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# Wader numbers and distribution on Eighty Mile Beach, north-west Australia: baseline counts for the period 1981–2003

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## ABSTRACT

This paper analyses ground counts and aerial surveys of high-tide wader roosts conducted over the 23-year period from 1981 to 2003, at Eighty Mile Beach, north-west Australia. It provides a baseline data set with which later count data can be compared. Over the study period, Eighty Mile Beach held a maximum of around 470,000 waders in any given year. This represented around 20% of the total number of migratory waders visiting Australia each year and around 6% of the total East Asian – Australasian Flyway migratory wader population. The most numerous species were great knot (169,000), bar-tailed godwit (110,000), greater sand plover (65,000) and oriental plover (58,000). Distribution of waders along the beach was not uniform, with up to 85% occurring in the section between 25 km and 80 km south of Cape Missiessy where, at peak, numbers averaged 7000 per kilometre of shore; however, distributions for some species diverged from this pattern. Count data showed that waders arrived in north-west Australia over an extended period from July to October. The majority of these birds remained at Eighty Mile Beach throughout the nonbreeding season (austral summer) although some smaller waders used Eighty Mile Beach as a staging point. Most adult birds left on northward migration in March–April of the following year. The number of (mainly) immature birds remaining at Eighty Mile Beach over the May–July period was equivalent to 9% of the peak spring/summer population. The counts also showed that Eighty Mile Beach, especially the southern half, is important for resident wader species. Threats to its ecological integrity are identified and the introduction of enhanced long-term protection measures recommended to ensure that key sections of Eighty Mile Beach are managed for the benefit of the internationally significant numbers of waders occurring there.

**Keywords:** conservation, counts, Eighty Mile Beach, north-west Australia, shorebirds, waders.

## INTRODUCTION

Eighty Mile Beach, which is actually 140 miles (220 km) long, lies on the north-west Australian coast between Broome and Port Hedland (Fig. 1). Tidal ranges along this coast are high, and intertidal areas extensive. During the austral summer these invertebrate-rich intertidal areas support large numbers of waders, mostly northern hemisphere migrants. Eighty Mile Beach's importance to migratory waders was first noted as recently as 1962 by Marshall and Drysdale (1962) and confirmed in 1980 by Simon Bennett (pers. comm.), who reported huge concentrations of wading birds, including many great knot (*Calidris tenuirostris)*, then considered a globally uncommon species.

This information was timely, as it came at the start of a Royal Australasian Ornithologists Union (RAOU) project aimed at conducting, between 1981 and 1985, a complete wader population census across Australia. As

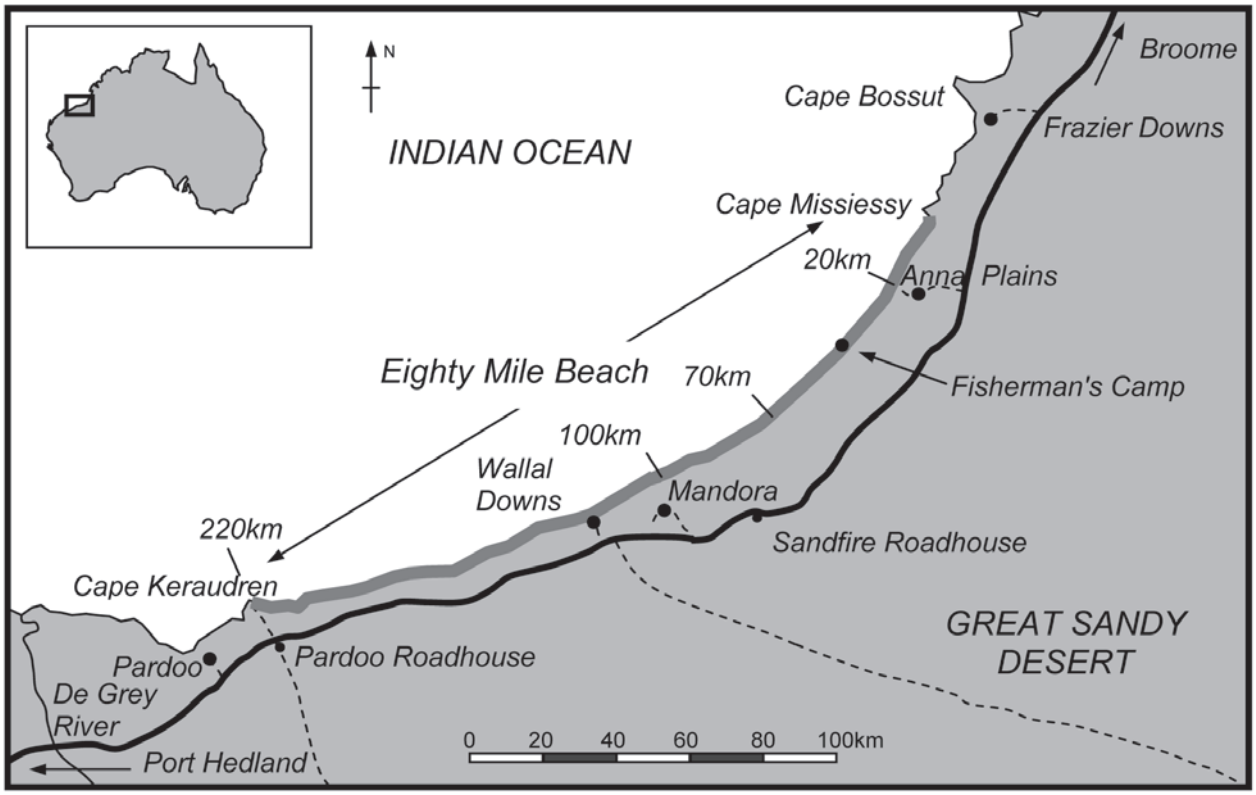


*Figure 1. Map of Eighty Mile Beach showing the distances from Cape Missiessy south to Cape Keraudren.*

part of this effort, the Australasian Wader Studies Group (AWSG) undertook a special expedition to north-west Australia during late August and early September 1981. An aerial survey and brief ground visit confirmed the presence of large numbers of waders on Eighty Mile Beach, particularly its northern sections. Since 1981, aerial surveys and/or ground counts of waders and terns have been undertaken there almost every year. Difficulties associated with surveying the entire length of Eighty Mile Beach meant that most counts covered only those sections of beach known to support good numbers of migratory waders.

