NORTHWARDS MIGRATION OF SHOREBIRDS THROUGH SAEMANGEUM, THE GEUM ESTUARY AND GOMSO BAY, SOUTH KOREA IN 2006

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Saemangeum, on the west coast of South Korea, was until recently recognised as the single most important staging site for migratory shorebirds in the East Asian–Australasian Flyway. However, construction of the Saemangeum sea-wall was completed in late April 2006. The 33 km dam across the Mangyeung and Dongjin Estuaries is part of the largest “reclamation” in the world, and will convert c. 400 km² of tidal flats to land and a freshwater reservoir. Here we report on systematic counts and scans for colour-band and flagged shorebirds in Saemangeum, the adjacent Geum Estuary and Gomso Bay in April and May 2006. This was the first of a planned series of surveys to assess the effects of the reclamation on shorebirds.

We counted a minimum of 198,031 shorebirds in Saemangeum, 15 of which (including the endangered Spoon-billed Sandpiper) occurred in internationally important numbers. Local distribution of the shorebirds changed after closure of the sea-wall caused a decline in tidal range (with dried out inner estuarine sites being abandoned by shorebirds) and a dramatic die-off of benthic molluscs. Many shorebirds fed on the dying molluscs and this temporary food source may have enabled them to stage successfully. We had no clear evidence that birds abandoned Saemangeum on northwards migration in 2006, but the area and quality of suitable habitat for shorebirds in Saemangeum is likely to be greatly diminished by the time of the next northwards migration.

On the Geum Estuary we counted a minimum of 82,990 shorebirds, including internationally significant numbers of at least 13 species; these include among the largest counts made at any single site of the globally endangered Nordmann’s Greenshank.

In at least two species, Bar-tailed Godwit and Great Knot, resightings of colour-banded birds indicated that the earliest migrants were dominated by birds from non-breeding grounds in eastern Australia or New Zealand, with a later influx of birds from north-western Australia which had probably staged on the coast of China. For Great Knots, and probably for several other species, the region appeared to be the final staging point before a direct flight to the breeding grounds. There was considerable interspecific variation in the timing of shorebird migration through the region, so peak numbers of particular species in the region can easily be overlooked in short-term surveys. The prolonged duration of our survey, in addition to the intensity of coverage achieved, may explain why the shorebird numbers we observed in the Geum Estuary were considerably higher than those reported in previous surveys. With the probable loss of Saemangeum to shorebirds, the Geum Estuary is now likely to be South Korea’s premier shorebird site. Unfortunately, it too is threatened by a major land reclamation project.

INTRODUCTION

In recent years it has become clear that the Yellow Sea is the most important staging area for migratory shorebirds in the East Asian–Australasian Flyway (Barter 2002). The discovery of the importance of the area for shorebirds has coincided with the realisation that intertidal habitats in the Yellow Sea are threatened, and diminishing rapidly in both area and quality, as a result of the huge and fast-growing human populations and economies of China and South Korea. The main cause of habitat loss in the Yellow Sea is reclamation of tidal flats for a variety of purposes, including agriculture, industrial development, mariculture, saltworks and freshwater reservoirs (Barter 2002).

The largest single reclamation project undertaken in the Yellow Sea has been the development of Saemangeum, on the west coast of South Korea. This site has been recognised as the single most important staging site for shorebirds in the Yellow Sea (Barter 2002) and ecologists expect its loss will cause substantial population declines of shorebirds in the East Asian–Australasian flyway (Moores in press; Moores et al. 2006). This view is not shared by proponents of the sea-wall, who have claimed that the reclamation will be “environmentally friendly” and that displaced shorebirds can simply move elsewhere. In 2003 the Korean Ministry of Agriculture and Forestry identified the Geum Estuary and Gomso Bay as areas to which shorebirds displaced by the Saemangeum reclamation will move. These claims are strongly undermined by the facts that over 50% of Korea’s tidal flat areas have been reclaimed since 1964, limiting the options for displaced shorebirds; that a major reclamation is also planned in the Geum Estuary; and that shorebirds displaced by reclamation elsewhere have been shown to suffer significantly increased mortality (Burton et al. 2006). Nevertheless, the existence of strongly conflicting viewpoints on the conservation impacts of reclamations such as Saemangeum make it difficult to ensure that key shorebird habitats in the Yellow Sea are protected. It is therefore extremely important that the effects of reclamation projects on shorebirds are measured and adequately documented.

With this consideration in mind, the Australasian Wader Studies Group (AWSG) and Birds Korea have formed a partnership to conduct the Saemangeum Shorebird
Monitoring Project (SSMP). The objective of the three-year program is to document the effect of the Saemangeum reclamation on shorebirds in Saemangeum itself and in adjacent estuarine systems (the Geum Estuary and Gomso Bay) which may receive displaced birds. The AWSG is also stepping up population monitoring counts of shorebirds in Australia (Gosbell & Clemens 2006), in part to assess whether the Saemangeum reclamation has detectable effects on non-breeding shorebird populations elsewhere in the flyway. Results of these studies will be disseminated widely to inform future conservation work in the East Asia–Australasian flyway.

In this paper we report on the first Korean field season of the SSMP. The work was undertaken in April and May 2006, coinciding with completion of construction of the Saemangeum sea-wall on 21 April 2006. Objectives of this report are:

1. To document numbers of shorebirds occurring in Saemangeum, the Geum and Gomso Bay on northwards migration, as a baseline against which subsequent surveys in these areas can be compared.
2. To document the timing of shorebird migration through the region, a necessary step if the overall number of birds using it as a staging area is to be estimated;
3. To make preliminary assessments of migratory origins of Saemangeum birds, so predictions can be made about where population declines caused by the Saemangeum reclamation will be observed;
4. To document roost locations, local shorebird movements and short-term effects of construction of the Saemangeum sea-wall.

METHODS

We carried out regular counts at seven high tide roosts in the Geum Estuary, at twenty roosts in the Saemangeum complex and at five sites in Gomso Bay (Figure 1). We refer to these sites combined as “the survey area” in the remainder of this paper. Fieldwork was carried out throughout April and May 2006, but particular effort was made to obtain comprehensive counts on the spring tide series that occurred in the study area over 15–17 April, 27–29 April, and 13–17 May. The actual period of surveying was much longer. Each of the main counts was preceded and followed by several days of additional surveying, so that we could ensure that we had located all the main shorebird roosts present, and so we could check that local shorebird movements did not cause us to “double-count” any birds.

