Revision of the East Asian-Australasian Flyway Population Estimates for 37 listed Migratory Shorebird Species

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Cover image: Bar-tailed Godwit *Limosa lapponica baueri*, Nome, Alaska by Dan Weller.

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Executive summary

This report provides an update of population estimates for the 37 species of migratory shorebirds in the East Asian - Australasian Flyway (EAAF) that regularly visit Australia. Population estimates for shorebirds in the EAAF are important in application of Australia's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The EPBC Act is triggered when proposed actions, such as developments or land use changes, are likely to have a significant impact on important habitat for migratory shorebirds, defined by criteria outlined in the Convention on Wetlands of International Importance (Ramsar Convention) and the Wildlife Conservation Plan for Migratory Shorebirds (2015). In these conservation instruments, shorebird habitat is considered internationally important if it regularly supports 1% of the EAAF population of a migratory shorebird species, and nationally important, under the Wildlife Conservation Plan for Migratory Shorebirds, if it regularly supports 0.1% of an EAAF population of any migratory shorebird species (with the exception of Latham's Snipe, for which the threshold is 0.05%).

An update of the EAAF estimates was considered important for several reasons. First, recent studies have demonstrated ongoing declines many species of migratory shorebird in Australia, so their populations may now be lower than they were at the time of the last assessment of shorebird populations in the EAAF. Secondly, there are now more shorebird count data on which to base population estimates. With the establishment of the Shorebirds 2020 program in 2007, there has been an increase in volunteer participation and site coverage in Australian shorebird counts; similarly, site coverage by shorebird counters is increasing in many other EAAF countries. Thirdly, accurate population estimates are needed to assess whether land development proposals should be referred for assessment under the EPBC Act. Finally, previous estimates of EAAF populations have not attempted to quantify the number of shorebirds in regions where no surveys have been done. The availability of more powerful analysis tools has enabled the interrogation of existing data in order to estimate numbers of non-counted shorebirds in remote and rarely visited regions.

Analytical approaches used in this project varied between species, according to data availability. Broadly, we collated shorebird counts carried out in the shorebird non-breeding season (November-March) from Australia (Shorebirds 2020 program), New Zealand (Ornithological Society of New Zealand) and 16 countries in Asia (Asian Waterbird Census). Generally, we calculated average numbers over the past five years on a site-by-site basis. We estimated the extent of unsurveyed coastal shorebird habitat using a global bathymetry map and a spatially-explicit global model of tidal amplitude to identify regions where tidal flats that could support shorebirds may occur. An extrapolation process was then used to estimate the number of shorebirds expected in these unsurveyed areas. Extensive consultation with shorebird counters and other experts with detailed local knowledge helped refine regional estimates and extrapolations.

For 18 (mainly coastal) species with the most reliable and extensive count data, we found a strong relationship between the population estimates, and breeding range and density.

The resultant model was used to estimate flyway populations for the remaining 19 shorebird species considered in this study, many of which are significantly undercounted on their non-breeding grounds because they occur in sites or habitats where few surveys are done.

Our work in compiling these population estimates has revealed a number of important knowledge gaps, which should be addressed in order to inform future revisions:

- inadequate shorebird monitoring across northern and inland Australia;

- the need for further exploration for shorebird sites in Indonesia and Papua New Guinea;
- a lack of intertidal habitat mapping around the flyway;
- a lack of mapping of shorebird count areas outside Australia.

We emphasize that any differences between these estimates and previous estimates cannot be used to draw conclusions about population change. The reader must instead refer to specialist studies aimed at detecting trends. Many of our estimates are higher than previous figures, principally as a result of improved knowledge about shorebird populations including increased count coverage, the estimation of shorebird numbers in unsurveyed areas and the use of an estimate based on breeding range size for non-coastal species. Nevertheless, ongoing population declines swamped these effects in some species, with current flyway population estimates now lower than previous assessments.

Common Name	Final population estimate	1% Flyway Population	0.1% Flyway Population
Asian Dowitcher	14,000	140	14
Bar-tailed Godwit	325,000	3250	325
Black-tailed Godwit	160,000	1600	160
Broad-billed Sandpiper	30,000	300	30
Common Greenshank	110,000	1100	110
Common Redshank	75,000-150,000	750	75
Common Sandpiper	190,000	1900	190
Curlew Sandpiper	90,000	900	90
Double-banded Plover	19,000	190	19
Far Eastern Curlew	35,000	350	35
Great Knot	425,000	4250	425
Greater Sand Plover	200,000-300,000	2000	200
Grey Plover	80,000	800	80
Grey-tailed Tattler	70,000	700	70
Latham's Snipe	30,000	300	30
Lesser Sand Plover	180,000-275,000	1800	180
Little Curlew	110,000	1100	110
Little Ringed Plover	150,000	1500	150
Long-toed Stint	230,000	2300	230
Marsh Sandpiper	130,000	1300	130
Oriental Plover	230,000	2300	230
Oriental Pratincole	2,880,000	28,800	2880
Pacific Golden Plover	120,000	1200	120
Pectoral Sandpiper	1,220,000-1,930,000	12,200	1220
Pin-tailed Snipe	170,000	1700	170
Red Knot	110,000	1100	110
Red-necked Phalarope	250,000	2500	250
Red-necked Stint	475,000	4750	475
Ruddy Turnstone	30,000	300	30
Ruff	25,000-100,000	250	25
Sanderling	30,000	300	30
Sharp-tailed Sandpiper	85,000	850	85
Swinhoe's Snipe	40,000	400	40
Terek Sandpiper	50,000	500	50
Wandering Tattler	10,000-25,000	100	10
Whimbrel	65,000	650	65
Wood Sandpiper	130,000	1300	130

Introduction

The conservation of migratory shorebirds poses a significant management challenge. Most migratory shorebirds that occur in Australia breed in the northern hemisphere and their annual migration routes encompass a wide variety of landscapes spanning many countries. In addition, the populations that spend the non-breeding season in Australia are often part of broader populations that also occur elsewhere. Thus, the actions in one country can result in changes to shorebird numbers in others.

In recognition of the need for international action to maintain migratory bird populations, Australia has signed bilateral agreements with China, Japan and the Republic of Korea to protect shorebirds and their habitats, and all are signatories to the Convention for the Protection of Wetlands of International Importance (Ramsar Convention). This brings with it the need to identify key habitats that support shorebirds throughout their annual cycle. To determine whether a site is nationally or internationally important, a robust understanding of population sizes and distribution is necessary.

The East Asian-Australasian Flyway

A flyway represents the collective migration routes of waterbirds, including shorebirds, between their breeding and non-breeding areas. There are nine flyways globally: the East Asian - Australasian Flyway (EAAF) encompasses Australia, New Zealand and another 21 countries, spanning nearly 120 degrees of latitude north to the Arctic. Many of the migratory species occurring in Australia also occur in other flyways. As the most appropriate unit for conservation and management of migratory species is often the flyway (Bamford et al. 2008, Musgrove et al. 2011), it is most convenient to treat occurrences of species in the EAAF as distinct units for conservation. To the east of the EAAF is the Central Pacific Flyway and to the west is the Central Asian Flyway (Figure 1).

Both the Ramsar Convention and the Convention on the Conservation of Migratory Species of Wild Animals have given considerable attention to developing guidelines on defining geographic populations. The Ramsar Convention has provided detailed guidance on flyways, populations and identifying sites of international importance based on supporting 1% of a population of waterbirds (Ramsar Resolution XI.8 Annex 2). Wetlands International hosts the Waterbird Population Estimates (WPE) online database which provides current and historic estimates, trends and 1% thresholds for waterbirds (http://wpe.wetlands.org). These estimates are updated every three years.

Population trends

Across the globe, migratory shorebirds are declining rapidly. These declines are prominent in the East Asian-Australasian Flyway, with significant regional declines identified in at least 18 species (Appendix 1). Recent research has highlighted the impact of changes in land use on shorebirds, in particular, loss of intertidal staging habitat in the Yellow Sea (Murray et al. 2014; Piersma et al. 2016).

Highlighting the rapidity of the declines, six migratory shorebird taxa were added to the EPBC Act threatened species list in May 2016. Bar-tailed Godwit (*Limosa lapponica menzbieri*) and Great Knot (*Calidris tenuirostris*) were listed as Critically Endangered, Red Knot (*Calidris canutus*) and Lesser Sand Plover (*Charadrius mongolus*) were listed as Endangered, and Bar-tailed Godwit (*Limosa lapponica baueri*) and Greater Sand Plover (*Charadrius leschenaultii*) were listed as Vulnerable.

This follows two previous threatened species listings in May 2015, of Eastern Curlew *Numenius madagascariensis* and Curlew Sandpiper *Calidris ferruginea*, both which were classified as Critically Endangered.

Why is an EAAF population estimate revision necessary?

Frequent revisions of any set of population estimates are needed to keep information current and relevant (Andres et al. 2012). There are two reasons why a revision of migratory shorebird populations in the EAAF is now required. First, many species are in rapid decline, some declining by several percent per year (Wilson et al. 2011; Clemens et al. 2016; Studds et al. in review). Existing population estimates are based on data collected between the mid 1980s and 2007 (Bamford et al. 2008), and will thus not reflect the rapid declines that have occurred in many species.

Second, there are now more shorebird data from more places than ever before. It is thus imperative that population estimates are able to take account of newly emerging information. Because population estimates form the basis for threshold-based conservation designations, their accuracy will better improve conservation decisions (e.g. whether or not a site should be designated a Ramsar site under Criterion 6 of the Ramsar Convention, or to guide identification of important habitat under the Australian Wildlife Conservation Plan for Migratory Shorebirds).

Species, subspecies and geographic populations

The focus of this revision is the 37 migratory species that regularly and predictably visit Australia during their non-breeding season (Table 1), and are thus listed under the EPBC Act as "migratory" (Commonwealth of Australia 2015). These include 34 species that were the focus of the previous flyway population estimate review (Bamford et al. 2008), plus three additional species: Pin-tailed Snipe (*Gallinago stenura*), Pectoral Sandpiper (*Calidris melanotos*) and Wandering Tattler (*Tringa incana*).

There are six species that have two or more recognised subspecies or distinct populations in the EAAF: Bar-tailed Godwit (two subspecies *menzbieri* and *baueri*), Common Redshank (*Tringa totanus*; three subspecies *ussuriensis*, *terrignotae* and *craggi*), Lesser Sand Plover (four subspecies *mongolus*, *atrifrons*, *schaeferi*, and *stegmanni*), Little Ringed Plover (*Charadrius dubius;* three subspecies *dubius, curonicus* and *jerdoni*), Red Knot (two subspecies *piersmai* and *rogersi*) and Pacific Golden Plover (*Pluvialis fulva*; one subspecies currently, but divided into two distinct populations: East/South-east Asia / Australasia and Oceania, and the Pacific Islands; Wetlands International 2016).

The Convention on the Conservation of Migratory Species of Wild Animals and the Ramsar Convention encourage conservation action at the "geographic population" level. However, it is often difficult to identify different "populations" of a species in the field which makes is very difficult to assign birds at a particular non-breeding site to the "population" level. This update of the flyway population estimates for the migratory shorebirds regularly visiting Australia has been conducted at the species level.

Spatial and temporal coverage

Most populations of migratory shorebirds that visit Australia migrate solely within the EAAF. However some populations visiting Australia migrate in the Central Pacific Flyway (Wandering Tattler, one population of Pacific Golden Plover) and one may breed in the Central Asian Flyway (Ruff *Calidris pugnax*).

The 37 species considered in this study vary considerably in their habitat requirements, breeding and non-breeding distributions. Some of the species we consider, such as Red Knot, are coastal obligates during the non-breeding season in Australia and New Zealand, where it is possible to count most of the population directly.

In some species the majority of the non-breeding population occurs in regions or habitats with few or no shorebird surveys; some other species (e.g. *Gallinago* snipes) have cryptic behaviour and a low tendency to congregate, making them very difficult to survey using methods traditionally used for other shorebirds. As these interspecific differences are so striking, it is not possible to use a single approach to derive flyway population estimates for all species. We have thus taken a pragmatic approach, using methods appropriate to the particular biology and data availability for each species, rather than a one-size-fits-all approach.

In the EAAF, shorebird monitoring data are captured in three main databases: (1) the BirdLife Australia Shorebirds 2020 program (referred to hereafter as S2020; previously known as the Australasian Wader Studies Group Population Monitoring Program), (2) the Ornithological Society of New Zealand National Wader Count Scheme and (3) the Asian Waterbird Census (AWC, coordinated by Wetlands International). These three databases form the primary quantitative data compiled here.

In Australia, shorebird counting is undertaken mostly by volunteers and is conducted at least biannually (austral summer and winter). Nearly 3500 sites supporting migratory shorebirds have been surveyed around Australia, but only a small proportion of these are regularly monitored and consistently counted in a repeatable manner. This presents difficulties for the exhaustive compilation of population estimates, particularly at national or international scales, as there is much variation in count effort among sites, and many sites that are not routinely counted are known or likely to support large numbers of shorebirds (Clemens et al. 2012). This is simply a reflection of the sheer scale of the coastline and the number of observers required to cover such vast areas in a short time period. Therefore, a major shortcoming of data from many regions is that shorebird counts only represent a certain proportion of the number of birds actually present (see Wilson et al. 2011 for a full discussion of errors in shorebird count data). This issue has received only limited attention in past population estimates due to the difficulty of accounting for spatial gaps when analysing count data. Addressing the issue of undercounting is a key focus of this revision and is embedded in the methodology.

We focus on count data from the ten year period between 2005/2006 and 2014/2015, a time bracket narrow enough to tie the estimates to relatively specific point in time, yet wide enough to allow us to use a broad range of data. We focus on the months November to March inclusive, which is during the middle of the non-breeding season for all species except the southern-hemisphere breeding Double-banded Plover (*Charadrius bicinctus*), and is a period when movement between non-breeding sites is considered at its minimum. Counts from the northward (March-May) and southward (August-November) migration periods are not included in our formal analyses, although consideration of turnover at staging sites can provide insights to population sizes when a species is known to stage in restricted locations (e.g. Red Knot in the northern Bohai Bay; Rogers et al. 2010). The one exception to this seasonal pattern is the Double-banded Plover, which breeds in New Zealand during the austral summer, and part of the population migrates to Australia during winter. The target data period for that species was April-July.

For some species, too few counts are available from the non-breeding grounds to make realistic assessments of population size. In these situations, we have attempted to estimate population sizes based on their distribution and density on the breeding grounds, and although such data are often patchy, for some species it is the best information available. Using those species sampled most effectively on the non-breeding grounds we have modelled the relationship between size of breeding range and population size, an approach that allowed us to estimate flyway population for species that we consider are undercounted in existing shorebird monitoring programs.

Methods

Flyway survey areas & data sources

The focus of this study is the 23 countries of the EAAF, namely Australia, New Zealand, Papua New Guinea, Timor Leste, Indonesia, Brunei, Singapore, Malaysia, Bangladesh, Myanmar, Cambodia, Thailand, Laos, Vietnam, Philippines, Japan, Republic of Korea, Democratic People's Republic of Korea, People's Republic of China, People's Republic of China (Chinese Taipei), Mongolia, Russian Federation, United States of America (State of Alaska). The EAAF overlaps with the Central Pacific and Central Asian Flyways.

Sources of regular count data were the Australian Shorebirds 2020 (S2020) program, Queensland Wader Study Group (QWSG) database, Ornithological Society of New Zealand (OSNZ) national wader count database, and the Asian Waterbird Census (AWC) database administered by Wetlands International. Additional count data were sourced through the literature and communication with other shorebird researchers and survey coordinators. These were used to supplement the three main databases, which are deficient in some regions during certain time periods (Appendix 2).

Shorebird count data were sourced from all countries in the EAAF except Laos, Democratic People's Republic of Korea, Mongolia, Russian Federation and Alaska (USA), omissions that either have little numerical impact on the estimates, or are areas known not to support non-breeding populations of our focal species during the target analysis period (November-March). Data from Palau from the 2015-2016 austral summer (G. McKinlay pers. comm.) were incorporated into the estimates because the location of Palau places it in the flyway despite the fact it is not currently recognised as part of the EAAF (Appendix 2).

As with the previous EAAF population estimates revision (Bamford et al. 2008), it was beyond the scope of this project to systematically vet all records. However, data quality assessment and control processes have improved substantially since the previous revision, and conspicuous errors in species identifications and counts were of course corrected where these were noticed either by the project team or during the expert review process.

Data extraction & summary

Australia

To update the S2020 database prior to a complete database extraction, targeted engagement with regional counters was undertaken over the 2015-2016 summer period to;

- instigate surveys in areas which had not been covered in recent years (e.g. Port Pirie and Anderson Inlet);
- obtain and enter current data from areas which had been surveyed in recent years but not yet had the data submitted (e.g. Shoalhaven Estuary, Werribee/Avalon);
- obtain and enter current data for areas that was housed in alternative databases.

Counts of migratory shorebirds in Australia were extracted from the S2020 and QWSG databases and collated as outlined in Clemens et al. (2016).

The primary focus for analysis was Shorebird Areas (SBAs), and where coverage of Count Areas (CAs; smaller areas nested within SBAs) was relatively complete, data from CAs within each SBA at each count event were summed to provide a number of shorebirds at the SBA level for that particular SBA survey.

Where CAs occurred outside SBAs, or where data originated from sites not mapped as either an SBA or CA, they were treated as distinct sites.

The rest of the Flyway

New Zealand count data were summarised by 'Main Site', analogous to Australian SBAs. The boundaries of these sites are not mapped in a GIS, and close liaison between the project team and New Zealand count coordinators was necessary to resolve where potential overlaps occurred between adjacent counted areas. In most cases, the 'Local Site' counts were summed across Main Sites on any given day and used as the basis for modelling. Liaison with NZ national count coordinators helped deal with special cases, e.g. when likely double-counting might be occurring between nearby sites counted on the same day, or where adjacent areas counted on separate days could be considered as discrete groups of birds and not at risk of double-counting.

Data from the Asian Waterbird Census were collated for analysis.

Data analysis

An expert workshop was conducted during the early phase of the project, soon after S2020 data compilation was complete. After much discussion, participants in the workshop reached a consensus on the overall analytical approach to be used, resolved into four fundamental steps:

(i) Summarising count data from counted sites, incorporating modelling where necessary to fill in gaps, to generate an estimate for the average number of birds present in every survey done in the non-breeding season (November - March) across the 10 years between 2006/2007 and 2015/2016.

(ii) Estimating the average number of birds present at uncounted sites in the 10-year period, based on an assessment of the proportion of intertidal habitat that has been counted in each country / region.

(iii) Subjecting the results of (i) and (ii) to rigorous and extensive expert peer review by regional experts based around the flyway, and adjusting the resulting estimates accordingly, each adjustment being accompanied by a documented justification for overriding the numerical estimate from (i) or (ii).

(iv) Taking account of other information such as breeding range size, and counts from passage sites, to adjust estimates for species not well represented by steps (i) - (iii), such as Latham's Snipe, Red-necked Phalarope, and Common Sandpiper.

Modelling of Australian shorebird count time series to generate predictions of population size

We collated data for the last 10 years, but focused where possible on the last five years to maximise the currency of the estimates. For sites with at least three years of complete survey coverage in the last five years (2011/12-2015/16) we calculated the mean count for each species and fed this directly into the population estimates. For any site with at least 10 years of counts, data were analysed using generalised additive models fit with cubic regression splines (Zuur et al. 2009) to generate predicted numbers of birds present each year between 2011/12 and 2015/16.

These predicted numbers were then averaged and fed into the population estimates. These analyses were all conducted in R (R Development Core Team 2014), and associated scripts are available upon request.

There are some sites within Australia with extensive time series data, but that are too large to survey completely each year. In these cases the maximum count of each recent attempted census was used. This approach used for some of the larger sites in Queensland such as Moreton Bay, Great Sandy Strait and Mackay, where there are numerous roosts and complex patterns of roost occupancy.

Analyses for Australian sites with insufficient time series data

Where sites had complete spatial coverage on each count but fewer than three counts in the last five years, and fewer than 10 years of data, a simple linear regression was used to generate an average predicted count over the last five years, to feed into the population estimates. If there was only one count in the last ten years and no other data, that count was used as the estimate. If there were no counts at a site since 2007 (the last 10 years) we estimated the average number of individuals present in the last five years by applying a percentage change per year taken from statistically significant national trend estimates (Clemens et al. 2016) to the maximum count from the year of that maximum count. Species and sites that qualified for this approach were those with little recent data (Northern Territory coastline, excluding Darwin) or for species where data from the flyway was insufficient to update past estimates (e.g. Latham's Snipe).

In large SBAs with no recent complete counts of all possible count areas we made an estimate for each species at each CA, and then summed those estimates to form an SBA estimate. For CA with data in the last ten years we simply reported the average, and for CA with data more than ten years old a trend correction was applied as above to generate predicted counts that were averaged over the last five years. These averages or trend-corrected average predictions were summed within each SBA. The same procedure was run for many sites that do not fall into a formal SBA or CA. This allowed estimates to be made from as comprehensive a set of the data as possible, although the abundance of shorebirds in data derived from these extra sites was relatively low compared to the main SBA and CA.

The enormous variability in data completeness (see Clemens et al. 2012) necessitated this diversity of analytical methods, and subjecting the results to expert review ensured the best possible estimates emerged. The process for analysing data from Australia is illustrated in Appendix 3a and 3b.

Analyses on count data from outside Australia

Count data from New Zealand were analysed in the same manner as data from Australian SBAs. AWC data from elsewhere in the flyway were summarised on a national basis by computing the maximum count at any site over the austral summer period (November-March) in the years 2005/06-2014/15 (the most current data available at the time), and summing site maxima over each country. This figure was used as the basis for generating population estimates in each country.

Estimating shorebird numbers in uncounted areas

Shorebird count data are generally sparse, and in almost all regions of the flyway there is significant shorebird habitat that is outside counted areas. To adjust for this, we (i) estimated the proportion of potential coastal shorebird habitat that is not counted during systematic surveys, and (ii) modelled the abundance of migratory shorebirds using inland areas of Australia.

Extrapolating coastal counts to uncounted areas

We restricted application of this approach to those species that wholly or principally use intertidal habitats during the non-breeding period. No maps of intertidal habitat yet exist for the flyway, beyond products available for the Yellow Sea (Murray et al. 2012) and Australia (Dhanjal-Adams et al. 2016).

In the case of Australia, we overlaid polygon representations of SBAs (http://www.birdlife.org.au/projects/shorebirds-2020/counter-resources) onto an existing map of intertidal habitats classified directly from remote sensing data (Dhanjal-Adams et al. 2016) to produce an accurate estimate of the proportion of intertidal habitat counted in Australia (Appendix 4a). We circulated these estimates to regional experts, who used their knowledge to adjust these estimates of the proportion of counted habitat where necessary (Appendix 4a), noting in particular that habitat mapping alone does not provide information about the quality of sites, which can vary considerably..

For areas beyond Australia, we describe the methods in full below, but in brief we began by mapping areas in which intertidal habitat could potentially occur based on combining bathymetry and tidal amplitude data. We then superimposed the count sites onto the map of potential intertidal habitat to estimate the proportion of habitat that had been counted. This estimate was then calibrated using the fine scale analysis for Australia described above as a guide, and circulated among regional experts for verification. The final product was a best estimate of the proportion of the shorebird population in a country / region that had been counted. These proportions were used to estimate the number of uncounted birds (Appendix 4c).

First, to map potential intertidal habitat, we identified all pixels (1 km × 1 km) in a global bathymetry map (ETOPO1 Global Relief Model; https://www.ngdc.noaa.gov/mgg/global/global.html) that are shallow enough to be exposed by the tide (based on overlaying a global model of tidal amplitude from Lovelock et al. 2015). We removed any pixels with an elevation above zero metres, assuming these are not intertidal, and also removed all areas that are covered in sea ice in winter. We then clipped the dataset of potential intertidal areas to all areas with a 5 km buffer of the coastline, using a high resolution coastaline dataset (https://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html). This constrained our estimate of potential intertidal habitat to a reasonable proximity to the coastline, to limit over-prediction of potential habitat at great distances from the coastline.

Second, we needed to map the area covered by each of our count sites. Because comprehensive polygonal maps of shorebird count areas do not yet exist, we defined a buffer of 10 km around the coordinates of all AWC count sites that occur within 20 km seaward and 2 km landward of the coastline to estimate the area of habitat surveyed at that site. This buffer radius represents a reasonable estimate of the distance travelled by roosting birds from feeding areas, and the extent of habitat typically covered when counting shorebirds in a site; inevitably it can markedly over- or under-estimate for individual sites. The modelling approach used here cannot be expected accurately to map all available intertidal habitat, but the intention is that it provides a reasonable estimate of the relative occurrence of intertidal habitat inside and outside counted areas, on which basis we can estimate the proportion of habitat counted, and extrapolate the count data accordingly. Similarly, our habitat mapping does not incorporate variation in habitat quality, which is instead dealt with by expert review, where such information is available.

Third, we calculated the proportion of the total potential intertidal area that fell within a 10 km radius of a count site to generate a raw estimate of the proportion of habitat that had been counted in each country.

These raw estimates were then calibrated using the relationship between the accurately estimated proportions of counted habitat in eight regions around Australia and proportions estimated using the bathymetry / tidal amplitude method based on buffer site centroids ($y = 0.8088x + 0.2882$; $R^2 = 0.331$; N = 8; see Appendix 4b for details). This regression relationship provided a calibration between the coarse method employed outside Australia and the detailed method that we were able to use in Australia by virtue of the availability of mapped sites and remotely sensed habitat information. We circulated these estimates of the proportion of habitat that been counted to regional experts, who used their knowledge to adjust them where necessary (Appendix 4c).

Estimating the numbers of migratory shorebirds in inland Australia

Inland Australia is very sparsely covered by formal shorebird count data (Clemens et al. 2012), yet is known to support large numbers of certain species at times. To estimate the numbers of birds using inland Australia, we used the available count data to model summer shorebird abundance. First, all available data on shorebird distribution and abundance was gathered for 14 species of migratory shorebirds that use Australia's inland habitats. Datasets included the Atlas of Australian Birds (Barrett et al. 2003), eBird (Sullivan et al. 2009), the Atlas of Living Australia (ALA 2013), and a variety of published counts of these species in inland areas (Lane 1987; Halse 1990; Jaensch and Vervest 1990; Kingsford and Porter 1993; Wilson 2000a; Barter and Harris 2002; Jaensch 2004; Hassell 2005; Hassell et al. 2005; Bennelongia 2007; Paton et al. 2009; Reid et al. 2010; Paton and Bailey 2012). An inland site was defined as any location more than 1 km from the coast or coastal SBA boundary.