Data generated from aerial and ground counts between 1981 and 1986 provided the basis for the population estimates for Eighty Mile Beach (and Australia as a whole) derived by Lane (1987). Based on these estimates, Watkins (1993) ranked Eighty Mile Beach as the top site in Australia as far as total wader numbers were concerned, and the third most important in terms of the number of different wader species that had populations above the internationally significant (15 species) and the nationally significant (19 species) levels: for 11 species (10 migrant, one resident) Eighty Mile Beach held the highest concentrations in Australia. These rankings made it highly desirable that early wader population estimates be verified. Also, by the mid-1990s populations of several wader species were in decline elsewhere in Australia and it was desirable to know if trends were similar on Eighty Mile Beach. Therefore, a complete ground count was attempted in October 1998 and a similar, follow-up, count was undertaken in November 2001. The first complete count during the austral winter was conducted in July 2003.

This paper presents findings from an analysis of count data obtained at Eighty Mile Beach during the period up until 2003; particular importance is attached to data from the 1998 and 2001 complete counts. Results obtained during counts subsequent to 2003 have not been included since pressures on wader habitats in the Asia–Pacific Flyway have increased markedly recently, particularly in the Yellow Sea area (Barter 2003; Milton et al. 2003; van de Kam et al. 2010). Restricting the analysis to data from the 1981–2003 period, when disturbances to wader habitat in the flyway were less severe, enabled a reference data set for this period to be established. Having such baseline data available will be valuable when assessments are made of the nature, magnitude and causes of more recent and future changes in wader numbers, distributions and migration patterns.

The specific objectives of the work described in this paper were:

a) To determine the total numbers of waders and number of wader species using Eighty Mile Beach, and to establish how patterns of use vary seasonally.

b) To determine patterns of arrival for each species.

c) To establish how waders in general, and individual species in particular, are distributed along Eighty Mile Beach.

d) To identify key conservation sites and issues for Eighty Mile Beach.

# METHODS

## Site Description

Eighty Mile Beach extends south-west from Cape Missiessy (19° 02' S, 121° 32' E) to Cape Keraudren (20° 00' S, 119° 48' E; Fig. 1). For most of its length the beach consists of an extensive intertidal area and sandy beach, backed by sand dunes, which give way inland to narrow coastal plains. The daily tidal range varies from about 2 m on neap tides to 10 m during spring tides. At spring low tide the tidal flats adjoining the beach vary from 1.5 to >4 km in width and the maximum exposed area of mud and sandflats is about 60,000 ha (Pearson et al. 2005a).

Along the southern part of the beach, south of Wallal, there are occasional small rocky outcrops and, in the segment 160–165 km from Cape Missiessy, a low rocky cliff abuts the mudflats. No mangroves are present along the beach except for a few scattered bushes, 1 m high, in the small creek where the Mandora Marsh drains to the sea (CALM 2003).

The area experiences a semi-arid monsoonal climate, with a short wet season from late December to early March (Pearson et al. 2005a). Mean annual rainfall at Mandora Station, located midway along Eighty Mile Beach, is 341 mm (Wade & Hickey 2008); however, because the region regularly experiences cyclones, the amount and seasonality of rainfall events varies greatly (CALM 2003). Mean monthly maximum temperatures range from 28 °C in July to 36 °C in December (Wade & Hickey 2008).

Sediments are predominantly calcareous rather than siliceous in nature and become sandier towards the southern end of the beach (Pearson et al. 2005a). Sediment grain sizes are not uniform across the intertidal areas: the coarsest sediments are found at the highest intertidal level and finer sizes near the low-water mark (Honkoop et al. 2006; Wade & Hickey 2008). Benthic organisms on which waders feed are concentrated along the northern half of Eighty Mile Beach, right across the intertidal areas. The structure of benthic assemblages across intertidal areas is related to distribution of sediment sizes; however, unexpectedly large differences in benthic species composition are found between areas of comparable sediment characteristics at different localities along Eighty Mile Beach. It is speculated that these differences are caused by the cyclones that periodically disrupt intertidal sediments and their associated benthic fauna (Honkoop et al. 2006; Wade & Hickey 2008).

## Counts from the air

For both air and ground counts, counting was practical only when waders were driven off tidal flats by the rising tide and concentrated in roosting flocks along the sandy beaches. Counting was made easier by the tendency of flocks to roost on damp substrates along the tide edge. During aerial counts, a light aircraft was flown along the beach at heights under 200 ft (60 m). This ensured that all flocks flushed, enabling observers in the plane to identify the more distinctive species present. Flock sizes were estimated independently by two experienced observers while a third passenger recorded their observations. Such counts provided information on the total numbers and distribution patterns of waders present but complementary ground counts were needed to acquire detailed information on the numbers of each species.

## Counts on the ground

Ground counts were undertaken by teams of three to four observers driving along the beach in 4WD vehicles. For counting purposes, Eighty Mile Beach was divided into 5-km-long segments, denoted by their distance from Cape Missiessy (e.g. 0–5 km, 5–10 km, etc.). Each counting team was assigned a sector comprising two or more segments and counts were undertaken simultaneously during a 3–4 hour period during high tide. The procedure involved driving along the beach, stopping at strategic points to observe and record the numbers of different waders present. The number of birds in each 5-km segment was recorded separately. Along densely populated stretches of beach a counting team could only cover two segments in the 3–4 hours available. Where few roosting flocks were present, up to 20 km (or even 30 km on one sector) could be covered in the same timeframe. For the complete counts made in October 1998 and November 2001, six teams were required on each of the two days over which counts took place. Only four teams were needed on each day of the July 2003 count.