Our team was not large enough to carry out counts at all sites in the region in a single day, but it was possible to carry out simultaneous counts at all major roosts in the Geum Estuary on a single high tide, in the Mangyeung Estuary on a single high tide, and in the Dongjin Estuary to Gomso Bay in a single day. In the same spring tide series we carried out additional observations in targetted sites (Yubu Island and Gunsan Air Base) to see if there were any tide-related movements of birds between the Geum and Mangyeung estuaries, and at Simpo in case there were movements between the inner parts of the Mangyeung and Dongjin estuaries. Movements between the Mangyeung and Dongjin Rivers were recorded at Simpo, but they appeared to involve local birds from the local open mudflats rather than individuals from the inner parts of the Mangyeung and Dongjin. No major movements between Saemangeum and the Geum Estuary were seen within any particular high tide during our survey (though we did see such movements from Yubu Island in September 2006), and sites that were counted twice in the same tide series had similar bird numbers on each occasion, suggesting that we did not have any double-counting problems.

We treated the peak count of each species obtained from a spring tide survey as a minimum estimate of the number of shorebirds staging on northwards migration in each of the Geum, Saemangeum and Gomso Bay. These totals may however be an underestimate of the number of shorebirds staging in the region, as we did not make any corrections for potential migratory turnover. In addition, the numbers of relatively rare species at Saemangeum and the Geum Estuary could easily be underestimated; for example Spoon-billed Sandpipers can be difficult to find when mingling with a large flock of Dunlins.

The core activity of the expedition was counting shorebirds, but we also counted the globally endangered Black-faced Spoonbill Platalea minor, vulnerable Chinese Egret Egretta eulophotes and vulnerable Saunders’s Gull Larus saundersi if they were encountered during our surveys. We recorded all observations of colour-banded and leg-flagged shorebirds; scans for these were made opportunistically during counts, and more systematically during neap tides. Search effort for colour-marked birds was not recorded systematically, but was reasonably consistent throughout the expedition period. However, colour-marked birds were more difficult to detect in early and mid-April, when it was cold and windy, and shorebirds often fluffed up their plumage or sat down at roosts, concealing their legs. Migratory departure behaviour, which is readily recognised in shorebirds (Piersma et al. 1990) was recorded if seen. Finally, abdominal profiles of Great Knot were scored following the methodology of Wiersma & Piersma (1995) on several days during the expedition.

DR, NM and Ju-Yung Gi made a brief visit to Saemangeum and the Geum Estuary in late September 2006, and a few observations from this visit (including a count at Yubu Island) are also presented in this paper.

RESULTS

Notes on shorebird habitats and distribution within the study area

Geum Estuary

The distribution of shorebird habitat within the Geum Estuary has been extensively modified by human development. No shorebird roosts were found on the heavily urbanised southern shores of the lower Geum River, which are occupied by the industrial city and adjacent port of Gunsan. The upper reaches of the estuary have been unsuitable for most species of shorebird since the Geum River Barrage was built in the late 1980’s, forming a large freshwater lake that flooded the former tidal flats and saltmarsh. The great majority of shorebird habitat remaining in the Geum occurs on the reasonably large tidal flat.
remnants to the north of the river mouth (c. 10.5 km² exposed at low tide), and shorebirds also feed on tidal flats in those parts of the river channel below the Geum River Barrage.

Observations of birds flying into or out of high tide roosts suggested that the majority of shorebirds in the Geum Estuary fed on the Daejuk Tidal Flat, especially along the shores of the Gaeya Channel (Figure 2). At high tide these birds moved to roosts on Yubu Island and Daejuk Island (or, if the tide was not very high, on the sandflats between them), or to roosts on the mainland coast at Songsook Ri, Namjeon Ri or Daemoe, Janghang-Eup. These mainland roosts were partially to completely submerged by tides over 6.5 m high, and in such conditions shorebirds were forced to Yubu or Daejuk islands. The potential roosting areas on these islands were small on very high tides, and on 6.8 m tides in September 2006, some shorebirds (especially Grey Plovers) were seen leaving Yubu Island and flying to roosts in the Saemangeum system, probably near the US Air Force base at Gunsan. Such movements have been seen in the region before (NM unpubl.), but we had no evidence that they occurred during our northwards migration study period in 2006.

The lower parts of the Geum River channel are tidal; at low water extensive soft mudflats are exposed on Haemangdong Tidal Flat and Gupo Tidal Flat (Figure 2), and they are used as feeding areas by reasonably large numbers of shorebirds. These can be counted most efficiently on rising tides, which push the shorebirds into pre-roosts on mudflats on the northern shore of the Geum River. These pre-roosts are submerged at the peak of high tide. Some of the displaced shorebirds flew to high tide roosts at Daemoe Harbour, but we were unable to relocate all the Gupo Tidal Flat birds at high tide roosts. We suspect some of these,
particularly Black-tailed Godwits, Broad-billed and Sharp-tailed Sandpipers, must have had undiscovered roosts on rice fields inland of the Geum Barrage.

Saemangeum

The largest shorebird roosts found within the Saemangeum complex were at Okgu and Simpo (Figure 3); observations of birds flying into and out of these roosts suggested that both sites were used largely by birds feeding on the extensive outer tidal flats at the confluence of the Mangyeung and Dongjin rivers. At both of these sites, counts were dominated by Great Knot. Smaller shorebird roosts were found adjacent to the tidal flats north of the Mangyeung River channel (near Gunsan Airport; dominated by Dunlin), and adjacent to the tidal flats south-west of the Dongjin River channel (sandy flats, dominated by Eastern Curlew and Dunlin). Shorebird roosts on the inner reaches of the Mangyeung and Dongjin Rivers had relatively lower numbers of shorebirds (Figure 3). In contrast, in previous years tens of thousands of shorebirds had been counted coming into roosts in salt-marsh near Wolyeon, at Hapo/Mangyeung-Eup (Mangyeung) and along much of the entire northern shore of the Dongjin (N. Moores, unpubl.). Historically these roosts were used most by shorebirds on medium-high tides; on the very highest tides, when the salt-marsh was inundated, many of the shorebirds tended to roost at other easier-to-count roost sites, such as at Okgu or to a lesser extent, Gyewhado, where banding and counting efforts were largely concentrated.

