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What does the future hold for shorebirds in the East Asian–Australasian Flyway?

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Long-distance migratory shorebirds around the world are in trouble (International Wader Study Group 2003) and, although alarming rates of decline have been reported from the American (Morrison *et al*. 2004) and European Flyways (van der Vliet *et al*. 2015), some of the steepest and most widespread declines are seen in the East Asian–Australasian Flyway (EAAF) (Amano *et al*. 2010). The EAAF encompasses 22 countries from the high Arctic to Australia and New Zealand. Some shorebirds cover the entire length of the Flyway, completing a 30 000-km round-trip migration every year (Fig. 1). Management of the EAAF is hugely challenging, with vast human pressure on habitats and resources in individual countries combining to degrade the migratory landscape for birds on the move. This is especially true around the Yellow Sea region of East Asia (MacKinnon *et al*. 2012).

It was the pioneering work of Mark Barter (2002) that brought the Yellow Sea to world attention nearly 15 years ago. He estimated that more than 2 million shorebirds used the region during northward migration, but his experiences in China dramatically highlighted the rate at which tidal flats were being converted to land by coastal engineers (land claim, often referred to as reclamation): river mouths no longer existed and seawalls were kilometres off shores shown on previous satellite images. Since this time, numerous studies have described the massive extent of land claim around the Yellow Sea (Choi 2014; Wang *et al*. 2014; Murray *et al*. 2015; Piersma *et al*. 2016) and research has sought to identify the likely effects on shorebirds of complex losses of staging sites (Rogers *et al*. 2010; Piersma *et al*. 2016). Barter also identified other threats around the Yellow Sea, threats that are now diversifying and intensifying across the Flyway. Meanwhile, shorebird numbers are declining, sometimes drastically (BirdLife International 2015), indicating that conservation efforts have been inadequate or ineffective at stopping declines.

Clearly, the scale and importance of these habitat changes on migratory shorebirds is becoming evident. But there is still much to learn. Colour-marking has greatly contributed to the knowledge about links between sites (Minton *et al*. 2006), which is now being incorporated into models of migration (Iwamura *et al*. 2013), and studies using remote tracking have described migratory pathways and strategies to a level of detail that was previously unattainable (Gill *et al*. 2009; Conklin *et al*. 2010; Battley *et al*. 2012; Minton *et al*. 2013). A burning issue now is whether birds can successfully relocate to alternative sites when traditional sites disappear.

Although action is urgently needed in the Yellow Sea, shorebird conservation across the EAAF requires a cooperative approach to understand the full suite of threats and how those threats are affecting populations. Further efforts are needed to identify the key staging and non-breeding habitats in South-East Asia so that those habitats can be managed and protected. Efforts to minimise losses of shorebird populations at local wetlands need to continue at non-breeding habitats throughout the Flyway, with those sites of greatest conservation value being prioritised. Demographic research is needed to determine whether reduced breeding success or survival, or both, are contributing to rapid declines in individual species (BirdLife International 2015). In the longer term, the effects of climate change will need to be understood, both on the breeding grounds (Liebezeit *et al*. 2014) and at coastal habitats affected by sea-level rise (Iwamura *et al*. 2013), with a view to mitigating those impacts if possible. Finally, monitoring and analysis of shorebird populations needs to continue and improve in order to determine where intervention is most urgently needed, and whether conservation actions are delivering the intended restoration of shorebird populations to historical levels or at least arresting ongoing declines.

About the papers in this issue

The fundamental aim of the special issue is to highlight the plight of shorebirds migrating within the EAAF. In some ways this should not be necessary, as the precarious state of the Flyway is well recognised, but complex management scenarios require diverse and detailed information. Multiple lines of evidence may be needed to sway reluctant agencies, and understanding of the scale and causes of population declines is pivotal to this. There is a need to understand current and emerging threats, as well as habitat networks and the reliance of species on sites. The papers in this special issue bring new insight to how and when shorebirds move around the Flyway, into the challenges they face, and the challenges faced by site managers.