At Eighty Mile Beach, experience has shown that low (almost neap) tides, rather than spring high tides, are most suitable for counting waders in high-tide roosts along the tide edge. There are no tide gauges on the beach but field observations have shown that tide time and height is predicted reasonably well by published tide predictions from Roebuck Bay. The most appropriate tidal range for wader counts was 6.8 to 7.6 m. (The appropriate tidal range has been given as 6 to 6.8 m in several previous publications, e.g. Rogers [2005], but since then the National Tide Centre has raised the regional tide datum by 0.86 m.) Under these conditions the beach is generally wide enough to allow the counting vehicle to move around flocks without causing the birds to take flight. At the same time the flocks are close enough for counts and identifications to be made with reasonable accuracy. Morning counts are best because the sun is behind the observers. If counting is attempted on spring tides, many flocks flush as vehicles approach. Some birds circle back behind the counting team but others settle further down the beach. Under such circumstances, count accuracy diminishes markedly.

When devising a procedure for counting the birds present in each flock some unusual challenges had to be overcome. In most parts of the world waders tend to roost in discrete flocks comprising only a small number of species (often only a single species). However, in north-west Australia it is usual for roosting flocks to contain 10–15 species. Since flocks typically comprise 1000 to 5000 birds and are fairly tightly packed, accurately determining the numbers of each species present is difficult. When counting

such large, mixed flocks the total number of birds in the roosting flock was determined first, usually by means of the 'block method' (Howes & Bakewell 1989). The percentage of each species present in significant numbers in the flock was then estimated, enabling an approximate figure for each species to be arrived at.

## Limitations of the counting procedure

The limitations of the procedures used for counting waders in north-west Australia have been discussed by Rogers et al. (2006b). They concluded that the complex structure of roosting flocks is the major cause of error in count data, provided all observers are experienced wader-counters familiar with the counting sites. This was the case for counts discussed here since not only were the observers experienced but consistency between the 1998 and 2001 counts was maximized by arranging for four of the teams to have the same leader and cover the same areas on each count. Flock structure is a problem since most roosting flocks contain large numbers of birds, packed relatively closely together, so that many individuals are partly or wholly obscured from view. In addition, birds often change their relative positions within the flock. Hence observers are seldom able to get a clear view of every individual bird present. Despite these problems, the level of consistency between counts conducted by different observers suggests counts of more common species are reasonably accurate. However, it is likely that there is under-counting of a few species (e.g. lesser sand plover, *Charadrius mongolus*, and broad-billed sandpiper, *Limicola falcinellus*) that are uncommon on Eighty Mile Beach and are potentially difficult to distinguish from other species in roosting flocks.

## History of counts: 1981–2003

Thirty-six ground counts and 24 aerial counts of waders on Eighty Mile Beach were conducted between 1981 and 2003. All except one aerial count were conducted prior to 1986. Several covered the complete 220 km length of the beach from Cape Missiessy to Cape Keraudren but most only covered the section from Cape Missiessy to Mandora (100 km) or to Wallal (120 km). Most ground counts covered only the 70 km section (or parts thereof) south from Cape Missiessy (the 'Anna Plains' section). Aerial surveys showed that most of the waders using Eighty Mile Beach were found in this section. Counts fell into two categories: those conducted during formal expeditions, usually in March–April or August–October; and those conducted for the AWSG National Wader Population Monitoring Program (these have taken place in February and June each year since 1993).

Because juveniles of most migratory wader species arrive in Australia later than adults, the main counts in 1998 and 2001 were undertaken as late as possible in each expedition. In 1998 the complete census was undertaken in mid-October. This was preceded by a series of counts carried out on the northern section of the beach; these were designed to obtain information on the main arrival periods for different species and the rates at which their numbers increased. Evidence of onward movements to nonbreeding areas further south was also looked for. Based on experience acquired in 1998 and subsequently, a date in mid-November was chosen for the 2001 complete ground census. This count was also preceded by a count of the northern section of the beach. Details of the timing and areas covered in both the partial and complete 1998 and 2001 counts are given in Table 1.

**Table 1**

Count dates at Eighty Mile Beach in 1998 and 2001.

| Date | Sector Counted |
|---|---|
| 5 August 1998 | 0–70 km |
| 19 August 1998 | 0–100 km |
| 14 September 1998 | 0–100 km |
| 17–18 October 1998 | 0–220 km (entire beach) |
| 29 September 2001 | 0–70 km |
| 12–13 November 2001 | 0–220 km (entire beach) |

To complement the 1998 and 2001 censuses a complete ground-count of Eighty Mile Beach was carried out in July 2003. Whilst this count was undertaken primarily to determine the number of migrant waders that remain behind in Australia during the austral winter, it also provided an opportunity to assess the use made of Eighty Mile Beach by non-migratory waders over this period.

# RESULTS AND DISCUSSION

## Peak numbers in the overall population

Close to 479,000 waders, terns and gulls were present on Eighty Mile Beach during the ground census in November 2001, the vast majority being waders (Table 2). A strikingly similar count total was obtained in October 1998. The July 2003 count demonstrated the importance of Eighty Mile Beach as a feeding ground for over-wintering waders (Table 2).

The peak count of 479,000 was well above the population estimate of 300,000 (± 10%) derived from aerial counts conducted during 1981–86. Estimates from the three complete aerial counts were: 302,000 (September 1982), 337,000 (mid-November 1982) and 287,000 (mid-October 1984). Although two of the surveys were conducted before wader populations reach

**Table 2**

Wader counts for all of Eighty Mile Beach (220 km) in 1998, 2001 and 2003.

| | 17–18 Oct. 1998 | 12–13 Nov. 2001 | 8–9 July 2003 |
|---|---|---|---|
| Waders | 465,890 | 472,418 | 41,498 |
| Terns | 6,520 | 5,653 | 4,298 |
| Gulls | 1,008 | 615 | 1,056 |
| Total | 473,418 | 478,686 | 46,852 |

their peak, these results nonetheless suggest aerial counts underestimate wader numbers. Encouragingly, the complete ground censuses agreed closely with the population estimate of 508,539 in Lane (1987), later used by Watkins (1993) in his national population estimates. However, agreement at the individual species level is not as good, with Watkins' estimates being too high in some instances and too low in others (Table 3).