Shorebird habitat and distribution within Saemangeum changed markedly during the study period. The natural tidal range in Saemangeum was over 7 m during the biggest spring tides, but construction of the sea-wall has greatly reduced exchange of estuarine and Yellow Sea waters. The 33 km sea-wall was officially completed on 21 April, with the only remaining gaps being the 540 m of sluice gates opposite the Dongjin River. The sluice gates were open throughout our study period, but tidal range nevertheless dropped markedly: in late April and May it was less than a metre, even on spring tides. As a result, high tides no longer reached tidal flats in the upper reaches of the estuaries. This is probably why shorebird counts at the inner Saemangeum roosts (sites 5, 10 and 11 in Figure 3) were highest in early April, despite the fact that the number of shorebirds in the

<table>
<thead>
<tr>
<th>#</th>
<th>Roost name</th>
<th>Peak count in April-May 2006</th>
<th>* Peak historic count</th>
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<tr>
<td>1</td>
<td>Yubu Island</td>
<td>40,582</td>
<td>31,268</td>
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<td>2</td>
<td>Daejuk Island</td>
<td>15,215</td>
<td>NA</td>
</tr>
<tr>
<td>3</td>
<td>Daemoe, Oknam Ri</td>
<td>22,443</td>
<td>22,532</td>
</tr>
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<td>4</td>
<td>Namjoen Ri</td>
<td>4,094</td>
<td>3,396</td>
</tr>
<tr>
<td>5</td>
<td>Songsok Ri (Janggu Bay)</td>
<td>1,122</td>
<td>645</td>
</tr>
<tr>
<td>6</td>
<td>“Geum Barrage S”</td>
<td>8,994</td>
<td>NA</td>
</tr>
<tr>
<td>7</td>
<td>“Geum Barrage N”</td>
<td>1,527</td>
<td>5,618</td>
</tr>
</tbody>
</table>

*These data should not be considered comprehensive as few other data sources have been checked.
The lack of tidal inundation on the upper flats of the Saemangeum system caused a massive die-off of shellfish in late April and May. Large numbers of shellfish came to the surface of the mudflats and died, gaping open and providing a ready food source for shorebirds (Figure 4). In particular, thousands of Great Knots and Dunlin were seen picking the flesh out of dying or freshly dead cockles in the Simpo area. Shellfish species that were observed dying included the brachiopod *Lingula anatina*, solenoid bivalves (probably *Solen strictus*), the cockle *Mactra veneriformis*, several smaller species of bivalve (*Sinonovacula constricta*, *Nuttalia obscurata*), the gastropod *Umbonium thomasi* and the crabs *Macrophthalmus japonicus*, *Philyra pisum* and *Portunus trituberculatus*. Local fisherfolk operating crab traps on...
areas of the lower tidal flats that still received tidal waters reported that 30–40% of crabs found in their traps were dead, suggesting a loss of condition (usually crabs are captured alive in these traps).

We did not have time to make quantitative observations of the scale of the shellfish die-off. In theory doing so would have been straightforward, as the dying shellfish were easily seen on the surface, and the zones in which they occurred were extensive (hundreds of metres wide) and sharply defined. In May it was noted that the “dead shellfish zones” were expanding seawards, and that they occurred not only in areas no longer inundated by high tides, but also in areas that were only occasionally inundated. At the same time, dead shellfish that had been longest exposed had been scavenged or decomposed to the point that they no longer provided a food source, so those areas of the “dead shellfish” zones at the highest tidal levels were abandoned by feeding shorebirds. In September 2006, when DR and NM revisited the same sites at Simpo, these habitats had changed considerably in appearance. The Saemangeum Development Corporation had apparently employed people to collect the remains of dead shellfish from the surface and to scatter seeds of halophytes, transforming large areas of open mudflat to saltmarsh.

Several dead shorebirds were found on a large sandflat island roost off Okgu, in Saemangeum. Two Great Knot corpses were found there on 29 April, and a further 7 (plus one Dunlin) on 15 May. In early September 2006, 14 dead juvenile Red-necked Stints and a dead juvenile Spoon-billed Sandpiper were found at the same site. Interestingly, no dead shorebirds were found on sandflat roosts on the Geum Estuary, despite the fact that a similar amount of time was spent there by observers, and that the presence of two dead passerines in the flats at Yubu Island (a Dusky Thrush and a Siskin) suggests that the tides had not caused bird corpses on the Geum sandflats to be washed away. It is therefore possible that the death of the Saemangeum birds was related to the reclamation, perhaps because food supplies were insufficient or because birds became ill as they were forced to eat carrion. However, the cause of death of these birds is unconfirmed; those found in spring did not appear to be emaciated.

The reduction in tidal range in Saemangeum must also have influenced lower tidal levels, as large mudflat areas are now permanently inundated, and are no longer exposed to low tides (or feeding shorebirds). We have no data on how this might have affected the local benthos.

Gomso Bay
This is a large, mostly sandy bay, approximately 15 km in length and 5 km wide at its mouth, fed however by only two significant streams. Much of the bay’s hinterland remains potentially attractive to shorebirds (with salt-pans and wet rice fields for example, especially in the north), and while all...
such areas were checked during the survey, the most-used roosts were in the bay proper (most especially a stretch of rocky shore in the northwest, and a rather small area of salt-marsh in the innermost part). At lower tides, in good light, scans across the whole inner bay were also conducted from several vantage points. Despite adequate coverage, we found few shorebirds in total. Local fisherfolk complain of the bay’s rather low productivity, presumably in part due to the combination of sandly substrate and marine-influence, and this is reflected not only by the low number of shorebirds found during the survey period, but also by the relative scarcity of other waterbird species at other seasons. Despite the small numbers of shorebirds there, Gomso Bay was still found to be internationally important for Whimbrel (most of which were found in the northwest part of the bay), held a single Black-faced Spoonbill during the survey period, and also supported up to 10 endangered Oriental White Stork Ciconia boyciana in early January 2007 (Ju Yong-Gi pers. comm. 2007)

Species totals and peaks

Species totals observed in the complete counts on the spring tide series from 14–17 April, 27–29 April and 13–17 May are summarised in Table 1. A minimum of 82,993 shorebirds were found in the Geum Estuary, including 13 species that occurred in internationally significant numbers; given that our counts were likely to be underestimate, we consider it probable that a fourteenth species (Sanderling) was also present in internationally significant numbers. A minimum of 198,031 shorebirds were found in Saemangeum, including 15 species that occurred in internationally significant numbers. Gomso Bay had far fewer shorebirds (a minimum of 1,139) but still had one species, Whimbrel, in internationally significant numbers.

Few observations of migratory departures were made during the expedition, largely because we only had a small team in mid- and late May, when most departures are thought to have occurred. Some departures were seen from the Geum Estuary on 15 May (74 Common Greenshank from Namjeon Ri; 14 Lesser Sand Plovers, 115 Bar-tailed Godwits and 50 Dunlin from Daemoe Harbour), and 63 Terek Sandpipers were seen departing from Simpo on 26 May. Expedition members Kevin and Kelly White made almost daily visits to Simpo (the largest easily accessible roost in Saemangeum in mid-May) from 13 May to 21 May, and although they did not have the time or light conditions to conduct complete counts of the site, they observed a very obvious decline in shorebird numbers and considered that most departures occurred between about 15 and 20 May; by 26 May they found only 233 shorebirds at this site, though it had held 50,000 shorebirds on 13 May.

