Identification of potentially important northward migration staging areas for 'long-jump' migrant waders in the East Asian-Australasian Flyway.

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We document the current information on the route of Great Knots, Red Knots and Bar-tailed Godwits as they migrate northwards from their non-breeding areas in Australia to the breeding grounds in Russia and Alaska. We especially focus on migration through the Yellow Sea region of north-east China and use data on departure and arrival times, population sizes, counts, leg flag sightings and band recoveries of each species in the Yellow Sea, Japan and Sea of Okhotsk to show that there is a period of three to four weeks during migration (in April - May) when these species are missing. We demonstrate that these species are probably feeding on the extensive mudflats in the northern Yellow Sea during this time and suggest that these areas are the final staging areas before the birds reach the breeding grounds.

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INTRODUCTION

Migratory waders are dependent on the availability of suitable wetlands for the successful completion of their annual movements between breeding and non-breeding areas. These wetlands are under worldwide threat and nowhere is this more evident than in the East Asian-Australasian Flyway (Melville 1997). The "Summary Statement" of the March 1996 Conference on Shorebird Conservation in the Asia-Pacific Region, reflecting the views of 145 participants from 16 countries, expressed "particular concern at the destruction of critically important staging sites in China, Korea and Japan" Anon (1997).

The waders most affected by habitat loss are those which fly long distances between staging sites (*i.e.* "long-jumpers"). Such species typically collect in large numbers at a few sites (Cramp & Simmons 1983), the loss of which may seriously affect their ability to migrate successfully and, therefore, to breed and maintain a viable population. Within the East Asian-Australasian Flyway, knowledge of the important staging sites used by 'long-jump' waders is limited. Even when key sites are known, the way in which they are used (eg. arrival and departure timings, turnover rate, energy needs to reach the next site) is generally sketchy or non-existent. Incomplete knowledge of the important sites long-jump waders use, and how they use them, makes planning for their conservation difficult. Effective conservation action can only be based on accurate scientific data which are in short supply for much of the East Asian-Australasian Flyway. However, possible migration strategies and potential key staging sites can be identified by a desk top study and this information can be used in planning field studies to collect essential data.

There is considerable evidence that Great Knot *Calidris tenuirostris*, Red Knot *C. canutus* and Bar-tailed Godwit *Limosa lapponica* adopt a 'long-jump' strategy. They fly nonstop from non-breeding areas in north-western Australia (Barter & Wang 1990, Tulp *et al.* 1994, Barter 1996) to the southern Yellow Sea coastal areas of east China and South Korea and to the Yellow River delta in the north-west Yellow Sea, where they congregate in large numbers (Long *et al.* 1988, Wang & Tang 1990, Wang *et al* 1992, Barter *et al.* 1997a, Wang 1997, Barter *et al.* in prep.[a,b], Lee in prep.). Little is known about their movements within the Yellow Sea region or their onward migration strategy to the breeding grounds. Tomkovich (1997) suggests that Great Knot migrate across the Russian Far East during a few days in the last third of May (Figure 1)

Possible strategies for the three species on northward migration through the Yellow Sea (Figure 2) were studied by drawing together information on:

- population sizes;
- timing of departures from north-western Australia;
- timing of visual observations in the Yellow Sea region, Japan and the Sea of Okhotsk, Russia;
- band recoveries and flag sightings in the Yellow Sea region and Japan;
- timing of arrival on the breeding grounds;
- intertidal areas potentially available for foraging waders in the Yellow Sea region;
- northern winter and early spring climate in the northern Yellow Sea and the Sea of Okhotsk.