Inland Australia was divided into 10 km x 10 km grid cells for data collation and analysis. Checklists that recorded other birds but not the species in question were coded as a zero, and records with the species recorded as present were coded as a one. The resulting presence / absence dataset was therefore highly zero-inflated with over 80% zeros for all species. One widely used approach when modelling such zero-inflated data is to generate a binomial presence absence model and a second abundance-if-present model assuming a Poisson distribution. Resulting predicted abundance is then simply the probability of presence given by the first model multiplied by the predicted abundance given by the second model (Barry and Welsh 2002), and recent work has applied these steps using boosted regression trees (BRT; Elith et al. 2008) to successfully predict waterbird abundance in Africa (Cappelle et al. 2010). We used a very similar technique to this previous study. Data were grouped into 10 by 10 km grid cells, and where counts existed, the maximum value was taken for each grid cell for each month of each year from 1980 - 2013. Presence only data were ignored when coding abundance data. The presence-absence models and the abundance models were developed for each species using the gbm package (Ridgeway 2015) in R (R Development Core Team 2014), with binomial and Poisson distributions respectively, and using boosted regression trees with a tree complexity of seven, a learning rate of 0.01, a bag fraction of 0.75, and with the maximum number of trees set to 30,000.

Nineteen predictor variables were selected as they were thought to be related to the availability of water in flat open wetlands free of tall vegetation with suitable soil to support benthic invertebrates. All variables were averaged and where necessary resampled across 10 x 10 km square grid cells. Nine of these variables did not vary temporally so the same value for each grid cell was used across time. These variables included: average elevation, derived from Geoscience Australia's 9 second DEM http://www.ga.gov.au/scientific-topics/national-location-information/digital-elevation-data; Soil Bulk Density http://data.daff.gov.au/anrdl/metadata_files/pa_sbdaar9cl__05111a00.xml; estimated mean ground water level (Fan et al. 2013); the variability of upper soil moisture levels (STDV of lower soil moisture – see below); area of forest cover www.ga.gov.au/earth-observation/landcover (Lymburner et al. 2010);

length of inundated wetland edge that was flat and did not border trees derived from the above forest coverage, the DEM (slope less than 1%) and Geoscience Australia's Inundated wetland layer; a variable representing regional availability of suitable wetland edges was derived by summing the wetland edge lengths from a neighbourhood of 10 cells in each direction from the central cell (the sum in each 100km^2 cell was inclusive of the surrounding wetland edge lengths in a large neighbourhood of 210 x 210km); a variable including the area of fresh water wetland, and a variable of the area of salt water wetland both of which were derived by reclassifying the inundated wetland polygons as either fresh or salt based on the Directory of Wetlands https://www.environment.gov.au/water/wetlands/australian-wetlands-database/directory-important-wetlands and other available classifications i.e. http://www.dlra.org.au/ref-salt-lakes.htm.

All ten remaining variables were also averaged or resampled to the 10 km x 10 km grid cells but were additionally averaged or resampled monthly over the whole of the time series 1981 – 2013, and included: the broad climatic variables of average monthly rainfall, average temperature, and vapour pressure (http://www.bom.gov.au/climate/averages/climatology/gridded-data-info/gridded-climate-data.shtml); soil moisture, upper, lower, the difference in the cumulative upper soil moisture over the last two years and the cumulative soil moisture over the previous two years to that, and the difference between the cumulative soil moisture in the last year and the cumulative soil moisture in the previous year ftp://ftp.eoc.csiro.au/pub/awap/Australia_historical/Run26j/ http://www.csiro.au/awap/ (Raupach et al. 2009); the average NDVI value from NOAA satellite data https://lta.cr.usgs.gov/noaa_cdr_ndvi ; stream flow data from 3500 locations, measured daily in cubic metres per second but with many missing values over time, monthly averages were used that were then interpolated across Australia using simple *ts* splines in each month, cumulative totals of the interpolated flow data over the previous two years was also used https://data.gov.au/dataset/water-data-online.

Resampling to standardised spatial and temporal resolution, defining map projections, snapping grids to overlay, and extracting values or writing values to grids were steps done using python in ArcGIS (ESRI 2011), and the raster package in R (Hijmans 2014). Predicted results from the models above were made for each grid cell in Australia for each summer month from October to March from 1981 to 2013. Those predicted abundance values were summed for each month for the whole of Australia.

Australia-wide monthly models showed large variation in the predicted abundance for many species from one month to the next with a slight decline evident over time, suggesting there has been a decrease in the suitability of Australia's inland wetlands to support migratory shorebirds. This may be a reflection of changes in annual rainfall, especially during the 'millennium drought' years. However, the rate of decline was far less steep than observed for the same species when counted at primarily coastal habitats. A recent analysis of coastal count data has indicated that steep declines in migratory shorebirds seen at the coast appear to be driven most by factors outside Australia (Clemens et al. 2016). Therefore, we believe that the recent predicted abundance of inland shorebirds is likely higher than the number actually now visiting Australia each year. To account for this we averaged the predicted abundances observed between 1981 and 1990, and applied a trend correction based on rates of decline recently determined for coastal shorebirds across Australia (Clemens et al. 2016). The trend correction was simply a percentage change per year which we applied to the pre-1990 average to generate predicted abundances for the last five years which were then averaged to generate our estimate of the number of migratory shorebirds currently using inland Australia.

These models generally under-predicted abundance at sites that have supported large numbers of shorebirds, because the vast majority of other sites support only a few birds.

Therefore, the final step in estimating inland abundance was to append average or predicted counts from any area over the last five years which was thought consistently to hold large numbers of individual shorebirds of a given species.

Expert elicitation

Expert elicitation was conducted via two targeted workshops and via email communication. The first workshop was scheduled during the early phase of the project, when data had been compiled but methods were still being developed.

The purpose of this workshop was to seek input from experts about the best approach for handling the data and any idiosyncrasies of the data that might require special analytical consideration. The second workshop was convened after the major analyses had been conducted to assess the results and agree upon adjustment and extrapolation approaches, both within Australia and overseas. Regional count coordinators and other experts in Australian and British shorebird studies were invited to participate in these workshops.

After the completion of the second workshop, discussion points and feedback obtained were used to amend population estimates for each sites and species in each Australian state. Count data estimates for each AWC country were also compiled along with extrapolation figures determined during the workshop, from the spatial modelling. Estimates for each flyway country were circulated to count coordinators for review and expert opinion on the validity of extrapolation figures.

No attempt was made to estimate uncertainty surrounding expert opinions, and there are no calculations of errors arising from bias or variability in expert judgment.

Australian state-based adjustments

Australia population estimates were categorised by state (in some cases regions within states) and distributed to state count coordinators for verification and error checking. Coordinators were asked to assess the validity of the overall numbers as well as site totals. They were also asked to make a judgement, on the basis of their experience with count sites, of how well certain species were detected during surveys and what proportion their count region or the state is covered by regular surveys. The outcomes of this expert review were used to identify errors and gaps in the data, refine estimates where this was judged necessary, and adjust the spatial extrapolation figures generated from the intertidal modelling process.

Population estimates based on breeding distribution and density

Breeding distribution shapefiles were obtained from BirdLife International & NatureServe (2015). We regarded birds as ‘belonging’ to the EAAF if they migrated through the flyway to non-breeding destinations within the flyway.

The polygon for each species was modified when necessary to cover the area of the breeding distribution relating to the EAAF for each species, based on literature review (most notably Lappo *et al.* 2012) and consultation with experts. Maps of the breeding distributions applied in this analysis are shown in Figure 3, and a summary of the assumptions made is provided in Appendix 5. This delineation involved a combination of (i) mapping areas of the breeding distribution of birds that spend the non-breeding season in the EAAF, (ii) extracting areas only in close proximity to wetlands for seven species that depend specifically on wetlands for breeding.

Each species was classified into one of the following three breeding density categories:

1. High density: species known to nest in high densities in the core of their breeding range (or expected to nest in high densities by comparison with closely related species);
2. Moderate density (default)
3. Low density: species known to nest in relatively low densities in the core of their breeding range (or expected to nest in low densities by comparison with closely related species); this category also included species in which calculated breeding range was suspected to be inflated because the range map included habitats that are unsuitable for nesting.

We analysed the relationship between breeding range and density with the estimated flyway population of 19 species, derived during this study (Appendix 5 & 6). These 19 species were chosen because their population estimates were considered likely to be reasonably accurate.

In most cases the flyway population estimates were based on counts on the non-breeding grounds, and the species in question have a coastal non-breeding distribution, with their non-breeding strongholds occurring largely in regions where shorebirds are monitored. We also included some species which occur in both coastal and inland Australia, for which the numbers in inland Australia had been modelled (see Inland Estimates section). We also included Latham's Snipe in this analysis, as its population had previously been estimated on the basis of focussed surveys on the breeding grounds (Naarding 1986).

A generalised linear model was constructed in SYSTAT 13 (Systat Software, San Jose, CA), using number of birds counted on the non-breeding grounds (Appendix 6, estimates included extrapolations) as the dependent variable, and breeding range size and breeding density as the independent variables. The model formula was:

ln Population = ln BR + High + Low

where

ln Population = natural log of number of birds in the EAAF Population;

ln BR = natural log of Breeding Range in km^2;

High = A binary variable representing species that nest at high density (=1 for species in which average nesting density is high, 0 for species in which it is not);

Medium = A binary variable representing species that nest at medium density (=1 for species in which average nesting density is medium, 0 for species in which it is not; this term was not included in the final model);

Low = A binary variable representing species that nest at low density (=1 for species in which average nesting density is low, 0 for species in which it is not).

No constant was included in the model, as it was assumed that if breeding range was zero, the population would also be zero.

The coefficients generated from these regressions were used to estimate flyway populations of species for which count data from the non-breeding grounds were considered inadequate, and were also helpful in assessing whether estimates generated from other methods appeared reasonable.

Flyways and population considerations

In most shorebird species, breeding range estimates were confined to birds that nest within the formal boundaries of the EAAF and migrate to non-breeding grounds within the flyway. However, modifications were needed for a number of species. For example, some Grey-tailed Tattlers nest west of the formal boundary of the EAAF, but migrate to non-breeding grounds within the EAAF; these birds were included in our breeding range assessments.

At the other extreme, migration studies have shown that in some species, populations breeding in Alaska or near the western boundaries of the EAAF migrate into other American flyways; we did not consider such birds to be part of the EAAF and trimmed them from the breeding range estimates. These decisions are documented in Appendix 5.

Pectoral Sandpiper estimates were drawn from the data from the American flyways as current knowledge suggests that the species is represented by a single taxonomic population with a wide breeding distribution that largely migrates to the Americas. The small number of birds occurring in non-breeding grounds in Australia and New Zealand are considered to spill over from the large American population, not a discrete EAAF population. Similarly, the small numbers of Ruff occurring in this Flyway were considered to spill over from the large population migrating largely to Africa and central Asia.

For management purposes, differentiating species estimates by subspecies or populations is not practicable (i.e. it will often be very difficult for field surveyors to distinguish between subspecies). On this basis, estimates were not generated by subspecies although we recognise that some species have populations using different flyways that geographically overlap.

Adjustment of predictions and estimates

Estimates derived from the modelling and other analyses were produced for each species in Australia and New Zealand. Summary of AWC data from other flyway countries provide the initial set of estimates for Asia.

The following steps were used to determine flyway estimates (and see Appendix 3a & 3b):

1. First pass estimates derived from coastal site data (all countries) and for predominantly coastal species at inland sites, summarised by state (Australia only)
2. Extrapolations applied to account for uncounted habitat (all countries), generally applied equally across all species
3. Estimates plus extrapolation figures sent to coordinators for expert review (all countries)
4. Reviewer feedback used to adjust estimates by selecting more appropriate metrics or adding missing data (all countries); state-based and / or species-based extrapolations amended (Australia only)
5. Revised estimates and extrapolations returned to coordinators for further review and adjusted where necessary (all countries)
6. Alternative estimates derived from breeding range and density analyses (considered, in the first instance, as most applicable for species which are non-coastal obligates)
7. Estimates from other sources used to adjust special case species (e.g. other flyway data)
8. Trend correction applied to pre 2005 data, where relevant

9. The best estimate selected for each species to produce a current flyway population estimate

The general rule for selecting the best estimate was as follows:

- For species considered coastal obligates in Australia, spatially extrapolated counts were used;
- For species considered non-coastal obligates (more commonly associated with inland waterbodies and / or grasslands), breeding range and density estimates were used;
- For species where insufficient count data rendered spatial extrapolations unrepresentative, breeding range and density estimates were used;
- For species where only a very small proportion of the population uses the EAAF, estimates from other sources were used (e.g. another flyway estimate);
- Species for which none of the above categories were valid, another estimate was used and its derivation documented.

Results

Count coverage and site data quality

Spatial survey coverage of known and potential shorebird habitat and data quality within routinely monitored survey sites varied substantially within and between flyway countries. Details are provided in the sections below.

Australia and New Zealand

The Australian Shorebirds 2020 database builds upon decades of shorebird monitoring data, initiated with the Royal Australian Ornithologists Union (RAOU) National Wader Count which commenced in 1981. Over time the program has grown in both spatial coverage and volunteer membership, particularly with the conversion of the Population Monitoring Program to Shorebirds 2020 in 2007 (and just prior to the previous population estimate revision). This has resulted in more shorebird records from more locations across the country. Despite this increase in survey effort in recent years, there are still numerous gaps in the S2020 database and monitoring site network. Some of these gaps were addressed through a process of the targeted engagement of regional counters and coordinators over the 2015-2016 summer, but many more were identified during the expert review process (see below). More details on coverage and quality of data in S2020 (and its predecessor the AWSG Population Monitoring Program) and the QWSG database can be found elsewhere (Gosbell and Clemens 2006, Milton & Driscoll 2006, Wilson *et al.*, 2011, Clemens et al. 2012, Clemens et al. 2014, Clemens et al. 2016).

The proportion of CAs within any given SBA that are counted during a shorebird survey varied from 2% to 100% in a summer count (Clemens et al. 2016), and was generally lower in winter than summer. In Australia, there were 2632 CAs occurring within 422 SBAs, although in some regions there were CAs that did not occur within any defined SBA although still routinely counted and containing significant numbers of certain species. In addition, there were also 'Shorebird Sites', unrelated to formal CAs or SBAs, consisting instead of some 3500 point count surveys around Australia. There were some instances where 'missing' count data has been recovered through this process, uncovered while sorting through these Shorebird Site records, having been entered without the correct labelling or survey area nomenclature. Such examples have resulted in these data being reallocated to the correct Shorebird Area or Count Area and analysed accordingly.

Within Australia, count coverage also varied significantly among and within states, to the extent that different spatial extrapolation factors were required (See Appendix 4a). Generally, count coverage decreased from southern states to northern states. Count coverage is largely driven by proximity to human population centres and area access considerations (Clemens et al. 2012), and given the extent of the country and highly variable coastal geomorphology, surveys in remote, sparsely populated areas are logistically difficult and not undertaken on a frequent basis. For example, Western Australia had the largest amount of mapped intertidal area, but also the lowest proportion of counted intertidal habitat. Northern Territory also had a low proportion of counted intertidal habitat, while South Australia and Victoria showed much higher proportions (55% and 97%, respectively; Appendix 4a).

Some gaps in the S2020 database were filled during the targeted engagement of regional counters and coordinators over the 2015-2016 summer, but many more were identified during the expert review process.

Consultation with experts yielded contact with new counters or researchers conducting monitoring counts in important but under-counted areas in northern Australia that were otherwise unknown to S2020 or had not been included in previous analyses e.g. Ashmore Reef and Adele Island (R. Clarke, unpubl. data), Port of Darwin (A. Lilleyman, unpubl. data), and Port MacArthur and Limmen Bight areas in the NT (P. Barden, unpubl. data).

The coastline of the Northern Territory posed particular problems, as only a small proportion of it has been surveyed in recent years. A broad-scale survey was carried out in the 1990's (Chatto 2003), considerably earlier than our preferred cut-off date. As it involved much aerial survey, ~60% of the shorebirds counted were not identified to species level, and Chatto (2003) used extrapolation to estimate their numbers. Despite these issues, the broad geographical scope of Chatto's surveys made them the most suitable data source available for NT population estimates, though as the surveys were carried out almost 20 years ago, it was necessary to apply time-trend corrections to those species in which significant Australia-wide declines have been reported (Clemens et al. 2016, Appendix 1).

In comparison with Australian shorebird count databases, the OSNZ monitoring program comprises a well-structured network of monitoring sites and a National Wader Count Database that houses a high quality migratory shorebird monitoring dataset. The judgement of experts in New Zealand was that approximately 90% of intertidal area is covered during the biannual monitoring surveys. As a result, rather little data manipulation was required to make New Zealand shorebird count data ready for incorporation into the flyway population estimates.

The Flyway, beyond Australia and New Zealand

In contrast with New Zealand and Australia, data from elsewhere in the flyway were highly sparse, had extremely variable levels of coverage within and among countries, had patchy coverage over time, and lacked detailed information on the boundaries of counted areas. Brunei had the highest estimated count survey coverage of any flyway country, with 91% of available shorebird habitat being covered. New Zealand follows with 90%, Australia 40%, Japan 28%, Republic of Korea 33%, and China 13%. Indonesia had only an estimated 4% coverage, yet the second largest potential intertidal habitat area of all flyway countries included in this project (Appendix 4c). Many central flyway countries such as Timor-Leste had very few repeat surveys over the target monitoring period. Outside of Australia and New Zealand, the most comprehensive national shorebird monitoring data was from Japan and the Republic of Korea, where surveys are undertaken regularly within defined areas and are relatively comparable. The Philippines has a large data set but fewer repeat surveys. There was a bias toward coastal monitoring in most countries resulting in low reporting rates of species that preferentially use inland areas such as Little Curlew, Wood Sandpiper and Swinhoe's Snipe. Overall, there were total of 3750 surveys outside Australia and New Zealand covering 1400 monitoring sites, contributing a total of 1.5 million counted birds.

Many of the flyway countries included in this analysis have substantial amounts of shorebird count data falling outside the austral summer survey window and therefore not included in the analysis. For example, austral summer count data for Papua New Guinea are very limited, and many West Papua surveys were point counts from a small portion of the potential coastal shorebird habitat. Some of these data included in the AWC also lack sufficient detail on site location. For almost all flyway countries the count effort only covered a small proportion of the potential intertidal habitat (Appendix 4c), and the mean number of counts of any given AWC site is less than two.

The number of shorebird monitoring sites counted in each country varied from 235 to only 1. The number of surveys per site also varied significantly from 6.5 (Japan) to 1.2 (Myanmar), demonstrating a general absence of structured monitoring surveys across the flyway.

Coverage in the austral summer survey window is also limited for countries such as Laos, China, Timor-Leste and Papua New Guinea and generally of limited use for the purposes of this project.

For several countries, important recently collected shorebird count data for the target period has not yet been submitted to Wetlands International for the purposes of the AWC (e.g. Gulf of Mottama, Myanmar) and has therefore not been available for use in these analyses.

Modelling predictions

For the Australian S2020 data, there were 235 shorebird areas that had sufficient coverage and data quality for Generalised Additive Modelling. Ten metrics were produced from the modelling: actual and predicted means in last 5 and 10 years, 95% confidence limits of 5 and 10 year means, predicted and actual maximum in last 5 years, actual maximum count in last 10 years and over the whole time series. The primary choice of metric was made during the second expert workshops (see below). For the remainder of SBAs, CAs and other sites (3300), a single metric was used to derive species-site estimates. Metrics from the two analyses were summed across all shorebird sites in each state to produce a state-based estimate.

New Zealand Main Sites were subject to the same analytical procedure as Australian S2020 Shorebird Areas and in all cases with one exception, the metric produced from the modelling (actual or predicted mean of the last 5 years) was used as the estimate for that species. The exception was Double-banded Plover, where the estimate computed by Southey (2009) was used instead on the basis that counts do not adequately detect this species and the Southey approach was based on better knowledge of their distribution in NZ. The difference between these estimates was minimal (modelled 5885 versus Southey 5900).

Inland estimates

The data were used to broadly estimate the average summer abundance of shorebirds using sites located in inland habitats for Sharp-tailed Sandpiper, Red-necked Stint, Curlew Sandpiper, Common Greenshank, and Marsh Sandpiper (Appendix 7). Model predictions of population size for these species were not precise, with large confidence intervals. Nonetheless this modelling constitutes an improved estimate of inland shorebird numbers using the best predictive models yet produced. Predictions for the remaining nine species were all notably lower than the actual population thought to exist in Australia (Bamford et al. 2008).

Model fit for major inland sites such as the Coorong and the Ord River was relatively poor and produced unlikely estimates when compared to actual data (e.g. modelled estimates were around 1% of the actual five year estimate). This was most likely due to the model underpredicting in areas with very large numbers of shorebirds. The main example of this, the Coorong, had estimates derived from the GAM analyses (performed on coastal sites), which were retained and included with other coastal sites. In all other cases, estimates for inland sites for predominantly inland freshwater and grassland species, derived from the GAMs, were separated from coastal site results. These estimates are reported separately for comparison against modelled estimates (see Appendix 7).

To be consistent with the time period used for GAM analysis of coastal site data, we repeated the inland modelling using a 5 year trend adjusted figures to produce estimates for Sharp-tailed Sandpipers, Red-necked Stint, Curlew Sandpiper, Common Greenshank and Marsh Sandpiper. The logic for choosing these species was that they are reliant to some extent on the Yellow Sea and have declined in recent years consistent with other species.

In contrast, the maximum predicted value in the last 10 years in any given month was used to generate inland estimates for Black-tailed Godwit and Oriental Plover. The reason for this disparity is that the available data does not reflect their distribution and thus, the method under-samples their distribution, resulting in lower than expected numbers.

The classification of inland sites produced some inconsistencies, most which were identified during the expert review process (see below). For example, the "coastal lakes" complex in south-east South Australia, Jack Smith lake in Gippsland (eastern Victoria), count areas in King Island's interior (Bass Strait between Tasmania and Victoria), Lake George in south-eastern South Australia, The Broadwater and Broadwater swamp in NSW, and the Tiwi Islands off the Northern Territory coast. This may be a result of the extent of the estuarine influence upstream (inland). In some cases, these were manually adjusted during the expert review process but in many cases it could not be altered without affecting the treatment of inland species-site data in the modelling. Future analyses using this approach should be combined with careful site-by-site and species-by-species scrutiny in close consultation with experts.

Adjustments and expert review

Expert workshops

During the second expert workshop, participants discussed general approaches for both selecting metrics from GAMs and conducting a spatial analysis to extrapolate from counted coastal areas to uncounted area.

Participants agreed on the following rule for choosing the most appropriate GAM metrics for each species: if data for a site are sufficient, the average over the last five years is used and where site data are lacking, the predicted mean in the last five years is used. Exceptions were Oriental Plover, Wandering Tattler and Whimbrel, for which the maximum in the last 5 years was used. The focus on metrics from the last five years was intended to reflect recent, sharp declines in many species. When it was necessary to depart from this rule (e.g. state coordinator review indicated an alternative and more likely value, e.g. maximum in last 10 years - see below), then a species-site estimate was adjusted.

For example, counts of Asian Dowitcher fluctuate considerably in Roebuck Bay, ranging between zero and ~400 individuals (Rogers et al. 2000). Local experts suspect the species is always present in Roebuck Bay, and is sometimes forced (by tides or disturbance), to a roost at Bush Point where they can be counted; however they are often overlooked because they prefer a remote section of the bay where human access is very difficult. In 2015, there was a count of 167 birds at Bush Point, which was comprehensively covered during that survey. This count is more accurately represented by the maximum than a five year average or predicted average. This reflects differences in detectability between species at different sites, which was a topic of discussion during the workshop.

Workshop participants agreed that it was not possible during this project to explicitly account for variation in detectability between sites and species. Therefore, it was agreed that the state coordinator expert review process would provide a means for identifying where estimates depart substantially from realistic site totals. These exceptions are documented in the appendices.

Australian state-based adjustments

Responses were received from around two dozen count coordinators and experts (Appendix 8). Most respondents provided commentary on species estimates and particular sites they were familiar with.

As a result of feedback, all state estimates were substantially amended and in most cases, the original estimate of the proportion of birds uncounted was adjusted. This resulted in a change in extrapolation factors for most states (Appendix 4a). For example, the original extrapolation factor of 1.72 for NSW, based upon the intertidal modelling, was amended to 1.14 by consensus among NSW coordinators.

The most common issue identified by reviewers was gaps in the data used in analyses, which almost always reflected data missing from the S2020 database. This usually represented recent data not being lodged data with the database, but also in some cases highlighted historical issues with database design and curation. As a result, recent data from 32 SBAs / CAs were identified as missing (eight in NSW, four in VIC, 11 in SA, six in WA and 3 in NT) and added to the database, and a further 23,000 records were discovered miscategorised in the database and previously considered missing. Duplicates were identified by some experts, which were subsequently removed.

For Western Australia (WA), Whimbrel data were treated differently on the basis that expert review highlighted the tendency for this species to occur in uncounted near-coastal creeks within the Kimberley area at an approximate frequency of 2-3 birds per creek (for large creek systems only). The number of near-coastal (within 15 km) creeks was quantified using WA Hydrology layers in ArcGIS and used as a species-specific multiplier.

The most comprehensive data for Northern Territory (NT) was from two major surveys conducted by Chatto (2003 and 2012). Data from the S2020 database poorly represents most of the NT except for the Darwin area. However, the data contained within the Chatto reports were problematic to analyse. The data from the first study (Chatto 2003) covered most of the NT coastline but was from outside the project's temporal window and the method for extrapolating from ground counts to aerial counts was not clearly explained or justified. The data from the second study (Chatto 2012) only covered a fraction of the coastline compared to the first study, and the data were only presented as proportions rather than as actual counts. This necessitated extraction and interpretation of the actual figures by back-calculating from species' proportions and regional count totals.

Analysis of the Chatto NT data was done using two approaches: (1) extraction of counts from 2010 report with a spatial extrapolation applied to adjust for areas not counted, and (2) a trend correction applied to 2003 data (ground and aerial), to account for known changes in population sizes in Australia as well as to account for the likely presence of staging birds during counts. Figures derived from option two were cross-checked against more recent count data (austral summer 2015-2016) provided by P. Barden: these data spatially overlap several Chatto sites in the Gulf of Carpentaria, and were obtained through more rigorous observation and extrapolation (including careful inspection of mixed sand plover flocks). Where total counts for a species were higher in recent (P. Barden) data, these were used in favour of the Chatto trend-adjusted counts, on the basis of greater observational rigour in the most recent study. Trends used for adjustments were taken from Clemens et al. (2016) (see Appendix 1).

We did however, make an exception to this rule for Red Knot alone for the following reasons: (1) In Chatto's repeat survey of part of the NT coast in 2012, he found very few Red Knots in an area where he had previously reported large numbers. This could represent a true decline, but it is more likely that their numbers were overestimated in the original surveys in 1990's. Red Knot can be a difficult species to count accurately (especially if the observers are not experienced) and surveys in north-western Australia have shown that the distribution of Red Knots is extremely patchy (Rogers et al. 2009, 2010; Minton et al. 2013).

Extrapolation from limited ground surveys to large areas is therefore specuative in this species; (2) Australia-wide data for Red Knot are inconsistent, with time-trends being obscured by much year-to-year variation in the NW Australia sites where the largest numbers are counted. This variation is probably related to local behaviour and movements, and obscures any time-trends that exist.

On these bases, we applied the trend-correction for Red Knot, derived from southern Australian populations only (Clemens et al. 2016) to adjust the Chatto (2003) data. This was done in preference to no correction to avoid overestimating the true Red Knot population size in Northern Territory, where the data collection and analysis approach has differed from that used in other states.

