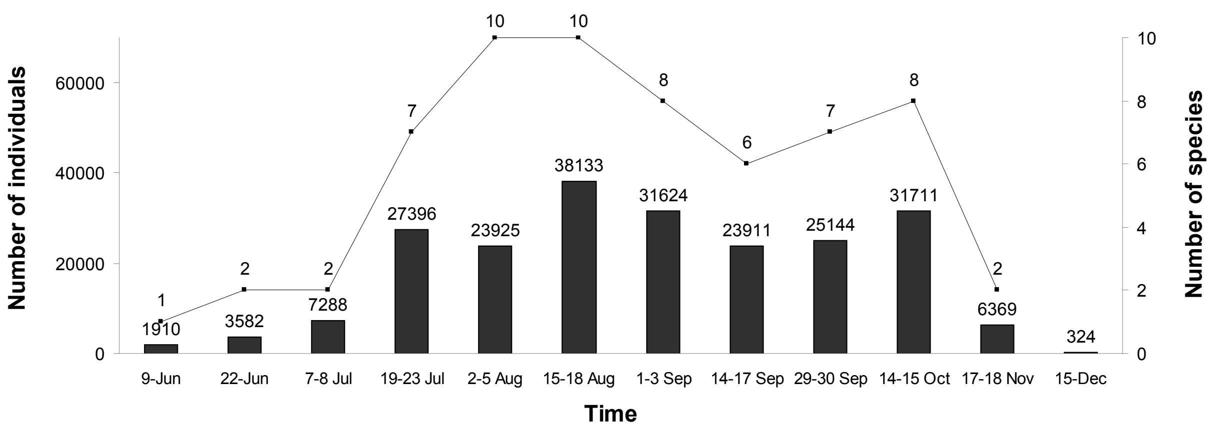

Figure 3. The number of shorebirds counted in each survey at Yalu Jiang coastal wetland during southward migration in 2012. Bars represent count data and were plotted against the left axis (number of individuals). Solid line represents the number of species that exceeded the 1% of the East Asian-Australasian Flyway population and was plotted against the right y-axis.

Important species

Using our peak count data during southward migration in 2012, 13 species occurred at Yalu Jiang coastal wetland in numbers that exceeded their 1% EAAF estimates. These were Bar-tailed Godwit, Whimbrel *Numenius phaeopus*, Eurasian Curlew, Far Eastern Curlew, Spotted Redshank *Tringa erythropus*, Common Greenshank *Tringa nebularia*, Nordmann's Greenshank *Tringa guttifer*, Terek Sandpiper *Xenus cinereus*, Dunlin, Far Eastern Oystercatcher *Haematopus [ostralegus] osculans*, Grey Plover *Pluvialis squatarola*, Kentish Plover *Charadrius alexandrinus* and Lesser Sand Plover *Charadrius mongolus* (**Table 4**).The peak number of Whimbrel, Far Eastern Curlew, Common Greenshank, Nordmann's Greenshank, Terek Sandpiper, Lesser Sand Plover and Kentish Plover recorded in autumn 2012 were higher than any historical record at Yalu Jiang coastal wetland (Bamford et al. 2008; China Coastal Waterbird Census Group (2011)).

The species composition and relative abundance during southward migration was different to northward migration. The number of Common Greenshank, Terek Sandpiper, Lesser Sand Plover and Kentish Plover recorded during southward migration were higher than those during northward migration. In fact, the number of Kentish Plover recorded during southward migration was more than 10 times higher than the number during northward migration. In contrast, the numbers of Bar-tailed Godwit and Great Knot recorded during southward migration were more than 10 times smaller than the numbers during northward migration (Riegen et al. 2013, Choi et al. in press). These results indicate that some species use different migration routes during northward and southward migration. The proportion of juvenile birds was very low in some species, such as the Bar-tailed Godwit, Far Eastern Curlew and Grey Plover throughout the southward migration period. This might indicate different migration routes between different age classes in these species, or could result from poor breeding success in 2012. More systematic surveys during southward migration on other important shorebird sites are needed to determine this.

Table 4. The highest count of different waterbird species recorded during southward migration at Yalu Jiang coastal wetland in 2012. The flyway population estimates were based on Wetlands International (2013) unless stated otherwise. In the status column, EN denotes Endangered, LC for Least Concern, NT for Near Threatened and VU for Vulnerable (IUCN 2012).

Species	IUCN status	Highest count	Recorded date	% of flyway population
Far Eastern Curlew *Numenius madagascariensis*	VU	7,486	19-23 Jul	23.4
Far Eastern Oystercatcher *Haematopus [ostralegus] osculans*	LC	642	16-17 Aug	9.2
Nordmann's Greenshank *Tringa guttifer*	EN	42	14-16 Sep	8.4
Kentish Plover *Charadrius alexandrinus*	LC	5,459	12 Aug	5.5

Terek Sandpiper *Xenus cinereus*	LC	2,075	20-22 Jul	4.2
Eurasian Curlew *Numenius arquata*	NT	4,079	17-18 Nov	4.1
Bar-tailed Godwit *Limosa lapponica*	LC	5,902	16-18 Aug	3.9*
Grey Plover *Pluvialis squatarola*	LC	3600	1-3 Sep	3.6
Lesser Sand Plover *Charadrius mongolus*	LC	1,902	17-18 Aug	2.8
Dunlin *Calidris alpina*	LC	20,921	14-15 Oct	2.2**
Common Greenshank *Tringa nebularia*	LC	2,045	16-18 Aug	2.0
Spotted Redshank *Tringa erythropus*	LC	456	29 Sep	1.8
Whimbrel *Numenius phaeopus*	LC	600	4-5 Aug	1.1
Great Knot *Calidris tenuirostris*	VU	1,411	2-4 Aug	0.49
Broad-billed Sandpiper *Limicola falcinellus*	LC	73	21-23 Jul	0.29
Ruddy Turnstone *Arenaria interpres*	LC	80	2-4 Aug	0.28
Saunders's Gull *Larus saundersi*	VU	774	15-17 Sep	9.1
Swinhoe's Egret *Egretta eulophotes*	VU	76	14-15 Sep	2.2
Common Shelduck *Tadorna tadorna*	LC	1,803	14-15 Oct	1.5

* Flyway estimate was based on subspecies *L. l. menzbieri* only because the other subspecies *L. l. baueri* does not stop at Yalu Jiang during southward migration (Battley et al. 2012).
** Flyway estimate was based on Bamford, Watkins et al. (2008) because the latest estimate (Wetlands International 2013) was complicated by different subspecies estimates.