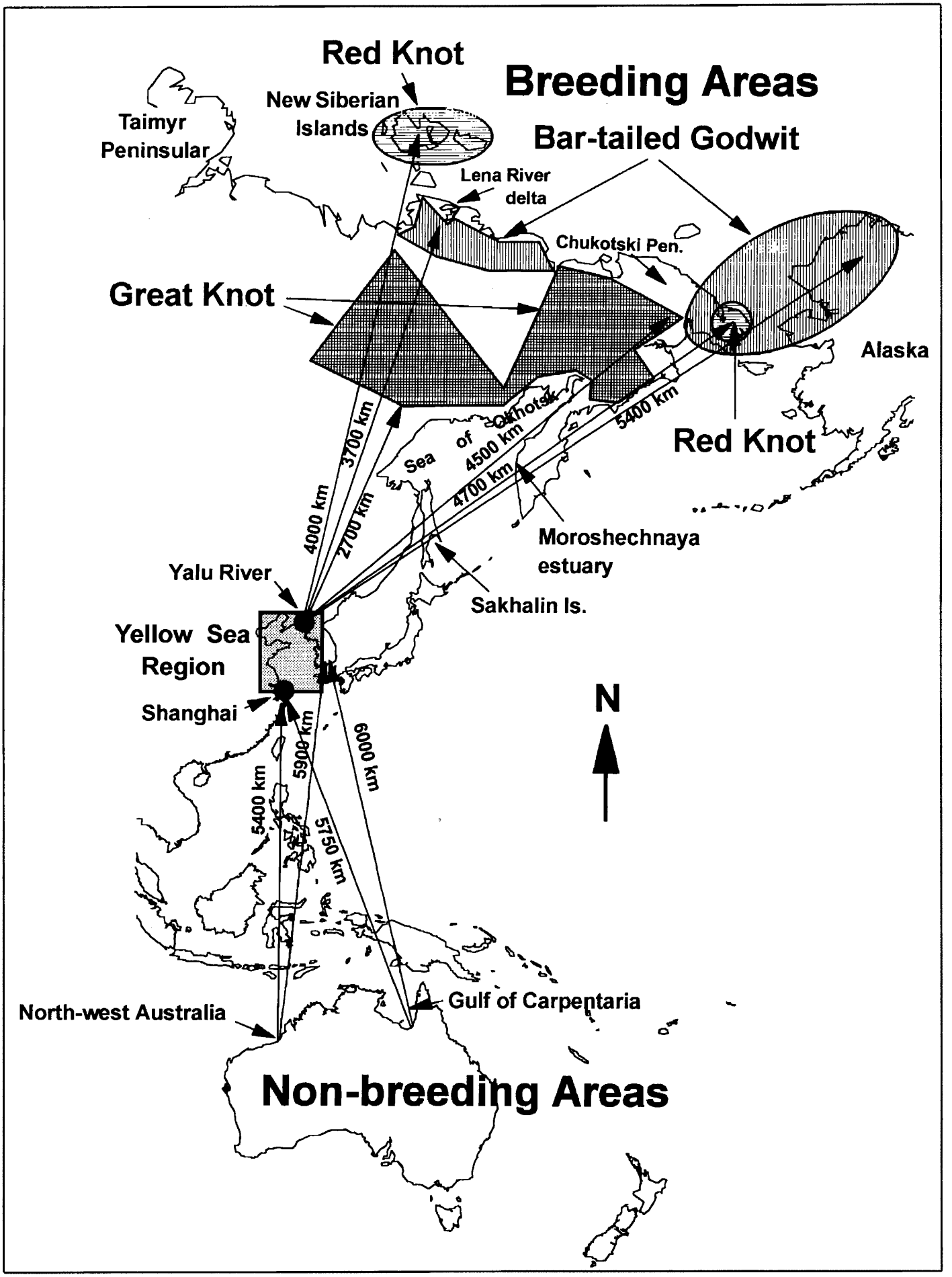

Figure 1. East Asian-Australasian Flyway, showing breeding and non-breeding areas, the Yellow Sea Region, great circle flight distances and locations referred to in the text.