Species estimates for Tasmania were also treated in a slightly different manner to other states, after receiving expert review. A number of site duplicates were identified and removed. Site treatment was amended for several sites (where they had been incorrectly assigned to the 3-5 year category or the 0-2 year category). Several sites were considered to be more poorly covered during systematic surveys: these were removed from the general pool of sites subject to GAMs and treated separately, with their own spatial extrapolation factor applied on the basis of known count coverage. Furthermore, several species were treated individually (Double-banded Plover, Ruddy Turnstone and Sanderling), owing to the relatively poorer detection of these compared to other species. In these cases, each species was subject to a separate extrapolation on top of other adjustments.

All multipliers are considered to be conservative but realistic as first-pass estimators of total numbers in Tasmania. Double-banded Plover are known to use coastal wetlands (in many cases, largely inaccessible), inland pastures and fields so counts at winter coastal roosts will most likely be an under-estimate of the population. Extensive potential habitat for Ruddy Turnstone exists in North-east Tasmania and along much of the West Coast. Various small islands are known to support small flocks of 10 - 30 birds; with King Island, theFurneaux Group and the West Coast likely to be significant sites for turnstone in Tasmania.

Thus, the final figure for Tasmania produced by the expert review included site- and species-specific extrapolations. Appendix 9 provides a breakdown of extrapolations (multipliers) and calculations to derive the final state estimates.

Overseas adjustments

National and sub-national Asian Waterbird Census coordinators were requested to provide feedback on any concerns with the national estimates, but no responses were received. Feedback was received from two experts in New Zealand. No changes were made to estimates and extrapolation factors in New Zealand, nor any AWC country (Appendix 4c).

Relationship between breeding range and density with population estimates

Breeding range estimates used in these analyses are summarised in Appendix 5. Assumptions made about breeding distribution of EAAF populations are summarised in Appendix 6. Maps illustrating breeding distributions of the populations are provided in Figure 3.

There was a strong relationship between breeding range and density, and estimated flyway population size for the 18 species for which we had the best count data from the non-breeding grounds (R2 > 0.997, full output provided in Appendix 10). The model was used to estimate population size of the 19 species which we considered inadequately counted on the non-breeding grounds (Table 2).

Selection of final estimates

Reviewer / coordinator feedback resulted in substantial changes to the first set of estimates from Australia. Figures for extrapolating coastal count data to uncounted areas were amended on the basis of reviewer feedback and applied to coastal count totals (Appendix 11).

Extrapolated coastal estimates were then treated in two ways. Firstly, inland species count data (from S2020 and other sources) were added to the extrapolated coastal total (Appendix 11). Secondly, results of the inland modelling were added to the extrapolated coastal total (Appendix 11). Totals using both actual and modelled inland data are presented to allow comparison between each, the former with many gaps in coverage, and the latter with substantial uncertainty around the estimate.

The modelling of intertidal habitat in the rest of the flyway, calibrated against counts in Australia, produced rather more conservative figures for extrapolation than was initially proposed during discussions in the second workshop. The percentage of potential shorebird habitat covered by AWC sites was as low as 1% and 2% in some countries (in this case, Papua New Guinea and eastern Indonesia, respectively), but the highest extrapolation factors were 3.38 and 3.33, based on evidence from Australia that where counting is sparse, sites where shorebird habitat is concentrated are preferentially chosen (Appendix 4b, c). These extrapolation factors were applied to summed maximum counts on a country-by-country basis (although in several cases on a regional basis, e.g. Indonesia) to produce an extrapolated figure for that country or region for all coastal species (Appendices 12a-d). Data from Palau (Appendix 2) were included without adjustment (Appendix 12d).

The total count of shorebirds across all flyway countries for which we had data was 2,892,898 (Table 2) and the extrapolated total for the flyway was 3,953,332 (Table 2, Appendix 12d). The use of inland modelling values instead of actual inland count data from Australia did not make a substantial difference to the overall estimate: 3,769,680 (data not shown - derived by replacing the values for Australia in Appendix 12d with the values in column 6, Appendix 11).

Flyway totals for some species were clearly too low: Latham's Snipe (1260), Long-toed Stint (587), Pectoral Sandpiper (78), Pin-tailed Snipe (10), Red-necked Phalarope (98), Ruff (5), Swinhoe's Snipe (68), and Wandering Tattler (400). Whilst we have provided extrapolated count figures for these species (Table 2), to be consistent with other species, we do not consider these figures representative of true population sizes.

It was clear that available data were not sufficient to estimate population size of many species that are not coastal obligates, that is, species using freshwater and / or grassland habitats as well as (or in preference to) marine habitats (Table 1). Therefore, the results of breeding ground estimates were used as our flyway population estimates for Common Greenshank, Common Sandpiper, Little Curlew, Little Ringed Plover, Long-toed Stint, Marsh Sandpiper, Pin-tailed Snipe, Red-necked Phalarope, Ruff, Swinhoe's Snipe and Wood Sandpiper, as well as being used to cross-check estimates for other species.

For the two sand plover species, it was difficult to choose between estimates generated from extrapolated counts and breeding range size, in large part because both species are prone to misidentification during field surveys. Estimates for these two species are therefore given as a range, with the recommendation that the lower end of the range is treated as the best estimate available at the present time. Similarly, we presented a range of values for Common Redshank as it was not possible to assess whether the estimate based on counts, or the estimate based on the (poorly known) breeding range was more accurate.

The majority of the population of Wandering Tattler and Pectoral Sandpiper occur in the American Flyways, and estimates generated from these flyways were considered more appropriate than estimates derived from EAAF count data.

As there is currently no genetic evidence to support divergence of either species between the two flyways, and the proportion of the global population that occurs in the EAAF is negligible, the estimates from the Pacific Flyway and Waterbird Population Estimates 5 (Wetlands International 2016) are used here in preference to figures generated from EAAF data. A similar approach was used for Ruff, as most of the world population occurs in other flyways and we did not have sufficient data to improve existing estimates.

Where only old information was available that pre-dated our 10-year temporal window, we sought to adjust such counts using a trend correction.

Latham's Snipe and Oriental Pratincole required this approach as neither had sufficient recent information to update previous estimates (12 years old for Oriental Pratincole and 30 years old for Latham's Snipe). The only trend estimate for Latham's Snipe comes from boreal spring survey data in Japan, which found a significant population change of -0.065 over 10 years. If this is applied to the 1986 population estimate from the breeding grounds of 36,000, the trend adjusted figure dropped to 30,000. No trend information exists for Oriental Pratincole and thus, this estimate remained unchanged from previous (Wetlands International 2016).

The final population estimates are presented in Table 2.

Discussion

Summary of new estimates and species-specific commentary

Three main EAAF population estimates were produced from this analysis:

1. 2,892,898 birds, based solely on actual count data (Table 2, column 1),
2. 3,953,332 birds, based on spatially-extrapolated count data (Table 2, column 2)
3. 5,767,544 birds, based on breeding ground densities and modelled abundance (Table 2, column 3) , but not including Ruff, Wandering Tattler or Pectoral Sandpiper as the majority of their populations migrate to other flyways.

The differences among these figures indicates that a large proportion of potentially suitable shorebird habitat in the EAAF is not being regularly counted. Thus, estimates of flyway populations based solely on count data are likely to be substantial underestimates. In this report we have used several different approaches to make best estimates of the numbers of 'uncounted' shorebirds in this flyway. Estimating the numbers of uncounted birds has resulted in figures that are less likely to be underestimates than uncorrected data, and the reliance on extrapolation will decline as more count data become available in the future.

The final choice of method underpinning each species' population estimate depended on our current knowledge about the ecology and distribution of each species. For example, Pectoral Sandpiper has a very scattered and widespread breeding range but the vast majority of birds migrate to the Americas, suggesting there is no distinct EAAF population of this species. In this case, we used the current population estimate from North America (Morrison et al. 2006) as our final figure. In the case of Latham's Snipe, count information across its non-breeding range is depauperate, due to the tendency of this species to be highly dispersed, in low numbers and with cryptic habits (Higgins and Davies 1996). Therefore, the most reliable estimates originate from census information on the breeding grounds (Naarding 1986). There were no updates to breeding ground census information available for this project and instead, a trend correction was applied to the 1986 census. This was considered most appropriate way to capture changes in population size (Amano et al. 2012) since the previous revision.

In a number of species, estimates derived from the breeding ground analysis were considered more robust than estimates from counts in non-breeding areas. These species were Common Greenshank, Common Sandpiper, Little Curlew, Little Ringed Plover, Long-toed Stint, Marsh Sandpiper, Pin-tailed Snipe, Red-necked Phalarope, Swinhoe's Snipe and Wood Sandpiper. The majority of these species are freshwater and / or grassland species, with the exception of the pelagic Red-necked Phalarope. These breeding ground-based estimates strongly suggest that the flyway population of these species is substantially greater than the numbers that have actually been counted on the non-breeding grounds. Surveys that focus on non-coastal habitats in Asia, including rice-paddies and aquaculture ponds, are necessary to fill this information gap. In addition to potentially refining flyway population estimates in the future, such surveys would be valuable simply to locate the strongholds of a number or species.

It is important to remember that the use of breeding ground data to generate population estimates is a first-pass attempt for the EAAF, and there are many imprecisions in the data on which the models are based.

Most migratory species in the EAAF breed in far northern Asia, in vast, remote regions where relatively few ornithological surveys are done. It is remarkable how much information has been obtained by a small number of determined ornithologists (see, for example, Lappo et al. 2012), but breeding range maps are nevertheless based on sparse data. Furthermore, much of the survey work that has been carried out has been opportunistic, without the resources to sample all habitats in a systematic manner (in contrast with more intensive monitoring that has been carried out in the North American Arctic; Bart and Johnston 2012). As a result, we could only classify breeding densities on a coarse three-category scale. It is also important to remember that distribution maps can include large areas that do not provide breeding habitat, because suitable habitat is often discontinuous throughout a breeding range. Some refinement on a species-by-species basis was possible based on proximity to wetlands mapping, but further refinement could undoubtedly improve further the accuracy of this approach. Therefore, estimates derived using this method require similar caution to those generated using the other modelling approaches.

Choices about the final estimates given in this report have been driven by careful analysis and consideration of extensive expert review. Final estimates are usually a single value, but in cases where we have relied upon other sources of information to generate estimates (Wandering Tattler), or where we cannot resolve uncertainty (sand plovers and redshank) the estimate is reported as a range. Where we have reported a range, we use the value at the bottom of the range to determine the 1% threshold. This reflects our genuine uncertainty about which estimate is more correct.

Australian Estimates

Australia has some of the most comprehensive data available anywhere in the flyway, and we were able to apply robust quantitative methods in most cases. Australia is the terminal destination for many species of EAAF shorebirds, and therefore a preferred location to count shorebirds because the majority visit Australia during their non-breeding season, whereas the same birds cannot be adequately counted at many stopover sites. As such, our confidence in Australian estimates is much higher than those countries further north in the flyway. However, there are several avenues for building on what we have done in the future.

Firstly, the results for each site / species combination would benefit from detailed scrutiny, though this requires a level of time investment we were unable to make in this project. It is likely that site-specific factors could influence estimates of the abundance of each species at each site, for example variation in detectability, survey coverage, or interpretation of missing values. For example, Franklin Harbour in South Australia had a predicted mean of 652 Grey Plover, which is about 10 times higher than an expert assessment of the number of birds present at the site. Expert input enabled this, and other such anomalies to be corrected. Site-by-site inspection of species' individual modelling results may have resulted in more sites having different metrics applied (which was the case after expert review on some site estimates: see Appendix 8). While such scrutiny would no doubt improve the accuracy of underlying figures, investigation at this level of detail for thousands of sites would be enormously time consuming and costly, necessitating lengthy consultation with individual counters around the country.

Secondly, whilst a number of expert reviews were received from each state, most reviewers had limited knowledge of the whole state site network and focused their feedback in areas where they had the most experience. As there are thousands of sites across the country, many smaller sites, particularly those not mapped or allocated to the existing shorebird site network, were not closely reviewed. Many of these sites contain only small numbers of birds and their overall contribution to the flyway population is negligible.

However, future revisions should ensure that feedback from experts and counters is sufficient to be confident that modelling metrics are reasonable representations of the known population any given site.

This would ideally include an analysis of uncertainty surrounding expert opinions, as in some cases, we had to rely on a single source of feedback for correcting estimates and / extrapolations (e.g. NSW expert adjustment to extrapolation figure). This reflects the difficulty in eliciting representative expert review in short timeframes.

Thirdly, our extrapolation approach was focused on quantifying uncounted habitat, rather than estimating the number of birds remaining undetected during counts. The likelihood of birds being missed varies both according to species (e.g. Whimbrels often roost in mangroves where they are hard to find) and on a site-specific basis.

In some cases, we made corrections for problems of this kind following the advice of local experts. For example, in the case of Roebuck Bay (WA) local experts considered the maximum count of Whimbrel over the past five years to be more representative of local numbers, as they felt that in some counts all Whimbrels were recorded, while in others some Whimbrels flew unobserved into mangroves, resulting in a low count that dragged the average down. In contrast, at Eighty Mile Beach, where there are no mangroves, mean counts over the past five years were considered more representative. This approach should be also applied to other states or regions, for example, Whimbrel in Northern Territory which is also likely to be undercounted. To address this need, wider (and longer) expert elicitation is necessary and may be facilitated by targeted workshops or interviews.

Ideally, extrapolations across uncounted habitat should have been species-specific in all cases, but in reality this was not possible in the timeframe of the project. While we were able to make corrections of this kind where we had expert local input, we were unable to obtain similarly detailed feedback from all count sites in Australia. The future challenge for using this approach is to progressively minimise the uncertainty associated with detectability (Wilson et al. 2011), which might be achieved through site-by-site scrutiny to determine average proportion of habitat covered by regular counts for all of Australia.

Despite these caveats, estimates for Australia received by far the most expert scrutiny of all countries. Numbers generated from counts and spatial extrapolations received careful review and revision. Therefore, we consider our estimates produced for Australia to be a substantial improvement on previous figures.

State-based considerations

There are large gaps in count coverage for Northern Territory (NT) and Western Australia (WA), despite the increase in count effort in recent years. This was reflected in generally larger spatial extrapolations and higher adjustments to numbers in these areas than elsewhere in Australia. Large areas of the northern Australian coastline are still data deficient and our knowledge of shorebird population dynamics and habitat use is poor. Difficulties in accessing these often remote areas compound this problem. This clearly indicates that additional resources are required to address our knowledge gaps in northern Australia (particularly the Northern Territory, which holds significant populations of birds) if we are to increase the confidence in estimates derived from existing systematic monitoring.

For the NT (Chatto 2003, 2012), it was difficult to distinguish extrapolations between ground and aerial counts from observed numbers, and it is difficult to establish from the reports how many birds were counted on each date.

Gaps in count coverage in more recent data from the NT meant that we considered the trend-corrected older data (Chatto 2003) more reliable than the recent data (Chatto 2012). Count data provided by P. Barden, which overlapped with several Chatto sites in the Limmen Bight and Port MacArthur regions, were used as a cross-reference as well as to validate trend-corrected numbers.

Data supplied by A. Lilleyman for the Port of Darwin were added to the trend-corrected Chatto data, which were then both added to the spatially-extrapolated S2020 data to produce a state estimate. The NT surveys by Chatto (2003, 2012) remain extremely important data, and as it is perhaps unlikely that such broad-scale shorebird surveys will be undertaken again in the NT, we emphasise the need for more detailed analysis of the underlying raw counts.

AWC data considerations

Beyond Australia and New Zealand, data were typically much more sparse in space and time, and there are regions where large areas of presumably suitable shorebird habitat are essentially unrepresented in the data assembled for this analysis, primarily much of south-east Asia and China. In some cases, count data do exist, but are not available in the Asian Waterbird Census, but in the majority of cases there are significant gaps in coverage, and therefore our knowledge about the distribution and abundance of shorebirds. Our bathymetric spatial modelling suggests a number of sites where shorebirds are likely to occur during the non-breeding season, notably in PNG, eastern Indonesia and Sumatra, that warrant immediate future survey. Identifying and filling these gaps is an urgent priority, particularly in those regions proximal to Australia that potentially support high abundances of the 37 species considered here. Stronger collaboration with, and resourcing of the EAAF Partnership would facilitate addressing this knowledge gap.

Species considerations

Several species were treated as special cases. Since the previous estimate of 2.88 million for Oriental Pratincole (Bamford et al. 2008, Wetlands International 2016), there have been at least two very large counts (>500,000 birds; Piersma and Hassell 2010, Minton et al. 2015); although numbers recorded did not approach those recorded in 2004 (Sitters et al. 2004), it is possible that this was related to lower survey effort rather than changes in numbers. Ideally, the 2004 estimate would be trend-corrected, however, there is no information on trends for this species and we had little choice but to retain the old estimate. Estimates for Pectoral Sandpiper and Wandering Tattler derived from EAAF counts were considered of little relevance as only a fraction of the population visits this flyway, and thus existing estimates from the Americas flyways were used. Similarly, estimates for Ruff were also considered unrepresentative and the current Waterbird Population Estimates figures (Wetlands International 2016) was considered more robust.

Counts with spatial extrapolations of the two sand plover species combined were similar to numbers predicted on the basis of breeding range models. However, different estimates of the numbers of each of the two species were generated by the alternative methodologies. Counts on the non-breeding grounds (with spatial extrapolations) indicated that Lesser Sand Plover is more numerous than Greater Sand Plover, while breeding range suggested that Greater Sand Plover should be more numerous. Potential explanations for these discrepancies include: (1) Lesser Sand Plover may nest at higher densities than Greater Sand Plover; (2) some Greater Sand Plovers may be misidentified as Lesser Sand Plovers on the non-breeding grounds, as the two species are difficult to distinguish in non-breeding plumage. While we consider both of these scenarios (or a combination of them) to be plausible, at present we have no data to indicate which is most likely.

Accordingly, we present an estimate range for the population size of both Greater and Lesser Sand Plovers; in keeping with the precautionary principle we recommend that the lower end of these ranges are regarded as the population size when estimating 1% criteria for the identification of internationally important sites.

In the case of Common Redshank, our knowledge about movements of different populations and their breeding ranges is poor, and count information for the species in the EAAF is lacking. We were not confident about relying solely on the estimate derived from breeding distribution, nor from the spatial extrapolation, and so we have opted to employ a range for this species.

Oriental Plover were recorded in large numbers in February 2010 on 80 Mile Beach (Piersma and Hassell 2010), which forms a significant proportion of the flyway population estimate. This count, while unusual, was conducted systematically and represented a large aggregation of birds moving off the adjacent grasslands to the beach in the hottest part of the day, a behaviour often observed in the region (Rogers et al. 2011). Thus, it is considered more representative of numbers present in this region than other smaller counts.

Current knowledge of the non-breeding range of Asian Dowitcher is that over 50% of the population occurs in coastal north-east Sumatra near the mouths of large rivers (Bamford et al 2008). As there has been limited counts at the key sites in this area the updated population estimate may understate the current population size.

Sharp-tailed Sandpipers is an example of a species which may be found in large numbers in both estuarine and freshwater habitat. When inland areas dry out, Sharp-tailed Sandpipers are forced to refuges in coastal areas moving opportunistically between near coastal ephemeral freshwater and estuarine areas.

The Hunter Estuary is an example (Stuart 2015), where a regional population in some years may be internationally significant and contribute to both the coastal and inland population estimates of a shorebird species. However, the inland population estimates are considered to be relatively insensitive to the impact of such deficiencies in the methodology.

Inland modelling

The inland modelling introduced a novel approach to this revision, by estimating the numbers of birds occupying inland habitats over time via simultaneous analysis of S2020 count data and the BirdLife Australia Atlas. For the first time, we have an analytical approach that enables the investigator to quantify, and place confidence limits around estimates of population sizes occurring in remote and vast inland areas. In this respect, we believe the approach used here offers a new avenue for future revisions and will be strengthened with the acquisition of new data and increases in analytical capacity.

There are several caveats to the inland modelling method. The modelling only drew on sites for which some shorebird count data are available, and there are likely to be wetlands (especially in central and northern Australia) where shorebird counts have never been carried out, or never been carried out in optimal conditions. For example, Lake Sylvester (Barkly Tablelands, NT) can cover up to 2000 km^2 in flood conditions, potentially supporting large numbers of waterbirds – but in flood conditions access to the site is extremely difficult. Because of this limitation, we suspect the modelling approach is quite conservative. Nevertheless we feel it provides a more accurate estimate of inland shorebird numbers than uncorrected counts; we know that there are birds inland that are being missed in systematic surveys, in much the same way as the coastal counts and extrapolations.

The inland modelling approach produced unrealistic estimates for Black-tailed Godwit, Little Curlew, Long-toed Stint, Oriental Plover and Wood Sandpiper, all much lower than expected from anecdotal accounts and expert judgement. This reflects large confidence intervals in estimates generated from this method suggesting that if the models were run again with additional data, the results could change substantially. The modelling also underperformed when attempting to predict numbers for very high shorebird abundance locations like Lake Argyle (WA) and the Coorong (SA), due to the relatively rare occurrence of these types of sites. Furthermore, many variables used in the modelling were spatially auto-correlated potentially resulting in over-predictions of small numbers and under-predictions of large numbers. We limited the predictor variables to wetland-related variables, meaning that models for grassland species such as Oriental Pratincole and Little Curlew performed poorly. This problem can only be rectified with additional data, which currently do not exist.

The large variation in inland modelling estimates for most species reflects the large and dynamic movement patterns of birds that are presumed to occur between the coast and inland habitats when inland climatic conditions are suitable. For example, Sharp-tailed Sandpipers occur in internationally significant at the Hunter Estuary in some years, but not in others (Stuart 2015).

Extrapolation

In most countries around the flyway, much shorebird habitat is unsurveyed, and we attempted to correct for this by mapping potential intertidal area and extrapolating the available count data on this basis. The level of extrapolations ultimately applied to AWC data was relatively modest and considered reasonably realistic: a major outstanding issue with these count data are the gaps. However, it is quite possible that uncounted areas differ systematically from counted areas, for example if observers are more likely to count an area if it contains a high concentration of shorebirds. Although we attempted to account for such effects by calibrating our extrapolation using high quality data from Australia (see Appendix 4b), and subjecting all estimates to rigorous expert evaluation, there remains substantial unquantified uncertainty in the extrapolation process. Comprehensive mapping of the extent and character of intertidal habitats in the EAAF is urgently required.

Comparison with previous flyway population estimates

These flyway population estimates use newly available data and different analytical approaches to those used in previous population estimate assessments. **As a result, the numbers reported here cannot be compared with previous estimates to draw conclusions about population trends.** Dedicated analyses on data that are comparable over time are the only way to make conclusions about population trends (e.g. Amano et al. 2010; Wilson et al. 2011; Clemens et al. 2016). Any differences between our figures and previous estimates reflect an enormous increase in knowledge and information about shorebirds in this flyway over the past decade. They do not necessarily represent actual increases or decreases in population size and must not be used to infer trends in this manner.

In recent years, shorebird count effort in Australia alone has increased substantially. This was driven in part by establishment of the Shorebirds 2020 program in 2007, which resulted in an increase in volunteer participation and coverage of new areas. This also reflects a more general trend across the flyway of greater count coverage by volunteers. Consequently, there has been an increase in the overall numbers of birds recorded in available databases.

Population estimates were more than 10% higher than past estimates for 17 species (Table 2). Increases in Broad-billed Sandpiper, Great Knot, Grey-tailed Tattler, Oriental Plover, Red-necked Stint and Sanderling were due to an increase in the amount of data available for analyses and the application of the spatial extrapolation. However, increases in Common Sandpiper, Little Ringed Plover, Long-toed Stint, Marsh Sandpiper, Pin-tailed Snipe, Red-necked Phalarope, Swinhoe's Snipe and Wood Sandpiper were due to the use of breeding range and density estimates. Common Redshank, and the two sand plover species had increases driven by both methods.

In some species, revised population estimates are lower than previous estimates, consistent with population declines identified by specialised analyses (e.g Clemens et al. 2016). In other species, revised population estimates are higher than those previously estimated, the most extreme case being Long-toed Stint (820% difference; Table 2). In most such cases, the main reasons for this discrepancy is that (a) there is more data on a species as a result of greater count information, and / or (b) previous assessments did not attempt to estimate the numbers of shorebirds in regions where shorebird surveys have yet to be carried out. This is clearly reflected in the Greater Sand Plover example, where counts prior to spatial extrapolation are nearly double the previous estimate (Wetlands International 2016).

Considerations for future population estimate revisions

During this project, we identified several further options for future research and analysis that could further improve future population estimates:

- Use of staging data to help verify estimates - this was an approach posed during workshops and discussions that warrants future investigation.
- Exploration of the influence of species-specific differences in distributional heterogeneity across available habitat on the extrapolation methods employed here.
- Greater for time soliciting feedback from counters for adjusting site numbers and state estimates, and assessment of uncertainty surrounding these expert opinions. As a minimum, we suggest that six months is required to allow people time to respond and values to be adjusted, before embarking on the process of selecting final flyway estimates.
- Investment in data collection from new areas, along with curation, error checking and analysis of existing datasets would further improve the robustness of shorebird monitoring data for future revisions.

Closing remarks

Populations of migratory shorebirds in the East Asian-Australasian Flyway are in rapid decline, and protecting remaining habitat along all stages of their migratory pathway is crucial for their stabilisation and recovery (Kirby et al. 2008; Murray and Fuller 2015). This is especially important given the continuing loss of shorebird habitat in the flyway, and the emerging evidence of additional threats impacting the birds, such as coastal habitat degradation (Murray et al. 2015), sea-level rise (Iwamura et al. 2013), hunting (Turrin and Watts 2016), and Arctic climate change (Wauchope et al. 2016). The updated population estimates presented here provide the underpinning data to assess the importance of any area of shorebird habitat throughout Australia.

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Tables

Table 1. List of East Asian-Australasian Flyway migratory shorebird species that visit Australia.

Habitat is the dominant habitat use in Australia and represented by either M=marine, IW=inland wetlands or G=grasslands. WPE5 estimate is the current global population estimates summed across relevant subspecies for the EAAF (Wetlands International 2016).
Conservation status refers to IUCN status listed in Garnett *et al.* (2010), except for Eastern Curlew, Curlew Sandpiper, Bar-tailed Godwit, Great Knot, Red Knot (Department of the Environment 2016).