Different species of shorebird migrated through the region at slightly different times (Figure 5). Specific notes on timing of migration are given in the annotated species list below, along with notes on migratory origins if colour-band and leg-flag resightings were made.

Eastern Oystercatcher Haematopus ostralegus osculans

Most of the 1,485 seen in the region occurred in the Geum Estuary, roosting on Yubu and Daejuk ISLANDS. In late September 495 Eastern Oystercatchers were found roosting on Yubu Island; they were followed by observers at low tide and almost all birds fed on sandy tidal flats north of the island. Previous surveys have shown that the numbers roosting at Yubu Island are highest in the non-breeding period (Barter 2002, Lee et al. 2002), with a maximum count of 5,700 – i.e. 57% of the estimated world population of 10,000 of this distinctive taxon; they also breed there and on surrounding islets in lower numbers (Lee 2004). Saemangeum had lower numbers of Oystercatchers but they were still in internationally significant levels during our survey. Most were found on tidal mudflats near the Gunsan airport, or on tidal sandflats at Simpo. There were small rocky islets at both of these sites, and oystercatchers are suspected to have nested in both these areas in the past.

Given that Eastern Oystercatchers occur in the region in largest numbers during the non-breeding season (i.e. the boreal winter), it is a little surprising that our count in mid-April was lower than that at the end of April (Figure 1), both in the Geum Estuary and Saemangeum. This may suggest there was some passage migration through the region. We did not find any colour-banded or flagged oystercatchers, but it is unlikely that many have been colour-marked elsewhere in the flyway.

Black-winged Stilt Himantopus himantopus

A few were found in the Saemangeum region in mid-April, some in flooded rice fields or fishponds near the coast and some on the tidal flats themselves.

Northern Lapwing Vanellus vanellus

A single bird was seen on mudflats in the Geum River (near the barrage) on 6 April.

Pacific Golden Plover Pluvialis fulva

Low numbers were seen in Saemangeum and the Geum in April; counts were lower at the end of mid-April, suggesting that numbers might have peaked before we began intensive surveying. No colour-marked birds were seen.

Grey Plover Pluvialis squatarola

A minimum total of 5,424 Grey Plover was recorded in the survey area, constituting 4.4% of the estimated flyway population. Highest counts were made in the Geum Estuary on Yubu Island and Daemoe Harbour. In Saemangeum, the highest numbers were seen at Okgu, roosts on the northern shores of the Dongjin Estuary, and (in early April only) on the mudflats near the Gunsan US Air-Force base. About 6,000 Grey Plover occur in South Korea during the non-breeding period, and such birds are likely to have still been present at the start of our survey. Numbers of Grey Plover increased gradually during the survey period, suggesting the
Table 1. Shorebird counts during the spring tide surveys in April-May 2006 at the Geum Estuary, Saemangeum and Gomso Bay. The total shorebird counts given are the sum of the peak counts observed during the surveys, and do not include any corrections for potential turnover; they are therefore minimum estimates of the numbers of shorebirds using these sites on northwards migration. The second column gives the 1% criterion for each species (in the East Asian–Australasian flyway, from Wetland International 2006, except for the Broad-billed Sandpiper estimate from Bamford et al. 2006 and the Spoon-billed Sandpiper estimate from Syroechkovsky 2005; Lesser Sand Plover estimate combines subspecies mongolus and stegmanni, Bar-tailed Godwit estimate combines subspecies baueri and menzbieri, Common Redshank estimate combines subspecies terrigotae and craggi, Dunlin estimate combines subspecies arctica and sakhalina). Sites where peak numbers exceed this total (i.e. >1% of the minimum flyway population estimate) are considered to be of international significance under the Ramsar convention on wetlands and are highlighted in boldface.

<table>
<thead>
<tr>
<th>Species</th>
<th>1% Level</th>
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<th>Gomso Bay</th>
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<td></td>
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<td>Late April</td>
<td>Mid-May</td>
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</tr>
<tr>
<td>Northern Lapwing</td>
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<td>1</td>
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<td>Pacific Golden Plover</td>
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<td>Marsh Sandpiper</td>
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<td>70</td>
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<td>19</td>
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<tr>
<td>Unidentified shorebirds</td>
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<td><strong>Other noteworthy species</strong></td>
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<td>Saunders's Gull</td>
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<td>25</td>
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<td>19</td>
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</table>

**Northward migration through Saemangeum**

80
arrival of passage migrants. No flagged or colour-banded birds were found, perhaps reflecting the low numbers of this species banded elsewhere in the flyway (at the time of our study, only 239 had been flagged in north-western Australia, and 86 in Victoria).

**Little Ringed Plover Charadrius dubius**

Low numbers were seen in Saemangeum and the Geum in April; mostly beside freshwater wetlands near the coast or on...
small pools on upper mudflats. No colour-marked birds were seen.

Kentish Plover *Charadrius alexandrinus*

A few were seen at most sites within Saemangeum and the Geum estuary, but high counts were only made on mudflats near the Gunsan US Air-Force base, with 552 there on a neap high tide on 14 April. Numbers declined steadily through April and May, suggesting that departure to the breeding areas occurred earlier than in species that breed at higher latitudes. Given the early passage of this species, it is likely our counts were an underestimate of the number occurring in the area on northwards migration. Numbers in the region are considerably higher on southwards migration, when peak counts of 2,500 have been made in the Geum Estuary, 11,000 in the Mangyeung Estuary and 8,500 in the Dongjin Estuary (Barter 2002). No colour-marked birds were seen.

Lesser Sand Plover *Charadrius mongolus*

A minimum total of 7,606 was recorded during our survey, comprising 5.9% of the estimated flyway population. Plumage characters suggested that most or all seen were in the *mongolus* subspecies group, which some workers consider to be a full species “Mongolian Plover” (Hirschfield et al. 2000). Five leg-flagged birds were seen. Two of these, with an orange-white flag combination, had been banded in Korea. A bird with a single orange flag, and another with a single white flag, may also have been birds that had been banded in Korea but subsequently lost a leg-flag; alternatively the orange-flagged bird may have come from Victoria, where 55 Lesser Sand Plovers have been flagged. Origins of a bird seen with a single blue leg-flag were unclear as the bird may have lost a leg-flag; this colour is part of the leg-flag codes for both Japan and Taiwan.

Greater Sand Plover *Charadrius leschenaultii*

Single birds were seen at Yubu Island (17 April) and Okgu (15 May).

Eurasian Woodcock *Scolopax rusticola*

A single bird was seen on Yubu Island on 9 April.

Common Snipe *Gallinago gallinago*

Up to five birds were seen on a flooded rice field next to Daemoe Harbour (Geum Estuary) between 24 and 26 April.

Asian Dowitcher *Limnodromus semipalmatus*

Single birds were seen on the northern shores of the Dongjin Estuary on 17 April and 14 May, with one further individual seen near Daemoe Harbour on 30 April.