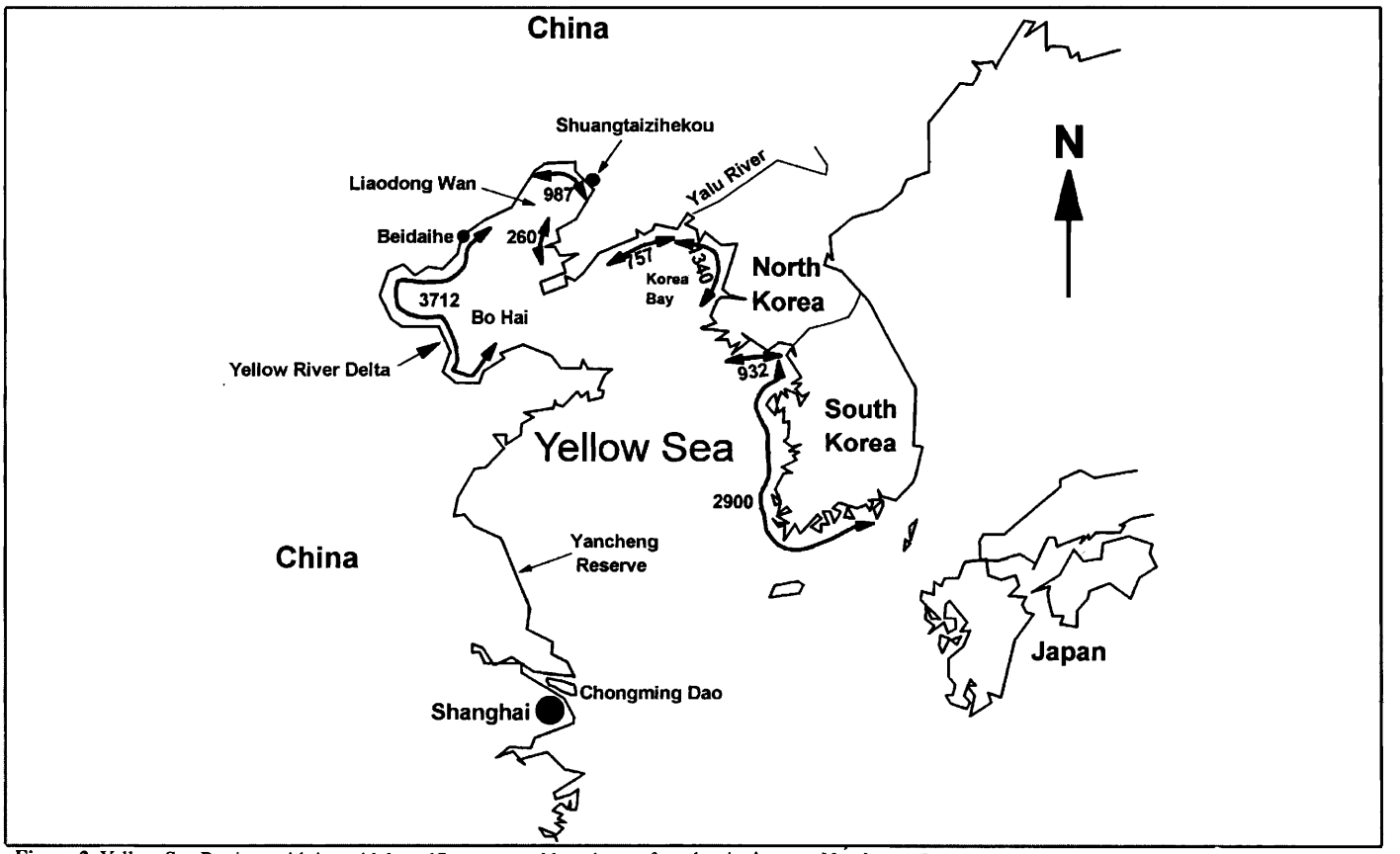

Figure 2. Yellow Sea Region, with intertidal mudflat areas and locations referred to in the text. Numbers refer to areas of mudflat in km².

METHODS

Population sizes

An approximate estimate of the number of Great Knots, Red Knots and Bar-tailed Godwits migrating to the breeding grounds has been obtained by using the species flyway population estimates from Watkins (1993) and assuming that the proportion of breeding birds is 80%. This figure was derived by comparing non-breeding and breeding season counts of each species in Australia and New Zealand. We found that theoretically between 10 and 50% of waders could be staying in Australia and New Zealand during the breeding season, depending on which data, assumptions and models were used. Although much more work needs to be done on the population dynamics of waders in Australia, we have assumed that the average proportion overwintering is 20%. It has also been assumed that all individuals migrate through the Yellow Sea. Whilst we know from flag sightings and observations that some pass through Japan, these represent only a very small proportion of the population of each species (Mundkur 1993, Japan Wetland Action Network unpub. data).

Timing of departure

Most departure information available from Australia are data obtained from the north-west of the country (Lane & Jessop 1985, Tulp *et al.* 1994 and Barter 1996). Much of the data collected by Broome Bird Observatory and the Australasian Wader Studies Group (AWSG) have yet to be published.

Visual observations

Count data are relatively sketchy for China and the Sea of Okhotsk, especially at migration times. There are no count data for North Korea. The situation in South Korea is improving quickly and regular counts at some west coast sites have been published. Counts were made at many sites in Japan in the period late April to early May in 1973-1975, 1981-1984 (Mundkur 1993) and 1996-1997 (Tobai 1997).

Band recoveries and flag sightings

Band recovery data and the more recent flag sightings have been obtained from the Australian Bird and Bat Banding Schemes (ABBBS). Earlier flag sightings were obtained from Stilt (Jessop & Minton 1995, Driscoll 1995, Minton & Jessop 1995, 1996, 1997, Minton 1995), the Victorian Wader Study Group Bulletin (Minton 1993, Minton 1997) and Queensland Wader, the newsletter of the Queensland Wader Study Group (Taylor 1995/1996, 1996a, 1996b, 1996/1997).

Arrival dates on breeding grounds

We have used arrival times on the Taimyr peninsula for Red Knots (Tomkovich & Soloviev 1996). Although the populations involved are different to those spending the non-breeding season in Australia, the Taimyr is in the same climatic region as, and at a similar latitude to, the breeding areas of Australian Red Knots and, therefore, arrival times are probably similar. Arrival times for Great Knots and Bar-tailed Godwits on the breeding grounds used by Australian birds are available from the literature (Tomkovich 1996, Higgins & Davies 1996).

Intertidal areas

Maps of the Yellow Sea region were studied at the National Library of Australia, Canberra, which holds very good and detailed 1:50,000 maps of North Korea published by the U.S.A. Defence Mapping Agency Topographic Centre, Washington D.C. Most of the maps were produced in 1976, a few in 1977 and two in 1986. The library only has 1:250,000 maps of the northern Chinese coastline. They were published by the U.S. Army Map Service, Washington D.C., mostly in 1954, but two in 1956. Not surprisingly, the Chinese maps are not as detailed as those for North Korea. The China maps show the extent of the mudflats without details of the tidal channels; the Korea maps show tidal channels and offshore mudbanks in detail, including the depths at which the flats are uncovered. The areas of intertidal mudflats were measured using an electronic planimeter.

Climate

The northern parts of the Yellow Sea and, especially, the Sea of Okhotsk, are cold during winter and it is necessary to check whether the intertidal flats are covered with ice during the northward migration season, thus making food unavailable to waders. Weather data published by the Meteorological Office in London and the U.S.Navy have been used. Although the data we have been able to find are mostly 40 years old or more, it probably still reflects today's situation.

RESULTS

Population sizes.