The above results indicate that, when wader numbers are at their peak, Eighty Mile Beach supports close to half a million waders: more than any other Australian site. Given that significant numbers of smaller waders use Eighty Mile Beach as a staging point while on migration, the number of waders regularly using the food resources of Eighty Mile Beach in any one year will be higher still. On occasions, conditions on Anna Plains Station create favourable foraging habitat for grassland species such as little curlew (*Numenius minutus*) and oriental plover (*Charadrius veredus*; Piersma & Hassell 2010) and, later in the season, oriental pratincole *(Glareola maldivarum)*. These species regularly roost on nearby sections of Eighty Mile Beach during the hotter periods of the day, significantly increasing the numbers of roosting waders. The most striking example was in February 2004, when an estimated 2.88 million oriental pratincoles were present along Eighty Mile Beach (Sitters et al. 2004). Assuming the normal summer population of waders on Eighty Mile Beach is around 470,000, this site holds about 20% of migrant waders visiting Australia and 6% of waders in the East Asian – Australasian Flyway (Bamford et al. 2008).

## Peak numbers of individual wader species

Thirty-three wader species were recorded on Eighty Mile Beach during the complete counts (Table 3). Of these, eight species were present in small numbers (<10 individuals) on every count, while numbers of another four species never exceeded 50. Of note is that the percentages of black-tailed godwits (*Limosa limosa)*,

**Table 3**

Maximum counts for each wader species along the full length of Eighty Mile Beach.

| | 8-9 Jul 03 | 17-18 Oct 98 | 12-13 Nov 01 | Maximum | *Previous estimates |
|---|---|---|---|---|---|
| Great knot | 10,665 | 158,082 | 169,044 | 169,044 | 160,000 |
| Bar-tailed godwit | 13,767 | 110,290 | 97,403 | 110,290 | 34,300 |
| Greater sand plover | 3,597 | 63,482 | 64,584 | 64,584 | 30,400 |
| Oriental plover | 0 | 57,619 | 41,278 | 57,619 | 18,400 |
| Red knot | 2,316 | 24,891 | 29,679 | 29,679 | 80,700 |
| Red-necked stint | 5,094 | 16,766 | 24,005 | 24,005 | 60,000 |
| Grey-tailed tattler | 124 | 10,436 | 14,647 | 14,647 | 8,500 |
| Terek sandpiper | 296 | 7,989 | 9,820 | 9,820 | 3,000 |
| Curlew Sandpiper | 363 | 2,859 | 7,984 | 7,984 | 60,000 |
| Ruddy turnstone | 227 | 3,480 | 1,649 | 3,480 | 740 |
| Sanderling | 1,001 | 2,230 | 3,219 | 3,219 | 100 |
| Red-capped plover | 2,965 | 2,512 | 3,077 | 3,077 | 9,600 |
| Common greenshank | 152 | 1,738 | 2,432 | 2,432 | 2,440 |
| Grey plover | 138 | 1,416 | 1,585 | 1,585 | 1,650 |
| Eastern curlew | 163 | 709 | 552 | 709 | 480 |
| Pied oystercatcher | 615 | 653 | 694 | 694 | 190 |
| Little curlew | 0 | 224 | 215 | 224 | 12,000 |
| Sharp-tailed sandpiper | 0 | 9 | 193 | 193 | 25,000 |
| Whimbrel | 9 | 185 | 148 | 185 | 180 |
| Marsh sandpiper | 2 | 76 | 171 | 171 | 140 |
| Lesser sand plover | 1 | 162 | 0 | 162 | 5 |
| Pacific golden plover | 0 | 24 | 12 | 24 | 440 |
| Black-tailed godwit | 0 | 22 | 7 | 22 | 110 |
| Sooty oystercatcher | 1 | 3 | 13 | 13 | 0 |
| Broad-billed sandpiper | 0 | 12 | 3 | 12 | 55 |
| Australian pratincole | 0 | 9 | 1 | 9 | 100 |
| Common redshank | 0 | 5 | 0 | 5 | 0 |
| Common sandpiper | 0 | 3 | 2 | 3 | 0 |
| Black-fronted dotterel | 0 | 0 | 1 | 1 | 0 |
| Black-winged stilt | 2 | 1 | 0 | 2 | 0 |
| Beach thick-knee | 0 | 1 | 0 | 1 | 0 |
| Oriental pratincole | 0 | 1 | 0 | 1 | 0 |
| Asiatic dowitcher | 0 | 1 | 0 | 1 | 0 |
| Others | 0 | 0 | 0 | 0 | 9 |
| Total waders | 41,498 | 465,890 | 472,418 | 503,897 | 508,539 |

*Lane (1987); also quoted by Watkins (1993).

broad-billed sandpipers, Asian dowitchers (*Limnodromus semipalmatus*), whimbrels (*Numenius phaeopus*) and lesser sand plovers in local wader populations were much lower at Eighty Mile Beach than at Roebuck Bay, Broome, only 200 km to the north (unpublished AWSG data).

The most numerous species were great knot, bar-tailed godwit (*Limosa lapponica*) and greater sand plover (*Charadrius leschenaultii*). Maximum counts for these species were, respectively, 169,000 (a little under half the estimated world population), 110,000 (around a third of the estimated population for the East Asian – Australasian Flyway), and 65,000 (nearly two thirds of the estimated world population; Bamford et al. 2008). Together, these three species made up almost 70% of peak wader populations. The combined contribution of these three species was also at much the same level (67%) for the winter (July 2003) count.

Peak population estimates from the October 1998 and November 2001 counts were encouragingly similar for many species. For the three principal wader species, changes in the estimated peak population size over the three-year period were all less than 15%: great knot (+7%), bar-tailed godwit (–12%) and greater sand plover (+2%). For most other species, the differences in numbers between the two counts were reasonably small, and probably resulted from more juvenile birds being present in November 2001 than in October 1998. This happened because the 2001 count took place a month later and because waders bred more successfully in northern Siberia in 2001 than in 1998 (Minton et al. 2002a). The differences may also reflect actual changes in population size over the three-year period associated with variations in breeding productivity and survival rates. However, the numbers recorded for a few species differed considerably between the counts, and other factors are likely to have contributed to the differences in the recorded size of the peak population:

a) Oriental plover (–28%). The October 1998 count coincided with the peak arrival date, in a year of excellent breeding productivity. Also, this species feeds primarily on grasslands inland of the beach dune system and only moves to the beach to roost, in numbers that fluctuate in response to changes in local weather conditions.

b) Red-necked stint (*Calidris ruficollis*; +43%). This increase is consistent with marked increases across Australia during the 1998–2001 period after a series of above average breeding seasons (Minton et al. 2002b).

c) Curlew sandpiper (+79%). 2001 was the first good breeding season after a long series of years of below average productivity (Minton et al. 2002b) that had led to a major population decline (Wilson 2001).