Species accounts

Count data of 15 shorebird species listed in **Table 4** were modelled to estimate the total number of birds that transited Yalu Jiang coastal wetland, and their passage times. Although the number of Great Knot and Broad-billed Sandpiper *Limicola falcinellus* did not reach the 1% EAAF level during southward migration in 2012, their numbers exceeded 1% EAAF estimates in 2011 during southward migration so they were included in analysis. Thirteen of these shorebird species yielded reasonable estimates (**Table 5**).

Table 5. Estimated total numbers, arrival dates, departure dates and stopover durations of shorebirds at the Chinese side of Yalu Jiang coastal wetland during southward migration in 2012. Ad denotes adults and HY denotes juvenile birds.

		Count		Modelled						
Species		**Peak period**	**Peak count**	**Estimated number**	**Mean arrival date**	**Arrival date SD**	**Mean departure date**	**Departure date SD**	**Stopover duration**
Bar-tailed Godwit	Ad	15-19 Aug	5,902	6,146	24-Jul	16.21	2-Sep	0.49	39
	HY	14-17 Sep	102	117	3-Sep	1.57	8-Oct	21.58	35
Whimbrel		2, 4, 5 Aug	600	631	22-Jul	7.58	17-Aug	0.33	26
Eurasian Curlew*		17-18 Nov	4,079	3,854	28-Sep	52.03	14-Dec	0.05	77
Far Eastern Curlew*		19-23 July	7,486	7,573	4-Jul	10.79	5-Sep	39.32	63
Spotted Redshank		29-30 Sep	456	456	17-Sep	1.59	18-Oct	5.77	30
Common Greenshank		15-19 Aug	2,045	2,362	1-Aug	17.61	1-Sep	2.00	31
Nordmann's Greenshank		14-17 Sep	42	42	4-Sep	1.41	28-Sep	1.60	24
Terek Sandpiper		19-23 July	2,075	2,657	10-Jul	1.67	3-Aug	16.91	24
Great Knot	Ad**	2, 4, 5 Aug	1,391	1,563	15-Jul	24.91	17-Aug	1.06	33
	HY**	29-30 Sep	1,362	1,578	3-Sep	12.32	13-Oct	11.81	40
Dunlin		14-15 Oct	20,921	19,541	22-Aug	34.74	12-Nov	3.56	82
Broad-billed Sandpiper		19-23 July	73	103	8-Jul	1.68	29-Jul	21.02	21
Far Eastern Oystercatcher***		15-19 Aug	642	286	22-Jul	1.27	30-Nov	0.87	131
Grey Plover	Ad**	15-19 Aug	3,572	3,809	4-Aug	11.33	25-Oct	25.25	82
	HY	29-30 Sep	119	148	18-Sep	14.38	14-Oct	0.02	26
Kentish Plover****		15-19 Aug	5,459	7,328	25-Jul	16.73	22-Aug	31.41	28
Lesser Sand Plover**		15-19 Aug	1,902	1,900	11-Jul	8.24	5-Sep	4.06	56

* Using a model that assumes 300 over-summer individuals.