Watkins (1993) estimated that there are 319,000 Great Knots in the flyway, almost all migrating to Australia, 255,000 Red Knots, of which 153,000 migrate to Australia and 87,700 to New Zealand, and 330,000 Bar-tailed Godwits, of which 165,000 migrate to Australia and 102,000 to New Zealand. Applying the notional 80% breeding proportion to the individual total populations indicates that approximately 255,000 Great Knots, 205,000 Red Knots and 265,000 Bar-tailed Godwits migrate northwards, *i.e.* a total of 725,000 birds of the three species.

Timing of departures from north-western Australia.

Great Knot

The main departures occur at the end of March and during the first days of April (Lane & Jessop 1985, Tulp *et al.* 1994, Barter 1996).

Red Knot

Some birds leave at the beginning of April, followed by a second wave in mid-April (AWSG unpub. data).

Bar-tailed Godwit

The main departures occur in the first half of April (Lane & Jessop 1985, Tulp *et al.* 1994, Barter 1996).

Visual observations in North and South Korea and China.

South Korea

Long *et al.* (1988), counted a maximum of 167,771 waders during a survey of the south and west coasts of South Korea between 10 April and 6 June. These included maxima of 35,588 Great Knots, 666 Red Knots and 15,720 Bar-tailed Godwits. They stated that, when turnover was taken into account, these numbers "are undoubtedly a considerable underestimate of the real number staging in coastal Korea". Long *et al.* (1988) suggested that peak passage for Great Knot and Red Knot was probably in late April, and for Bar-tailed Godwit in the last week of April and first week in May. Some Great Knot and Bar-tailed Godwit were present in late May.

North Korea

Mundkur (1993) mentions all the main intertidal areas, except the Yalu River estuary (Figure2), as possibly important wetlands. There was no information on migrating waders. We have been unable to find any published information for the country (but see Chong (1994) for limited data on four important coastal wetland areas).

The Chinese coast of Korea Bay

No information on waders is available. However, the presence of more than 30 species of economically important shellfish with a total available resource of 110,000 tonnes in the Yalu River estuary (Xiao *et al.* 1996) indicates that the area is very productive and could be important for waders.

Coasts of Liaodong Wan

Brazil (1992) made some observations on the shores of the Shuangtaizihekou National Nature Reserve between 20 April and 28 July 1991. The area of intertidal flat surveyed, which was near to or in the Reserve, was a very small proportion of the total along the Liaodong Wan coast (see Figure 2), and most of his bird counts were done in the Reserve away from the flats. Brazil's observations, therefore, only indicate the potential of this coast to support significant numbers of waders on northward migration. The first Great Knots were seen on 3 May (66) and birds were found on a number of occasions in May, June and July including 98 on 6 July and 1,140 on 24 July. The first Red Knots were seen on 17 May; 225 were recorded on 22 May, 6-10 on 29 May and 25+ on 15 June. No Bar-tailed Godwits were recorded. We have not found any additional published information on the waders of Liaodong Wan.

North coast of Bo Hai

At Beidaihe, Hebei Province, 1,500 Great Knots were recorded on 15 May 1992 and it was also stated that '"great numbers pass through on northward migration". Red Knots pass through in mid-May and Bar-tailed Godwits in late April to early May (Mundkur 1993).

Yellow River Delta

Counts at the Yellow River Delta between 10 April and 2 May

1992 gave a maximum of 72,000 waders (31,000 unidentified), including 3,645 Great Knots, 118 Red Knots and 2,578 Bar-tailed Godwits (Wang et al. 1992). Counts made between 18 April and 1 May 1997 recorded a total of 130,122 waders, including 11,957 Great Knots, 371 Red Knots and 10,678 Bar-tailed Godwits (Barter *et al.* in prep. [a]). It is estimated that 800,000 to 1,000,000 waterbirds, the majority of which are waders, stop and refuel in the Delta in their migratory passage periods (Wang 1994). An independent assessment by Barter *et al.* (in prep. [a]) came to the conclusion that the delta probably supports in excess of one million waders annually, half of these being on northward migration.

Yancheng Reserve, Jiangsu Province

On northward migration up to 3,271 Great Knots, 3,169 Red Knots and 562 Bar-tailed Godwits were recorded in 1990 of which 2,061 Great Knots, 2,513 Red Knots and 556 Bar-tailed Godwits were present in the period 15 to 20 May. (Wang & Liu 1994).

Shanghai region (Chongming Dao)

Counts from 13 to 14 April 1990 were 382 Great Knots and 93 Bar-tailed Godwits; on 2 May 1990, 20 Great Knots, 80 Red Knots and 4 Bar-tailed Godwits; from 25 to 31 March 1996, 5,761 Great Knots, 4 Red Knots and 309 Bar-tailed Godwits; on 15 April 1996, 1,262 Great Knots, 12 Red Knots and 93 Bar-tailed Godwits; from 9-10 April 1997, 2,333 Great Knots, 29 Red Knots and 290 Bar-tailed Godwits; on 15 April 1997, 1,810 Great Knots and 567 Bar-tailed Godwits. (Wang *et al.* 1992, Barter *et al.* 1997a, Barter *et al.* in prep. [b]). Barter *et al.* (1997b) suggest that the three species spend little time at Chongming Dao, although the suspected high turnover rate implies that the counts are significant underestimates of the total numbers using the area during northward migration.