For many species the peak numbers recorded in the 1998 and 2001 surveys differed from the estimates made by Lane (1987), based on counts conducted in the 1981–86 period (Table 3). Only in the case of great knot, common greenshank (*Tringa nebularia*), grey plover (*Pluvialis squatarola*), whimbrel and marsh sandpiper (*T. stagnatilis)* do the count data and Lane's estimates match closely. Species rankings (based on numbers present) also differ: whereas the 1998/2001 counts had great knot ranked first, followed by bar-tailed godwit and greater sand plover, Lane's (1987) estimates have great knot first, red knot second, with red-necked stint and curlew sandpiper equal third. These differences are partly attributable to shortcomings in the early count data. In particular, the early (9 September 1982) estimate of 80,700 for red knot (*Calidris canutus*) has long been considered questionable: only one ground count of red knot during the 1981–2003 period exceeded 10,000, and that was 20,000 in the 20–35 km section in November 1987. Conversely, the original estimate of 34,300 bar-tailed godwits appears far too low.

Differences in methodology also contributed to the above discrepancies. Whereas the 1998/2001 results were obtained from direct counts, estimates of species numbers in Lane (1987) were derived by extrapolating the results of restricted ground counts to fit total wader numbers observed during aerial counts. Later counts have shown that many wader species have non-uniform distributions along Eighty Mile Beach. For example, red knots occur primarily on particular northern sections of Eighty Mile Beach. So, if the limited-scale ground counts used by Lane (1987) were conducted on beaches where a species was locally abundant, overestimates would have resulted. Conversely, where the limited-scale counts used by Lane (1987) relate to beaches where a species was uncommon, underestimates would have resulted. For some species, additional factors may have contributed to the above discrepancies:

- Lane's (1987) estimates included 25,000 sharp-tailed sandpipers (*Calidris acuminata*) counted at an ephemeral freshwater wetland several kilometres inland, whereas other population estimates for Eighty Mile Beach have used shoreline counts only.
- The discrepancy between Lane's (1987) curlew sandpiper estimate and the 1998/2001 count data appears partly attributable to an overall population decrease associated with a series of poor breeding seasons in the 1990s (Minton et al. 2002b; Wilson 2001; Rogers & Gosbell 2006).
- Species underestimated by Lane (1987) that occur predominantly on the northern sections of Eighty Mile Beach include bar-tailed godwit, greater sand plover, oriental plover, grey-tailed tattler (*Heteroscelus brevipes*) and Terek sandpiper (*Xenus cinereus*). In the case of the oriental plover, the 1998/2001 counts were conducted at a time when large numbers of this species had recently arrived in north-west Australia and populations were close to their maximum. This species had a good breeding season in 1998 and the population was augmented by unusually large numbers of juveniles (unpublished AWSG data)—the count of 58,000 recorded at Eighty Mile Beach that year was nearly 50% above the previous population estimate for the entire flyway. Increases in numbers estimated for grey-tailed tattlers

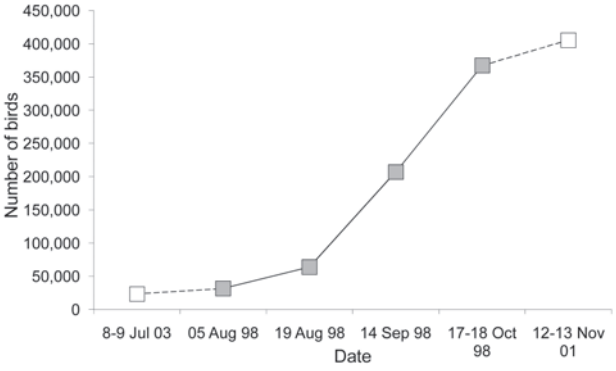


*Figure 2. The change in wader numbers on the 0–70 km section of Eighty Mile Beach over the period August–October 1998 (closed symbols). Open symbols show corresponding numbers from the counts along the same section of beach in July 2003 and November 2001. These are included to show the likely annual minima and maxima in wader numbers.*

and Terek sandpipers since the early 1980s may result from genuine population increases, but could also reflect improvements in identifying these species in large, mixed gatherings of waders. Other species whose numbers were underestimated by Lane (1987) include ruddy turnstone (*Arenaria interpres)*, sanderling (*Calidris alba)* and pied oystercatcher (*Haematopus longirostris*). These three species occur mainly on the southern half of Eighty Mile Beach, which was not covered in the 1981–1986 ground counts on which Lane (1987) based his estimates.

## Arrival patterns (August–November)

We used data from a series of four counts conducted between early August and mid-October 1998 on the northernmost 70 km section of the beach, where wader concentrations were highest, to determine patterns of arrival for each wader species. No counts were undertaken in July and November 1998, but indications of likely wader population sizes at the start and end of the wader-arrival period in 1998 can be obtained from the July 2003 and November 2001 counts (see Fig. 2).

In 1998, waders began arriving in numbers in early August. The main arrival period was mid-August to mid-October, though arrivals continued until mid-November (Fig. 2). Aerial counts conducted during August and September in 1982 and 1986 detected similar rapid rises in wader numbers after mid-August, as did ground counts conducted over a similar period in 1982 (Fig. 3).