** Excluded one influential count when modelling.

*** Poor modelled results with estimated number of birds much less than the actual counts.

**** Poor modelled results with high standard errors in the estimated number of birds.

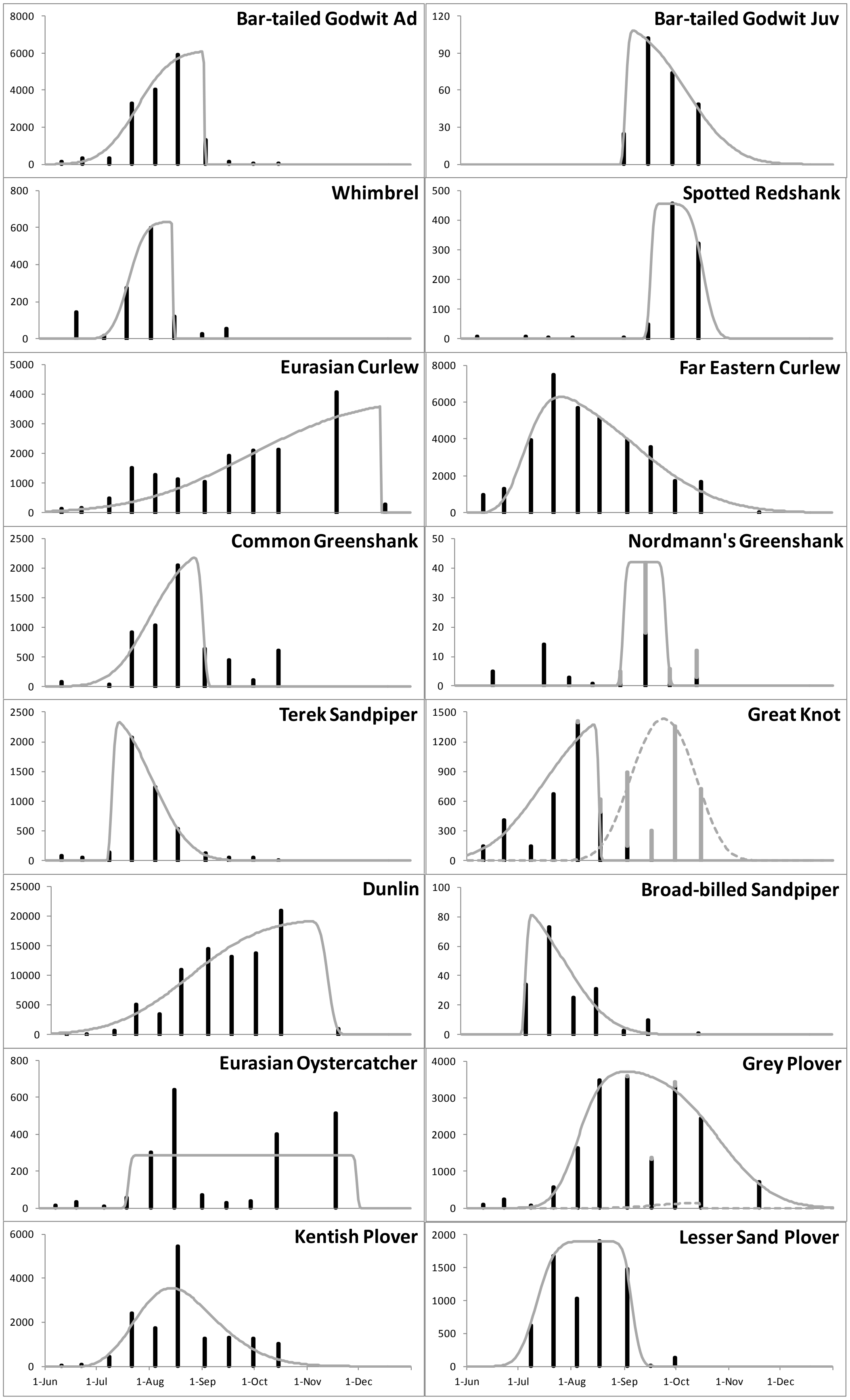
Bar-tailed Godwit Ad
Bar-tailed Godwit Juv
Whimbrel
Spotted Redshank
Eurasian Curlew
Far Eastern Curlew
Common Greenshank
Nordmann's Greenshank
Terek Sandpiper
Great Knot
Dunlin
Broad-billed Sandpiper
Eurasian Oystercatcher
Grey Plover
Kentish Plover
Lesser Sand Plover
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec

Figure 4. The numbers of shorebirds stopped over at the Chinese side of Yalu Jiang coastal wetland during southward migration in 2012. Black bars represent count data from surveys and the solid line the modelled estimate. For Nordmann's Greenshank, Great Knot and Grey Plover, the black bars represent counts of adults while grey bars represent counts of juvenile birds. In the latter two species, the solid line represents the modelled estimate for adults and dotted line the modelled estimate for juvenile birds.

Bar-tailed Godwit

Similar to the southward migration in the last few years, the number of godwits increased significantly from mid-July (**Figure 4**), marked by an influx of adults that still had breeding plumage. Modelled results indicate the actual number of birds that stopped might exceed 6,000, arriving mainly in late July and departing in early September, stopping for an average of 39 days (**Table 5**). This accords very well with the estimated stopover time of 40.8 days determined from satellite tracking (Battley et al. 2012). Juvenile Bar-tailed Godwits arrived later than adults; the first record of juvenile bird was on 3 September. The proportion of juvenile birds then increased until the end of the migration period, but the Bar-tailed Godwit population at YLJCW during southward migration was dominated by adults (**Figure 4**). The godwits were mainly found at pre-roost 2, which was also the case during northward migration (QQB, CYC unpublished).

Based on photos of flying Bar-tailed Godwits, the population at Yalu Jiang coastal wetland during southward migration was dominated by subspecies *L. l. menzbieri*, while *L. l. baueri* was present but rarely seen (**Figure 5**). Similarly, among the colour-flagged godwits recorded, *L. l. menzbieri* (yellow-flagged) was most common while *L. l. baueri* (white-, red or orange-flagged) was rarely seen.