Scientific Name	Common Name	Habitat	WPE5 estimate	Conservation status
Pluvialis fulva †	Pacific Golden Plover	M	135,000-150,000	
Pluvialis squatarola	Grey Plover	M	104,000	NT
Charadrius dubius †	Little Ringed Plover	M, IW	50,000-125,000	
Charadrius bicinctus	Double-banded Plover	M, IW	50,000	
Charadrius mongolus †	Lesser Sand Plover	M	188,500-218,500	E
Charadrius leschenaultia	Greater Sand Plover	M	79,000	V
Charadrius veredus	Oriental Plover	M, IW, G	145,000-155,000	
Gallinago hardwickii	Latham's Snipe	IW, G	25,000-1,000,000	
Gallinago stenura	Pin-tailed Snipe	IW, G	25,000-1,000,000	
Gallinago megala	Swinhoe's Snipe	IW, G	25,000-1,000,000	
Limosa limosa	Black-tailed Godwit	M, IW	139,000	V
Limosa lapponica †	Bar-tailed Godwit	M	279,000	CE * / V
Numenius minutus	Little Curlew	IW, G	180,000	
Numenius phaeopus	Whimbrel	M	55,000	NT
Numenius madagascariensis	(Far) Eastern Curlew	M	32,000	CE
Xenus cinereus	Terek Sandpiper	M	50,000-55,000	
Actitis hypoleucos	Common Sandpiper	M, IW	50,000	
Tringa brevipes	Grey-tailed Tattler	M	44,000	NT
Tringa incana	Wandering Tattler	M	10,000-25,000	
Tringa nebularia	Common Greenshank	M, IW	100,000	
Tringa stagnatilis	Marsh Sandpiper	M, IW	100,000-1,000,000	
Tringa totanus †	Common Redshank	M	45,000-1,200,000	
Tringa glareola	Wood Sandpiper	IW	100,000	
Arenaria interpres	Ruddy Turnstone	M	28,500	NT
Limnodromus semipalmatus	Asian Dowitcher	M	23,000	NT
Calidris tenuirostris	Great Knot	M	290,000	CE
Calidris canutus †	Red Knot	M	99,000-122,000	E
Calidris alba	Sanderling	M	22,000	
Calidris ruficollis	Red-necked Stint	M, IW	315,000	
Calidris subminuta	Long-toed Stint	M, IW	25,000	
Calidris melanotos	Pectoral Sandpiper	M, IW	1,220,000-1,930,000	
Calidris acuminate	Sharp-tailed Sandpiper	M ,IW	160,000	
Calidris ferruginea	Curlew Sandpiper	M, IW	135,000	CE
Calidris falcinellus	Broad-billed Sandpiper	M	25,000	
Calidris pugnax	Ruff	M, IW	25,000-100,000	
Phalaropus lobatus	Red-necked Phalarope	M	100,000-1,000,000	
Glareola maldivarum	Oriental Pratincole	IW, G	2,880,000	

† these species have two or more subspecies which are recognised in the EAAF. Population estimates and thus, 1% population criterion, differ between subspecies and hence, the 1% criterion for each species is not presented here. See Waterbird Population Estimates (2016) for the most recent values.

* Bar-tailed Godwit subspecies *menzbieri* listed as Critically Endangered and subspecies *baueri* listed as Vulnerable under recent (5 May 2016) EPBC Act changes.

Table 2. New East Asian-Australasian Flyway population estimates with adjustments

Estimates directly from counts & other data sources provides count data summed across each country, with no extrapolations and for Australia, inland count values (not inland modelled values). Estimate with spatial extrapolations uses Australian figures that incorporates inland modelled values (seventh column, Appendix 11. Final estimate basis: "Both" refers to species where the estimate is provided as a range, and the range is determined by values from both the extrapolated count and the breeding range and density analyses. Final revised estimates are rounded following the same rules as applied in Bamford et al. (2008): see below for details. Where the analysis process used in this report was not applied to a species, e.g. pectoral sandpiper, the alternative source of a population estimate is given.

Common Name	Scientific Name	Estimate directly from counts & other data sources	Estimate with spatial extrapolations	Estimate based on breeding range & density	Final estimate basis	Final population estimate
Asian Dowitcher	*Limnodromus semipalmatus*	4837	14,172	12,673	Extrapolated count	14,000
Bar-tailed Godwit	*Limosa lapponica*	274,647	319,182	237,552	Extrapolated count	325,000
Black-tailed Godwit	*Limosa limosa*	90,981	159,652	157,800	Extrapolated count	160,000
Broad-billed Sandpiper	*Calidris falcinellus*	15,755	30,139	24,340	Extrapolated count	30,000
Common Greenshank	*Tringa nebularia*	34,367	62,953	105,216	Breeding range & density	110,000
Common Redshank	*Tringa totanus*	32,436	75,884	146,406	Both	75,000-150,000
Common Sandpiper	*Actitis hypoleucos*	22,846	55,238	193,024	Breeding range & density	190,000
Curlew Sandpiper	*Calidris ferruginea*	85,086	92,294	68,494	Extrapolated count	90,000
Double-banded Plover	*Charadrius bicinctus*	13,057	18,786	19,559	Extrapolated count	19,000
Far Eastern Curlew	*Numenius madagascariensis*	24,914	33,840	34,862	Extrapolated count	35,000
Great Knot	*Calidris tenuirostris*	359,719	419,186	536,565	Extrapolated count	425,000
Greater Sand Plover	*Charadrius leschenaultia*	150,373	199,258	295,048	Both	200,000-300,000
Grey Plover	*Pluvialis squatarola*	42,812	77,616	100,324	Extrapolated count	80,000
Grey-tailed Tattler	*Tringa brevipes*	61,612	71,016	74,220	Extrapolated count	70,000
Latham's Snipe	*Gallinago hardwickii*	1124	1260 #	35,127	Trend correction ‡	30,000
Lesser Sand Plover	*Charadrius mongolus*	146,168	284,105	182,910	Both	180,000-275,000
Little Curlew	*Numenius minutus*	36,648	76,913	109,105	Breeding range & density	110,000
Little Ringed Plover	*Charadrius dubius*	21,707	48,761	154,970	Breeding range & density	150,000
Long-toed Stint	*Calidris subminuta*	582	587 #	230,939	Breeding range & density	230,000
Marsh Sandpiper	*Tringa stagnatilis*	50,014	102,439	130,457	Breeding range & density	130,000
Oriental Plover	*Charadrius veredus*	190,388	232,124	160,468	Extrapolated count	230,000
Oriental Pratincole	*Glareola maldivarum*	588,972	587,051	1,274,398	Existing estimate ‡‡	2,880,000

Common Name	Scientific Name	Estimate directly from counts & other data sources	Estimate with spatial extrapolations	Estimate based on breeding range & density	Final estimate basis	Final population estimate
Pacific Golden Plover	*Pluvialis fulva*	66,402	122,379	176,009	Extrapolated count	120,000
Pectoral Sandpiper	*Calidris melanotos*	89	78 #	231,533	Existing estimate †	1,220,000-1,930,000
Pin-tailed Snipe	*Gallinago stenura*	6	10 #	168,125	Breeding range & density	170,000
Red Knot	*Calidris canutus*	97,005	112,920	147,501	Extrapolated count	110,000
Red-necked Phalarope	*Phalaropus lobatus*	50	98 #	249,671	Breeding range & density	250,000
Red-necked Stint	*Calidris ruficollis*	282,882	477,990	285,343	Extrapolated count	475,000
Ruddy Turnstone	*Arenaria interpres*	24,191	29,367	30,670	Extrapolated count	30,000
Ruff	*Calidris pugnax*	3	5 #	271,526	Existing estimate †	25,000-100,000
Sanderling	*Calidris alba*	22,554	29,835	33,605	Extrapolated count	30,000
Sharp-tailed Sandpiper	*Calidris acuminate*	71,642	85,829	120,684	Extrapolated count	85,000
Swinhoe's Snipe	*Gallinago megala*	22	68 #	41,511	Breeding range & density	40,000
Terek Sandpiper	*Xenus cinereus*	30,761	49,949	54,265	Extrapolated count	50,000
Wandering Tattler	*Tringa incana*	322	400 #	58,456	Existing estimate ††	10,000-25,000
Whimbrel	*Numenius phaeopus*	38,208	66,701	48,364	Extrapolated count	65,000
Wood Sandpiper	*Tringa glareola*	9717	15,249	127,339	Breeding range & density	130,000
		2,892,898	3,953,332	6,329,059		

extrapolations unrepresentative as count data insufficient to derive estimates for these species.

† WPE5 (Wetlands International 2016)

†† WPE5 (Wetlands International 2016); 10,000 (Morrison et al. 2001)

‡ Applies a trend correction (Amano et al. 2012) to 1986 estimate (36,000) from the breeding grounds

‡‡ Uses previous population estimate (Bamford et al. 2008)

Population size rounding: <10 000 nearest 500; 10 000 – 25 000 nearest 1 000; 25 000 – 100 000 nearest 5 000; 100 000 – 250 000 nearest 10 000; >250 000 nearest 25 000.

Figures

Figure 1. East Asian-Australasian Flyway.

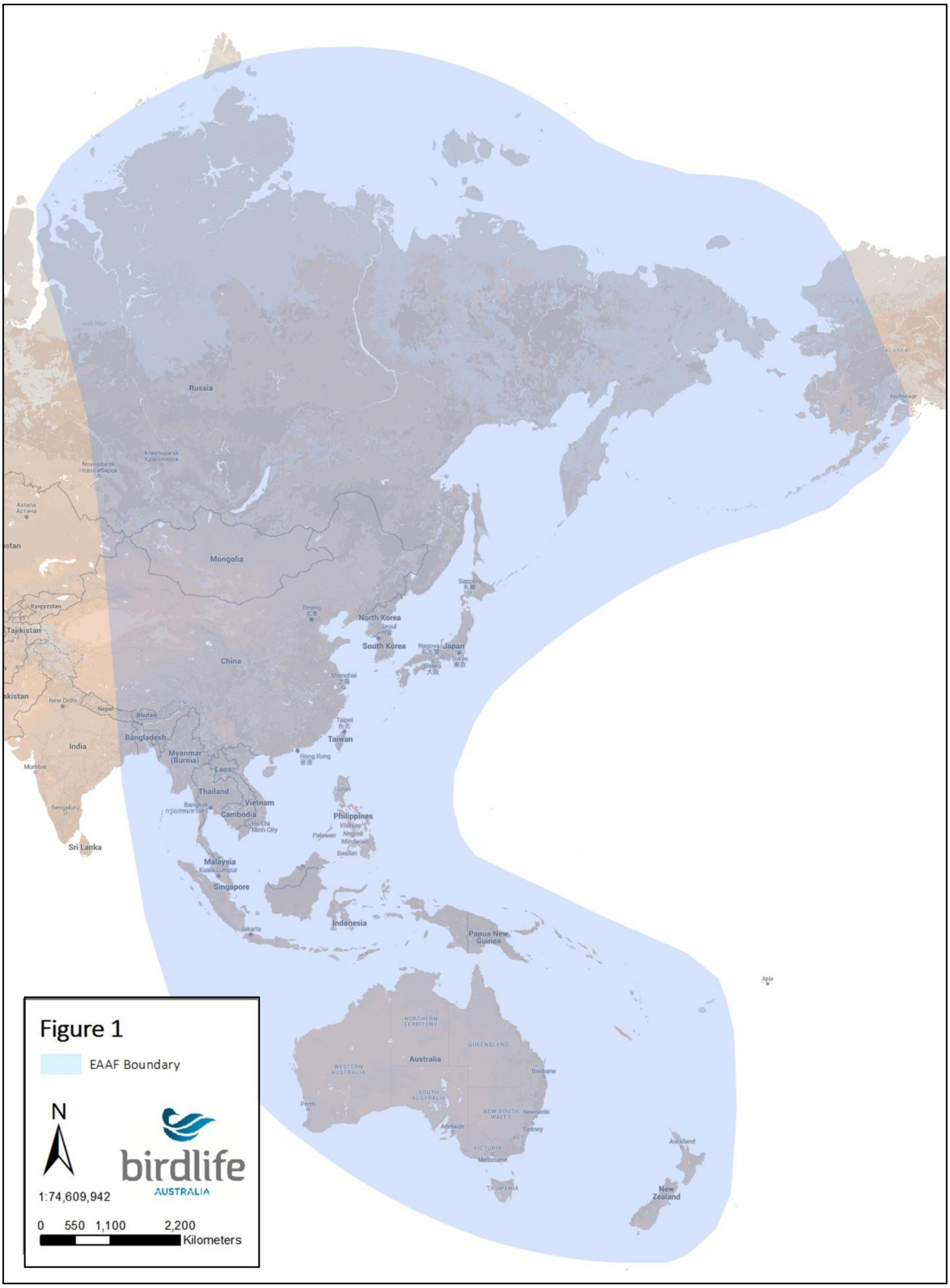


Figure 2. Example of a migration range map from Birdlife International - Sharp-tailed Sandpiper *Calidris acuminata*.

Breeding range shown in orange, non-breeding destinations in blue, and yellow regions used while migrating. Map source BirdLife International and NatureServe (2015).

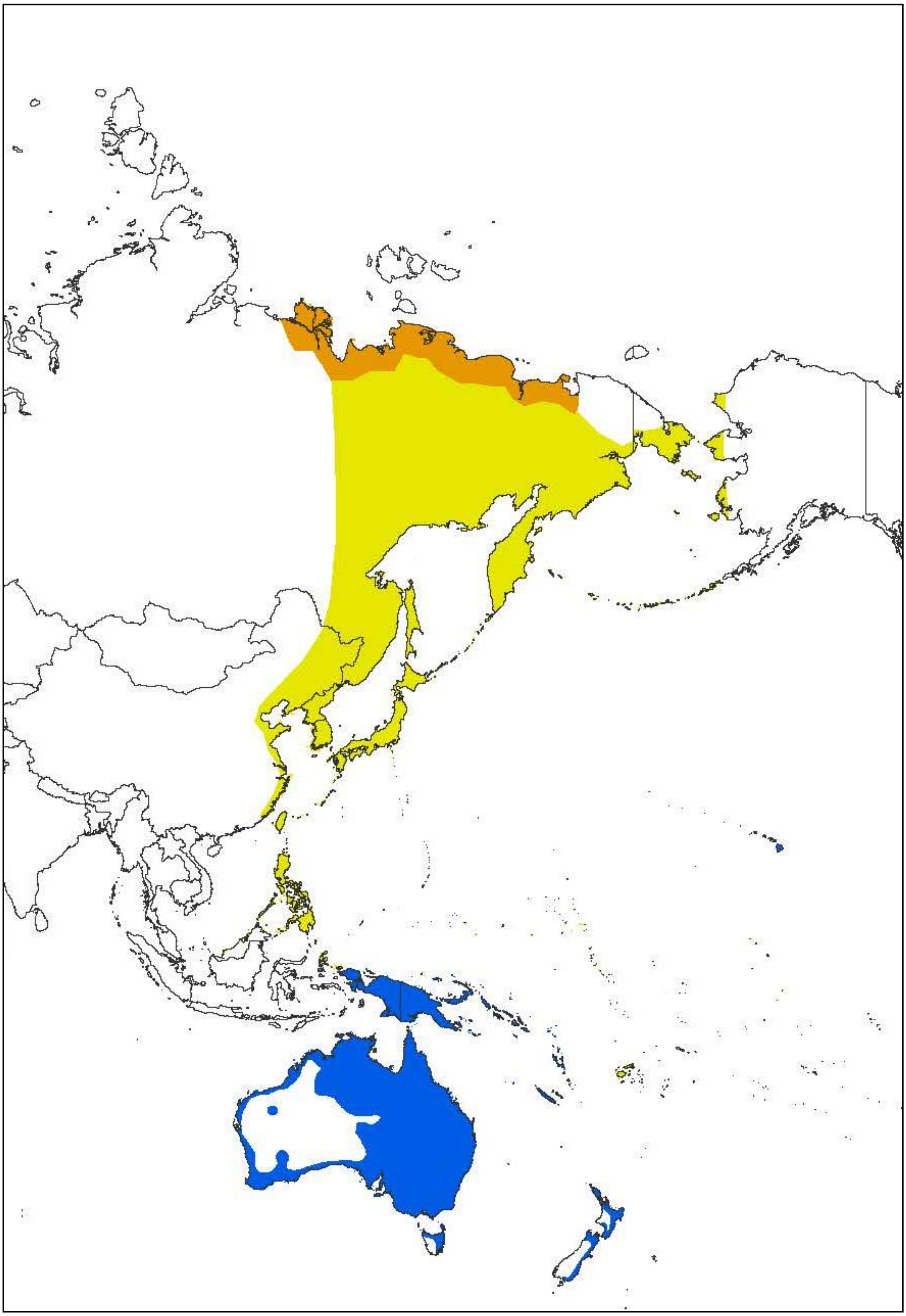


Figure 3. Example of the breeding range and distribution of all 37 East Asian-Australasian Flyway shorebird species regularly visiting Australia

Breeding distribution shapefiles were obtained from BirdLife International & NatureServe (2015). We regarded birds as 'belonging' to the EAAF if they migrated through the flyway to non-breeding destinations within the flyway.

The breeding range polygon for each species was modified where necessary to cover the area of the breeding distribution falling within the EAAF for each species, based on literature review (most notably Lappo *et al.* 2012), and also through consultation with experts. Maps of the breeding distributions applied in this analysis and a summary of the assumptions made are provided in Appendices 5 and 6. This delineation involved a combination of (i) mapping areas of the breeding distribution of birds that spend the non-breeding season in the EAAF, and (ii) extracting areas only in close proximity to wetlands for seven species that depend specifically on wetlands for breeding.

Light blue shading depicts the extent of the EAAF; Green depicts the breeding range specific to each species; darker blue shows the areas of wetland within the breeding range of species which are dependent on wetland areas for breeding.