Visual observations in Japan

There was a maximum of 3,522 Great Knots, 69 Red Knots and 3,306 Bar-tailed Godwits in Japan on northward migration in the years 1973 to 1975 and 1981 to 1984 (Mundkur 1993). Counts at 223 sites in 1997 gave totals of 487 Great Knot, 12 Red Knot and 2809 Bar-tailed Godwit out of 116,117 waders counted (Tobai Sadayosi pers. comm.).

Visual observations in the Sea of Okhotsk

At Lunskiy Bay, Sakhalin Island, the northward migration of waders is largely during the third ten-day period of May with 26% being Dunlin *Calidris alpina* and 51% Red-necked Stint *Calidris ruficollis*. Only one Great Knot, no Red Knot and no Bar-tailed Godwit were recorded (Zykov 1997). Tomkovich (1997) states that in the Russian Far East "the similarity of the main passage dates for Great Knots is striking and implies that the main migration across the whole region is occurring over a few days in the last third of May, almost without staging". He lists observations of birds on northward migration. The most important site in the Russian Far East is the Moroshechnaya River estuary, west Kamchatka Peninsula, where 12,000 to 15,000 Great Knots have been recorded from 21-29 May and the total number of passage birds was estimated to be 35,000-40,000. Tomkovich suggests that the estuary is being used as an "emergency site". Gerasimov & Gerasimov (1997) estimated a total of 300,000 waders, including 40,000 Great Knots, 3,000 Red Knots and 1,000 Bar-tailed Godwits, could be using this site in the second half of May.

Band recoveries and flag sightings.

Figure 3 shows the dates of band recovery/flag sightings, in five-day intervals, of Australian-marked Great Knot, Red Knot and Bar-tailed Godwit in the Shanghai region of China, South Korea and Japan. Other than one flagged Bar-tailed Godwit, there have been no band recoveries or flag sightings of these species north of the Shanghai region on the east China coast, on the north China coast or in North Korea.

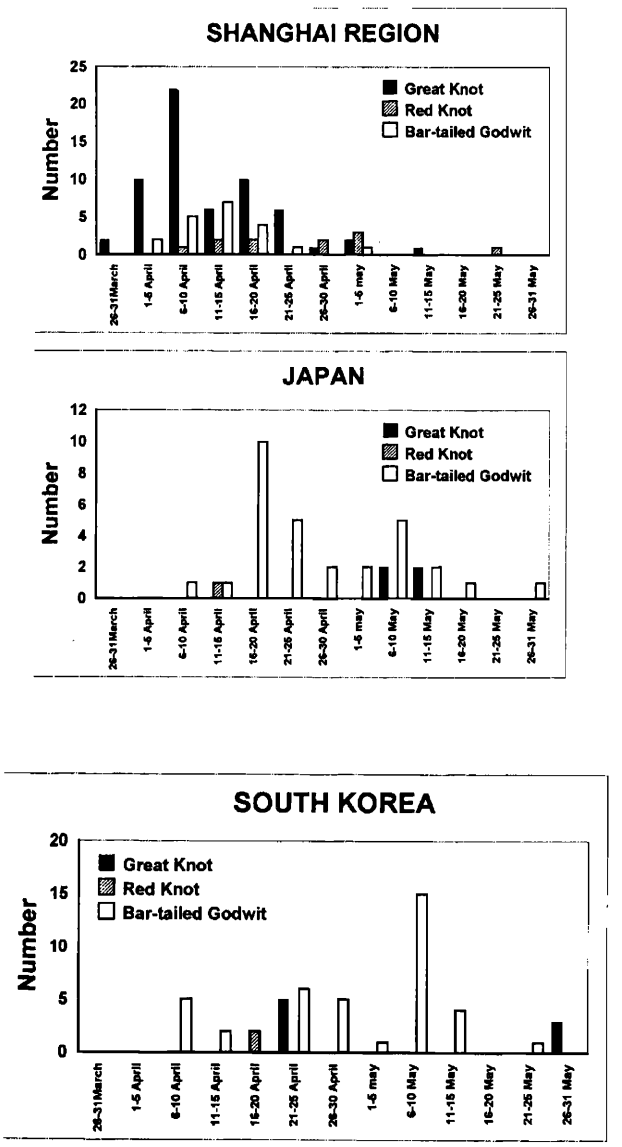

Figure 3. Numbers of band recoveries and leg-flag sightings in the Shanghai Region, South Korea and Japan in five-day periods during March, April and May.

Great Knot
In the Shanghai region, most of the recoveries/sightings (n=55) were in April with peak numbers occurring from 6-10 April. Two were at the end of March; only three were in May, with two from 1-5 May and one from 11-15 May. In South Korea, five were from 21-25 April and three were at the end of May. In Japan, there were four from 6-15 May.

Red Knot
In the Shanghai region recoveries/sightings were between 6 April and 5 May (10), except for a late bird on 21 May. This was a second-year bird which may have migrated late or may not have been travelling all the way to the breeding grounds. In South Korea, two occurred in the period 16-20 April. In Japan there was one during 11-15 April.