In 1998, many individual species showed arrival patterns similar to the overall pattern (Fig. 4). Numbers of the three principal species (great knot, bar-tailed godwit and greater sand plover) increased strongly between August and October. However, their respective peak arrival periods differed considerably. For great knot the main influx occurred in late August and early September, while most bar-tailed godwits only arrived a few weeks later. Greater sand plover numbers only started to increase rapidly after mid-September; this seems somewhat

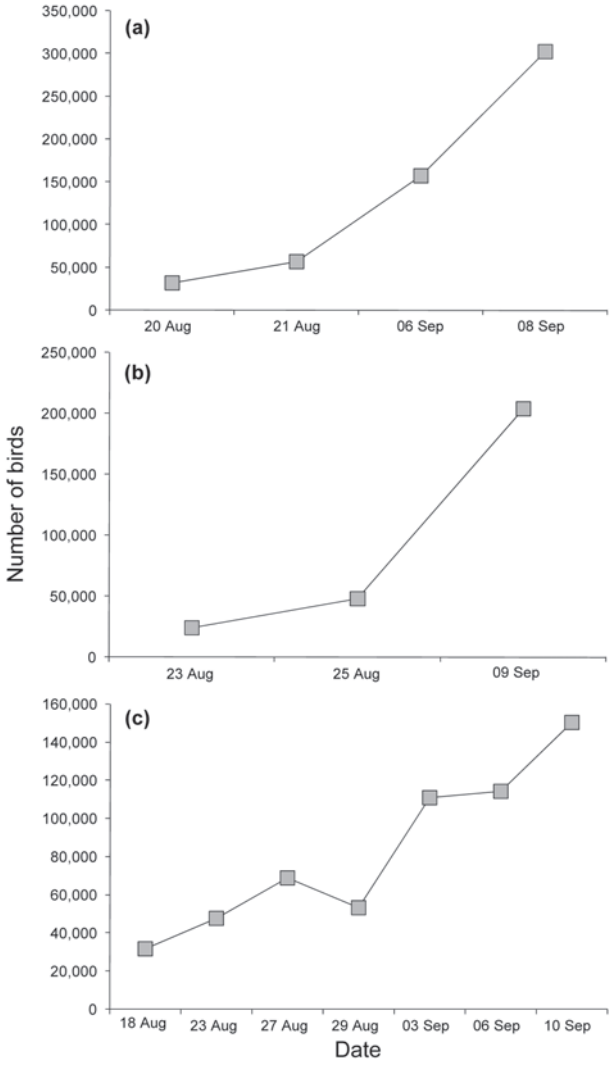


*Figure 3. Series of counts along Eighty Mile Beach from 1982 and 1986 showing an increase in wader numbers during August and September: (a) wader totals from aerial surveys of the full 220 km of beach in 1982; (b) wader totals from ground surveys of the 100 km sector from Cape Missiessy to Mandora in 1982; (c) wader totals from aerial surveys of the 120 km sector from Cape Missiessy to Wallal in 1986.*

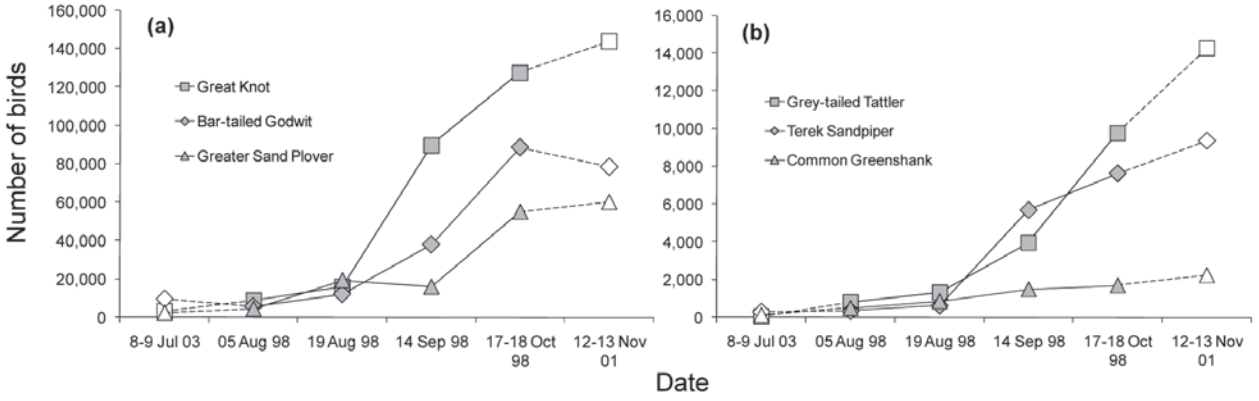


*Figure 4. Data for six species that showed an overall increase in numbers along the 0–70 km section of Eighty Mile Beach during August–October 1998 (closed symbols): (a) great knot, bar-tailed godwit and greater sand plover; and (b) grey-tailed tattler, Terek sandpiper and common greenshank. Corresponding counts from July 2003 and November 2001 (open symbols) are also included.*

anomalous since observations and banding data from other years all indicate an earlier arrival date for the bulk of the greater sand plover population. Numbers of Terek sandpipers and grey-tailed tattlers both built up quickly after mid-August; however, peak arrival times differed, being mid-August to mid-September for the former species and mid-September to mid-October for the latter. Common greenshanks, although much less numerous, showed an almost linear build up in numbers, with an overall average increase of 170 birds per week.

Some larger species showed no increase in numbers over the August to October period (Fig. 5) with eastern curlew (*Numenius madagascariensis*) numbers remaining stable at around 500–600 birds. This species breeds further south than most other waders, enabling it to complete its breeding cycle and undertake southward migration much earlier than species breeding in the Arctic (Minton et al. 2011). Most would already have reached north-west Australia by the time of the first count. Whimbrels arrive mainly in the first half of August, later than eastern curlews, while grey plovers show an initial influx in early August but little change thereafter (Fig. 5). This pattern differs from that at Roebuck Bay, Broome, where the main arrival of grey plovers does not occur until mid-September or later.

For red-necked stints, curlew sandpipers and red knots, the count data suggest a passage through Eighty Mile Beach (Fig. 6). Numbers of all three species peak in mid-September and then decrease in October, suggesting that many birds arriving in August are feeding up during September before proceeding further south. Evidence from banding studies supports this, at least for the first two species, as a number of birds originally banded, leg-flagged or colour-dyed in north-west Australia have either been recaptured or sighted later in the year in southern Australia (unpublished AWSG data). However, as yet there is no independent evidence of major onward movements south by red knots.