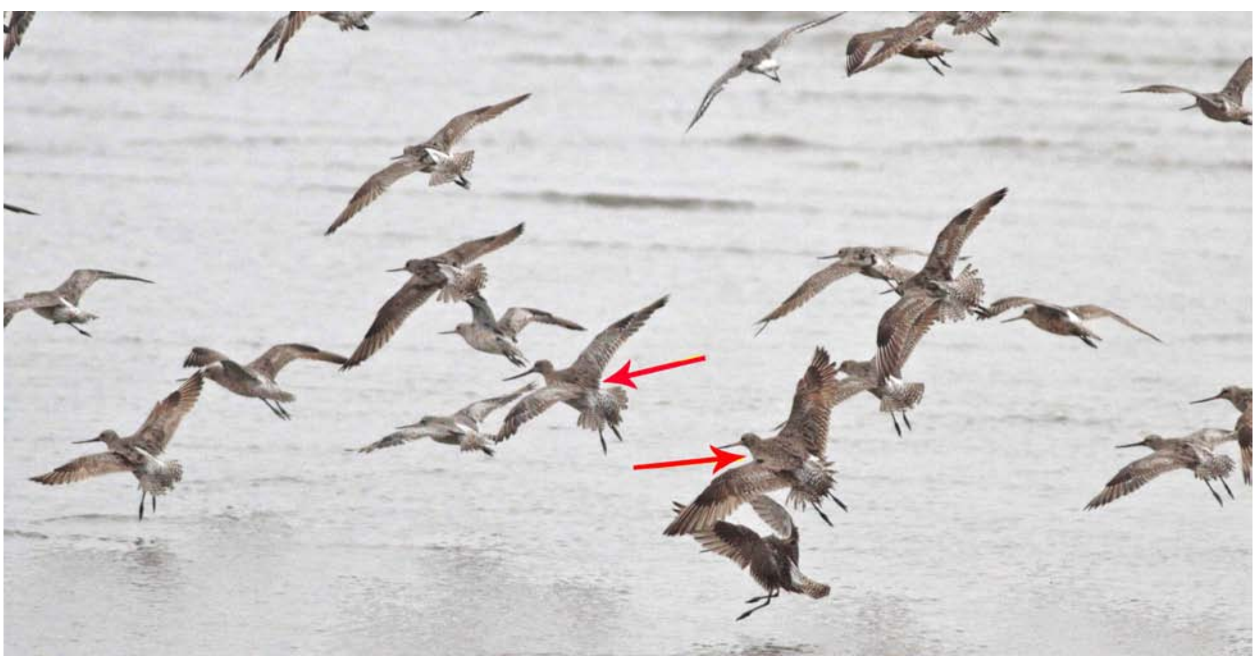

Figure 5. *Limosa lapponica baueri* (arrowed) together with *L.l. menzbieri* at Yalu Jiang coastal wetland,1 September 2012. (Photo by Qing-Quan Bai).

Whimbrel

Whimbrels were mostly distributed at the reclamation pond at pre-roost 1A, where 531 individuals were recorded on 5 August. They mainly arrived in late July, stopped for four weeks and left in mid-August (**Table 5**).

Poor weather or wind condition might affect stopover decisions for shorebirds (Ma et al. 2011), and the recorded high number of Whimbrels in our study may be a case in point. The peak count for Whimbrel was on 5 August and only half of that number was recorded on 2nd August. Sustained heavy rain occurred at Yalu Jiang coastal wetland from the evening of 2 August to 3 August - perhaps such poor weather forced some Whimbrels to make an emergency stopover.

Eurasian Curlew

Eurasian Curlew was the fifth most abundant shorebird species recorded during southward migration with the highest count of more than 4,000 birds. Their numbers increased rapidly from early July, then stabilized for 3 months before peaking in mid November. Most of the birds apparently stayed at YLJCW for more than 2 months and left within a narrow window in December (**Figure 4, Table 5**). This is one of the last species to leave YLJCW. The first juvenile bird was recorded on 18 August and the percentage of juvenile birds was 0.95% (210 individuals aged) in mid-August, 0.99% (335 individuals aged) in early September and 0.83% (120 individuals aged) in mid-September. Many Eurasian Curlews initiated primary moult as early as June, which was earlier than that in Far Eastern Curlews.

Far Eastern Curlew

The Far Eastern Curlew was the second most abundant shorebird species at the YLJCW during southward migration. The record of 7,486 Far Eastern Curlews, representing 23.4% of the total EAAF population, is the largest count for a single site along the whole flyway (Bamford et al. 2008). Given that five pre-roosts were not surveyed and there was no proper count for pre-roosts west of the Dayang River (Sites 12 – 15), the actual number of Far Eastern Curlews staging at YLJCW could be higher than that reported here. It is clear that the study area plays a very important role for this vulnerable species. Far Eastern Curlew was also the most widely distributed species, occurring in numbers that exceeded 1% EAAF estimates in 8 out of 13 surveyed pre-roosts. The reclamation pond in pre-roost 1A was the most important roost for Far Eastern Curlew, with 4,534 individuals recorded on 23 July (**Figure 6**). They often congregated in big numbers when the predicted tide height exceeded 680 cm, and usually arrived in several small flocks. This location was easy to access and therefore, provided accurate and reliable results.

Figure 6. Part of the roosting flock of Far Eastern Curlew in the reclamation pond at pre-roost 1A on 23 July 2012. (Photo by Qing-Quan Bai).

The number of Far Eastern Curlew increased rapidly from late June, which is in accordance with satellite tracking records (Driscoll et al. 2002). The number peaked in late July and declined steadily afterwards (**Figure 4**). The mean arrival and departure dates were early July and early September respectively, and they stopped at YLJCW for about 2 months on average (**Table 5**) – this also being in accord with satellite track data (Driscoll et al. 2002). The first juvenile bird was recorded on 2 August. Juvenile birds were often seen foraging near the seawall and mixed with the early-returning adults to forage during ebb tide. The percentage of juvenile bird was low throughout the migration period, with 0.75% (n=1745) recorded in mid August, 0.6% in early (n=1667) September and 0.17% (n=589) in mid September – it is not known if this is reflection of poor breeding success or that fact that thay use a different migration route to adults. Some Far Eastern Curlews initiated primary moult at the study area.

Spotted Redshank

Spotted Redshank was not a very abundant species at YLJCW. Similar to observations made in previous years, the Spotted Redshank did not arrive in big numbers until near the end of migratory season (**Figure 4**), and most individuals were recorded on the intertidal mudflat at pre-roost 1A. They arrived in mid September, stopped for a month on average, and departed mainly in mid-October (**Table 5**).

Common Greenshank

Common Greenshanks were widely distributed in the surveyed locations, with more than 2,000 birds recorded during the peak count. They often left the intertidal mudflat and started roosting in the aquaculture ponds long before other species, therefore the best time to survey this species was during ebb tide except at the ash pond in pre-roost 1A where they often congregated during flood tide. Like the observations from previous years, the number of Common Greenshank peaked in mid-August (**Figure 4**). Most of the birds arrived in early August, stopped for a month, and departed in early September (**Table 5**).

Nordmann's Greenshank

Although only 42 Nordmann's Greenshanks were present during the peak count, that represents more than 8% of the total population along the EAAF. This species was recorded in 4 locations (pre-roost 1A, 2, 8 and 10); pre-roost 2 was the most important site for the species. They were recorded in every survey between July and October, with a maximum of 17 individuals counted from a single location (pre-roost 2). Adults dominated in the late July peak while juvenile birds increased substantially in September (**Figure 4**). The mean arrival, departure dates and stopover duration for this endangered species were early September, late September, and 3 weeks respectively (**Table 5**).