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Fig. 1. The East Asian–Australasian Flyway represents one of nine major global avian migratory flyways, and extends from the Alaskan and Siberian breeding grounds to the non-breeding grounds in Australia and New Zealand. Fifty four shorebird species use this Flyway (Bamford *et al*. 2008).

Melville *et al*. (2016) focus on the threats along the Chinese Yellow Sea coast, which is of critical importance to threatened and declining species such as the Spoon-billed Sandpiper (*Calidris pygmaea*), a species that, during migration, uses sites in the Yellow Sea almost exclusively. Despite the crucial international importance of the Chinese coastline to shorebirds, economic development is having massive and diverse effects on their coastal habitats. Melville *et al.*'s (2016) review is extensive, and as is the case with several other papers in this special issue, a wealth of additional information is presented in the online supplementary material. Whereas reclamation of tidal flats for industry, port developments and aquaculture is clearly the most pressing issue, the remaining tidal flats face reduced sediment deposition, colonisation by an invasive weed (*Spartina*), high levels of pollution, the risk of oil-spills, wind-turbine strike and unmanaged wild harvesting of tidal infauna. Most of the Chinese coast is not managed for shorebirds – and even protected areas are subject to land claim. In their review, Melville *et al.* (2016) suggest some priorities for safeguarding shorebird populations on China's Yellow Sea coast. The problems are daunting but it is encouraging that in 2013, China's Central Government proposed The Ecological Protection Red Line to protect critical sites (Zhang *et al*. in press).

The importance of internationally coordinated management strategies is made obvious when evaluating population changes in migratory birds. Clemens *et al*. (2016) examine geographic variation in shorebird population trends within Australia. Using a citizen-science framework, they bring together long-term population databases for Australian populations of 19 species of migratory shorebird. Twelve species show significant declines Australia-wide; declines occurred concurrently at multiple independent sites, with some species-specific associations between rates of decline and latitude, but no clear associations with local habitat quality. It follows that factors extrinsic to Australia are primarily responsible for the large-scale declines seen across species. This theme is continued by Moores *et al*. (2016), who document the decline in shorebird numbers brought by construction of a massive seawall at Saemangeum, in the Republic of Korea. Unsurprisingly, the reclamation caused catastrophic local declines in shorebird numbers, with some 20% of the Great Knot (*Calidris tenuirostris*) population of the Flyway among the shorebirds that have disappeared. Even more disturbingly, there was no evidence of shorebirds displaced from Saemangeum relocating to any of the other remaining shorebird sites on the coast of the Republic of Korea, most of which were impacted upon to varying extents by other reclamation projects. Proponents of development have often claimed that shorebirds displaced by reclamation of tidal flats will simply move to other sites, but the study of Moores *et al*. suggests that habitat loss on the Yellow Sea coast has been so extensive that displaced shorebirds have nowhere to go.

As pressure increases on the remaining suitable habitat within the EAAF, the amount of disturbance to the remaining sites is likely to increase. Quantifying the impact of these effects is the motivation behind the work of Lilleyman *et al*. (2016). Assessing the effects of disturbance on the feeding behaviour of both sand plovers (*Charadrius* spp.) and knots (*Calidris* spp.), the authors estimate how the daily energy budget of these species would be affected by daily disturbances when feeding on mudflats near Darwin, Australia. These effects compound the pressures on declining shorebird populations and need to be taken into account when considering development decisions that will affect the remaining sites.