Figure 3.1 – Ruddy Turnstone

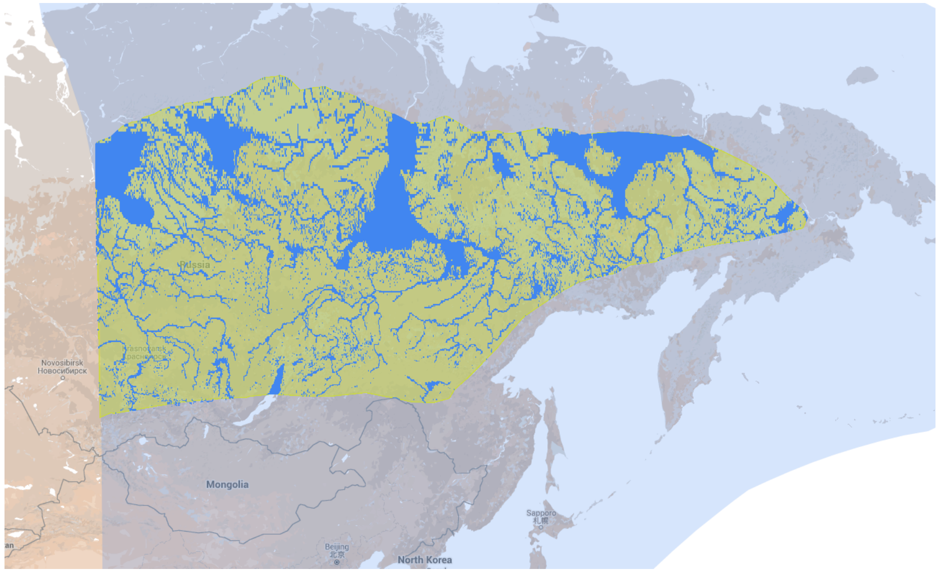


Figure 3.2 – Terek Sandpiper

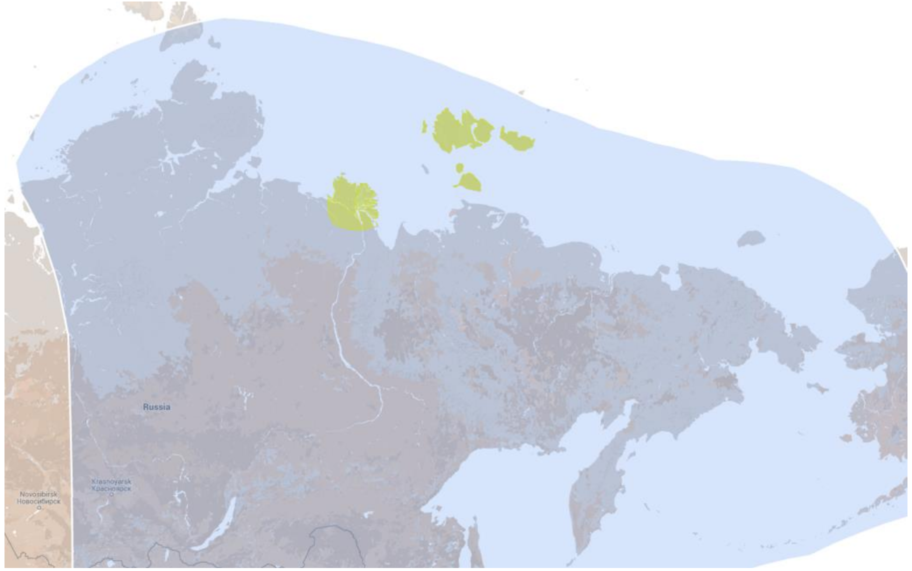


Figure 3.3 - Sanderling

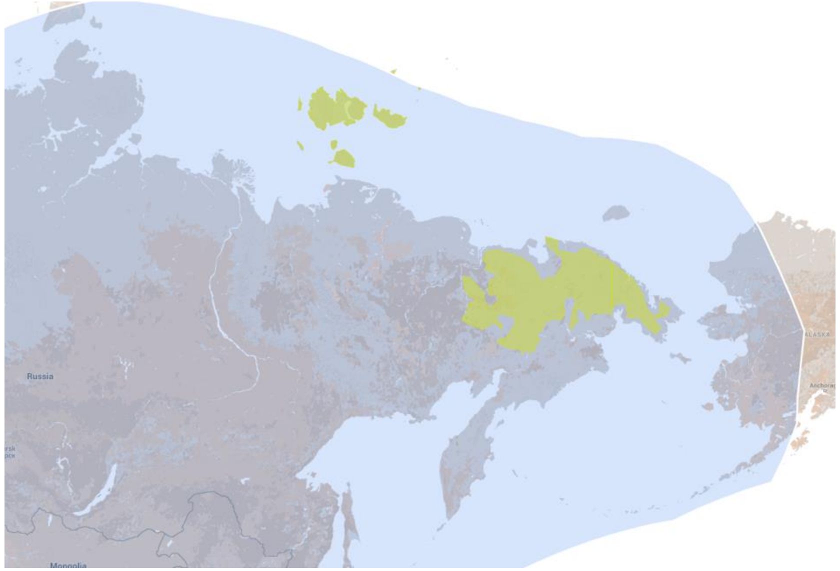


Figure 3.4 – Red Knot

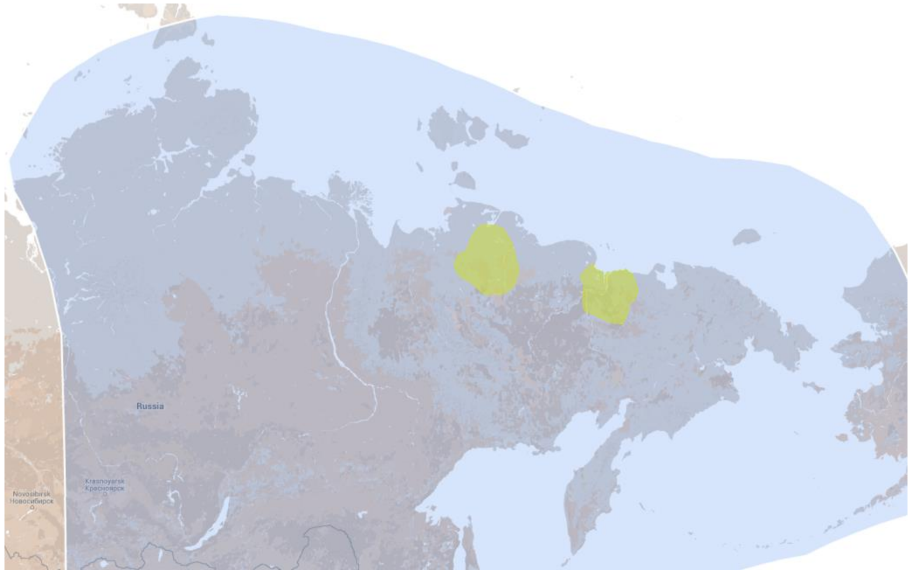


Figure 3.5 – Broad-billed Sandpiper

Figure 3.6 - Curlew Sandpiper

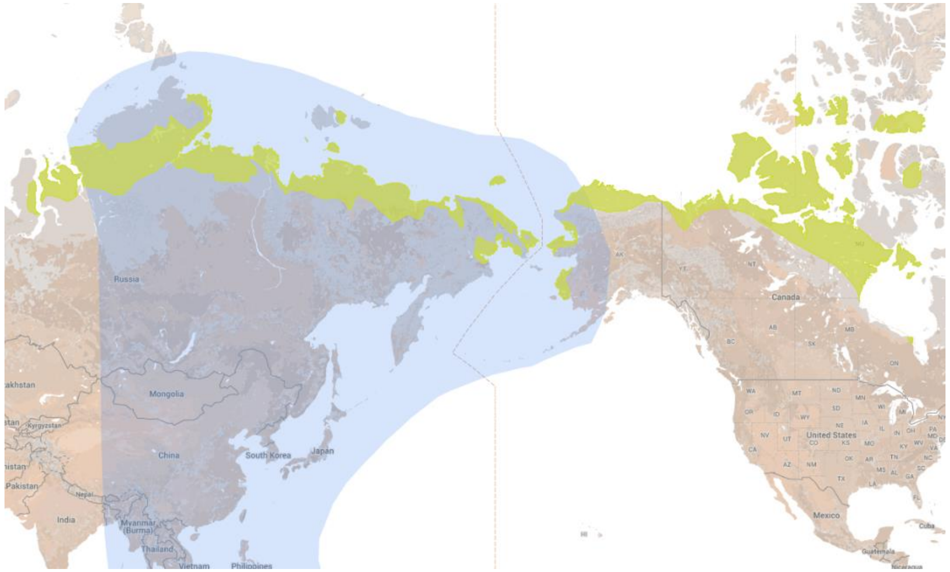


Figure 3.7 – Pectoral Sandpiper

Figure 3.8- Ruff

Figure 3.9 – Red-necked Stint

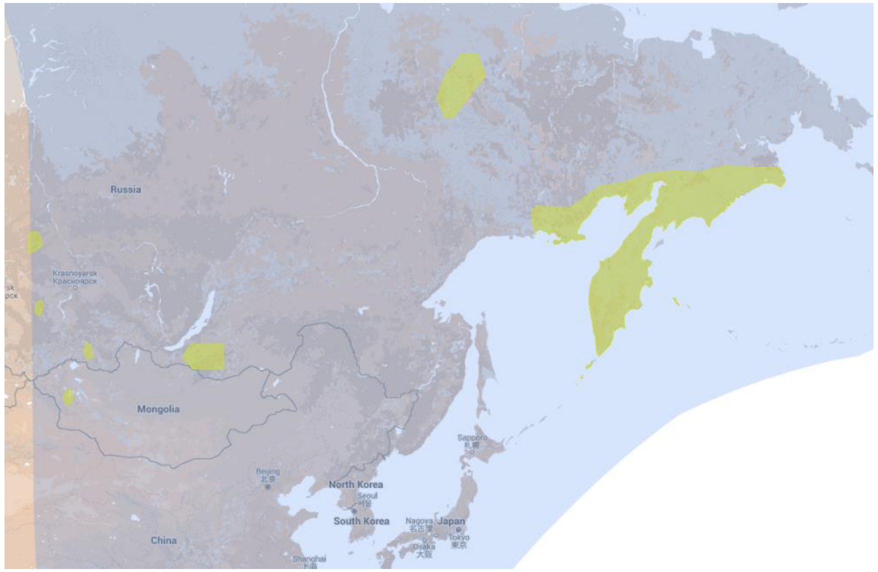


Figure 3.10 – Long-toed Stint

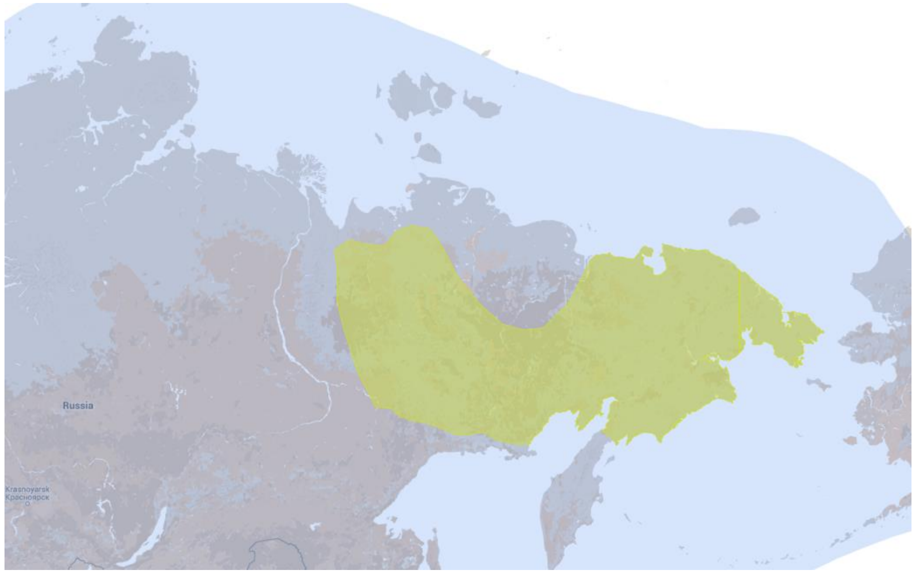


Figure 3.11 – Great Knot

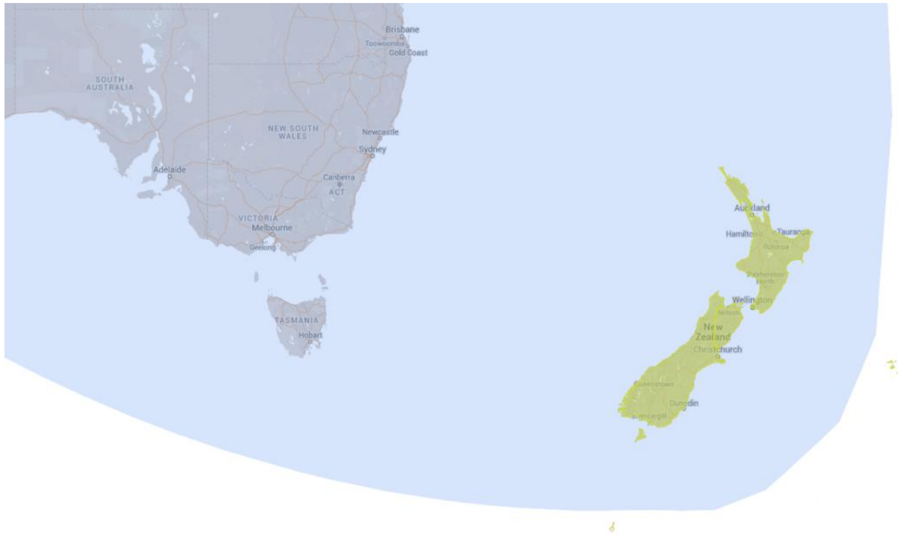


Figure 3.12 – Double-banded Plover

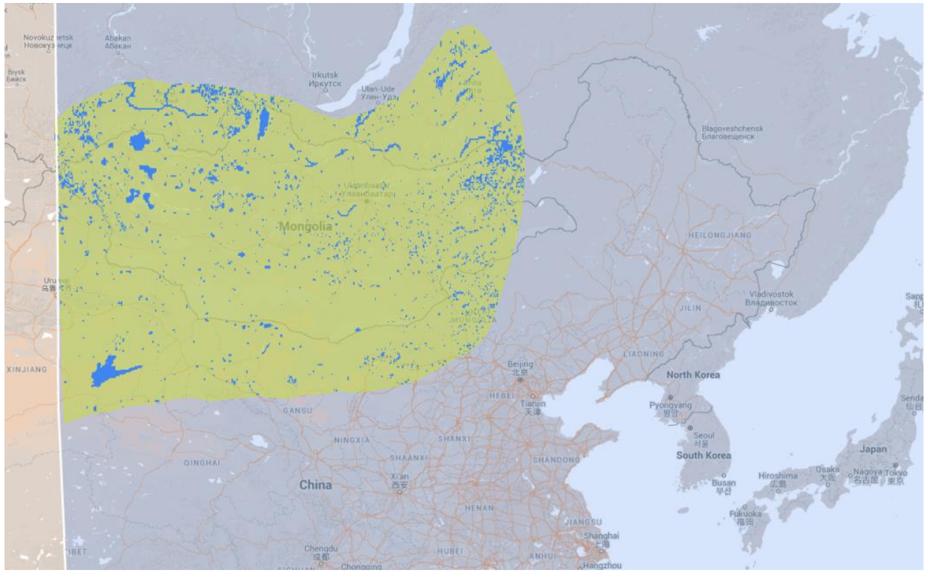


Figure 3.13 – Greater Sand Plover

Figure 3.14 – Lesser Sand Plover

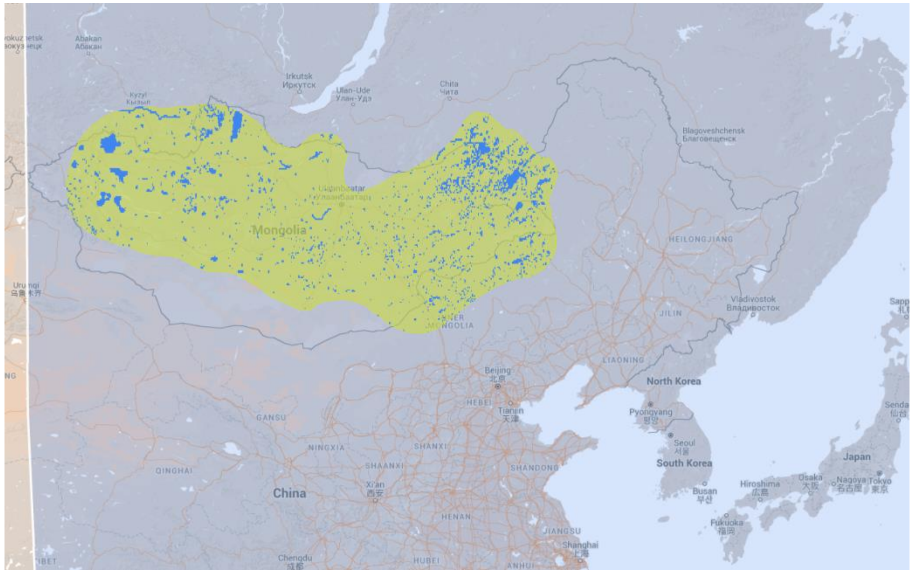


Figure 3.15 – Oriental Plover

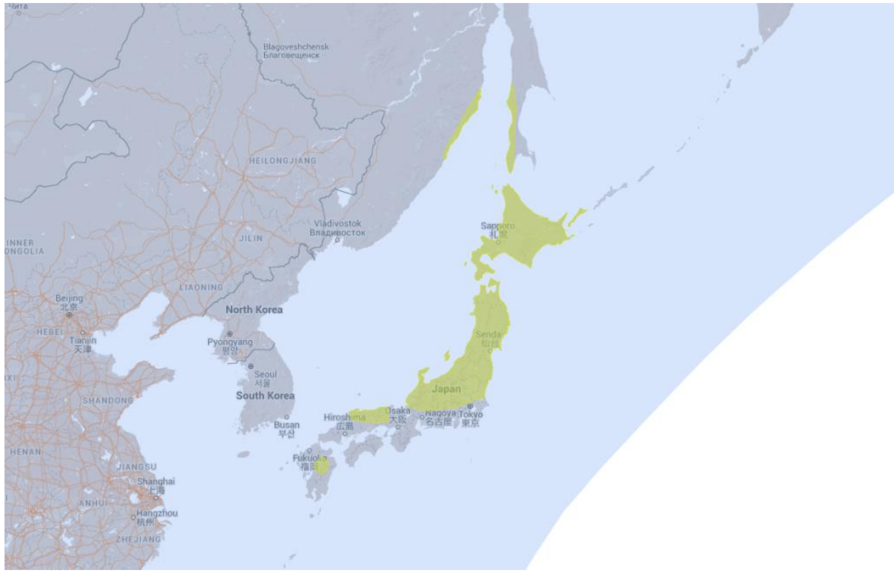


Figure 3.16 – Latham's Snipe

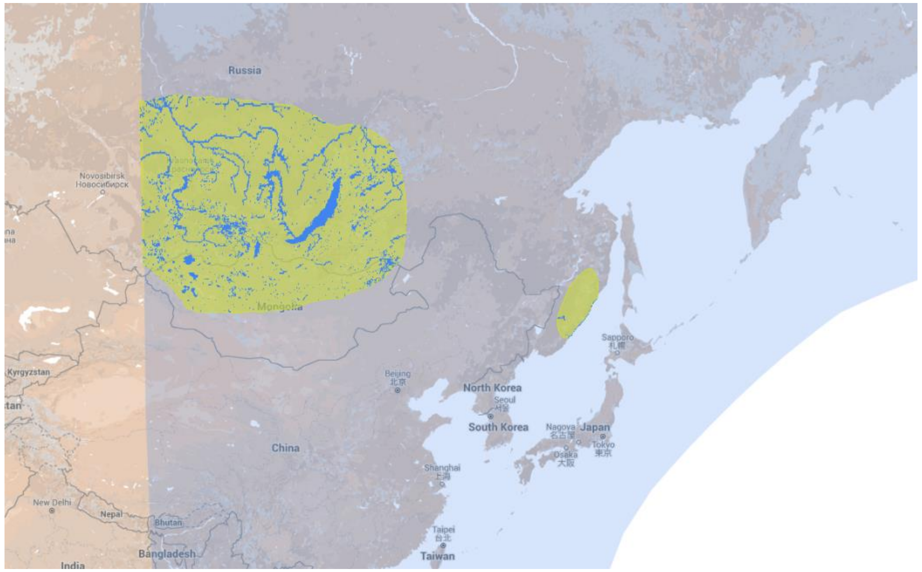


Figure 3.17 – Swinhoe's Snipe

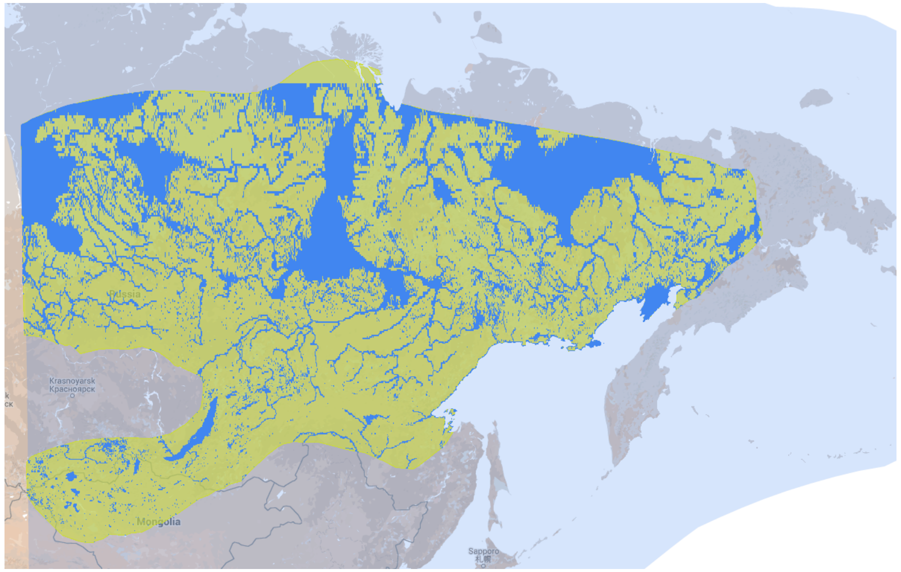


Figure 3.18 – Pin-tailed Snipe

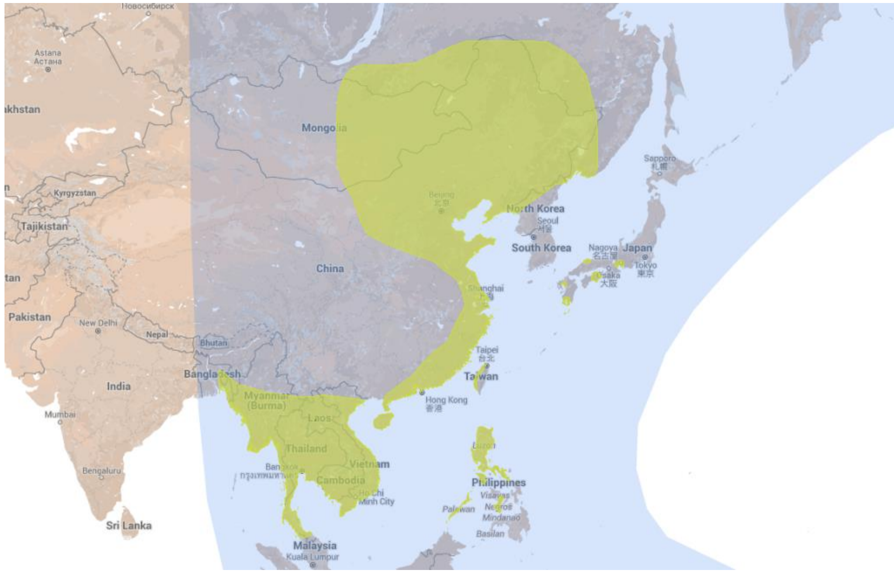


Figure 3.19 – Oriental Pratincole

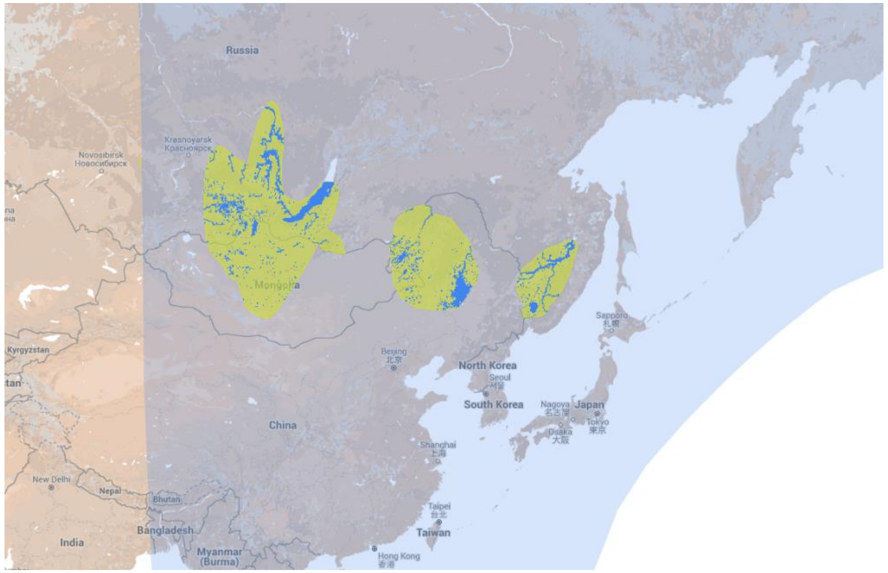


Figure 3.20 - Asian Dowitcher

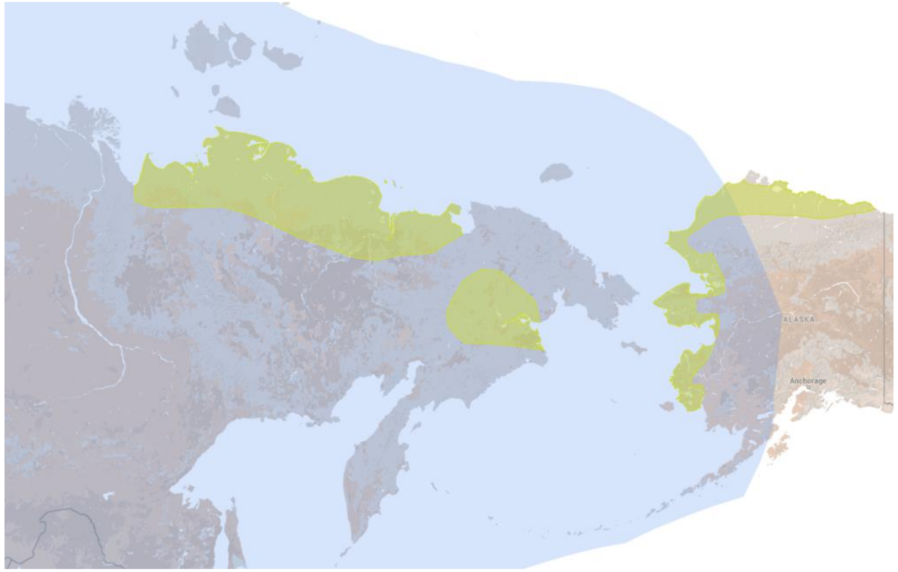


Figure 3.21 – Bar-tailed Godwit

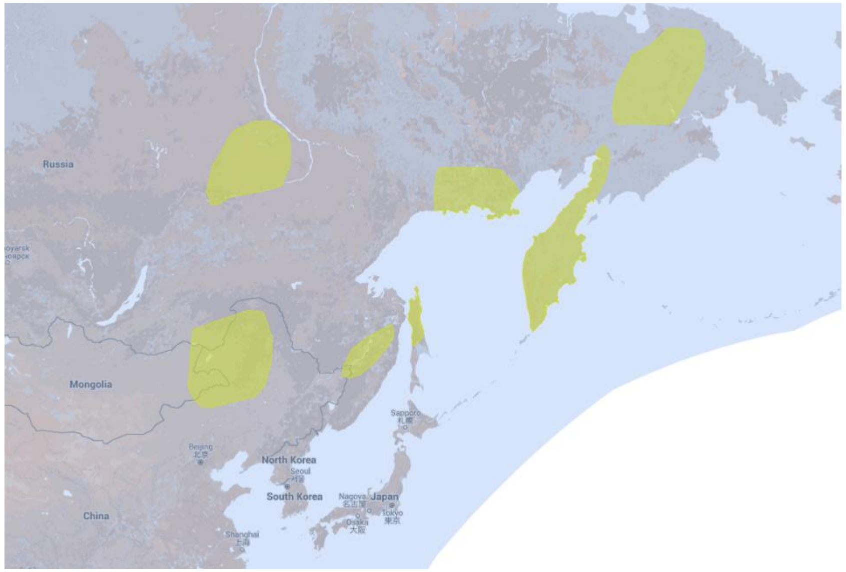


Figure 3.22 – Black-tailed Godwit

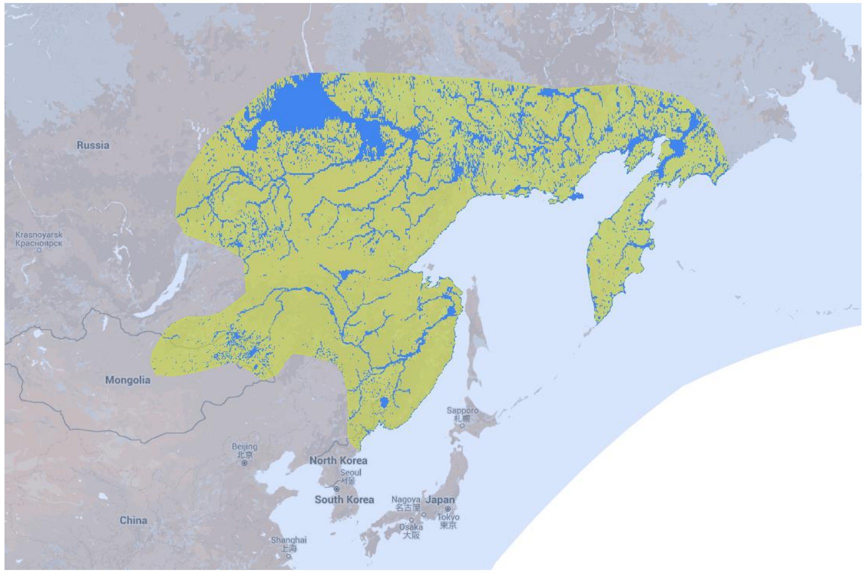


Figure 3.23 – Eastern Curlew

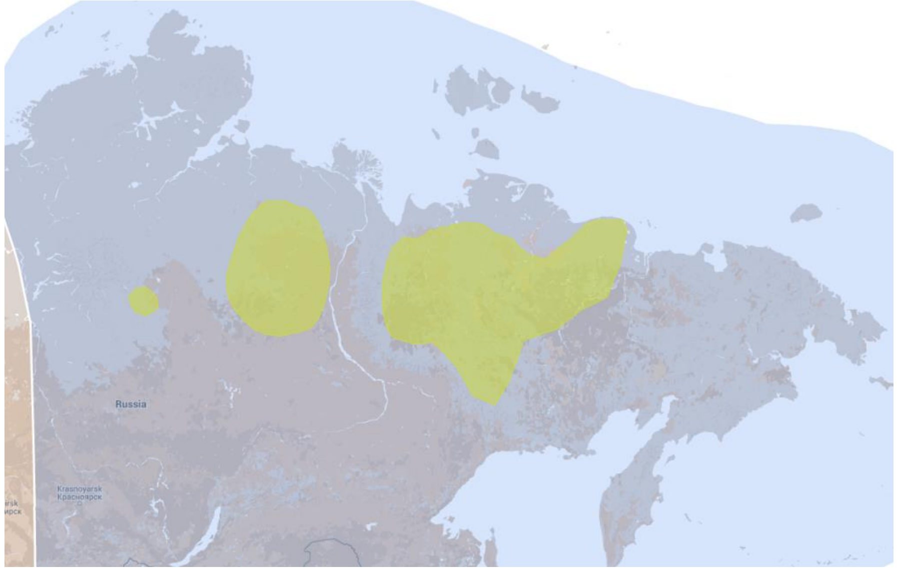


Figure 3.24 – Little Curlew

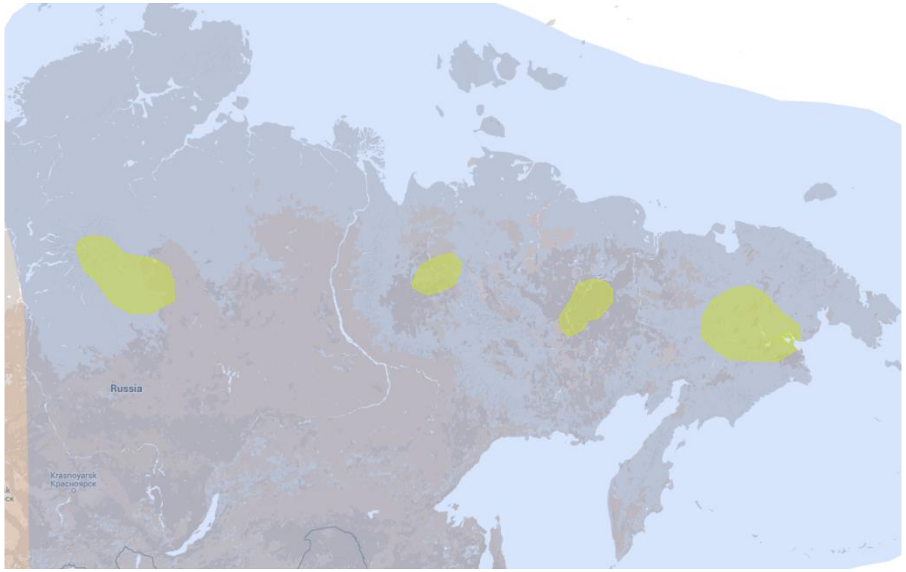


Figure 3.25 - Whimbrel

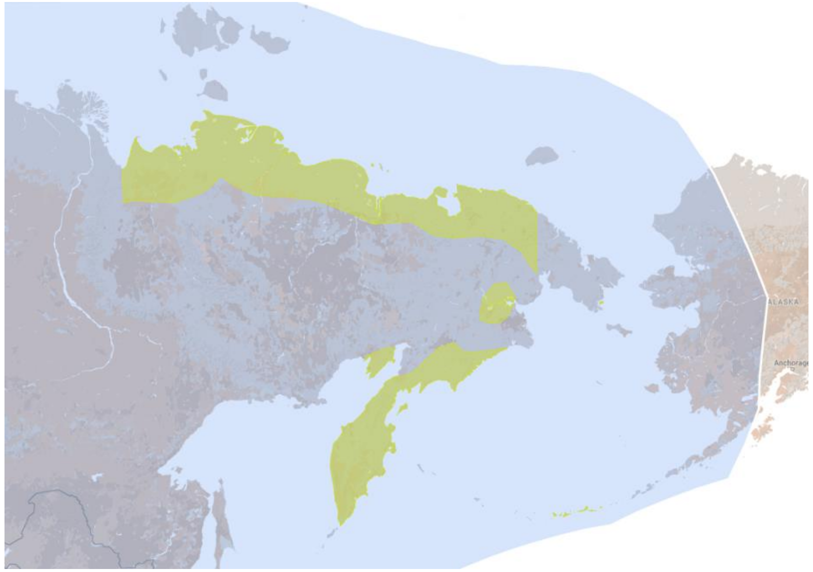


Figure 3.26 – Red-necked Phalarope

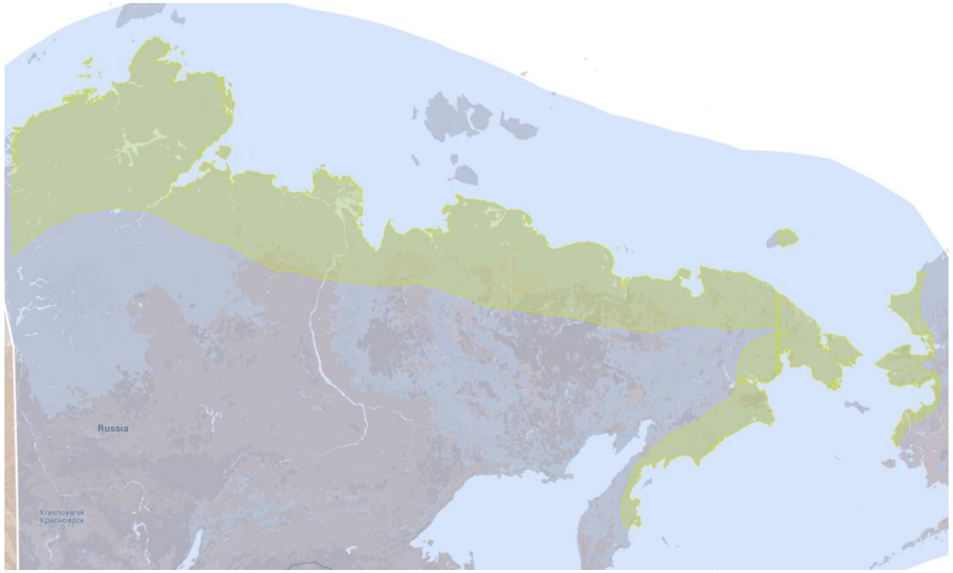


Figure 3.27 – Pacific Golden Plover

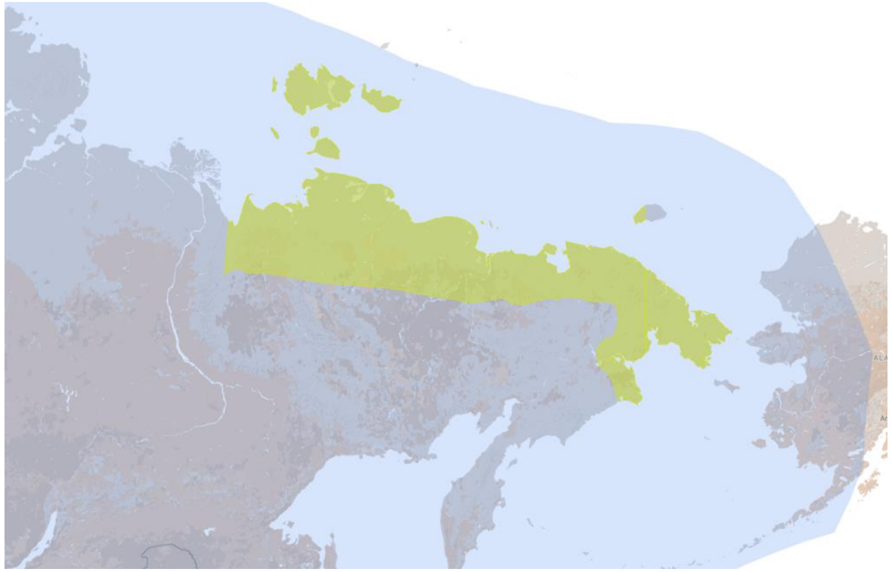


Figure 3.28 – Grey Plover

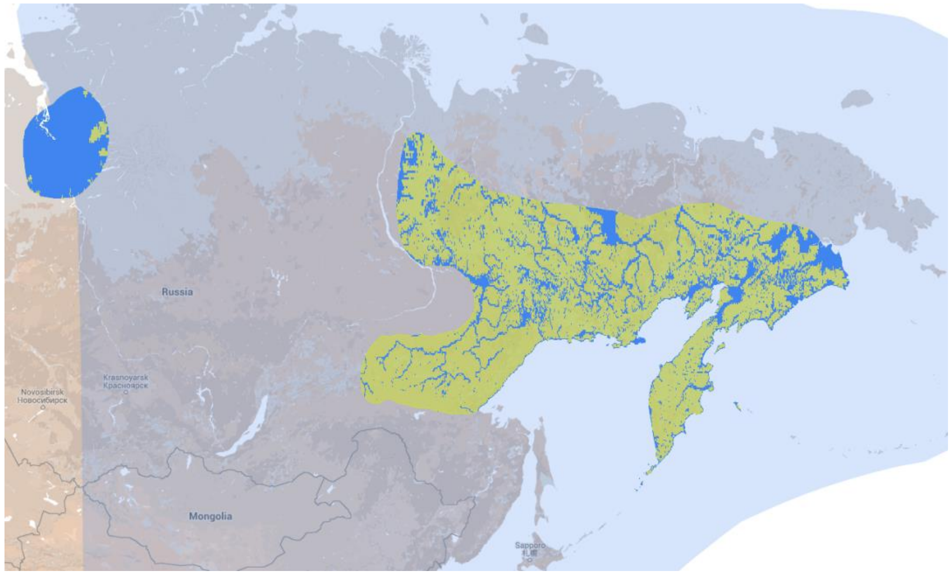


Figure 3.29 - Grey-tailed Tattler

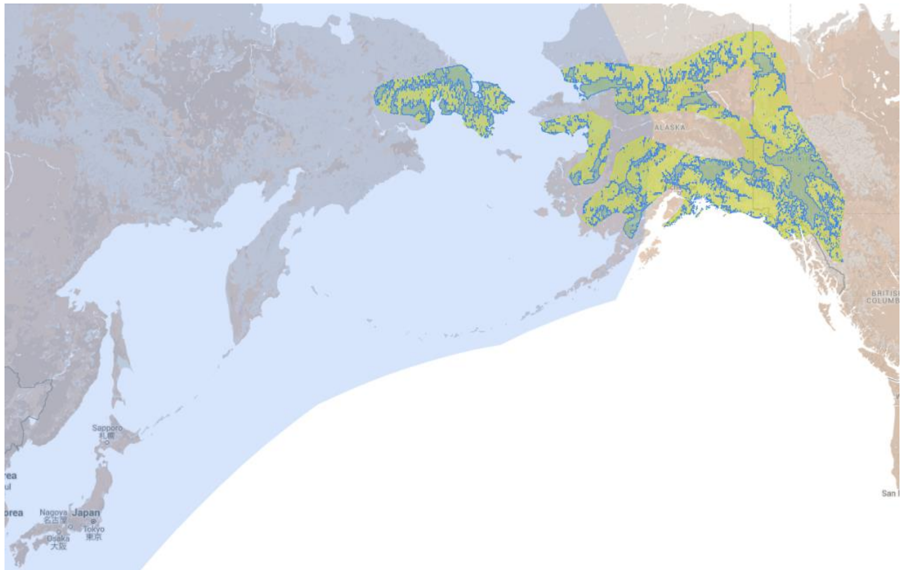


Figure 3.30 – Wandering Tattler

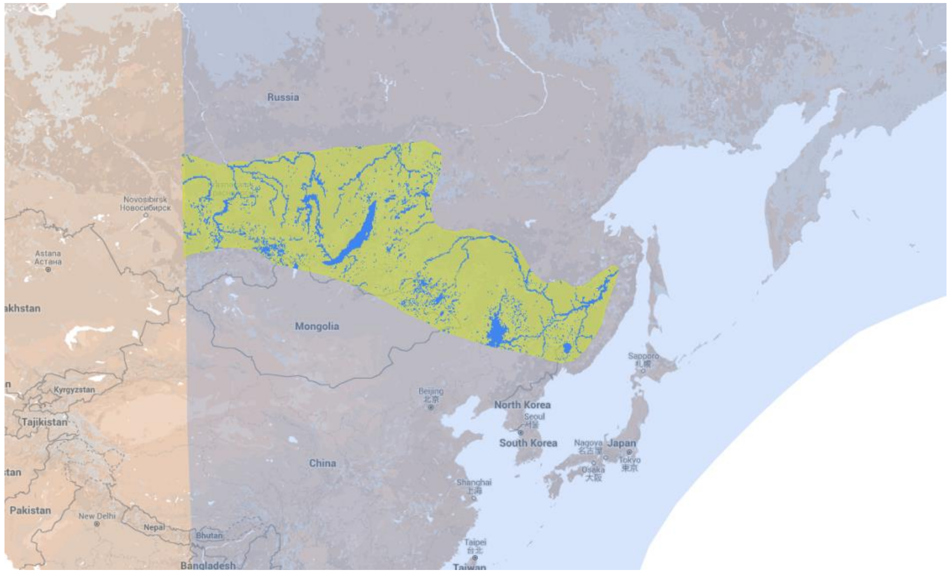


Figure 3.31 – Marsh Sandpiper

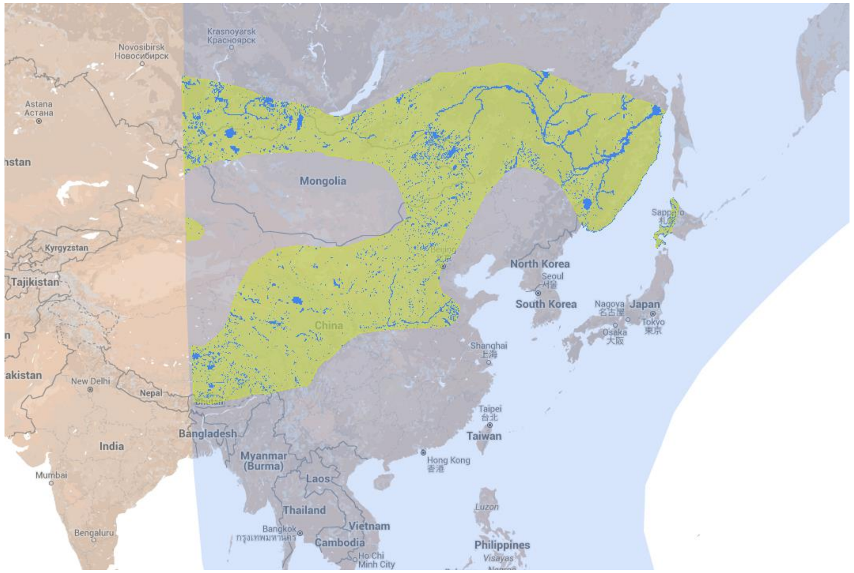


Figure 3.32 – Common Redshank

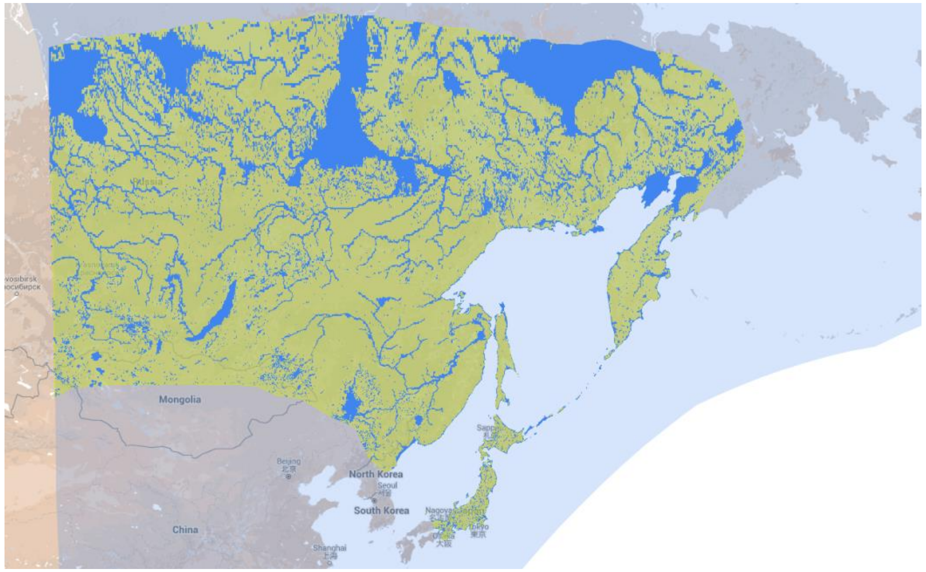


Figure 3.33 – Common Sandpiper

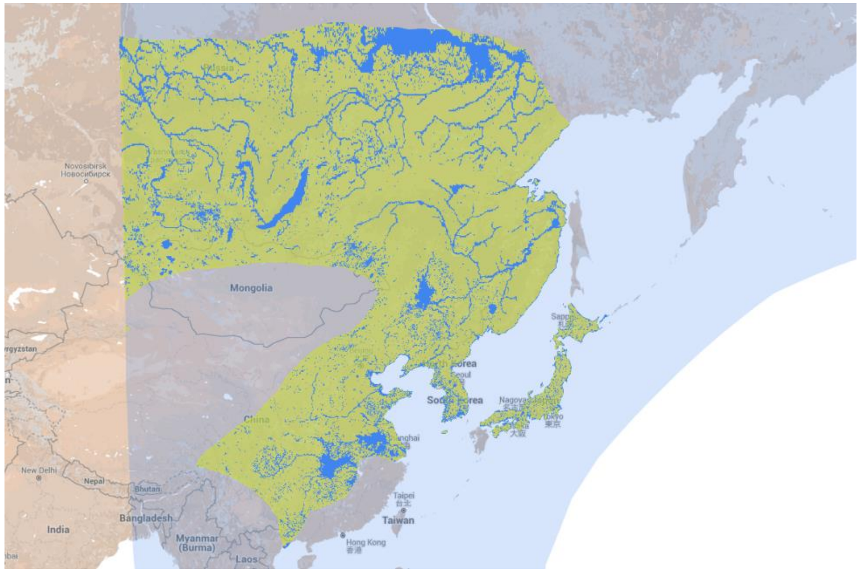


Figure 3.34 – Little Ringed Plover

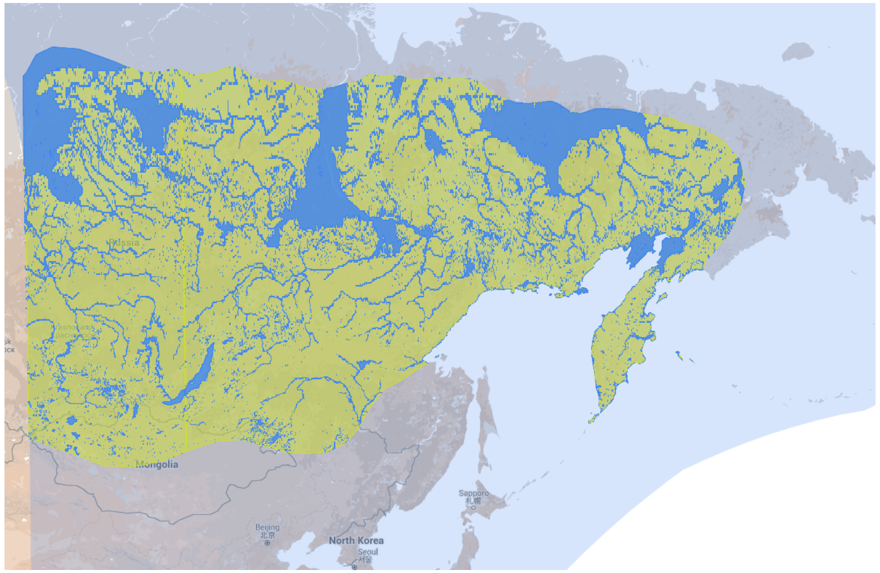


Figure 3.35 – Wood Sandpiper

Figure 3.36 – Sharp-tailed Sandpiper

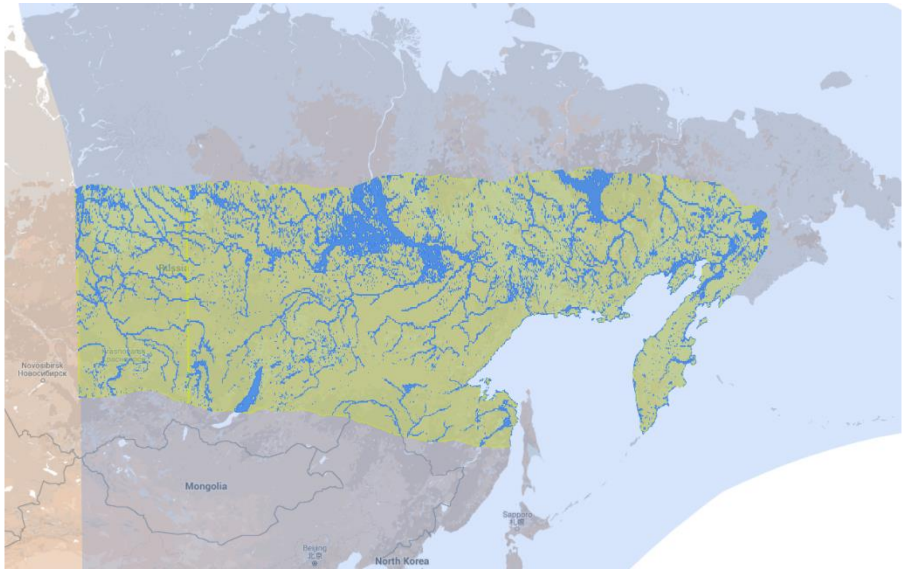


Figure 3.37 –Common Greenshank

Appendices

Appendix 1. Trend data compiled from the literature.

Figures represent statistically significant longitudinal trends, expressed as the percentage change per year in all but one study (with rounding, where appropriate). Figures reported in Amano et al. (2012) and Studds et al. (in review) were multiplied by 100 to convert them to a percentage. Decreasing species are highlighted in bold text. Bar-tailed Godwit trends are reported for two different subspecies (*menzbieri* and *baueri*). Studies A, C, D, E, F, G and K represent analyses of multiple sites within any given state or region. Codes for each reference are given below the table. Trend adj. indicates the trend adjustment figures used in this study, supplied by R. Clemens, for trend adjusting species when only old data were available for a given site(s).

Region	Oceania		NZ	Nationwide		WA	SA		VIC					TAS		NSW	QLD	Trend
Reference	A SPR	A AUT	B	C	D	E	F †	G	H	I	F †	G	J GT	J CP	F †	F †	K	adj.
Asian Dowitcher																		
Bar-tailed Godwit *menz.*	**-9.0**		**-2.3**	**-6.0**	**-3.2**	**-7.6**							**-2.4**				**-6.4**	**-3.2**
Bar-tailed Godwit *baueri*				**-1.0**														**-3.2**
Black-tailed Godwit		7.0			**-5.4**												**-0.4**	
Broad-billed Sandpiper		10.0																
Common Greenshank		5.0			**-2.0**				**-3.4**	**-1.8**			1.6				**-5.9**	**-2.0**
Common Redshank	6.0																	
Common Sandpiper																		
Curlew Sandpiper			**-8**	**-8.0**	**-9.5**	**-8.4**	**-19.6**	**-3.2**	**-3.4**		**-247.47**	**-2.5**	**-2.4**	**-2.9**	**-36.3**	**-28.4**	**-4.0**	**-9.5**
Double-banded Plover			**-2.9**														3.4	
Eastern Curlew			3.9	**-6.0**	**-3.0**	**-5.8**			**-2.1**	**-2.4**	**-13.95**		**-2.2**		**-1.85**	**-0.2**	**-2.4**	**-3.0**
Great Knot				**-5.0**	1.4	**-3.4**			**-3.4**								**-4.4**	
Greater Sand Plover		7.0			0.5	**-9.2**			**-2.9**								**-6.0**	
Grey Plover	**-4.0**				**-2.0**	**-4.0**			**-2.2**								**-4.4**	**-2.0**
Grey-tailed Tattler		**-6.0**			1.9	**-6.5**											**-0.8**	
Latham's Snipe	**-7.0**																	
Lesser Sand Plover				**-6.0**	**-7.2**												**-3.8**	**-7.1**
Little Curlew																		

Region	Oceania		NZ	Nationwide		WA	SA		VIC				TAS			NSW	QLD	Trend
Reference	A SPR	A AUT	B	C	D	E	F	G	H	I	F †	G	J GT	J CP	F	F	K	adj.
Little Ringed Plover	4.0	-4.0																
Little Stint																		
Long-toed Stint																		
Marsh Sandpiper					-0.9												-2.0	-0.9
Oriental Plover																		
Oriental Pratincole																		