Terek Sandpiper

More than 2,000 Terek Sandpipers were recorded during the peak count, they were mainly distributed at the ash pond in pre-roost 1A, where 1,700 individuals were recorded on 21 July (**Figure 4**). This species arrived mostly in mid-July and departed in early August, stopping for about 3 weeks (**Table 5**). Three northwest Australia-flagged and one Indonesia-flagged Terek Sandpipers were found between 7 and 21 July.

Great Knot

Special attention was given to Great Knot counts due to its threatened status and high abundance during northward migration (Barter et al. 2004; Riegen et al. 2013, Choi et al. in press). The first peak in early August was dominated by adults while the second peak in late September was dominated by juvenile birds (**Figure 4**). The total number of Great Knots that used the study area was 0.9% of the EAAF estimates if the peak number of adults and juvenile birds are summed. Both age classes stopped for about 5 weeks, but adults arrived mostly in mid-July, departed in mid-August, while juvenile birds arrived in early September and left in mid-October (**Table 5**). It is noteworthy that the largest single count of Great Knots in the study area was 3,220 individuals, recorded on 19 August 2011 at pre-roosts 1A and 2.

Most of the resighted individuals were banded in northwest Australia and Chongming Dongtan, followed by Yalu Jiang coastal wetland, Thailand and South Australia (**Appendix 2**).

Broad-billed Sandpiper

Only a small number of Broad-billed Sandpipers (73 individuals) was counted during southward migration in 2012; it did not meet the 1% criterion, but the number counted in 2011 did (QQB, CYC unpublished). The mean arrival, departure dates and stopover duration of this sandpiper were early July, late July and 3 weeks, respectively (**Table 4**).

Dunlin

Dunlin was the most abundant shorebird species recorded during our study with more than 20,000 individuals recorded during peak count. Their mean arrival and departure dates were late August and mid-November respectively, staging for almost 3 months (**Figure 4**). The sole record of Dunlins that exceeded 1% EAAF estimates was at pre-roost 2. The highest numbers of Dunlins at pre-roost 2 were often recorded during ebb tide. There were still thousands of Dunlins returning to pre-roost 2 during ebb tide even two hours after the mudflat was exposed, thus numbers are probably conservative. Moreover, several thousands of Dunlins were often recorded in pre-roost 1A and 10.

Far Eastern Oystercatcher

Far Eastern Oystercatchers had two peaks during southward migration at Yalu Jiang coastal wetland, with the first one in mid-August and the second in mid-November (**Figure 4**). This seemed to lead to poor modelled estimates on the number of oystercatchers and passage dates. The 642 oystercatchers recorded during the peak count represented 9% of the total flyway population. The birds were mainly distributed at pre-roost 2 and 10 during southward migration in 2012. Similar to previous years, several hundred Eurasian Oystercatchers underwent primary moult at Yalu Jiang coastal wetland. In early and mid-August, many individuals were found moulting their primaries based on photos taken at pre-roost 10 (**Figure 7**). On 16 August, 273 individuals were recorded at pre-roost 2, with at least one individual showing ‘droopy wings’, which suggested that the bird might have recently arrived at Yalu Jiang coastal wetland.

It has become clear that Far Eastern Oystercatchers regularly breed in YLJCW, although the exact number is uncertain. Their nests were often found in undeveloped reclaimed land just inside the seawall and on rocky surfaces. They also nested on the rocky surface on the bunds between aquaculture ponds. The earliest nest was found on April 18 and hatch dates started from May 12 until at least mid-June, when no further effort was made to search for nests.

Figure 7. Far Eastern Oystercatchers in active primary moult at the Yalu Jiang coastal wetland during southward migration in 2012; 17 August pre-roost 10. (photo by Qing-Quan Bai).

Grey Plover

Grey Plover was the sixth most abundant shorebird species at YLJCW, with 3,600 individuals recorded during the peak count. They arrived in early August and left in late October, stopping for almost 3 months (**Figure 4**). Pre-roost 2 was the main location where this species was recorded, with 2,600 individuals seen on 29 September. Pre-roost 1A used to be the stronghold for this species during southward migration in previous years (QQB, CYC unpublished), but the highest record in 2012 was only 960 individuals recorded on 2 August. There was an increasing percentage of juvenile birds as time passed, with 0.4% (n = 259) on 2 September, then 4% (n=100) on 14 September and 3.4% (n=29) on 30 September (**Figure 4**), but the overall population was dominated by adults.

A first-summer Grey Plover with an alpha flag ‘L8’ banded in Hong Kong on 22 March 2012 (aged as juvenile) and was last seen there until 28 April. It was then recorded in YLJCW on 22 June and 21 July, which suggests that some Grey Plovers may spend their first summer in YLJCW and may undergo primary moult there (birds of uncertain age were photographed in active primary moult in between June and October, **Table 6**).

Kentish Plover

Kentish Plover was the fourth most abundant species at YLJCW during southward migration, with more than 5,000 individuals recorded during the peak count. They arrived in the study area from July and remained until mid-October (**Figure 4**). However, the modelled number of birds had high standard errors and was not robust. Surveys undertaken in recent years indicated that Kentish Plovers were mainly distributed in pre-roost 1A during southward migration (QQB, CYC unpublished). In 2012, more than 1,000 individuals were found at the ash ponds from late July and the maximum number reached 5,250 on 18 August. However, part of the ash ponds became inaccessible from September making a full census impossible, which might lead to the lower numbers since September. Pre-roost 10 was another important location for this species, with more than 1,000 individuals recorded in late September.

Like the Far Eastern Oystercatchers, some Kentish Plovers regularly breed in YLJCW although the exact numbers were unclear. Their nests were often found in undeveloped reclaimed land just inside the seawall and on rocky surface. They also nested on the rocky surface on the bunds between aquaculture ponds. The earliest nest was found on April 30 and hatch dates started from May 27 or earlier.