Black-tailed Godwit *Limosa limosa*

This species occurred in largest numbers on inner tidal flats of estuarine systems. The highest counts were made in the Geum Estuary, with 830 on the Haemangdong and Gupo Tidal Flats on 16 May. In Saemangeum, the highest counts were made on the northern shores of the Dongjin River, and at Okgu. Black-tailed Godwit was a late migrant through the region, with numbers increasing five-fold between the end of April and mid-May. The late arrival of this species suggests that it stages elsewhere before reaching Korea: this suggestion is supported by the single leg-flag resighting, a bird banded at Chongming Dao (near Shanghai, on the Chinese coast). No north-west Australian leg-flags were seen, although 586 Black-tailed Godwits had been flagged in north-western Australia in the years before our expedition began.

Bar-tailed Godwit *Limosa lapponica*

Two subspecies of Bar-tailed Godwit occurred in the study region, *baueri* (which breeds in Alaska and spends the non-breeding season in eastern Australia and New Zealand) and *menzbieri* (which breeds in Yakutia and spends the non-breeding season in north-western Australia). The presence of both subspecies would have been apparent simply from field observations, as the whiter rump of subspecies *menzbieri* was reasonably easy to detect when birds were in flight. However, we had still stronger support for the presence of both subspecies from leg-flag and colour-band resightings. We made 131 observations of colour-marked birds, this high total being caused by a combination of: (1) large numbers colour-marked in the flyway (c. 7,900 had been flagged in north-western Australia, c. 2,230 flagged in south-eastern Australia, and 1,248 in New Zealand before our survey began); (2) ease of detection, leg-flags or colour-bands often being visible on this long-legged species in cold weather when bands or flags on the tibia of other species were concealed by fluffed-up feathers; and (3) particular attention being paid to Bar-tailed Godwits by expedition participants seeking birds from their own banding projects.

Resightings of colour-marked birds confirmed that *baueri* was by far the most abundant subspecies of Bar-tailed Godwit in the region, with 130 birds being resighted from New Zealand (n = 38), Victoria (85), Queensland (4) and New South Wales (3). Only 22 north-west Australian *menzbieri* were relocated, despite more Bar-tailed Godwits having been leg-flagged in north-western Australia than in south-eastern Australia and New Zealand. At least 23 birds were with individual colour-band combinations from New Zealand, one of which was seen just 11 days after last being seen in New Zealand. Five of these individuals were seen more than once; one of these remained in the study area for at least 11 days, and another for at least 25 days. This indicates that some Bar-tailed Godwits stage in the region for a long period, presumably undertaking substantial pre-migratory fuelling in that time.

Despite this evidence for some *baueri* staging for long periods, it was clear that many other *baueri* did not remain in the region throughout our study period. Numbers of Bar-tailed Godwits decreased sharply after the end of April. However, numbers of north-west Australian *menzbieri* rose in the same period (Figure 6), indicating that they were moving into the area as *baueri* departed. Most Bar-tailed Godwit departures from the north-west Australian non-breeding grounds occur in the first fortnight of April.
suggesting that *menzbieri* arriving on the west coast of Korea in May must stage somewhere *en route*. This idea is supported to some extent by the five Bar-tailed Godwits flagged in Chongming Dao (China) that were found in our study area. Three of these birds were found between 22 and 29 April, and another on 19 May. However, one Chongming Dao bird was found so early in the study period (3 April) that it seems unlikely to have staged in China before reaching Korea.

In view of the population turnover occurring in Bar-tailed Godwits, peak counts observed in late April must have been an underestimate of the total number of birds staging. Nevertheless, internationally significant numbers were found in both Saemangeum and the Geum Estuary. The most important roosts in the Geum Estuary were on Yubu Island (peak count of 9,000) and in Daemoe Harbour (peak count of 6,000). In Saemangeum Bar-tailed Godwits were reasonably widespread on roosts closest to outer estuarine tidal flats, with counts of over a thousand being made at Okgu, Simpo, the Gunsan US Air-Force BASE, a roost on the northern shores of the Dongjin River, and the south-west coast between the Dongjin River and the Saemangeum sea-wall.

**Little Curlew *Numenius minutus***

Singles or pairs were seen at three separate sites between 10 and 23 April (only one of these was seen in a spring tide period, but the others are included in the totals in Table 1.)

**Whimbrel *Numenius phaeopus***

A late migrant through the region, with numbers peaking in mid-May. Internationally significant numbers were found in Saemangeum, the Geum Estuary and Gomso Bay; they were widespread in the study region, occurring at most roosts. No colour-marked birds were seen, but this may reflect the low number that have been flagged – only c. 280 have been leg-flagged in Australia.

**Eurasian Curlew *Numenius arquata***

Internationally significant numbers were found in the Geum Estuary, mostly roosting on Yubu Island. Here they tended to roost separately from Eastern Curlews; at other sites where numbers were smaller, they often mingled with Eastern Curlew flocks and were therefore easily overlooked. In both the Geum Estuary and Saemangeum, numbers

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**Figure 6.** Timing of flag and band resightings of Bar-tailed Godwit and Great Knot from the Saemangeum area in April-May 2006.
increased between mid-April and late April, suggesting that the birds present included passage migrants. They may also have included birds that had spent the non-breeding season in the area (non-breeding counts of c. 1200 Eurasian Curlew have been made in the Geum Estuary, Lee et al. 2002). The highest previous count of Eurasian Curlews in the Geum Estuary (2,800 – 7.3 % of the flyway population) was made during southwards migration at the end of August (Barter 2002, Lee et al. 2002); consistent with this pattern, we counted 1,450 at Yubu Island on 24 September.

**Eastern Curlew Numenius madagascariensis**

Internationally significant numbers were counted in both Saemangeum and the Geum Estuary, with concentrations tending to be largest at the roosts closest to outer estuarine habitats. In the Geum Estuary counts were highest at Yubu Island, with good numbers also being found on Daejuk Island and adjacent mainland roosts. In Saemangeum, they were widespread but the largest numbers were seen south of the mouth of the Dongjin River, along the coast to the Saemangeum sea-wall.

Eastern Curlews were early migrants, and their numbers declined considerably between the middle and end of April; it is possible that their numbers peaked before our survey began. Five colour-marked individuals were seen, all from Victoria, south-east Australia (544 had been flagged in Victoria before our surveys, compared with 169 flagged in north-western Australia).

**Spotted Redshank Tringa erythropus**

Low numbers were seen, mostly at roosts on the inner shores of the Dongjin River (Saemangeum) and the Haemangdong and Gupo Tidal Flats of the Geum Estuary. Counts in Saemangeum were lower at the end of April than those in mid-April or mid-May; we do not know if this was caused by population turnover in this typically early migrant or by a failure to find roost sites in the late April counts.