A challenge in understanding population dynamics changes is how effects at the individual level are reflected at the population level. Conklin *et al*. (2016) document declining rates of survival of adult Bar-tailed Godwits (*Limosa lapponica baueri* at non-breeding sites in New Zealand, declines that correspond with declining survival of another subspecies of Bar-tailed Godwit (*L. l. menzbieri*) at non-breeding sites in north-western Australia (Piersma *et al*. 2016). These two subspecies of Bar-tailed Godwit breed on different continents and migrate to non-breeding destinations that are thousands of kilometres apart. The common thread is that they share the same staging areas on the Yellow Sea coast, and it seems plausible that changes in these staging sites have driven their declines in survival. However, the declining survival rates in New Zealand reported by Conklin *et al*. occurred during a period when census data suggested that Godwit numbers were reasonably stable, a situation that could only be maintained with increasing recruitment of young Bar-tailed Godwits. The declining survival of adult Bar-tailed Godwits renders the species vulnerable to dramatic declines should there be consecutive years of low breeding success, which often occur in Arctic-breeding shorebirds (Underhill *et al*. 1993; Aharon-Rotman *et al*. 2015). Conklin *et al*.'s paper highlights the importance of using more than one monitoring approach if future trends are to be predicted.

Subspecies are also compared by Verhoeven *et al*. (2016), who assess the compromises that must be reached in the competing demands of moult and migration in Red Knots (*Calidris canutus*), examining the influence of age, sex and subspecies. Unexpectedly, they found that departure dates from the non-breeding grounds were driven more by non-breeding origin rather than breeding destination; as a result, Red Knots from north-western Australia have a shorter period available to refuel in the Yellow Sea than do Red Knots from New Zealand. Red Knots from the two regions may therefore show different responses to loss of staging areas in Asia.

Uncovering the exact routes and schedules of migration of shorebirds is critical to the identification (and protection) of the sites on which they depend. Lisovski *et al*. (2016) analysed geolocator data from migrating Sanderlings (*Calidris alba*), describing a new analytical approach that makes it possible to track birds with higher precision. In addition to describing the migration routes of Australian Sanderlings to an unprecedented level of detail, they compare the resultant picture of migration with that obtained from count data and resightings of leg-flagged birds. The findings highlight biases in direct observational data that need to be taken into account when unravelling migration strategies.

Although highly desirable, migration studies using remote tracking data are not yet feasible for many shorebird species in the EAAF, and other data, especially counts, are necessarily used in establishing conservation priorities. Much of the migration research carried out in the EAAF has focussed on northwards migration, and far less is known about stopover strategies of southbound migrants. This problem is tackled by Choi *et al*. (2016), who make the first cross-species comparison of the phenology of shorebirds on southward migration in this Flyway. Their count-based models indicate that whereas arrivals of large migratory shorebird species in Australia are consistent with a non-stop flight from the Yellow Sea, arrival times of smaller shorebird species indicate additional stops during southward migration. This is perhaps unsurprising (and is consistent with the Sanderling remote-tracking results of Lisovski *et al*. 2016), but it highlights the urgent need to identify the many sites used by smaller species, in addition to protecting key sites that are already known. The modelling approach uses repeated counts carried out at a site at intervals of 1 month or less, and much data of this kind in the EAAF remain unexplored.

In their paper Zhou *et al*. (2016) examine the degree to which the migratory strategies of species using the EAAF overlap and whether as a consequence species might be competing for resources locally. They conclude that the northward migration (in the boreal spring) is more synchronous than southward migration in the boreal autumn, the drivers being selection for an optimal arrival time for breeding in relation to the location of the breeding ground and body size. This paper highlights not only the selection pressure on species to optimise migratory strategies, but also the coevolution of species within a network of migrating shorebird species, some of whom compete for resources and habitat.

Aharon-Rotman *et al*. (2016) use a modelling approach to test the importance of wintering habitat quality for population stability, focussing on the Ruddy Turnstone (*Arenaria interpres*), a species in which migration routes and schedules are particularly well known through intensive geolocator studies (Minton *et al*. 2010, 2013). Their study models the responses expected under different habitat degradation regimes that reduce foraging intake by different amounts. Although confirming the importance of Asian staging sites, the modelling highlights still more strongly the importance of high-quality non-breeding habitat in Australia, where shorebirds fuel for the longest single flight of their northward migration. Combining what is known of migration strategies with theoretical considerations on necessary extent and rate of fuel-gain provides a different perspective on conservation priorities. While the problems in the Yellow Sea weigh heavily on the minds of shorebird ecologists, it is clear that conservation effort throughout the range of shorebird species is essential. With this in mind, Dhanjal-Adams *et al*. (2016) attempt for the first time to document the intertidal habitats available to shorebirds in Australia. By documenting where these sites occur and highlighting the state-level conservation legislation that protects them, the authors seek to highlight the areas of most conservation concern for the future.