Lesser Sand Plover

More than 1,900 Lesser Sand Plovers were recorded during peak count. They arrived from early July and stayed until early September, stopped for almost 2 months (**Figure 4, Table 5**). Like the surveys from previous years (QQB, CYC unpublished), Lesser Sand Plovers were mainly distributed in pre-roost 1A, mixed with Dunlins and Kentish Plovers. More than 1,000 individuals were recorded in pre-roost 1A in late July and the highest count at that location was recorded on 18 August, when 1900 individuals were found.

Modelling accuracy

Our modelled numbers of transiting birds were generally within reasonable range of the peak counts in field, indicating that the modelled results were reasonably good, except for Far Eastern Oystercatcher and Kentish Plover. The former was complicated by two peaks while the latter was affected by the exceptionally high count in mid August (**Figure 4**). It was interesting to note that these two species were also the only species that were found breeding regularly in our study area. This might have an impact on our modelling approach as this violated the assumptions for normal distribution in arrival and departure dates. In addition to giving estimates of the total number of birds transiting the site, our modelling results also gave reliable estimates of passage days. In the case of Bar-tailed Godwits, our modelled estimates for arrival, departure dates and stopover duration were 24 July, 2 September and 39 days respectively, and these matched the satellite tracking results fairly well (19 July, 29 August and 41 days) (Battley et al. 2012). Similarly, the same modelling approach also gave close passage dates estimates when compared to tracking records in Bar-tailed Godwits during northward migration (Choi et al. in press). The extensive geolocator studies currently underway should allow further testing of the validity of our modelling approach on other species and at other locations. In accordance with our field observations, our modelling results indicated that some species such as the Eurasian Curlew, Dunlin and Grey Plover, stopped for more than 80 days, which was longer than that during northward migration.

Meanwhile, it is important to differentiate the different age-classes where possible. In species such as Great Knot and Nordmann's Greenshank, adults arrived before the juvenile birds and each of them resulted in a peak for the species counted. In our Great Knot example, the modelled results gave poor estimates of the number of birds and passage dates if both age-classes were combined for analysis. However, the modelled results improved substantially when the two age classes were analyzed separately. More importantly, these indicated that the total number of Great Knots transiting was almost twice as many as the peak count indicated because the two peaks were composed of different age classes (**Figure 4**). The impact of different age-classes was not as big in species such as Bar-tailed Godwit, Far Eastern Curlew and Grey Plover because their populations at YLJCW were dominated by adults.

Importance of different parts of the coastal wetland

Western branch of Yalu Jiang Estuary

Based on the results of our surveys, the western branch of Yalu Jiang Estuary (pre-roost 1A), although located 10 km outside the nature reserve boundary, was the most important roosting area for shorebirds during southward migration. Nine species were found in numbers greater than 1% of their EAAF estimates in a single count at this location (Far Eastern Curlew, Whimbrel, Eurasian Curlew, Nordmann's Greenshank, Terek Sandpiper, Kentish Plover, Lesser Sand Plover, Grey Plover and Spotted Redshank).

The reclamation pond, ash pond and intertidal mudflat near pre-roost 1A hold the largest number of several species during southward migration. For example, 5,200 Kentish Plovers and 1,902

Lesser Sand Plovers were recorded on 18 August in the reclamation pond accounting for 95% and 99.9%, respectively of the total numbers counted during that survey period. Similarly, 1,700 Terek Sandpipers were recorded on 21 July in Ash pond 1, equivalent to 82% of the total number of Terek Sandpipers recorded during that survey period. The 456 Spotted Redshanks recorded on the intertidal mudflat near pre-roost 1A on 29 September was the total number of that species recorded in that survey period.

The number of birds found in this area declined from September, which might partly be caused by the decreasing high spring tide level. A predicted tidal height of less than 680 cm left some of the bare intertidal mudflat exposed and shorebirds could roost on the intertidal mudflat instead of flying into the ash ponds. However, even during high spring tide, the numbers of birds recorded in the reclamation pond varied over consecutive days. For example, on the 20, 21 and 23 July, the maximum predicted tidal heights were 692, 692 and 682 cm respectively, but the number of Far Eastern Curlews changed from 3,100, to 2,300 and 4,534, respectively. Moreover, the maximum predicted tidal height on 2 and 5 August were both near 700 cm, but the total number of Far Eastern Curlew, Eurasian Curlew and Whimbrel recorded were 2,745 and 5,229 respectively. There seem to be other roosting sites along the western branch of Yalu Jiang (probably in North Korea) that might cause the variation in numbers of birds recorded in the reclamation pond. Repeated surveys within 2-3 days therefore, provided more reliable results.

Accessibility was another problem when conducting surveys in pre-roost 1A. The pathway between two ash ponds was fully vegetated and that made survey very difficult. Some of the Terek Sandpipers, Nordmann's Greenshanks and Common Greenshanks could easily be overlooked if effort was not made to survey both ash ponds thoroughly. Meanwhile, the landlord of the reclamation pond restricted public access to the area from mid-August, which meant that we were unable to visit the whole site – this might have resulted in the relatively smaller number of Kentish Plovers recorded in September.

Pre-roost 2

Two observation points were used at pre-roost 2, where birds congregated during the flood tide. These birds often flew towards the new port development sites when the entire intertidal flat was inundated. The best time to count birds was just before the birds took off for roosting sites during flood tide.

There were five species with recorded numbers that exceeded their 1% EAAF estimates: Far Eastern Curlew (1,450 individuals recorded on 16 September), Nordmann's Greenshank (21 individuals, 14 September), Dunlin (12,660 individuals on 15 October), Grey Plover (2,600 individuals on 29 September) and Far Eastern Oystercatcher (513 individuals on 17 November).