Bar-tailed Godwit
In the Shanghai region nearly all recoveries/sightings occurred in April (19); there was only one in May (1-5 May). In the Yellow River Delta there was one on 1 May (pers. obs.). In South Korea, most were between 6-10 April to 11-15 May (37); one was at the end of May. In Japan, most were from 1-6 April to 11-15 May (28), with two being in the second half of May.

Arrival dates on breeding grounds
Great Knots arrive from 22 May (Tomkovich 1996). A leg-flag sighting and two banding recoveries indicate that the breeding grounds of north-west Australian Red Knots are on the New Siberian Islands, as suggested by Tomkovich (1995), whilst it is likely that those from eastern Australia and New Zealand breed on the Chukotski Peninsular (Barter 1992). Red Knots arrive on the Taimyr breeding grounds from 7-10 June in average or early springs, and in late springs from 13-14 June or even on 21 June (Tomkovich & Soloviev 1996). Red Knots breeding on the New Siberian Islands are not likely to arrive earlier than those on the Taimyr. Bar-tailed Godwits from western Australia (race *menzbieri*) breed in central Siberia, while those in eastern Australia (race baueri) breed on the Chukotski Peninsular and Alaska (Barter 1989, Higgins and Davies 1996). Bar-tailed Godwits do not arrive on the Far East Russian and Alaskan breeding grounds until late May or early June (Higgins & Davies 1996 p.88).

Intertidal areas
Areas of intertidal mudflats measured from maps are shown in Table 1 and Figure 2. The calculated areas are subject to unquantifiable error. The tidal range on the Korean west coast is one of the highest in the world, ranging from 4.6 m to 9.1 m on spring tides. In contrast, on the west coasts of Bo Hai the tides range from 1.8 m to 4.1 m (British Admiralty Sea Charts No. 1258. 1983. Korea - West Coast and No. 1250. 1980. China - Bo Hai). It is not clear if the flats shown on the maps represent what is uncovered at spring tides or mean low water. Also, considerable reclamation has obviously taken place in North Korea, with the construction of numerous small barrages across the bays, sea walls enclosing salt marshes, saltpans or fishponds on the mudflats, etc. It is not known what additional reclamation has taken place since 1977. More limited reclamation had taken place in China up to 1954, but it may have increased considerably since then.

Wang *et al.* (1991) estimated the Yellow River Delta had 1,500 km^2 of intertidal flats. Our estimate of 2,745 km^2 includes intertidal areas to the north and south of the delta (Figure 2).

Table 1. Areas of intertidal mudflats in the Yellow Sea and selected major staging/non-breeding areas in the East Atlantic flyway.

YELLOW SEA	ref.	area/sq. km.	numbers of waders	density/ no.m^2
South Korea	1	2,900		
North Korea	1	2,272		
China - Korea Bay	1	757	NO INFORMATION AVAILABLE	
China - Liaodong Wan	1	1,247		
China - Bo Hai	1	3,712		
Total northern Yellow Sea		10,888		
EAST ATLANTIC FLYWAY				
West Iceland	2	343	285,854	833
Waddensee (Netherlands, Germany, Denmark)	3	4,000	2,000,000	500
Wash, UK	4	298	203,826	684
Morecombe Bay, UK	4	337	168,275	499
Solway, UK	4	277	84,708	306
Banc d'Arguin, Mauritania	5	540	2,247,500	4,160
Guinea-Bissau	6	1,570	979,490	625

References. 1. Yu Keun Bae 1994, 2. Gudmundsson & Gardarsson, 3. Smit & Wolf 1981, Davidson *et al.* 1991, Cranswick *et al.* 1995, 5. Zwarts et al. 1990, 6. Zwarts 1988.

An evaluation of South Korea's tidal flats in 1979 estimated that they covered 3,000 km^2 (Yu 1994). From 1981 to 1989, 10,427 ha were reclaimed. Thus, by 1989 there were about 2,900 km^2 of intertidal flats remaining. We have used this figure, and have not measured South Korea intertidal areas from the maps.

We have not been able to do any ground truthing of the maps or measure areas from satellite imagery. The maps, however, do indicate that there are huge potential feeding areas available for waders in the northern Yellow Sea, in addition to those already known on the east China and South Korea coasts.

To put these intertidal areas in perspective, we compared them with important staging and non-breeding areas on the East Atlantic Flyway (Table 1). The west and south coasts of the Korean peninsula and the China coast of Korea Bay have 5,929 km^2 of intertidal area which, when treated as one complex, rates as the largest intertidal area in the world. If it is assumed that the wader carrying capacity is similar to that of the Wadden Sea, *ie.* 500 birds/km^2, the region could hold 3,000,000 waders. The west coast of the Bo Hai, which includes the Yellow River Delta, has 3,712 km^2 of intertidal flats and these could hold 1,850,000 waders and the shores of Liaodong Wan have 1,247 km^2 of intertidal flats, which could carry 600,000 waders. Thus, the Yellow Sea coastline from the Yellow River Delta to South Korea could have a total carrying capacity of around 5,500,000 waders during the migration period.