For oriental plovers, the main influx to Eighty Mile Beach in 1998 occurred from mid-September to mid-October (Fig. 7). However, observations in other years have shown that the peak arrival period for this species is

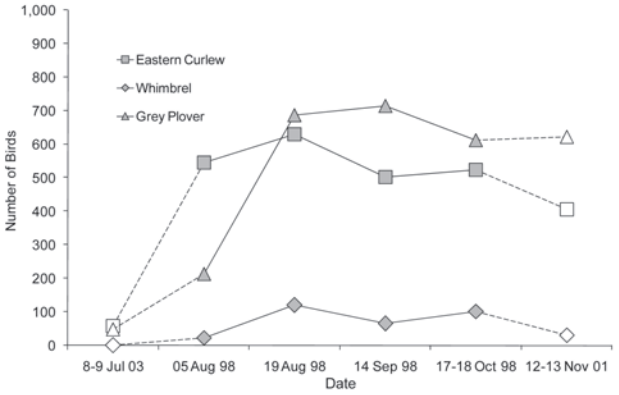


*Figure 5. Data for three species (eastern curlew, whimbrel and grey plover) that showed a limited increase or relatively stable numbers in the 0–70 km sector of Eighty Mile Beach during August–October 1998 (closed symbols); corresponding counts from July 2003 and November 2001 (open symbols) are also included.*

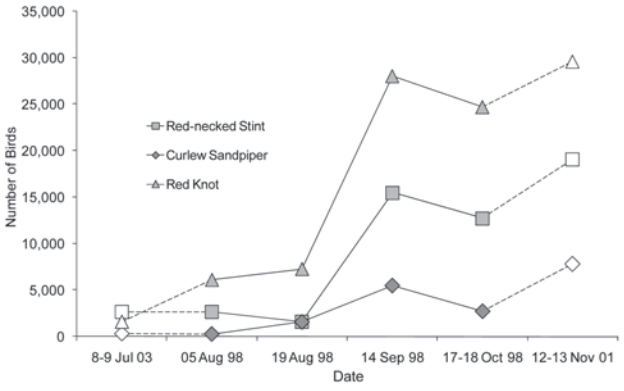


*Figure 6. Data for three species (red-necked stint, curlew sandpiper and red knot) in the 0–70 km sector of Eighty Mile Beach that showed a mid-period peak in numbers during August–October 1998 (closed symbols); corresponding counts from July 2003 and November 2001 (open symbols) are also included.*

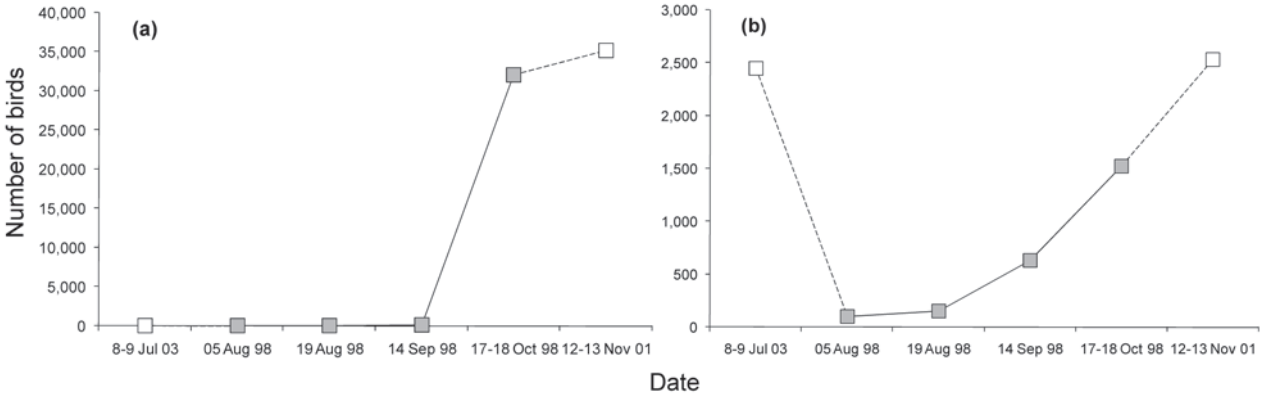


*Figure 7. Changes in the numbers of (a) oriental plover and (b) red-capped plover along the 0–70 km section of Eighty Mile Beach during August–October 1998 (closed symbols); corresponding counts from July 2003 and November 2001 (open symbols) are also included.*

more usually mid–late October to mid-November, considerably later than peak arrival times for most other species. Unlike most other migratory waders that commence moult of their primaries only once they reach Australia (Marchant & Higgins 1993; Higgins & Davies 1996), oriental plovers undergo much of their annual moult at some other location, presumably in Asia, before migrating to Australia. This helps explain their late arrival as well as the fact that juveniles of this species arrive at much the same time as adults.

Some red-capped plovers (*Charadrius ruficapillus*) on Eighty Mile Beach are breeding residents, but most are birds that have moved to the coast once inland breeding locations have dried up. Numbers generally follow a pattern of continuing increase throughout the August to November period as the dry season progresses (Fig. 7). However, in 2003 there was a poor wet season and high numbers were already present on the coast in July (Fig. 7).

## Annual patterns of beach use by waders

Combining the above count data with other observations at Eighty Mile Beach provides a good general understanding of annual patterns of beach use by different wader species. Our observations indicate that the first adult migratory waders (predominantly eastern curlews and greater sand plovers) start to return at the end of July. Adults of most species arrive mainly between the third week in August and the end of September. Adults of species that feed away from the coast arrive later: October is the main arrival period for little curlews and oriental plovers, while oriental pratincoles normally appear in large numbers only in December. Juveniles of most species arrive a month or more after the adults. Although the first juvenile greater sand plovers arrive in late August, juveniles of most species arrive mainly in October, with some only arriving in the first half of November.

Whilst north-west Australia is the migration endpoint for most species, some, such as sanderlings and ruddy turnstones, use this area primarily as a stopover site. Many red-necked stints, curlew sandpipers and sharp-tailed sandpipers arriving in north-west Australia also move on, spending the nonbreeding season in southern Australia. Most oriental plovers and many little curlews move inland once the wet season commences.

Little movement, and hence little change in numbers, occurs between mid-November and mid-March. Eastern curlews commence their northward migration in the second week of March. Massive departures of great knot take place from about 20 March, and many greater sand plovers, together with the first cohorts of red knot, curlew sandpiper and bar-tailed godwit, start to move northwards towards the end of March. The main departures of adult birds occur in the first three weeks of April and most have left by 25 April.