**Common Redshank Tringa totanus**

Uncommon in the region; numbers at Saemangeum peaked in mid-May.

**Marsh Sandpiper Tringa stagnatilis**

Uncommon in the region; most seen were found in the inner Dongjin, or on ponds beside Okgu.

**Common Greenshank Tringa nebularia**

Common Greenshanks occurred in internationally significant numbers in the Geum Estuary and numbers approached this level in Saemangeum. They occurred in small numbers at nearly all roosts, with unusual concentrations of birds being found at a roost at Okgu (418 on 15 May) and on the tidal flats within the Geum River Channel (920 on 16 May). They were late migrants, with numbers increasing by a factor of 12 between late April and mid-May; a migratory departure of 74 birds from Namjeon Ri (Geum Estuary) was observed on 15 May, suggesting that migratory turnover may cause an underestimation of the number of birds staging in the region. A single individual leg-flagged in north-western Australia was found in the Geum Estuary on 16 May; about 150 Common Greenshank had been leg-flagged in north-western Australia and about 450 had been leg-flagged in Victoria at the time our survey began.

**Nordmann’s Greenshank Tringa guttifer**

This endangered species was found in internationally significant numbers in both Saemangeum and the Geum Estuary. Counts from the Geum were particularly noteworthy, with the 70 found in mid-May (including a single flock of 69 birds at Yubu Island) constituting about 7% of the world population. At the time of observation the Yubu Island flock appears to have been the largest concentration of this species seen in at least 20 years until a flock of 70 was found in Peninsular Malaysia on 3 February 2007 (David Li, posting to Asia-Pacific Migratory Bird network). Another concentration of Nordmann’s Greenshank was also found at Daejuk Island (25 birds on 26 April); other observations were of single birds or small flocks (less than 10 birds) at roosts relatively close to outer estuarine mudflats. Almost all of the Nordmann’s Greenshank seen at roosts were mingling with flocks of Grey Plover.

Internationally significant numbers of Nordmann’s Greenshank were also found in the Geum Estuary on southwards migration, with a minimum of 31 individuals (possibly as many as 38) being found at Yubu Island on 24–25 September 2006.

**Green Sandpiper Tringa ochropus**

A few birds were seen, mostly on freshwater wetlands or inner estuarine mudflats.

**Wood Sandpiper Tringa glareola**

A few birds were seen, mostly on freshwater wetlands or inner estuarine mudflats.

**Common Sandpiper Actitis hypoleucos**

A few birds were seen, mostly on freshwater wetlands or inner estuarine mudflats.

**Terek Sandpiper Xenus cinereus**

Internationally significant numbers were found in both Saemangeum and the Geum Estuary, with moderate numbers occurring on most roosts adjacent to outer estuarine mudflats; large numbers (579) were also found feeding on the Haemangdong and Gupo Tidal Flats of the Geum Estuary on 16 May. This species was a late migrant, with numbers increasing over five-fold between late April and mid-May. Five colour-marked birds were found: four from north-western Australia (where 3,679 birds had been flagged by 2005) and one from Chongming Dao, China. All these birds were found in mid-May, except for one north-west Australian bird found on 25 April. This may suggest that, as in Bar-tailed Godwit and Great Knot, a late influx of Terek
Sandpipers to the west coast of Korea consists largely of north-west Australian birds that have stayed in China.

**Grey-tailed Tattler Heteroscelus brevipes**

Fairly small numbers were seen, with the largest counts being made in Saemangeum (especially on the flats opposite the US Air Force base in Gunsan, and on the coast between the Dongjin River and the Saemangeum sea-wall). In the Geum Estuary, most birds were seen at Namjeon Ri. Grey-tailed Tattlers were late migrants with nearly all seen in mid-May. No colour-marked birds were seen.

**Ruddy Turnstone Arenaria interpres**

Internationally significant numbers were found in both Saemangeum (mostly at Simpo and near the Gunsan airbase) and the Geum Estuary (mostly on Yubu Island and at Namjeon Ri). They were late migrants, with numbers increasing three-fold between late April and mid-May. A single white-flagged bird, presumably from New Zealand, was seen at Simpo on 2 May.

**Great Knot Calidris tenuirostris**

The most abundant shorebird in the study region, with the total minimum count (116,126) comprising 30.6% of the world population of this species. Internationally significant numbers were found in Saemangeum (22.7% of the world population) and the Geum Estuary (7.9% of the world population), with only tiny numbers found at Gomso Bay (none during spring tide periods). Within Saemangeum, much the largest concentrations of Great Knot were found at Okgu, where there was a single flock of about 60,000 Great Knot at the end of April (three independent counts of this flock ranged from 56,000 to 60,840). By mid-May numbers of Great Knot at this locality dropped to 34,850, but there was a roughly corresponding increase in numbers at Simpo, where Great Knot numbers increased from 10,843 in late April to 40,000 in mid-May. This shift in distribution might have been a response to the shellfish die-off, as Great Knots were feeding on very extensive beds of dying shellfish in the Simpo area during May. Elsewhere in Saemangeum, Great Knots were found in moderate numbers (hundreds or low thousands) at several outer estuarine roosts. In May numbers increased considerably on the coast between the southern mouth of the Dongjin River and the Saemangeum sea-wall (225 in mid-April, none in late April, 9,874 in mid-May). In contrast, counts decreased during the survey period at inner estuarine roosts in the Dongjin (1,301 in mid-April, 1,030 in late April, 134 in mid-May) and no Great Knots were found at all at the innermost roosts of the Mangyeung River, at sites that have held up to 30,000 Great Knot on spring tides in previous years. These changes in distribution were probably related to the decreasing tidal range and shellfish die-off within Saemangeum following completion of the seawall.

In the Geum Estuary the largest roosts of Great Knot were found on Yubu Island (peaking at 23,190 on 16 May), Daejuk Island (maximum of 6,335 on 26 April) and Daemoe Harbour (maximum of 6,500 on 13 April). We suspect many Great Knots moved between these roosts, being forced to

Yubu Island on the highest tides. Great Knot numbers increased in the general region during the study period (Figure 5). Most of this increase occurred in the Geum Estuary, where counts almost doubled between the end of April and mid-May; in contrast Great Knot numbers in Saemangeum were almost equal in the late April and mid-May surveys. It is possible that some birds moved from Saemangeum to the Geum as habitat conditions within Saemangeum deteriorated. Alternatively, the increase in numbers of birds at the Geum might have been caused by incoming migrants selecting this site in preference to Saemangeum.