Climate

The mean air temperatures on the north coast of the Yellow Sea are about -4°C to -7°C in December to February, but then increase to 0°C in March, 7°C in April and 13°C in May (U.S. Navy 1958). The sea surface temperatures are about 4°C in December, 0°C in January and February, 2°C in March, 4°C in April and 10°C in May. (Meteorological Office 1947). The town of Yingkow on the north coast of Liaodong Wang has maximum average air temperatures of -4°C in January and minimum of -12°C, but in April the averages are 14°C and 3°C and in May 22°C and 11°C (Meteorological Office 1966)

These temperatures are not exceptionally low when compared to those occurring in northern European wader staging areas. In the German Wadden Sea, the average air temperature in January is 0.2°C, in March 2°C, in April 5.9°C and in May 10.5°C (Prokosch 1988). The staging areas for Knots in northern Norway are mostly ice covered in winter and ice can still be present in early May. Davidson & Evans (1986) recorded air temperatures of 2-4°C in the first half of May 1995, and mud temperatures were below 5°C in early May, increasing to 8-10°C at the end of May.

The temperatures indicate that intertidal areas of the Yellow Sea are available to feeding waders in April and May. This is also confirmed by the presence of large numbers of waders in the Yellow River Delta in late April and observations on the north coast of Liaodong Wan in May.

Sites lying further north, in the Sea of Okhotsk, which are used by many waders on southwards migration (Gerasimov & Gerasimov 1997, Tomkovich 1997, Zykov 1997) must be very inhospitable in May. For example the average air temperature on the west coast of the Kamchatka Peninsular in mid May is 2.4°C, whilst the average sea surface tempearature is 1.7°C (NOAA 1997) .

SYNTHESIS

Great Knot

Departure timing from north-western Australia fits well with recoveries in the Shanghai region in early April (Figure 3), assuming a non-stop flight. Band recoveries and flag sightings indicate that the main passage through Shanghai is in April. Large numbers have been seen in the Yellow River Delta in the second half of April, although their status there in May is unknown as no field work has been carried out during this month. Some (2,061) however have been recorded in Yancheng area, south of the Yellow River, in the second half of May. The main passage in South Korea is stated to be in late April with some birds staying until the end of May. Recoveries/sightings in Japan indicate that passage occurs in the first half of May. They do not reach the breeding grounds until the last third of May.

The band recoveries/flag sightings and visual observations suggest that large numbers of Great Knots are 'missing' for about the first three weeks of May.

Red Knot

The later departure of Red Knots from north-western Australia compared to Great Knots ties in with the two week later migration schedule indicated by band recoveries in the Shanghai district (Figure 3). No large flocks of Red Knots have been found in the Shanghai District of China, or the Yellow River Delta, although 2,513 have been seen on the Yancheng reserve in the period 15 to 20 May. South Korea (maximum 666) and Japan (maximum 69) seem to be off the main migration route. The band recoveries/flag sightings and visual observations imply that most Red Knots pass through the southern Yellow Sea in the last three weeks of April and the first week of May, and most may overfly this region.

As birds do not arrive on the breeding grounds until early June (Tomkovich & Soloviev 1996) and have left Shanghai by early May, they appear to be "missing" throughout most of May.

Bar-tailed Godwit

Departure dates from north-western Australia fit in well with recoveries in the Shanghai region in the first half of April, assuming a nonstop flight. Band recoveries/flag sightings and visual observations indicate that the main passage of Bar-tailed Godwits through Shanghai is mid-April, and through

South Korea and Japan it is during the second half of April and the first ten days of May, although some birds are present in the latter two regions until the end of May. Large numbers have been seen in the Yellow River Delta in the second half of April and 556 were seen on the Yancheng reserve in the period 15-20 May.

As Bar-tailed Godwits do not arrive on the breeding grounds until late May or early June many seem to be 'missing' for about three weeks in May.

DISCUSSION

The Yellow Sea lies strategically placed on the migration route between non-breeding areas in Australia and breeding areas in Russia (Figure 1). Great Knots, Red Knots and Bar-tailed Godwits probably fly non-stop from north-western Australia to the Shanghai district of China (Barter & Wang 1990), but it seems likely that Shanghai is mainly used by less fit birds or as emergency staging sites if winds are unfavourable, as hunters mainly catch birds when winds are from the north (Barter *et al.* 1997c). Banding and count data from the Shanghai area (Barter *et al.* 1997a, 1997b) indicate that the favoured strategy for Great Knots, Red Knots and Bar-tailed Godwits on leaving northern Australia is to fly non-stop to the south or west coasts of the Korean peninsular, to the Yancheng reserve, to the Yellow River Delta or, possibly, to other sites in the northern Yellow Sea, as yet unidentified.

Whilst counts show that the west coast of South Korea holds large numbers of Great Knots and Bar-tailed Godwits in April, the timing of the peak concentrations, supported by band recovery/flag sighting information, implies that many birds go ›missing" for some weeks during their northward migration. Major staging sites for Red Knots have not yet been identified. The only large numbers recorded were on the Yancheng Reserve and at the Moroshechnaya Estuary.