Pacific Golden Plover			-0.1		-2.0								-2.8	-1.7			12.3	-2.0
Pectoral Sandpiper																		
Pin-tailed Snipe																		
Red Knot	10.0		-2.6	-4.0	-1.7	3.2			-3.3								-9.1	
Red-necked Phalarope																		
Red-necked Stint			1.4		-3.4						225.4		-3	-1.1	-28.8	-11.7	10.5	-3.2
Ruddy Turnstone	-4.0	-10.0	-3.3		-3.2	-4.3			-3.2				-2.1	-2.8			-6.1	-3.2
Ruff																		
Sanderling					0.1													
Sharp-tailed Sandpiper			-3.2		-5.7				-2.8					-1.7			10.7	-5.7
Swinhoe's Snipe																		
Terek Sandpiper					-5.4	-7.6											-1.6	-5.4
Wandering Tattler																		
Whimbrel	-3.0	-8.0	-5.7		0.7				22.1								-3.8	
Wood Sandpiper																		

Reference codes: A= Amano et al. (2012) (SPR=boreal spring and AUT=boreal autumn); B= Southey (2009); C= Studds et al. (in review).; D= Clemens et al. (2016); E= Rogers et al. (2011); F= Gosbell & Clemens (2006); G= Wilson (2000b); H= Minton *et al.* (2012); I= Hansen *et al.* (2015); J= Cooper *et al.* (2012) (GT=George Town and CP=Cape Portland); K= Wilson *et al.* (2011).

† these values are expressed as the number of birds per year

Appendix 2. Sources of data used for generating new flyway population estimates.

Location	Source	Data range	Frequency / timing
Systematic monitoring			
Australia	BirdLife Australia S2020	1971-present	Bi-annual (summer & winter)
	Queensland Wader Study Group	1981-present	Bi-annual (summer & winter)
New Zealand	Ornithological Society of New Zealand	1983-present	Bi-annual (summer & winter)
Asia	Asian Waterbird census	1984-present	Annual summer(some winter counts)
Published or unpublished data not available through any of above databases			
Australia			
QLD Broad sound	Jaensch (2009)	2008-2009	November-February
QLD Gulf of Carpentaria	Driscoll (2014)	2013	March-April
WA Ashmore Reef & Adele Island	Clarke unpubl.	2011-2014	November
WA Barrow Island	Bamford *et al.* (2011)	2006	February-March
WA East Kimberley	Hassell *et al.* (2005)	2005	November-December
WA Lacepedes	Rogers *et al.* (2011)	2004	November
WA 80 Mile Beach	Piersma & Hassell (2010)	2010	February
WA Shark Bay / Carnarvon	L. George (unpubl. data)	2012-2016	Summer (various months)
NT Darwin Port	A. Lilleyman (unpubl. data)	2013-2015	November-March
NT coastline	Chatto (2012)	2010-2012	Summer (various months)
NT Gulf of Carpentaria	P. Barden (unpubl. data)	2010-2016	January / February
New Zealand	Southey (2009)	1994-2003	Bi-annual (summer & winter)
Asia – Palau	G. McKinley (unpubl. data)	2015-2016	February

Appendix 3a. Process for summarising and analysing shorebird count data.

The estimates derived from each data source were summed after the final step to arrive at the flyway population estimate for the 37 target species.

Data source	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Final step
Shorebirds2020 plus other Australian data	generate national estimate (see fig A below)	spatial extrapolation	seek count coordinators review	Adjust estimates by state and apply new extrapolations	Estimates returned to coordinators for further review	species list D † generate estimate from breeding ground information Use this adjust estimates from Step 4	Special case species estimates from other sources.	compile species' estimates from steps 4, 6 and 7
OSNZ	generate national estimate ††	as above	as above	Adjust estimates and apply new extrapolations	As above	as above	as above	as above
AWC	generate national estimates (sum of max. count per site per season)	as above	as above	as above	As above	as above	as above	as above

† List D species: Latham's Snipe, Little Curlew, Little Ringed Plover, Long-toed Stint, Pin-tailed Snipe, Red-necked Phalarope, Swinhoe's Snipe

†† the process for analysing the OSNZ data was very similar to the S2020 data, whereby 'Main site' and 'Local sites' were considered analogous to SBA and CA. The main exception is that there was no treatment for "inland" species or "inland" sites.

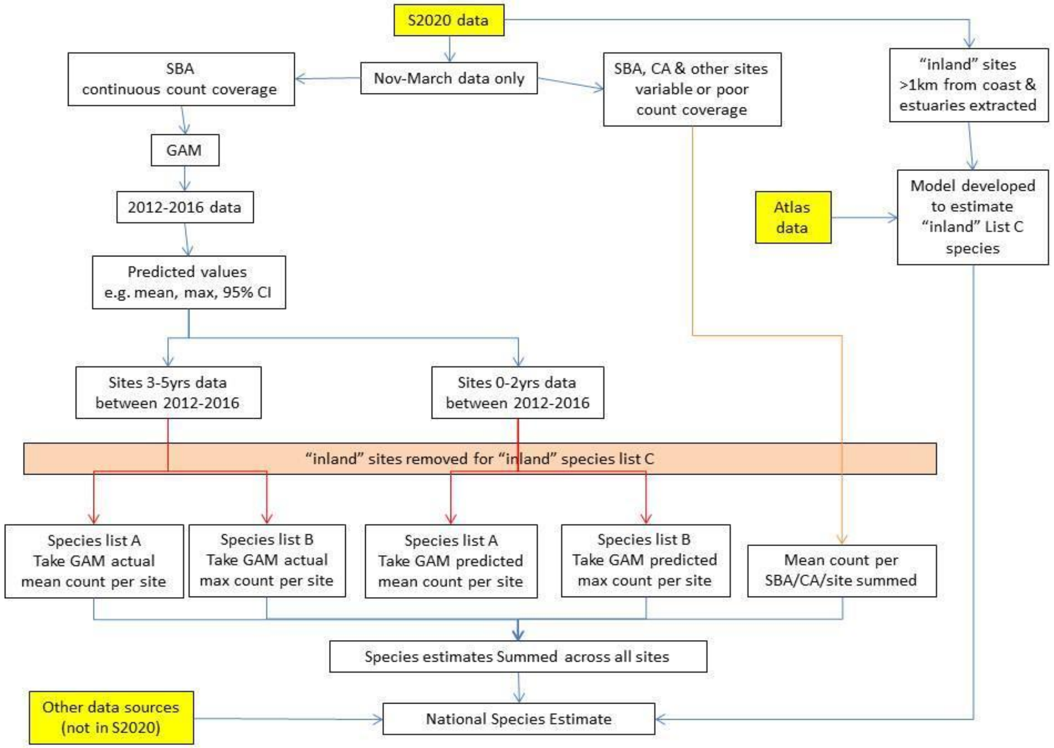
Appendix 3b. Process for analysing Australian shorebird data.

S2020=Shorebirds 2020; SBA=shorebird area; CA=count area; GAM=generalised additive model; CI=confidence interval. See Appendix 3a for data treatment steps.

List A species: Asian Dowitcher, Bar-tailed Godwit, Black-tailed Godwit, Broad-billed Sandpiper, Common Greenshank, Common Redshank, Common Sandpiper, Curlew Sandpiper, Double-banded Plover, Eastern Curlew, Great Knot, Greater Sand Plover, Grey Plover, Grey-tailed Tattler, Lesser Sand Plover, Marsh Sandpiper, Pacific Golden Plover, Pectoral Sandpiper, Red Knot, Red-necked Stint, Ruddy Turnstone, Ruff, Sanderling, Sharp-tailed Sandpiper, Terek Sandpiper, Wood Sandpiper.

List B species: Oriental Plover, Wandering Tattler, Whimbrel

List C species: Black-tailed Godwit, Common Greenshank, Common Sandpiper, Curlew Sandpiper, Little Curlew, Long-toed stint, Marsh Sandpiper, Oriental Plover, Pectoral Sandpiper, Red-necked Stint, Sharp-tailed Sandpiper, Wood Sandpiper.



Appendix 4a. Spatial extrapolation factors for Australia.