The latter interpretation is more consistent with sightings of colour-marked birds made during the expedition (Figure 6). Most colour-marked birds recorded were from north-western Australia (80) or mainland China (34), with smaller numbers from Victoria, south-east Australia (11), south-eastern Queensland, eastern Australia (2), Kamchatka, Russia (1) and South Korea (3). The number of colour-marked birds from eastern Australia was lower than that from north-western Australia, but this must to some extent be a reflection of the number of Great Knot flagged in both regions. By 2006, only 313 Great Knot had been flagged in Victoria and there were unlikely to be many flagged Great Knot in the flyway from Queensland, as flagging stopped there about six years ago; in contrast, 12,484 had been flagged in north-western Australia by the time we undertook our Korean fieldwork. Bearing this in mind, the colour-band records suggest that proportionately more Great Knot from eastern Australia migrate through South Korea than those from north-western Australia.

Numbers of birds from south-eastern Australia seemed reasonably consistent through the study period, but the proportion of sighted birds from north-western Australia and (especially) mainland China increased markedly in May. This suggested that birds from north-western Australia were moving into the region in May after staging in China, and we indeed had confirmation that staging in mainland China occurred. Eight of the sighted Chinese birds, all seen between 13 and 18 May, had been marked at Chongming Dao in March/April 2006 (flag colours at this site were reversed in 2006 so birds from this season could be distinguished from birds flagged in previous seasons). It is very likely that these birds had previously spent the non-breeding season in north-western Australia, as a strong migratory link between the Great Knots of north-western Australia and Chongming Dao has been established in the past (e.g. Battley et al. 2000).

Most migratory departures of Great Knot from the region are thought to have occurred between 15 May and 20 May. Few Great Knots could be found in the Simpo area after this period, although there was an abundance of dying shellfish to feed on, and there had been up to 40,000 Great Knot present there on 13 May. Average abdominal profiles of Great Knots in Saemangeum declined sharply after the middle of May (Figure 7), suggesting that the heaviest birds were departing on reaching departure mass. Abdominal profile scores in the Geum Estuary (on Yubu Island) were higher than those in Saemangeum in mid-May, suggesting that birds were experiencing better feeding conditions there,
Northward migration through Saemangeum

or perhaps that the heaviest birds had moved into the Geum from Saemangeum.

**Red Knot Calidris canutus**

An uncommon, late migrant through the region, usually found mingling with large flocks of Great Knot. Three leg-flagged birds were seen in Saemangeum on 14–15 May: one each from New Zealand, Victoria (south-eastern Australia) and north-western Australia.

**Sanderling Calidris alba**

Most birds seen were on sandy island roosts at Yubu Island (Geum Estuary) and off Okgu (Saemangeum), usually mingling with flocks of Dunlin and Lesser Sand Plover. Numbers were much higher in late April than in either mid-April or mid-May (Figure 6), suggesting that this species staged rather briefly; it is therefore likely that migratory turnover could have led to an underestimate of the number of Sanderling staging in the region. No colour-marked birds were seen.

**Red-necked Stint Calidris ruficollis**

Widespread within the study region, with the largest numbers being found at Okgu (over 2,000 on 13 and 15 May). This species was a late migrant, and numbers increased more than six-fold between late April and mid-May. Four leg-flagged birds from Victoria were seen; a bird with a white flag was probably a bird from previous banding work in Korea that had lost an orange flag.

**Temminck's Stint Calidris temminckii**

Two birds were seen in a brackish pond on Yubu Island on 13 and 15 April.

**Pectoral Sandpiper Calidris melanotus**

A single bird was seen on the inner Dongjin Estuary on 5 April.

**Sharp-tailed Sandpiper Calidris acuminata**

A late migrant through the area, with numbers increasing by a factor of 15 between late April and mid-May. The largest counts made were on the Haemangdong and Gupo Tidal Flats of the Geum Estuary, where 970 birds were found feeding on 16 May. In Saemangeum most Sharp-tailed Sandpipers were found at Okgu, with a peak of 459 on 15 May. A single colour-marked bird, flagged in Victoria, was found on the Gupo tidal flat (Geum Estuary) on 12 May.

**Curlew Sandpiper Calidris ferruginea**

An uncommon, late migrant through the region. No colour-marked birds were seen.
Dunlin *Calidris alpina*

The second most abundant shorebird species in the region; it was found on almost all roosts, although counts tended to be highest on those near outer estuarine tidal flats. Numbers of Dunlin increased gradually over the study period, peaking in mid-May. We do not know if migratory turnover in this species might have influenced our estimates of the numbers of staging birds. Dunlin have a broad breeding distribution, with many distinct subspecies that may have different migratory schedules, and the subspecies occurring in Saemangeum have not been fully resolved. Resightings of two colour-banded birds banded near Barrow in Alaska indicate that they include subspecies *arctica*, and the resighting of a bird flagged in Chukotka, Russia suggests that subspecies *sakhalina* is also present. Other leg-flagged Dunlin were seen from mainland China (n = 7), Taiwan (1) and South Korea (4).

*Spoon-billed Sandpiper* *Eurynorhynchus pygmeus*

An uncommon, late migrant through the region, but the world population of this species is so small (c. 1000 birds, Syroechkovsky 2005) that the numbers seen at Saemangeum are of international significance. The only concentrations seen were at Okgu (peak of 21 birds on 15 May) and Simpo (peak of 12 birds on 18 May), with singles also recorded opposite the Gunsan military airbase and the inner Dongjin. Single birds (possibly the same individual) were recorded at Yubu Island on 13 April and 17 May; the former record (on a neap tide and hence not included in Table 1) was unusually early in the season for this species in Korea. Fifteen Spoon-billed Sandpipers, including a colour-banded adult from the breeding grounds, were found during an opportunistic count at Yubu Island on 24 and 25 September 2006, confirming that the species also occurs in the Geum Estuary in internationally significant numbers. It is quite possible that we underestimated numbers of this species in both Saemangeum and the Geum Estuary, as it usually mingles at roosts with large flocks of similarly sized waders.

Spoon-billed Sandpipers at Simpo, Okgu and Yubu were usually active through much of high tide, feeding on the waterline on reasonably firm sandy substrates. They usually fed by pecking firmly at the substrate, with their bills angled at about 45 degrees. We were seldom able to identify the prey taken, but Jan van de Kam photographed an adult capturing a slender polychaete about 4 cm long.

*Broad-billed Sandpiper* *Limicola falcinellus*

A late migrant through the region; almost all birds seen were found in Saemangeum (at Okgu and the inner Dongjin) in mid-May. A bird leg-flagged in north-western Australia was found at Okgu on 15 May. Larger numbers were seen in the Geum Estuary on southwards migration (600 at Yubu Island on 24–25 September, all juveniles), a trend also noted in Saemangeum by Barter (2002).