Finally, the complexities associated with the management of a vast network that transcends international boundaries are highlighted by Szabo *et al*. (2016). In their review they discuss the economic drivers for development, rather than conservation of key shorebird habitat. Whereas the challenges of both brokering and implementing any international agreements are obvious, there is considerable international motivation to improve the situation. The effectiveness of bilateral and multilateral environmental agreements depends on their provisions being translated into national policy, legislation, actions and financing. In this, they are competing with policies, plans and financing from other sectors, usually more powerful and better funded, that may have contradictory directives governing the same habitats. The existence of bodies such as the East Asian–Australasian Flyway Partnership provides a mechanism for international governmental and non-governmental organisations to work together to achieve meaningful change.

Further hope comes from the passion that shorebirds inspire. A disproportionate number of birdwatchers devote their main energies towards shorebirds and they facilitate intensive research and advocacy efforts. Most of the papers in this special issue would not have been possible without the intensive input of amateurs; their roles have not only included data collection (which would otherwise be prohibitively expensive; see Minton 2015), but often project conception, analyses and active co-authorship. It is fairly unusual for large shorebird research projects to be fully funded in this flyway, with some of the most important initiatives having been built upon funding from Europe (e.g. Piersma *et al*. 2016) or the USA (e.g. Gill *et al*. 2009) rather than local sources. Even in these cases, scientists would acknowledge that the largely unpaid shorebird community has played an important role in giving shorebirds such a profile that funds are available for conservation-oriented research.

There is a further reason for hope: the shorebirds themselves. Although much of this special issue focusses on applied conservation issues, scattered throughout the papers is abundant evidence of the superb adaptations of shorebirds to their specialised life history. Tiny Sanderlings migrating from South Australia to the Arctic in only 40 days; Red Knots that migrate 6000 to 10 000 km from their non-breeding grounds to one small (but high-quality) staging area in Bohai Bay before undertaking another huge flight to breeding areas that they unerringly locate (Tomkovich *et al*. 2013); Bar-tailed Godwits making the longest non-stop journey known in the animal kingdom, directly across the Pacific from Alaska to New Zealand (Gill *et al*. 2009). The ability of shorebirds to make these remarkable movements is testimony not only to their flight abilities, but also to their ability to locate foraging grounds spread across huge areas and to exploit them efficiently enough to refuel on a tight schedule. Considering the huge pressure their habitats now face, perhaps one of the questions we should be asking about shorebirds in the EAAF is why their declines have not been more severe. Applied research on shorebirds is essential to determine priorities for conservation effort and to understand how to manage appropriately the crucial sites on which shorebirds depend. But curiosity-driven research on shorebirds should not be neglected. It is the stories of how and why shorebirds make their extraordinary migrations that engage the public, and ultimately, hopefully, the governments and other decision-makers on whom the continued survival of shorebirds depends.

Over a decade ago, Mark Barter's *Shorebirds of the Yellow Sea* was reviewed in *Emu Austral Ornithology* and the author noted that the publication was timely, yet also potentially a timepiece (Battley 2004). The review ended with the hope that we will look back on *Shorebirds of the Yellow Sea* as having been a stimulus for increased shorebird work in Asia, rather than a document of 'what used to be'. It is clear that Mark Barter's legacy in terms of monitoring and research initiatives around the Flyway is immense and it is for this reason that this special issue is dedicated to Mark's memory (1940–2011). Mark would acknowledge that the challenge remains to turn this increased knowledge into effective conservation action.

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