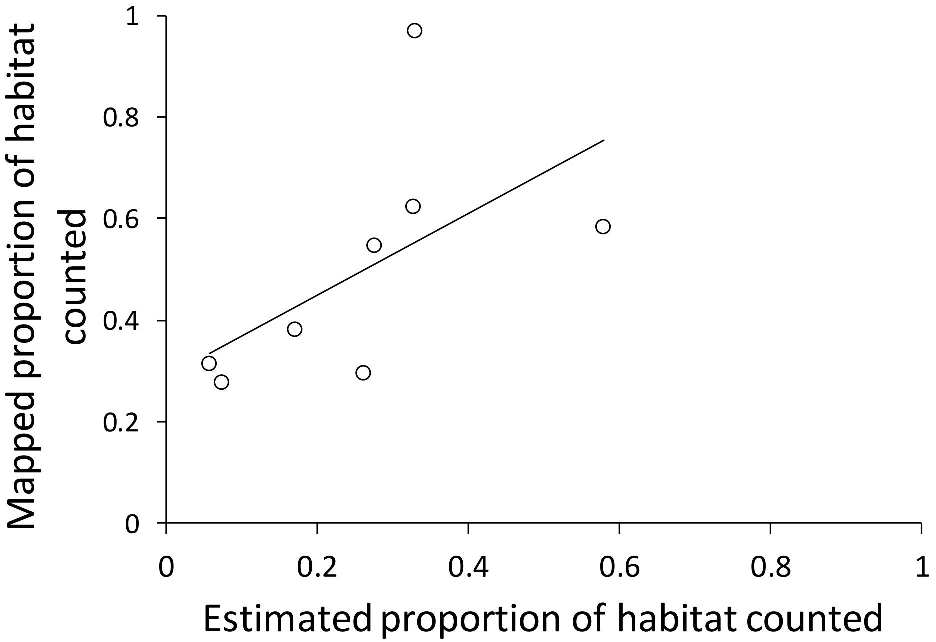
The table shows the basis for regional estimates of the proportion of the shorebird population that has been counted in Australia. Data are based on overlaying shorebird count areas with explicitly mapped tidal flats (Dhanjal-Adams et al. 2015; see text).

Region	Area of mapped intertidal habitat region (km^2)	Area of counted intertidal habitat region (km^2)	Proportion of mapped intertidal habitat that is counted	Extrapolation factor based on habitat mapping	Final, expert adjusted extrapolation factor	Rationale for expert adjustment
NSW	96	56	58%	1.72	1.14	Believe that 1.72 is too high (Hunter Bird Observers Club: A. Lindsey, A. Stuart, M. Newman, L. Crawford, C. Herbert)
NT	2214	693	31%	3.20	3.20	Only applied to S2020 data. Trend-adjusted & cross-validated Chatto (2003) data requires no extrapolation, as already extrapolated during original study (D. Rogers)
QLD (East coast)	1617	1006	62%	1.61	1.25	Potentially have counts of up to 90% of the coastal habitat on the east coast of QLD, 80% coverage considered conservative
QLD (Gulf of Carpentaria)	1076	410	38%	2.62	1.67	36% estimated coverage in the March-April 2013 survey; Good coverage in the limited number of sections of the west Gulf; difficult to judge as highly dynamic from season-to-season
SA	936	510	55%	1.83	2.00 SE SA 1.14 all except Coorong	the factor of 1.83 appears high as a general multiplier (K. Gosbell); probably ~90% in Fowlers Bay-Lake Newland region (J. Cooper); in SE SA region more like 50% coverage (M. Christie & J. Campbell).
TAS	87	26	29%	3.39	Variable	see text in results section for explanation and

Region	Area of mapped intertidal habitat region (km²)	Area of counted intertidal habitat region (km²)	Proportion of mapped intertidal habitat that is counted	Extrapolation factor based on habitat mapping	Final, expert adjusted extrapolation factor	Rationale for expert adjustment
						rationale
VIC	228	221	97%	1.03	1.03	Reasonable approximation for Victoria, as it is a state that has had good and consistent coverage over a long period of time (K. Gosbell)
WA	3597	999	28%	3.60	1.33 south 2.00 north-central 2.65 north-west	Southern coast reasonably well covered, probably no more than 25% of habitat uncounted; North-central (Carnarvon - Pardoo) coverage probably around 50%. NW coast, apart from Broome and 80 Mile beach region also poorly covered. May be missing as many as 65% of shorebird habitat although rare surveys in Derby suggest mudflats hold relatively few birds (B. Greatwich, L. George, D. Rogers)

Appendix 4b. Using high quality information available in Australia to calibrate the estimate of uncounted habitat in the rest of the EAAF.

The figure shows the relationship between “mapped” counted habitat, created by overlaying maps of shorebird areas onto remotely-sensed habitat maps, and “estimated” counted habitat, created by overlapping buffered centroids of count sites onto estimates of intertidal areas using bathymetry / tidal amplitude models. The relationship is strongly positive, albeit with some degree of scatter, and the fact the intercept of this relationship is well above zero suggests that in situations where few sites are counted in a region, these often tend to be those sites with the greatest concentration of suitable habitat. This regression relationship provides a basis on which to estimate the true proportion of counted habitat for a country and the rather coarse estimate from the buffered centroids / modelled intertidal areas method. The equation for this regression is y = 0.8088x + 0.2882, so for example a region estimated to have 25% of its habitat counted using the coarse buffered centroids / modelled intertidal areas method is estimated to have 49% (0.8088 * 0.25 + 0.2882) of its shorebird habitat counted in reality.



Appendix 4c. Spatial extrapolation factors outside Australia.

The table shows the basis for regional estimates of the proportion of the shorebird population that has been counted outside Australia. Data are based on overlaying maps of potential intertidal habitat with a 10km buffer around coordinates for shorebird count sites (see text for full details). New Zealand was excluded from the mapping process, and instead a single expert-informed estimate of the extrapolation factor was used.

Country	Area of potential intertidal habitat with 5km of coastline (km^2)	Area of potential intertidal habitat that is counted (km^2)	Proportion of potential intertidal that is counted	Extrapolation factor based on mapping	Extrapolation factor expert adjusted	Rationale for expert adjustment
Bangladesh	736	332	45%	1.53	1.53	
Brunei	52	48	91%	1.00	1.00	
Cambodia	144	27	19%	2.26	2.26	
China	3558	470	13%	2.46	2.46	
Chinese Taipei	99	78	79%	1.07	1.07	
Indonesia - East	2844	44	2%	3.33	3.33	
Indonesia - Java Borneo	1990	144	7%	2.89	2.89	
Indonesia - Sumatra	2831	86	3%	3.20	3.20	
Japan	379	105	28%	1.95	1.25	We think that the Japanese shorebird populations are overestimated. Average numbers at each site would be more plausible than maxima. Since our monitoring scheme covers major shorebird sites in winter, the adjustment value "1.95" is too large. Values of 1.2-1.3 would be more appropriate (T. Moriya)
Korea DPR	410	11	3%	3.00	3.00	
Korea Ro	1207	398	33%	1.80	1.80	
Malaysia	1295	276	21%	2.17	2.17	
Myanmar	1452	138	10%	2.74	2.74	
New Zealand	1138	no data	no data	no data	1.11	>90% of habitat counted (A. Riegen, D. Lawrie)
Papua New Guinea	1127	11	1%	3.38	3.38	
Philippines	2612	411	16%	2.41	2.41	

Singapore	54	16	30%	1.88	1.88
Thailand	968	259	27%	1.98	1.98
Timor-Leste	17		0%	3.47	3.47
Vietnam	1177	96	8%	2.82	2.82

Note in relation to North Sumatra: Past surveys in Asahan District of 16km of coastal habitat (<14% of district's coastline) produced ~30,000 waders in the migration period. Prediction of ~100,000 waders along entire coastline during migration (Crossland et al. 2009)

Appendix 5. Breeding density data analysis used for adjustment.

This table summarises modifications made to Birdlife International maps to estimate breeding range of shorebirds in the East Asian – Australasian Flyway.

Common Name	Comments on methods	Breeding range size for analysis km^2
Asian Dowitcher	clipped BirdLife International breeding range to EAAF boundary	1,722,559
Bar-tailed Godwit	split up subspecies, removing *menzbieri* W of Lena River; *baueri* is 227077.6, *anadyrensis* is 170718.6, *menzbieri* is 383446.0	781,242
Black-tailed Godwit	clipped BirdLife International breeding range to EAAF boundary, removing western birds of subspecies *L. l. limosa*	1,501,623
Broad-billed Sandpiper	clipped BirdLife International breeding range to EAAF boundary; removed western population	162,917
Common Greenshank	clipped BirdLife International breeding range to EAAF boundary - main range is 5140563.7; western little bit is 1055861.2; total range before excluding non-wetland area is 6196425.0; area of all 5km grid cells that intersect wetland is 1088581.1, and if the western bit is excluded, that number drops to 927690.1	927,690
Common Redshank	clipped BirdLife International breeding range to EAAF boundary; selected all 5km grid cells that intersected wetland; total range before excluding non-wetland area is 5643646.7	439,561
Common Sandpiper	clipped BirdLife International breeding range to EAAF boundary; selected all 5km grid cells that intersected wetland; total range before excluding non-wetland area is 10251755.1, after doing this it drops to 1907818. 7	1,907,819
Curlew Sandpiper	clipped BirdLife International breeding range to EAAF boundary; clipped off Alaska - full range with Tamryr (374695.2) is 931729.8	557,035
Double-banded Plover	clipped out anything < 1km from coast; entire global breeding range is 259795.3, S Island excluding Marlborough is 125637.8	125,638
Eastern Curlew	total range before excluding non-wetland area is 4949274.0. Was not possible to make any corections for potential declines in breeding range in recent times.	748226
Great Knot	Extended into area shown; Lappo et al. (2012)	2,057,114

Common Name	Comments on methods	Breeding range size for analysis km^2
Greater Sand Plover	clipped BirdLife International breeding range to EAAF boundary	3,158,672
Grey Plover	excluded Alaska and birds W of Lena River	876,665
Grey-tailed Tattler	included W Yenesie birds in EAAF, i.e. global range is EAAF; selected all 5km grid cells that intersected wetland; total range before excluding non-wetland area is 2713785.9	612,795
Latham's Snipe	range likely to be an overestimate but not easily corrected	251,927
Lesser Sand Plover	used Hirschfield et al (2000) ranges - clipped *mongolus* and *stegmanni* to only areas below 1000m (none of *atrifrons* or *schaeferi* is below 1000m) *atrifrons* is 479728. 1; *schaeferi* is 1134748.4; *mongolus* is 319932.9; *stegmanni* is 423736.5	2,358,146
Little Curlew	range might be underestimate - not easily corrected at this stage	968,572
Little Ringed Plover	clipped out resident part of the BirdLife International breeding range, and clipped to EAAF; selected all 5km grid cells that intersected wetland; total range before excluding non-wetland area is 10106048.2, after doing this it drops to 1469675.5	1,469,675
Long-toed Stint	appended Lappo et al. (2012) range map to BirdLife International breeding range, which is probably an underestimate; clipped to EAAF; global range before this clip is 829794. 8	755,469
Marsh Sandpiper	clipped BirdLife International breeding range to EAAF boundary; selected all 5km grid cells that intersected wetland; total range before excluding non-wetland area is 2947205.6	383,264
Oriental Plover		1,531,833
Oriental Pratincole	clipped BirdLife International breeding range to EAAF boundary	5,749,858
Pacific Golden Plover	clipped BirdLife International breeding range to EAAF boundary, removed Siberian patch - Alaska is 108001.5; Siberia is 1601678.8	1,709,680
Pectoral Sandpiper	world range is 2368148.73288; N America is 1337403.7; Siberian alone is 1030745.1	1,030,745

Common Name	Comments on methods	Breeding range size for analysis km^2
Pin-tailed Snipe	clipped BirdLife International breeding range to EAAF boundary; selected all 5km grid cells that intersected wetland; total range before excluding non-wetland area is 7637489.9	1,619,073
Red Knot	clipped to only *piersmai* and *rogersi*; extended breeding range into Chukotka; *rogersi* is 405059.4, *piersmai* is 38413.3	443,473
Red-necked Phalarope	deleted Alaska and birds to W of Lena River	828,827
Red-necked Stint	clipped BirdLife International breeding range to EAAF boundary	971,357
Ruddy Turnstone	clipped BirdLife International breeding range to EAAF boundary; Clip off Alaska; Clip off all but easternmost Taymyr	214,418
Ruff	global range calculated, as treating as a single population	8,576,241
Sanderling	Clipped off Alaska and Taymyr	76,481
Sharp-tailed Sandpiper	clipped BirdLife International breeding range to EAAF boundary	349,396
Swinhoe's Snipe	clipped BirdLife International breeding range to EAAF boundary; selected all 5km grid cells that intersected wetland; total range before excluding non-wetland area is 2851818.9	307,225
Terek Sandpiper	clipped BirdLife breeding range to EAAF boundary; selected all 5km grid cells that intersected wetland; total range before excluding non-wetland area is 5947871.5	1,265,842
Wandering Tattler	global range all lumped together; selected all 5km grid cells that intersected wetland; total range before excluding non-wetland area is 156057.1 (Chukotka) and 1117798.6 (N America). After excluding non-wetland, the range is 81344.4 (Chukotka) and 380085.4 (N America)	461,430
Whimbrel	Just Siberian populations	368,386
Wood Sandpiper	clipped BirdLife International breeding range to EAAF boundary - without also clipping out the western extent, the range is 8751672.3, with this extent missing the range is 5905691.0; area of all 5km grid cells that intersect wetland is 1693125. 1, and if the western bit is excluded, that number drops to 1163805.2	1,163,805

Appendix 6. Parameters used and species selected in developing models describing the relationship between breeding range and population size.

The final three columns present the populations predicted on the basis of the models, and their lower and upper 95% confidence limits

Common Name	Breeding range (km^2)	Breeding density	Number counted on non-breeding grounds	Used in models	Population estimate predicted by breeding area models	Lower 95% confidence limit of estimate	Upper 95% confidence limit of estimate
Asian Dowitcher	224,825	Low	14,172	Yes	12,673	8,189	19,612
Bar-tailed Godwit	781,242	High	319,202	Yes	237,552	165,032	341,940
Black-tailed Godwit	1,501,623	Med	159,660	Yes	157,800	142,378	174,893
Broad-billed Sandpiper	162,917	Med	30,160	Yes	24,340	21,961	26,976
Common Greenshank	927,690	Med	63,563	No	105,216	94,933	116,613
Common Redshank	439,561	High	76,021	No	146,406	101711	210,741
Common Sandpiper	1,907,819	Med	55,484	No	193,024	174,159	213,933
Curlew Sandpiper	557,035	Med	92,303	Yes	68,494	61,800	75,914
Double-banded Plover	125,638	Low	18,786	Yes	19,559	17,647	21,678
Eastern Curlew	748,226	Low	33,860	Yes	34,862	22,528	53,949
Great Knot	2,057,114	High	419,304	Yes	536,565	372,762	772,348
Greater Sand Plover	3,158,672	Med	199,549	No	295,048	266,211	327,008
Grey Plover	876,665	Med	80,935	Yes	100,324	90,519	111,191
Grey-tailed Tattler	612,795	Med	71,156	Yes	74220	66,966	82,260
Latham's Snipe ‡	251,927	Med	30,000 ‡	Yes	35,127	3,1694	38,932
Lesser Sand Plover	1,789,627	Med	285,505	No	182,910	165,033	202,723
Little Curlew	968,572	Med	76,913	No	109,105	98,442	120,923
Little Ringed Plover	1,469,675	Med	49,016	No	154,970	139,824	171,756
Long-toed Stint	755,469	High	587	No	230,939	160,438	332,421
Marsh Sandpiper	383,264	High	102,478	No	130,457	90,631	187,783
Oriental Plover	1,531,833	Med	232,124	No	160,468	144,784	177,850
Oriental Pratincole	5,749,858	High	587,051	No	1,274,398	885,348	1,834,409

Common Name	Breeding range (km^2)	Breeding density	Number counted on non-breeding grounds	Used in models	Population estimate predicted by breeding area models	Lower 95% confidence limit of estimate	Upper 95% confidence limit of estimate
Pacific Golden Plover	1,709,680	Med	125,120	Yes	176,009	158,806	195,074
Pectoral Sandpiper	2,368,148	Med	78	No	231,553	208,904	256,613
Pin-tailed Snipe	1,619,073	Med	10	No	168,125	151,693	186,336
Red Knot	443,473	High	112,531	Yes	147,501	102,472	212,318
Red-necked Phalarope	828,827	High	98	No	249,671	173,451	359,385
Red-necked Stint	971,357	High	484,129	Yes	285,343	198,233	410,731
Ruddy Turnstone	214,418	Med	30,472	Yes	30,670	27,673	33,992
Ruff	8,576,241	Low	5	No	271,526	175,460	420,191
Sanderling	76,481	High	34,399	Yes	33,605	23,346	48,372
Sharp-tailed Sandpiper	349,396	High	86,741	Yes	120,684	83,842	173,717
Swinhoe's Snipe	307,225	Med	68	No	41,511	37,454	46,008
Terek Sandpiper	1,265,842	Low	49,962	Yes	54,265	35,066	83,977
Wandering Tattler	461,430	Med	400	No	58,456	52,743	64,788
Whimbrel	368,386	Med	66,927	Yes	48,364	43,637	53,603
Wood Sandpiper	1,163,805	Med	15,372	No	127,339	114,893	141,132

‡ Used a population estimate of 30,000 in the modelling, which was estimated by trend correction of previous estimate (36,000:Bamford et al. 2008)

Appendix 7. Inland species modelling estimates derived analyses of S2020 data and BirdLife Australia Atlas data

"best estimate" is the source of values used for other analyses. Conf.= confidence in estimates. "Actual count …" provides a summary of count data from S2020 inland sites. "Max. pred." = maximum predicted.

Common name	best estimate	method best_estimate	Conf.	2004-2013 pred. average	1982-1990 pred. average	1982-1990 average trend corr 20 yrs	max pred. late 10 yrs in any month	Max pred. all times	5 yr trend corr.	Actual count (summed across "inland" sites)
Sharp-tailed Sandpiper	54000	1982to1990av_trend_corrected	medium	151,783	62,694	46,633	1,062,509	4,190,063	54,000	42609
Red-necked Stint	160000	1982to1990av_trend_corrected	medium	242,978	287,164	149,225	256,976	617,517	160,000	44833
Curlew Sandpiper	25000	1982to1990av_trend_corrected	medium	101,299	141,298	19,065	125,985	647,730	25,000	47711
Common Greenshank	10000	1982to1990av_trend_corrected	medium	11,616	14,572	9768	16,487	36,318	10,000	2897
Black-tailed Godwit	3200	1982to1990av_trend_corrected	low	2080	2433	805	3211	4883	928	111
Oriental Plover	43000	max_predicted_last_10yrs	very low	24,994	29,530	NA	42,874	192,013		1299
Little Curlew	18000	max_predicted_all_time	very low	3195	3797	NA	7817	17,593		9371
Marsh Sandpiper	39000	1982to1990av_trend_corrected	low	50,537	46,065	42,178	93,618	567,215	39,000	14333
Wood Sandpiper	1600	2004to2013_predicted_average	low	1595	1833	NA	3647	17,416		2800
Common Sandpiper	1300	max_predicted_last_10yrs	low	711	844	NA	1290	2916		244
Long-toed Stint	60	max_predicted_last_10yrs	low	33	36	NA	56	90		527
Latham's Snipe	†	presence absence averaged with previous	very low	447	411	NA	711	997		
Pectoral Sandpiper	60	2004to2013_predicted_average	low	64	59	NA	294	294		73

† Use current breeding ground estimates

Appendix 8. Details of reviewer / coordinator feedback on Australian state estimates.

State	Summary of feedback	Reviewers
Nationwide	Treatment of inland sites needs more careful verification and potential adjustment. There is a risk that sites located along estuaries but also well inland (beyond the analytical buffer distance of 1km) are being incorrectly handled in analyses	M. Newman, C. Minton, K Gosbell, A. Stuart
	Inland modelled figure of 60 Long-toed Stint too low, e.g. up to 40 birds recorded just on Lake Eda, WA (not in database). Rely on actual inland counts (435 for WA and 527 for nation).	C. Hassell, A. Boyle
QLD	Estimate of the amount of little curlew habitat counted is 5% or less. Counts from Karumba plain (Gulf of Carpentaria), can be treated separately to other Gulf species data, and a conservative extrapolation of 10x applied to little curlew totals.	D. Milton / A. Keates
	Number of inland sites in QWSG data analysis considered insignificant to exclude in same manner as other states. Only little curlew extracted and treated separately as per comment above	D. Milton
	Separate trend correction applied to Lesser Sand Plover and Terek Sandpiper at Mackay. Amended values used for Bar-tailed Godwit, Grey-tailed Tattler and Terek Sandpiper at Great Sandy Strait.	D. Milton
	Proportion of shorebirds counted along the eastern coast considered much different to the Gulf of Carpentaria. Separate extrapolations are required, agreed figure of 80% along the east coast and 60% in the gulf	D. Milton, D. Weller, R. Fuller
	QWSG data used for analyses contain few inland sites. S2020 data used for inland modelling so potential for duplication between sites considered minimal	R. Clemens
	Additional data available from Shoalwater provided on the 14 June 2016. Should be included in future revisions	R. Jaensch
TAS	Detailed commentary on missing sites, replication between sites in different analyses and need for species- and site-specific extrapolations. Further details in main report body and Appendix 9.	E. Woehler, M. Newman, R. Cooper
	Issues with extra site counts being added by other counters to S2020 that is not verified by regional coordinators. Has made it difficult to QA/QC data for sites like Cape Portland. Management of data input to S2020 and detailed database inspection and error checking for Cape Portland highlighted as a high priority for future work	R. Cooper, M. Newman

State	Summary of feedback	Reviewers
NSW	Hunter estuary estimates seemed OK except for Red Knot; whilst they can peak at 600-700 birds during migration (or more), by February which is the best time to count knot as their population has stabilised, the actual number would be less than 2. There were data missing from Lake Macquarie, so some species estimates were unrealistic, e.g. bar-tailed godwit should be under 110 (not 113), whimbrel should have a count between 1 & 15 (not NA), eastern curlew grey-tailed tattler and red-necked stint estimates were OK but perhaps a touch too high. Black-tailed Godwit, Common Greenshank, Curlew Sandpiper, Lesser Sand Plover, Pacific Golden Plover, Ruddy Turnstone and Sharp-tailed Sandpiper shouldn't be there at all. Manning estuary had an erroneous count of black-tailed godwit, which was corrected. There was data missing or wrong for bar-tailed godwit, eastern curlew, pacific golden plover, sanderling, double-banded plover, and whimbrel, which was supplied / corrected	A. Stuart, L. Crawford, A. Lindsey, M. Newman
	The area of potential coastal habitat estimate for NSW seems low; Our survey sites represent much less than 100% of the Tweed Estuary. I would assume the same for Clarence and other large estuaries where surveyors most likely are unable to visit every high tide roost. My gut says 58% is too high for NSW. 11 Pacific Golden Plover seems too low for the Tweed. Report on shorebird of the NSW Norther Rivers was provided.	L. Brannian
VIC	Overall the figures looked reasonable for most species with, as strongly expected, quite marked downward revisions from previous published population estimates. However, when I came to look at each of the Victorian species there were six where I strongly questioned their veracity: Greenshank (too high), Common Sandpiper (possibly too high) –counter review suggests numbers reasonable for this species given that large lengths of estuaries and other areas supporting this species are uncounted; Great Knot (too high); Marsh Sandpiper (possibly too high); Oriental Plover (nonsense records made their way into the database); Wood Sandpiper (possibly too low). After further revision and correcting of errors (replication of some sites / subsites had inflated numbers of marsh sandpipers, greenshank and wood sandpipers): spurious Great Knot count from McLeod's Morass removed; Pacific Golden Plover figure considered too high (Anderson Inlet figure amended); seemingly very high count of Sharp-tailed Sandpiper at Woodlands (not removed as part of inland modelling) and similarly in East Port Phillip Bay (the latter amended by using predicted 5yr mean instead);	K. Gosbell, C. Minton, D. Weller, D. Rogers, B. Hansen
	New data supplied for Anderson Inlet, to correct dated information for that site. On this basis, new supplied data used to replace figures for Common Greenshank, Eastern Curlew; replaced Double-banded Plover with overall mean, replaced Red-necked Stint with mean 10yrs, Sharp-tailed Sandpiper and Pacific Golden Plover	S. Johnson, K. Gosbell

State	Summary of feedback	Reviewers
	original GAM metrics retained as not enough information in new data to support changing metric.	
WA	Many of first estimates too low, but expect that the extrapolations will work this problem out. Specific comments, particularly for NWA and Shark Bay, provided on species estimates that seemed to low and likely sources of data that might support this. Second estimates Black-tailed Godwit and Whimbrel numbers are too low, probably several whimbrel in every Kimberly creek	C. Hassell, L. George, D. Rogers
	If I understand correctly, using the methods in the Dhanjal et al paper, you have identified 28% of the WA coastline as intertidal and potentially suitable for shorebirds. Presumably you used the data from the study then extended the method to cover the areas not mapped in the paper. The maps in the paper look reasonable for the areas measured at the resolution presented, so a percentage of intertidal areas for WA derived using this method seems reasonable.	K. Onton
	Sites I couldn't locate were Upper Kent, Hopetoun, Owingup Swamp, Guilderton, Shoalwater Marine Park, Hardy Inlet, Alcoa Wellard Wetlands, Lake Joondalup and Champion Lakes (the latter three might be under the Swan Coastal Plains Lakes shorebird area). There were duplicates of several of the Not in Mapped Areas (NIMA) sites: Kogolup Lake and Lake Kogolup, Leschenault Estuary (several NIMA sites within the Estuary), Peaceful Bay and Peaceful Bay Beach. Some sites appear independently as NIMA's (e.g. Thomson's Lake) but should also be within a shorebird area (e.g. Swan Coastal Plain Lakes). I just had a look on the S2020 database - looks like some missing sites have been incorporated into other shorebird areas (e..g. Bannitup Lake is under 'Esperance' but also a stand alone shorebird area 'Lake Bannitup') , but not all of the count sites are in there. Hopefully this will be consolidated when everything goes into the new portal.	K. Onton
	Used different GAM metrics in Shark Bay to make estimates more realistic, based on most recent and comprehensive counts: mean10year for Bar-tailed Godwit and Red-necked Stint; max10year for Common Greenshank; pred95CI_5year for Eastern Curlew, Greater Sand Plover, Grey-tailed Tattler. Used max10years for Asian Dowitcher at Bush Point, to be more representative of recent counts. Used max5years for Black-tailed Godwit in Roebuck Bay as there are up to several thousands that are often missed on counts. Alfred Cove estimate for Great Knot changed to 18 from 7.	L. George, D. Rogers, C. Hassell
	Queries about large uncounted areas in Derby tidal flats, King Sound, Mandora Marsh; however, some one-off survey work by DR and CJH has revealed relatively low numbers of birds so thought to the less of an issue	B. Greatwich, C. Hassell, D. Rogers