Pre-roost 10

The best time to count birds at pre-roost 10 was during the flood tide, when birds arrived from pre-roost 7, 8 and 9 when the latter were inundated. Most of the birds seen at pre-roost 10 continued to fly towards the west to roost, although some roosted on the bunds in the aquaculture ponds at pre-roost 10. Four species occurred at pre-roost 10 in numbers that exceeded 1% of their EAAF estimates: Far Eastern Curlew (720 individuals on 15 September), Far Eastern Oystercatcher (397 individuals on 14 October), Eurasian Curlew (1,440 individuals on 14 October, which was equivalent to 67% of the total Eurasian Curlews found in that survey period) and Kentish Plover (1,100 individuals on 30 September).

Function of YLJCW

In addition to playing a role as refuelling site that allows migratory shorebirds to refuel, the Yalu Jiang coastal wetland also plays a role as a moulting site, with at least 13 species recorded in active primary moult during southward migration. These included: Bar-tailed Godwit, Eurasian Curlew, Far Eastern Curlew, Common Greenshank, Nordmann's Greenshank, Terek Sandpiper, Great Knot, Red Knot, Dunlin, Far Eastern Oystercatcher, Grey Plover, Kentish Plover and Lesser Sand Plover. Some species such as the Far Eastern Oystercatchers might undergo the entire primary moult at Yalu Jiang coastal wetland while other species, such as the Grey Plovers and Bar-tailed Godwits, primary moult was commonly seen in over-summering individuals in early June but it was unclear if they completed or suspended their moult before southward migration.

Table 6. The earliest and last dates that birds showed evidence of primary moult at Yalu Jiang coastal wetlands during southward migration. All records were based on 2012 field data except the latest date for Nordmann's Greenshank, which was obtained from 2009. All are based on sight records and/or photographs.

Species	Earliest date	Latest date
Bar-tailed Godwit	9-Jun	15-Sep
Eurasian Curlew	9-Jun	14-Oct
Far Eastern Curlew	22-Jun	15-Oct
Common Greenshank	9-Jun	21-Jul
Nordmann's Greenshank	21-Jul	22-Aug
Terek Sandpiper	20-Jul	21-Jul
Great Knot	9-Jun	29-Sep

Red Knot	20-Jul	
Dunlin	21-Jul	2-Sep
Far Eastern Oystercatcher	17-Aug	14-Oct
Grey Plover	9-Jun	14-Oct
Kentish Plover	7-Jul	15-Sep
Lesser Sand Plover	7-Jul	23-Jul

Several species, including Far Eastern Oystercatcher, Kentish Plover, Little Tern *Sterna albifrons* and Saunders's Gull (IUCN category Vulnerable, IUCN 2012) were found to breed in YLJCW. Several nests of the latter two species were seen at the reclamation pond at pre-roost 1A in May 2010, but were flooded when the pond owner decided to pump mud from the intertidal flat into the pond (**Figure 8**).

Moreover, new vegetation was found growing near pre-roost 11a as well as inside the reclamation pond at pre-roost 1A, which could decrease the habitat available to shorebirds (Gan et al. 2009) and effort should be made to identify the plant species involved and monitoring its spread on the mudflat.

Figure 8. The loss of a Saunders's Gull's nest in the reclamation pond at the western branch of Yalu Jiang Estuary, after pumping started to bring sediments from the intertidal flat into the pond. (Photos taken on 1 June 2010 by Chi-Yeung Choi).

Resights

There were 56 records of marked birds during our study, 24 of them were individually identified through alpha flags or unique colour band combinations. These marked birds involved 8 species that were originally marked in eleven different banding locations from seven countries (**Appendix 2**).

Community work

During the fieldwork, we often had opportunities to talk to local fishermen and tourists. As opportunities arose, we showed them the shorebirds and gave them a booklet (**Figure 9**) about the migration journey of Bar-tailed Godwits. This 12-pages booklet summarized the life history of Bar-tailed Godwits and emphasized their remarkable 10,000 km non-stop flight in 7 days from New Zealand to YLJ, as well as the 11,000 non-stop flight in 8 days from Alaska to New Zealand. The booklet became a useful tool for us to raise public awareness on shorebirds conservation.

Figure 9. The cover of booklet that was distributed to the public for raising their awareness of shorebird conservation.

Anthropogenic activities and local people's attitude towards waterbirds

The southward migration period for shorebirds is also the harvesting season for seafood such as jellyfish, Razor Clam (*Sinonovacula constricta*), prawn and sea cucumber. It was a common practice to lower the water level of the aquaculture ponds to facilitate the harvest of cultivated products. Such management activities created temporary feeding and roosting habitats for waterbirds, especially gulls, that would not be available during the rest of the year due to high water level (Hua et al. 2009; Choi et al. 2013; this study).

Shellfish farmers on the intertidal mudflat in general have a negative attitude towards shorebirds. In many cases the farmers seed the intertidal flats with spat in the spring. The seedlings have very soft shells and take up to a week to burrow themselves deep enough to escape from shorebird predation. Therefore, the seedlings are vulnerable to predation in their first week of cultivation on the tidal flats and local fishermen often use firecrackers to deter the shorebirds from the cultivated area when the intertidal flat is exposed. Poisoning of shorebirds was also reported by local people but no evidence of this was found during our study.

The dry bunds in aquaculture ponds were often used by roosting shorebirds while the ponds were seldom used due to the relatively deep water. However, other waterbirds such as gulls and egrets did feed in the ponds. Although these birds do not usually cause too much damage to the cultivated products, fishermen expressed concern that they could spread diseases between ponds. The potential benefit of birds removing diseased fish and crustaceans was also recognized by some fishermen.

Based on the comments given by local farmers in the agricultural farmland (mostly rice paddy), shorebirds such as curlews might feed in the area in mid-May occasionally when the farmland was flooded and the vegetation remained low. On the other hand, waterfowls such as ducks and geese often feed on the rice and wheat seedlings during the spring. They turned to the harvested rice and wheat during autumn and that could mean a substantial loss of profits to local farmers. It was not surprising that some farmers used firecracker to deter the birds and some might even use poisons even that was illegal.