It seems unlikely that the 'missing' birds are located on intertidal areas further north on the migration routes to the breeding grounds. The Sea of Okhotsk, which holds large numbers of waders on southward migration (Gerasimov & Gerasimov 1997, Tomkovich 1997, Zykov 1997) is only used on northward migration in late May, and then probably only for a very short period. Temperatures earlier in May indicate that the mudflats would still be ice covered and, thus, unsuitable feeding habitat. Further south on the Russian coast feeding habitat is limited due to the rocky nature of the Primorye coast.

We suggest that the "missing" Great Knots, Red Knots and Bar-tailed Godwits, move on to the extensive intertidal mudflats located around Korea Bay, Liaodong Wan and Bohai in areas which have not yet been investigated in May. We also suggest that these areas are the final staging sites before the breeding grounds. Some birds may reach these areas from Australia in one flight.

The northern Yellow Sea is within a single flight of the breeding grounds. For example, from the Yalu River estuary region of Korea Bay the most distant part of the Great Knot breeding area is 4,550 km away, whilst the nearest is 2,700 km. The distance to the emergency staging site on the Moroshechnaya River estuary from the most northern sites in the Yellow Sea is about 3,100 kms. The breeding areas for Red Knot on the New Siberian Islands lie at a distance of 4,000 kms, whilst those of the Bar-tailed Godwit on the Lena River Delta are 3,700 km away, but those in west Alaska are 5,400 km distant.

If there are very large numbers of Great Knots, Red Knots and Bar-tailed Godwits in the northern Yellow Sea, the lack of recoveries of marked birds at first seems remarkable. However, most recoveries in China are by hunters, as there is little banding activity and only very few people are looking for flags. We have little information on the the extent of hunting north of Shanghai. Hunting in the Yellow River Delta is limited to salt ponds (Wang *et al.* 1991) and does not occur on the intertidal flats (pers. obs.). It seems likely that low hunting activity, compared to the Shanghai area, explains the lack of recoveries.

Other examples of final northward migration wader staging areas are the Wadden Sea for birds flying to Siberia, north Norway for Red Knots and west Iceland for Red Knots and other species bound for Greenland and Canada, and Delaware Bay for birds headed for the Canadian arctic. Interestingly, as with the northern part of the Yellow Sea, these sites still lie far (up to 4,500 km) from the breeding grounds.

The quality of the final staging site is of key importance in enabling waders to store enough fat and protein to reach the breeding grounds in good condition to ensure successful breeding, especially if the flight is long. The coasts of the northern Yellow Sea are, therefore, probably amongst the most important in the whole East Asian-Australasian Flyway. Up to 725,000 Great Knots, Red Knots and Bar-tailed Godwits could be staging there. Other wader species could also be using these coasts, implying that more than a million birds in total could be present. Although the importance of the Yellow River Delta has been already been established, the possible huge size of wader migration through the northern coasts of the Yellow Sea is undocumented.

The fact that we still do not have on-the-ground evidence of exactly where the final key staging sites used on northward migration lie is probably the most important issue for investigation in the East Asian-Australasian Flyway. The suggestion in this paper that they are located in the northern part of the Yellow Sea needs to be followed up by ground-truthing as a matter of urgency, especially as this area may well be one of the most threatened in the whole Flyway.

We invite comments, contributions and discussion about this

paper, particularly from colleagues in China, North and South Korea and Russia. There may be additional information, either unpublished or in Chinese, Korean or Russian publications which are not generally available to non-speakers. This information may substantiate the theory that there are undocumented, hemispherically important intertidal areas for waders in the northern Yellow Sea.

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FOOTNOTE

The first comprehensive survey of the intertidal areas of the Shuangtaizihekou Reserve (40°52' to 41°03'N and 121°35' to 121°55'E) on the north coast of Liaodong Wan was made between 11 and 19 May 1998 (Barter & Wilson in prep). 63,641 waders were counted, including 24,915 Great Knot (7.8% of the world population), 949 Red Knot and 3,493 Bar-tailed Godwit. Three Great Knots, one Red Knot and one Bar-tailed Godwit which had been flagged in north-west Australia and one Bar-tailed Godwit flagged in Victoria (S.E. Australia) were seen. As far as is known this is the first ever survey made of waders on northward migration on the north coasts of the Yellow Sea.

Although large parts of the upper intertidal areas had been reclaimed for fish ponds and a fresh water resevoir, and in three places there were new roads across the mudflats to new oil rigs built on the intertidal areas, there were still large areas of mudflat which had not been developed. Although there had been changes from the 1954 maps because of reclamation, erosion and sedimentation, the survey confirmed that the old maps used in this paper did realistically depict the areas where there were large areas of mudflat. The lack of previous banding recoveries or flag sightings is due to the absence of hunting and that the reserve research staff have been mainly studying the breeding of the endangered Saunder's Gull *Larus saundersi* in the migration time for waders and they have not been censusing waders on the mudflats or looking for flagged birds.

This is the first confirmation that large numbers of waders may indeed be using the north coasts of the Yellow Sea on northward migration as suggested in this paper. It is hoped to do more extensive surveys of these coasts in 1999.