State	Summary of feedback	Reviewers
WA cont.	South of Carnarvon 25% missed considered representative. SB/Carnarvon-Pardoo 10% is too low, more accurate just for SB and Carnarvon regions alone. Inclusion of coastline all the way up to Pardoo would substantially raise the number of uncounted areas. This section includes Exmouth Gulf, Onslow and offshore islands, Karratha, Port Hedland and Pardoo, none of which have regular counts. My feeling would be 70% missed for this section of coastline. For example, recently had about 500 Red-necked Stint at just one roost site in Port Hedland. No extrapolation for Broome/80MB/Ashmore/Adele sounds good. Extrapolation NW excluding Broome/80MB 65% might be too low, maybe more like 90%? (see however counter response in previous comment above)	B. Greatwich
	Although Oriental Plover are counted on the coast they are not a coastal bird, and instead feed on open grassland. So need to be very careful with extrapolation of this species. On this basis, a potential repeat of 144,300 from 80MB removed and no extrapolation applied to this species' estimate. Snipe figures seem unrealistic but recognise that approach used for these species for the flyway will be a suitable alternative (i.e. relying on breeding range and density analyses). Ruddy Turnstone figures too high after extrapolation as they tend to associate with islands (where count coverage is reasonable), so extrapolation not applied to this species in NWA. A similar case with Sharp-tailed Sandpiper as they are no strongly coastal and applying coastal extrapolations not meaningful. Whimbrel probably only occur in big creeks and rivers - surprisingly few birds away from the large creeks, rivers and mudflats. Cambridge Gulf and King Sound very few birds. CJH flew Cambridge Gulf 2005 and AB in 2008 - only CoGr and GTTa, Whim, Tereks and CoSa observed. Nevertheless, extrapolated figure of 2994, based on 3 whimbrel per coastal creekline, considered a fair extrapolation. Wood Sandpiper virtually no birds on the coast however, totals not very high even after extrapolation (156 versus 112). Not resolved and extrapolation retained – requires further investigation. Long-toed Stint too low – see above (Nationwide)	C. Hassell, A. Boyle
NT	Treatment of Whimbrel, and to a lesser extent, to Eastern Curlew, Grey-tailed Tattler, Common Sandpiper and Terek Sandpiper, should mimic that applied to Whimbrel in WA. Using an estimate of length of estuarine waterway when performing spatial analyses might give a more realistic estimate of uncounted habitats. For consideration in future revisions. New data supplied for NT (Gulf of Carpentaria) from April 2008.	S. Garnett

State	Summary of feedback	Reviewers
SA	I don't think it practical to give the same percentage across all of the SA coast. If you look at just the two PMP sites (excluding sites like Nore Creina, Rivoil Bay / Beach port, Canunda), I would estimate that 50% of our total coastal population is counted. Though this is not as simple as it sounds – as shorebirds move from the coast to the 'inland' lakes (Lake's Bonney SE, George, Robe, St Clair, Eliza, Hawdon) are all very close to the coast. Sanderling are a real problem. The same flock (proved by flag sightings) use Discovery Bay (Vic), Green Point/Danger Point, Canunda (usually about 300), Nora Creina/Nene Valley (around 100). Probably 1,000+ all up. This movement makes them difficult to count. i.e. they tend to flock in Green Point/Danger Point area on arrival and departure; at count times scattered, many in Canunda. In the Brown Bay area (i.e. Piccaninnie Ponds to Stony Point) there are sometimes no Sanderling at all, but on occasions in the past there has been as many as 1000. We think this is because of their movement up and down the coast. It would probably be fair to put in 300-400 for this section. So Sanderling should be around 800 in SE SA, plus several hundred for Discovery Bay/Vic. Only 3 birds recorded against Discovery Bay, so the new extrapolated figure of 1190 (minus an erroneous Lake Bonney figure of 215) considered OK. In conclusion Sanderling requires a different approach as they move substantially – not may not be adequately captured in this population estimate revision.	M. Christie, J. Campbell
	Numbers of birds in Franklin Harbour are too high – the estimate for Grey Plover is completely overblown. To correct this, predicted 5 year means from GAM were replaced with mean 10 years, to make estimates for each species more realistic. Numbers of Grey Plover in the Streaky Bay – Tourville region more stable the in the gulfs (St Vincent and Spencer); probably around 600 on average. Lots of industrial activity in the Gulfs seems to driven shorebird numbers down. The section of coast from Streaky Bay to Fowlers Bay (~1200km coastline) is definitely not 100% counted, but an extrapolation factor of 1.14x would be reasonable.	J. Cooper
	Double Banded Plover move between beaches and "inland" lakes to take advantage of feeding and to avoid the worst of the winter high tides/storms. If you add coastal lakes and beaches together a figure of 1000 is probably too low. An estimate of 115 Curlew Sandpiper at Port MacDonnell seemed awfully high during last 5 years, but checking our data the average from the last five years was 101 (high of 161, low of 46) so 115 is near enough to the mark. I had 62 Lake George in 2015 count. So we consider that 242 is fine if Lake George considered 'coastal'	M. Christie, J. Campbell,

State	Summary of feedback	Reviewers
SA cont.	We think turnstone figures are hugely overestimated, this may have been caused by a misunderstanding. A 50% extrapolation is OK based on the amount of area not counted on PMP surveys. However, this table has counts from Rivoli Bay, Nora Creina, etc, etc – areas that we were covered by extrapolation. In the past we have done “back-of the-envelope” calculations of the Turnstone population, coming up with figures between 800-1,000.	M. Christie, J. Campbell, C. Minton
	There are problems with the treatment of what we in the SE of SA call the ‘Coastal Lakes’. Treatment has been inconsistent, with Lake Bonney SE classified as ‘coastal’ and Lake George as ‘inland’. For the sake of consistency I will list all those that I think should be ‘coastal’ (moving along the coast starting in the east): Lake Bonney, Lake Frome, Mullins Swamp, Lake George, Lake St Clair, Lake Eliza, Lake Hawdon**, Lake Robe, Fox Lake, The Pub Lake, Nadzab. Whether you go ‘coastal’ or ‘inland’ there is no justification for Lake Bonney to be one, and Lake George the other. As a result, Lake Bonney counts were moved to the “inland” category (when considering analyses of counts of “inland” species).	M. Christie, J. Campbell
Outside AUS	Of the recommended 34,000 Sanderling, the 14,000 from Australia is pretty credible. The remainder of the flyway contributes 22k which is then extrapolated to 33k. Of this, Japan records a count of 5.9K which is extrapolated to 11.5k. Have these counts and potential extrapolation factors been supplied by Japanese sources as to my knowledge they do seem rather high. The recommended estimate of 34k being 50% greater than the existing figure.	K. Gosbell

Appendix 9. Corrected figures for Tasmania derived from expert review.

RP / BB = Robbins Passage Boullanger Bay ; Explanation of totals: Total 1 = TOTAL EXCLUDING RP/BB, including MARION BAY and CAPE PORTLAND; Total 2 = TOTAL EXCLUDING Marion Bay, Cape Portland BUT INCLUDING L Swanport, Ocean Beach and Sandspit Point; Total 3 = REVISED FULL SITE LIST (SBA, CA or other sites not analysed using GAMs) EDITED TO REMOVE DUPLICATES, QUESTIONABLE DATA AND NON-TASMANIAN SITES [2]; Total 4 = Interim Tasmania totals to be multiplied by 1.14 [EXCLUDING DBPL, RUTU and SAND]; Total 5 = Interim Tasmania totals multiplied x 1.14 [EXCLUDING DBPL, RUTU and SAND]; Total 6 = Robbins Passage Boullanger Bay data multiplied by 1.3; Sub-total 1 = REVISED TASMANIAN TOTALS EXCLUDING DBPL, RUTU and SAND; Total 7 = SPECIES-SPECIFIC MULITPLIERS (see notes in main report); Total 8 = DBPL, RUTU, SAND estimates; Sub-total 2 = Tasmanian totals based on count data only with no multipliers

Common name	Total 1	Total 2	Total 3	Total 4	Total 5	RP / BB data	Total 6	Sub-total 1	DBPL, RUTU, SAND	Total 7	Total 8	Sub-total 2	Revised TAS pop. ests.
Asian Dowitcher	0	0	0	0	0	0	0	0				0	0
Bar-tailed Godwit	102	59	42	203	231	104	135	366				307	366
Broad-billed Sandpiper	0	0	0	0	0	0	0	0				0	0
Black-tailed Godwit	7	0	0	7	8	0	0	8				7	8
Common Greenshank	17	30	66	113	129	17	22	151				130	151
Common Redshank	0	0	0	0	0	0	0	0				0	0
Common Sandpiper	0	2	0	2	2	0	0	2				2	2
Curlew Sandpiper	10	15	8	33	38	117	152	190				150	190
Double-banded Plover	293	786	641			433			2153	3	6459	2153	6459
Eastern Curlew	71	20	38	129	147	53	69	216				182	216
Great Knot	0	6	9	15	17	12	16	33				27	33
Grey Plover	1	2	0	3	3	51	66	70				54	70
Greater Sand Plover	0	0	0	0	0	0	0	0				0	0
Grey-tailed Tattler	0	0	0	0	0	1	1	1				0	1
Latham's Snipe		0	28	28	32	0	0	32				28	32
Little Curlew	0	0	0	0	0	0	0	0				0	0
Little Ringed Plover			0	0	0	0	0	0				0	0
Lesser Sand Plover	0	1	0	1	1	1	1	2				2	2
Long-toed Stint		0	0	0	0	0	0	0				0	0
Marsh Sandpiper	0	0	0	0	0	0	0	0				0	0
Oriental Plover	0	0	0	0	0	0	0	0				0	0

Common name	Total 1	Total 2	Total 3	Total 4	Total 5	RP / BB data	Total 6	Sub-total 1	DBPL, RUTU, SAND	Total 7	Total 8	Sub-total 2	Revised TAS pop. ests.
Oriental Pratincole			0	0	0	0	0	0				0	0
Pectoral Sandpiper	0	0	0	0	0	0	0	0				0	0
Pacific Golden Plover	265	33	81	379	432	211	274	706				590	706
Pin-tailed Snipe			0	0	0	0	0	0				0	0
Red Knot	2	6	0	8	9	219	284	294				227	294
Red-necked Phalarope			0	0	0	0	0	0				0	0
Red-necked Stint	2751	1297	802	4850	5529	4744	6167	11696				9594	11696
Ruff	0	0	0	0	0	0	0	0				0	0
Ruddy Turnstone	116	271	80			536			1003	4	4012	1003	4012
Sanderling	12	246	26			2			286	2	572	286	572
Sharp-tailed Sandpiper	74	73	60	207	256	76	99	335				283	335
Swinhoe's Snipe			0	0	0	0	0	0				0	0
Terek Sandpiper	0	0	0	0	0	0	0	0				0	0
Wandering Tattler	0	0	0	0	0	0	0	0				0	0
Whimbrel	8	0	1	9	10	8	10	21				17	21
Wood Sandpiper	0	0	0	0	0	0	0	0				0	0

Appendix 10. Relationship between breeding range and flyway population: model structure and output

Results for QUALITY = 1.000000

Model Contains no Constant

Dependent Variable	LNPOP
N	19
Multiple R	0.999778
Squared Multiple R	0.999556
Adjusted Squared Multiple R	0.999501
Standard Error of Estimate	0.257649

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-Value
LNBP	0.841586	0.006235	0.984329	0.521250	134.974066	0.000000
D1	0.958963	0.133368	0.048002	0.622014	7.190330	0.000002
D3	-0.923690	0.170308	-0.032694	0.762902	-5.423659	0.000056

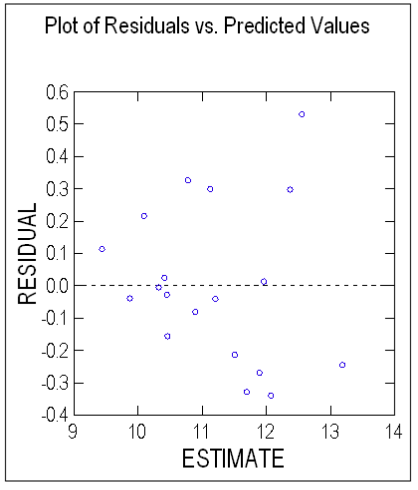
Analysis of Variance

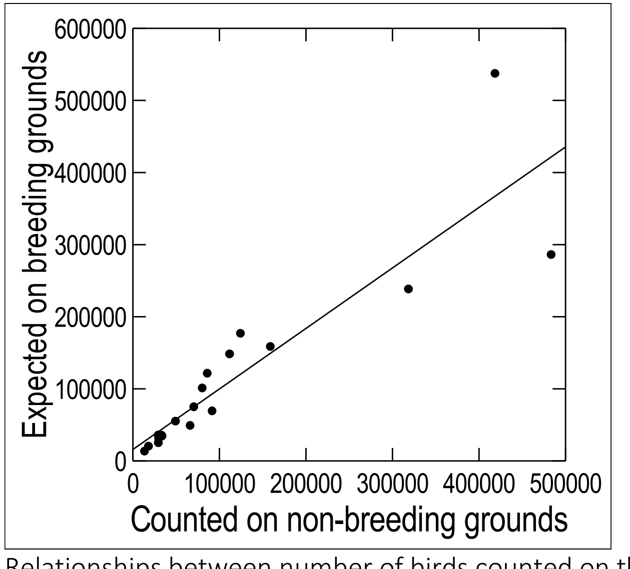
Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Regression	2393.530427	3	797.843476	12018.762538	0.000000
Residual	1.062131	16	0.066383		

Durbin-Watson D-Statistic	2.018586
First Order Autocorrelation	-0.046980

Information Criteria

AIC	7.120585
AIC (Corrected)	9.977728
Schwarz's BIC	10.898341





Relationships between number of birds counted on the non-breeding grounds, and number expected through modelling breeding parameters: (A, left): Predictions only based on breeding range; (B, right) Predictions of model based on both breeding range and breeding density.

Appendix 11. New estimates for Australia and adjustment steps.

The first column provides estimate directly from counts, derived using S2020 & QWSG data. The second column "Estimates Including other coastal data sources " adds coastal site data from other sources (Appendix 2) to the S2020 / QWSG totals. The third column applies extrapolations to all coastal data using the values specified in Appendix 4a. The fourth column provides count data from inland sites (see Appendix 7). The fifth column provides values from inland modelling (see Appendix 7). The sixth column adds the extrapolated coastal totals to inland count data. The seventh column adds the extrapolated coastal totals to the inland modelled values.

Common Name	Estimate directly from counts at coastal sites	Estimate including other coastal data sources	Extrapolated coastal estimate †	Inland count data only	Inland modelled values only	Extr. estimate including inland count data	Extr. estimate including inland modelling
Asian Dowitcher	188	460	473			473	473
Bar-tailed Godwit	135287	173664	189146			189146	189146
Black-tailed Godwit	6354	37041	47308	111	3200	47419	50508
Broad-billed Sandpiper	688	2692	3394			3394	3394
Common Greenshank	8995	15692	17463	2913	10000	20376	27463
Common Redshank	13	46	46			46	46
Common Sandpiper	686	940	1201	244	1300	1445	2501
Curlew Sandpiper	13932	18837	20485	47712	25000	68197	45485
Double-banded Plover	6681	7172	12312			12312	12312
Far Eastern Curlew	15854	22200	26405			26405	26405
Great Knot	174900	343375	381854			381854	381854
Greater Sand Plover	66649	118766	126616			126616	126616
Grey Plover	5421	10931	12120			12120	12120
Grey-tailed Tattler	30131	58715	64360			64360	64360
Latham's Snipe	1124	1124	1260			1260	1260
Lesser Sand Plover	11054	23600	27551			27551	27551
Little Curlew	571	27272	58908	9371	18000	68279	76908
Little Ringed Plover	5	8	10			10	10
Long-toed Stint	21	21	26	527	60	553	553
Marsh Sandpiper	1079	13767	14481	14333	39000	28814	53481
Oriental Plover	44655	189089	189124	1299	43000	190423	232124

Common Name	Estimate directly from counts at coastal sites	Estimate including other coastal data sources	Extrapolated coastal estimate †	Inland count data only	Inland modelled values only	Extr. estimate including inland count data	Extr. estimate including inland modelling
Oriental Pratincole	63062	586985	587051	1987		589038	587051
Pacific Golden Plover	6655	7773	9091			9091	9091
Pectoral Sandpiper	8	8	9	73	60	82	69
Pin-tailed Snipe	6	6	10			10	10
Red Knot	35254	61154	68927			68927	68927
Red-necked Phalarope	49	50	98			98	98
Red-necked Stint	154005	195901	229206	47600	160000	276806	389206
Ruddy Turnstone	9057	18756	20800			20800	20800
Ruff	3	3	5			5	5
Sanderling	10355	13249	15082			15082	15082
Sharp-tailed Sandpiper	20056	28559	31809	43065	54000	74874	85809
Swinhoe's Snipe	21	21	67			67	67
Terek Sandpiper	10706	17894	19115			19115	19115
Wandering Tattler	310	322	400			400	400
Whimbrel	13588	20453	24972			24972	24972
Wood Sandpiper	124	142	190	2800	1600	2990	1790

† Extrapolation factors for each species in each state can be found in Appendix 4a.

‡ Long-toed Stint value a special case where inland counts used over inland modelling values, determined on the basis of expert feedback

Appendix 12a. Species population estimates by country with spatial extrapolations applied: Japan to Vietnam

Ext. xx gives the count extrapolated by any stated numeric that country. Korea Ro=Republic of Korea (South Korea).

Common Name	Japan	Ext. 1.25	Korea Ro	Ext. 1.8	China	Ext. 2.5	PRC Taipei	Ext. 1.1	Viet.	Ext. 2.8
Asian Dowitcher		0		0		0	2	2	30	85
Bar-tailed Godwit	29	36		0	154	379	24	26	8	23
Black-tailed Godwit	11	14	30	54	780	1919	18	19	753	2123
Broad-billed Sandpiper	30	38	2	4	1	2	2554	2733	764	2154
Common Greenshank	955	1194	156	281	2072	5097	489	523	503	1418
Common Redshank	197	246	3	5	785	1931	393	421	606	1709
Common Sandpiper	566	708	289	520	328	807		0	175	494
Curlew Sandpiper	10	13		0	40	98	2	2		0
Double-banded Plover										
Far Eastern Curlew	28	35	588	1058	3	7	5	5	25	71
Great Knot	169	211		0	28	69	6	6	146	412
Greater Sand Plover	415	519		0	35	86	500	535	459	1294
Grey Plover	4741	5926	7378	13280	8804	21658	1284	1374	615	1734
Grey-tailed Tattler	200	250	35	63	2	5	31	33	30	85
Latham's Snipe										
Lesser Sand Plover	2000	2500	248	446	175	431	523	560	364	1026
Little Curlew										
Little Ringed Plover	365	456	116	209	325	800	1761	1884	256	722
Long-toed Stint										
Marsh Sandpiper	55	69	1	2	2884	7095	930	995	109	307
Oriental Plover										
Oriental Pratincole										
Pacific Golden Plover	3915	4894		0	782	1924	9799	10485	135	381
Pectoral Sandpiper										
Pin-tailed Snipe										
Red Knot	4	5		0	15	37	91	97	44	124
Red-necked Phalarope										
Red-necked Stint	864	1080	2337	4207	298	733	2206	2360	267	753
Ruddy Turnstone	469	586	11	20	58	143	819	876	1	3
Ruff										
Sanderling	5905	7381	866	1559	235	578	331	354	198	558
Sharp-tailed Sandpiper										
Swinhoe's Snipe										
Terek Sandpiper	19	24	18	32	9	22	7	7	2	6
Wandering Tattler										
Whimbrel	323	404	246	443	37	91	167	179	71	200
Wood Sandpiper	176	220	8	14	303	745	1523	1630	8	23
COUNTRY TOTAL	21446	26808	12332	22198	18153	44656	23465	25108	5569	15705

Appendix 12b. Species population estimates by country with spatial extrapolations applied: Cambodia to Malaysia

Ext. xx gives the count extrapolated by any stated numeric that country.

Common Name	Camb.	Ext. 2.3	Philip.	Ext. 2.4	Brunei	Ext. 1.0	Thai.	Ext. 2.0	Malay.	Ext. 2.2
Asian Dowitcher	16	36	393	947		0	25	50	301	653
Bar-tailed Godwit	534	1207	1913	4610		0	1273	2521	1999	4338
Black-tailed Godwit	14	32	3540	8531		0	12579	24906	254	551
Broad-billed Sandpiper	214	484	3379	8143		0	2879	5700	804	1745
Common Greenshank	857	1937	3732	8994	185	185	633	1253	612	1328
Common Redshank	675	1526	4626	11149	210	210	1717	3400	6043	13113
Common Sandpiper	887	2005	13245	31920	283	283	669	1325	645	1400
Curlew Sandpiper	192	434	1161	2798		0	2900	5742	1706	3702
Double-banded Plover										
Far Eastern Curlew		0	390	940	1	1	1	2	197	427
Great Knot		0	7024	16928		0	5601	11090	791	1716
Greater Sand Plover	517	1168	13386	32260	8	8	3791	7506	1730	3754
Grey Plover	109	246	4525	10905	59	59	821	1626	519	1126
Grey-tailed Tattler		0	2035	4904	2	2	17	34	68	148
Latham's Snipe										
Lesser Sand Plover	489	1105	9928	23926	65	65	16841	33345	6446	13988
Little Curlew										
Little Ringed Plover	263	594	15400	37114	158	158	571	1131	144	312
Long-toed Stint										
Marsh Sandpiper	104	235	8903	21456	32	32	5806	11496	364	790
Oriental Plover										
Oriental Pratincole										
Pacific Golden Plover	109	246	12097	29154	416	416	991	1962	2208	4791
Pectoral Sandpiper										
Pin-tailed Snipe										
Red Knot		0	838	2020		0	311	616	790	1714
Red-necked Phalarope										
Red-necked Stint	7	16	13264	31966	172	172	5836	11555	3650	7921
Ruddy Turnstone	3	7	839	2022	1	1	230	455	189	410
Ruff										
Sanderling		0	413	995	20	20	154	305	128	278
Sharp-tailed Sandpiper										
Swinhoe's Snipe										
Terek Sandpiper	136	307	2033	4900	33	33	1445	2861	5047	10952
Wandering Tattler										
Whimbrel	172	389	2037	4909	82	82	728	1441	3486	7565
Wood Sandpiper	186	420	1053	2538	427	427	788	1560	265	575
COUNTRY TOTAL	5484	12394	130033	304031	2302	2154	68029	131882	38658	83298

Appendix 12c. Species population estimates by country with spatial extrapolations applied: Bangladesh to Timor Leste

Ext. xx gives the count extrapolated by any stated numeric for that country.

Common Name	Bang.	Ext. 1.5	Myan.	Ext. 2.7	Sing.	Ext. 1.9	Indo.	Ext. 3.3	Timor Leste	Ext. 3.5
Asian Dowitcher	53	81					3557	11845		
Bar-tailed Godwit	900	1377	532	1458	14	26	4966	16537		
Black-tailed Godwit	24833	37994	6252	17130			4740	15784	10	35
Broad-billed Sandpiper	788	1206	1586	4346	11	21	51	170		
Common Greenshank	1115	1706	2685	7357	1001	1882	523	1742	40	139
Common Redshank	3861	5907	7252	19870	2549	4792	3465	11538		
Common Sandpiper	222	340	935	2562	643	1209	2717	9048	7	24
Curlew Sandpiper	2150	3290	6308	17284	41	77	4009	13350		
Double-banded Plover										
Far Eastern Curlew	1	2					1462	4868		
Great Knot	769	1177	489	1340			1314	4376		
Greater Sand Plover	4632	7087	2505	6864	212	399	3283	10932		
Grey Plover	911	1394	512	1403	208	391	1224	4076		
Grey-tailed Tattler					1	2	271	902		
Latham's Snipe										
Lesser Sand Plover	43049	65865	26975	73912	8317	15636	7076	23563		
Little Curlew										
Little Ringed Plover	981	1501	1039	2847	28	53	286	952		
Long-toed Stint										
Marsh Sandpiper	858	1313	222	608	627	1179	971	3233	30	104
Oriental Plover										
Oriental Pratincole										
Pacific Golden Plover	11259	17226	8978	24600	5829	10959	1734	5774		
Pectoral Sandpiper										
Pin-tailed Snipe										
Red Knot	58	89	143	392			891	2967		
Red-necked Phalarope										
Red-necked Stint	696	1065	6783	18585	300	564	1867	6217		
Ruddy Turnstone	181	277	162	444	16	30	278	926		
Ruff										
Sanderling	318	487	285	781	22	41	419	1395		
Sharp-tailed Sandpiper										
Swinhoe's Snipe										
Terek Sandpiper	767	1174	1019	2792	29	55	2291	7629		
Wandering Tattler										
Whimbrel	984	1506	2605	7138	3051	5736	3364	11202		
Wood Sandpiper	572	875	440	1206	15	28	924	3077		
COUNTRY TOTAL	99958	152936	77707	212917	22914	43078	53275	172104	87	302

Appendix 12d. Species population estimates by country with spatial extrapolations applied: Papua New Guinea to Australia, plus flyway totals

Ext. xx gives the count extrapolated by any stated numeric that country (var.= extrapolations applied varied between states). Palau had no extrapolation applied. PNG=Papua New Guinea, NZ=New Zealand, Aust.=Australia. Australian totals incorporate modelled inland estimates (Appendix 7).

Common Name	PNG	Ext. 3.4	Palau	NZ	Ext. 1.1	Aust.	Ext. var.	Flyway sum	Flyway extrap
Asian Dowitcher						460	473	4837	14172
Bar-tailed Godwit			16	88621	97483	173664	189146	274647	319182
Black-tailed Godwit	15	51				40241	50508	94070	159652
Broad-billed Sandpiper						2692	3394	15755	30139
Common Greenshank	105	355	99			25692	27463	41454	62953
Common Redshank	5	17	3			46	46	32436	75884
Common Sandpiper	18	61	33			2240	2501	23902	55238
Curlew Sandpiper			5	13	14	43837	45485	62374	92294
Double-banded Plover				5885	6474	7172	12312	13057	18786
Far Eastern Curlew	2	7	4	7	8	22200	26405	24914	33840
Great Knot			7			343375	381854	359719	419186
Greater Sandplover	40	135	94			118766	126616	150373	199258
Grey Plover	53	179	118			10931	12120	42812	77616
Grey-tailed Tattler	10	34	195			58715	64360	61612	71016
Latham's Snipe						1124	1260	1124	1260
Lesser Sandplover	48	162	24			23600	27551	146168	284105
Little Curlew			5			45272	76908	45277	76913
Little Ringed Plover	5	17	1			8	10	21707	48761
Long-toed Stint			34			548	553	582	587
Marsh Sandpiper	11	37	7			52767	53481	74681	102439
Oriental Plover						232089	232124	232089	232124
Oriental Pratincole						586985	587051	586985	587051
Pacific Golden Plover	36	122	200	141	155	7773	9091	66402	122379
Pectoral Sandpiper				8	9	68	69	76	78
Pin-tailed Snipe						6	10	6	10
Red Knot				32666	35933	61154	68927	97005	112920
Red-necked Phalarope						50	98	50	98
Red-necked Stint	314	1061	439	81	89	355901	389206	395282	477990
Ruddy Turnstone			290	1888	2077	18756	20800	24191	29367
Ruff						3	5	3	5
Sanderling	4	14	7			13249	15082	22554	29835
Sharp-tailed Sandpiper			3	15	17	82559	85809	82577	85829
Swinhoe's Snipe			1			21	67	22	68
Terek Sandpiper	12	41				17894	19115	30761	49949
Wandering Tattler						322	400	322	400
Whimbrel	17	57	354	31	34	20453	24972	38208	66701
Wood Sandpiper	14	47	73			1742	1790	8517	15249
COUNTRY TOTAL	709	2396	2012	129356	142292	2372374	2557062	3076550	3953332