RECOMMENDATIONS

Our survey results, in combination with literature records (Bamford et al. 2008; Riegen et al. 2013), show that 20 shorebird species occur at the Yalu Jiang coastal wetland in internationally important numbers during northward and/or southward migration periods. Yalu Jiang coastal wetland thus ranks third in terms of importance in the EAAF after the Yancheng National Nature Reserve, China (40 species) and the Daursky Nature Reserve, Russian Far East (30 species), among hundreds of shorebird sites along the flyway.

It is now clear that the study area is important to shorebirds not only during northward migration (Barter et al. 2004; Riegen et al. 2013; Choi et al. in press), but also southward migration. In addition to being a refuelling site, YLJCW also plays an important role as a moulting ground for some species – there is scant information on sites used by moulting shorebirds in much of the EAAF. The site also supports breeding populations, albeit small, of several shorebird species.

For these reasons, we strongly encourage the reserve to continue to seek Ramsar recognition to promote the importance of this area to the residents and decision makers. The Yalu Jiang coastal area has relatively less development pressure compared to other areas within the Yellow Sea (MacKinnon et al. 2012), probably due to its National reserve status and remoteness. However, the recent loss of 34 km^2 of tidal flat through port development at the east of the reserve boundary was alarming. The long-term impact of such developments should not be overlooked. Previous reports of sediments at Yalu Jiang estuary being transported westwards under the influence of tides and waves (Wang et al. 1987) imply that the new 10-km seawall extending towards the sea might not merely mean an immediate loss of intertidal flat but a further loss of intertidal flat in the study area due to the loss of sediment supply from the river (**Figure 1**). Long-term monitoring is necessary to investigate how the shorebirds may respond to the changes.

Our results highlight the importance of the ash ponds and reclamation ponds located east of the reserve boundary. The existence of important roosting habitat outside the reserve, and activities outside the reserve that may have damaging effects on its natural values, indicate that the status of surrounding areas should be taken into consideration when making management decisions. It seems inevitable that the reclamation pond will be lost to development in the near future, however the ash ponds are currently not receiving additional fill material and there appears to be an opportunity to approach the landlord to discuss possible future management to safeguard the future of some, if not all, of these roosting habitats.

The intertidal mudflat at the Yalu Jiang coastal wetland is composed mainly of bare mudflat with very occasional *Phragmites*-dominated saltmarsh (only on the upper tidal flats on either side of the Dayang River). However during 2013 we found new vegetation near pre-roost 11a as well as inside the reclamation pond at pre-roost 1A. Currently the plant remains unidentified and it is unclear whether it has the potential to invade the tidal flats – as *Spartina alterniflora* has done further south on the Yellow Sea coast, and which could decrease the habitat available to shorebirds (Gan et al. 2009).

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APPENDIX

Appendix 1. Maximum number of different shorebird species recorded at Yalu Jiang coastal wetland during southward migration in 2012.

Species	Maximum Count	Species	Maximum Count
Red-necked Phalarope *Phalaropus lobatus*	1	Red Knot *Calidris canutus*	18
Black-tailed Godwit *Limosa limosa*	53	Sanderling *Calidris alba*	1
Bar-tailed Godwit *Limosa lapponica*	5,902	Red-necked Stint *Calidris ruficollis*	158
Whimbrel *Numenius phaeopus*	600	Long-toed Stint *Calidris subminuta*	42
Eurasian Curlew *Numenius arquata*	4,079	Sharp-tailed Sandpiper *Calidris acuminata*	25
Far Eastern Curlew *Numenius madagascariensis*	7,486	Dunlin *Calidris alpina*	20,921
Spotted Redshank *Tringa erythropus*	456	Curlew Sandpiper *Calidris ferruginea*	12
Common Redshank *Tringa totanus*	73	Broad-billed Sandpiper *Limicola falcinellus*	73
Marsh Sandpiper *Tringa stagnatilis*	61	Far Eastern Oystercatcher *Haematopus [ostralegus] osculans*	642
Common Greenshank *Tringa nebularia*	2,045	Black-winged Stilt *Himantopus himantopus*	27
Nordmann's Greenshank *Tringa guttifer*	42	Pacific Golden Plover *Pluvialis fulva*	26
Green Sandpiper *Tringa ochropus*	8	Grey Plover *Pluvialis squatarola*	3,600
Wood Sandpiper *Tringa glareola*	203	Little Ringed Plover *Charadrius dubius*	25
Terek Sandpiper *Xenus cinereus*	2,075	Kentish Plover *Charadrius alexandrinus*	5,459
Common Sandpiper *Actitis hypoleucos*	3	Lesser Sand Plover *Charadrius mongolus*	1,902
Grey-tailed Tattler *Heteroscelus brevipes*	42	Greater Sand Plover *Charadrius leschenaultii*	2
Ruddy Turnstone *Arenaria interpres*	80	Grey-headed Lapwing *Vanellus cinereus*	2
Great Knot *Calidris tenuirostris*	1,411		

Appendix 2. Origin of colour-banded and leg-flagged waterbirds observed at Yalu Jiang coastal wetland during southward migration in 2012.

Species	**Marking Origin**												**Total**
	Russia	Mongolia	Hong Kong	China mainland		Japan	Indonesia	Thailand	Australia			New Zealand	
	Sakhalin		Maipo	Shanghai	Panjin	Kyushu			Roebuck bay	Victoria	South Australia	South Island	
Bar-tailed Godwit				4				1	20	1		1	27
Great Knot				1				3	1		1		6
Red Knot				1					3				4
Red-necked Stint				1					2	1	1		5
Dunlin	2			1									3
Broad-billed Sandpiper				1					1				2
Terek Sandpiper							1		2				3
Grey Plover			5			1							6
Saunders' Gull					6								6
Mongolian Gull		1											1
Chinese Egret *Egretta eulophotes*													1
Total	2	1	5	9	6	1	1	4	29	2	2	1	64

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