*Ruff* *Philomachus pugnax*

An uncommon early migrant; most seen were found on the inner Dongjin (Saemangeum) in the first half of April.

Oriental Pratincole *Glareola maldivorum*

Single birds (possibly the same individual) were seen at Yubu and Taeching islands on 26 April.

**DISCUSSION**

Our surveys confirmed the importance of Saemangeum to shorebirds on northwards migration. Counts made in 2006 were broadly consistent with surveys in previous years by Moores (1999) and the Korean Ministry of Environment (Ministry of Environment 1998; KARICO 2003, 2004, 2005; for a summary of totals observed in these surveys, see Moores et al. 2006). For some species, the totals we observed were higher than previously recorded in Saemangeum: Eastern Oystercatcher, Common Greenshank, Nordmann’s Greenshank, Terek Sandpiper, Sanderling, Dunlin, Spoon-billed Sandpiper and Broad-billed Sandpiper. Internationally important counts of Eastern Oystercatcher, Common Greenshank, Nordmann’s Greenshank, Sanderling and Spoon-billed Sandpiper had not previously been published for Saemangeum during northwards migration (Barter 2002). It is unlikely that the higher counts of these species in Saemangeum in 2006 reflect a genuine change in population level. They are much more likely to reflect the intensive survey coverage we were able to achieve in April-May 2006, as our team was sufficiently large to visit all roost sites, and to count simultaneously at several different sites at the peak of high tide. Importantly, our team was also able to carry out counts throughout the migration period. Different species migrated through Saemangeum at different times, and there is no single date during northwards migration at which peak numbers of all species are present.

Counts made in the Geum Estuary turned out to be considerably higher than we had anticipated, with almost all species being found in higher numbers than previously reported. Overall we recorded a minimum of 82,993 shorebirds in the Geum Estuary, a considerable difference from the previously recorded peak of 34,198 shorebirds on northwards migration. These included 13 or 14 species that occurred in internationally significant numbers, and the second-highest count ever made in a single site of the endangered Nordmann’s Greenshank. Moreover, winter surveys have shown the Geum Estuary to support 57% of the world population of Eastern Oystercatcher. In short, the Geum Estuary is a site of very high conservation value and (given the deterioration that is likely to have occurred in Saemangeum over the past few months) it is probably the premier shorebird site remaining in South Korea. Unfortunately, it too is threatened with a major reclamation proposal (Lee et al. 2002).

In comparison with Saemangeum and the Geum Estuary, Gomso Bay is not an important shorebird site for species other than Whimbrel. The low numbers of shorebirds in Gomso Bay are somewhat surprising, given that the bay has extensive tidal flats, but presumably these do not support the benthic food supplies required by shorebirds.

The completion of the Saemangeum sea-wall had some immediately obvious ecological effects, the most striking of these being the reduction of the tidal range within Saemangeum and the resultant die-off of shellfish on the
intertidal flats. This die-off was in itself a considerable loss of biodiversity of the Saemangeum region; about 100 mollusc species are known from the estuarine waters of Saemangeum, including an extraordinary bivalve found only in symbiosis with the brachiopod *Lingula anatina*, which appears to be extremely rare outside Saemangeum, the Geum Estuary and Gomso Bay (Hong et al. 2007). In the short term, shorebirds may have managed to survive, and may even have benefited from, the shorebird die-off by eating the dying bivalves as they came to the surface. We suspect that by exploiting this temporary resource, most migratory shorebirds in Saemangeum were able to complete northwards migration in a reasonably normal manner in 2006. We did not have strong evidence for birds abandoning Saemangeum in April and May 2006, though the changes in food supplies might have prompted a possible movement of Great Knots from Saemangeum to the Geum Estuary in mid-May.

We can only speculate on the longer term effects of the sea-wall closure. At present the sea-wall gates have not been closed (for engineering reasons rather than conservation purposes) and there are still small tides within Saemangeum. The tidal range is now only about half a metre, and the intertidal area is perhaps only 10% of its previous size, but in such a large tidal system, this still amounts to a large intertidal area of potential conservation significance to shorebirds. However, the quality of the benthic prey reserves in the remaining intertidal area will be very much dependent on management of the sluice gates. Sato (2006) has demonstrated that in a reclamation in Japan most molluscs were killed by salinity changes or hypoxia shortly after sea-wall closure, but that a few species were reasonably tolerant of these changes and survived (and even increased) for some time, though these too died off eventually in the absence of improvement of environmental conditions. If the Saemangeum reclamation project is completed as planned, complete loss of the intertidal habitats is inevitable, as the plans involve conversion of the entire area to land and a freshwater lake system. Over half of the shorebird species occurring in the Saemangeum area are restricted to intertidal habitats during the non-breeding season and while staging, including most species for which this site is of particular conservation importance (e.g. Great Knot, Eastern Oystercatcher, Nordmann’s Greenshank and Spoon-billed Sandpiper). These species will presumably be lost from the Saemangeum system, as will the local shellfishery industry, which is estimated to provide a livelihood for 25,000 people (Moores et al. 2006, Hong et al. 2007).

Shorebirds that are unable to feed at Saemangeum will presumably look for alternative staging areas, but it is quite likely that they will have difficulty finding suitable sites, especially when the numbers of displaced birds (potentially c. 200,000 on northwards migration) are considered. Furthermore, our data suggested that for most species, Saemangeum was, in the northern spring of 2006, a site where a good deal of pre-migratory mass gain occurs. In more than half the species present, shorebird numbers built up during April and early May, with departure dates in the last half of May occurring shortly before snowmelt is likely to begin on the breeding grounds. In Great Knots, for example, average abdominal profiles increased through April and mid-May, with many individuals reaching the maximum fat stages of 4 or 5; most departures from the Saemangeum region appeared to occur between 15 and 20 May, and peak arrivals of this species on the breeding grounds (c. 4,000 km away) occur only a few days later, on 22 to 23 May (Tomkovich 1997). It therefore seems probable that Great Knots use Saemangeum as the final staging point before undertaking a long migratory flight to the breeding grounds.

It is likely that the Saemangeum reclamation will cause population declines in migratory shorebirds, and if this occurs, the effect should in theory be detectable on the non-breeding grounds. Resightings of colour-marked birds suggested that for a number of species (e.g. Great Knot, Bar-tailed Godwit, Eastern Curlew, Red-necked Stint) the majority of migrants through Saemangeum have migrated from eastern Australia or New Zealand. In at least two species, Bar-tailed Godwit and Great Knot, there was evidence of an influx of migrants from north-western Australia late in the migration period, in at least the case of Great Knots occurring after they had staged on the coast of mainland China. Careful monitoring of shorebird populations in eastern and north-western Australia and New Zealand is therefore of considerable importance in documentation of the effects of the Saemangeum reclamation.

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