Immature non-breeding birds remain in Australia. For smaller species these are exclusively one-year-old birds but, for most larger species, many two-year old and even some three- and four-year-old birds remain. These immature birds form the bulk of the wader population throughout May to July.

Superimposed on the annual pattern of migratory wader movements are sometimes less predictable weather- or season-related movements of resident wader species. For example, many red-capped plovers move to Eighty Mile Beach when inland areas dry up. Numbers of this species peaked in 1982, a time of national drought, and again in 2001 following the drying up of extensive inland ephemeral wetlands. A more consistent pattern is exhibited by pied oystercatchers that disperse to breeding territories along the southern half of Eighty Mile Beach during June to September, but form flocks at other times.

## Distribution of wader species along the beach during August to November

Wader distributions along Eighty Mile Beach in October 1998 and November 2001 were remarkably consistent and show how non-uniform the spread of waders is along the beach (Fig. 8). From information on intertidal mudflat distributions (Pearson et al. 2005a) it is evident that wader

concentrations are generally highest on sections of beach where the width of mudflat exposed at low tide is greatest: these sections also show the greatest species richness. Reflecting this, the northern 100 km of Eighty Mile Beach typically had 18–22 different species present within each 5-km segment, compared with 13–18 on the southernmost 90 km of beach.

In accord with earlier (and later) observations, the stretch of beach between 25 and 80 km south of Cape Missiessy (the core of the 'Anna Plains' section) held the

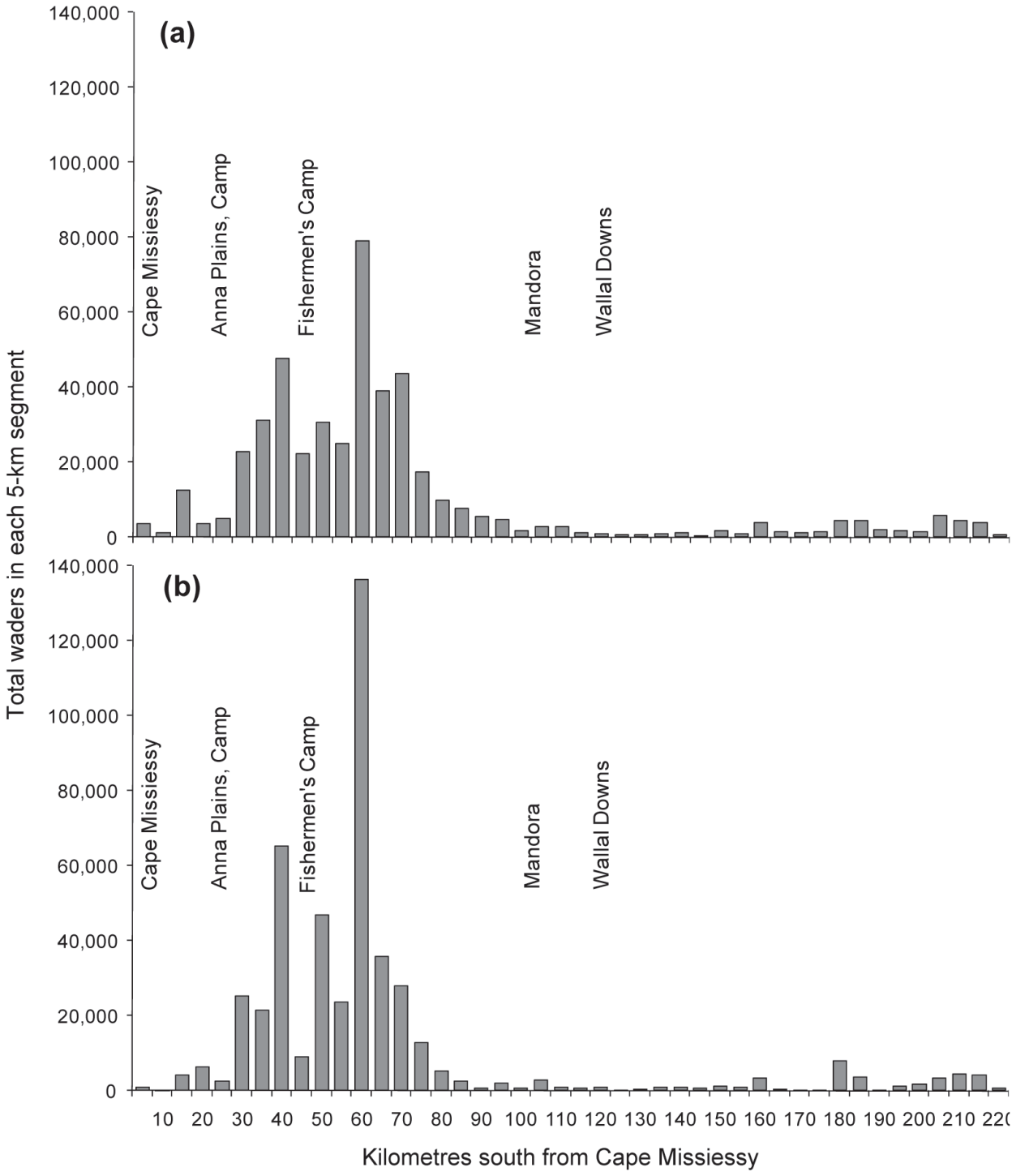


*Figure 8. Distribution of waders (total number of waders in each 5-km segment) along the full 220 km length of Eighty Mile Beach: (a) 17–18 October 1998 (total count = c. 466,000); (b) 12–13 November 2001(total count = c. 472,000). Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy. For clarity, only the unit for every second interval is shown.*

vast majority of birds. The 369,000 waders counted in October 1998 along this 55 km stretch represented 79% of the total beach population; in November 2001 it held 410,000 birds representing 87% of the total. This gives an average density of over 7000 waders per kilometre of beach. In July, the distribution of waders along Eighty Mile Beach was largely similar to that in summer (Fig. 9).

Distributions within the 25 to 80 km section also varied widely, and in both 1998 and 2001 a marked peak occurred in the 55–60 km segment (Fig. 9). Rogers (2005)

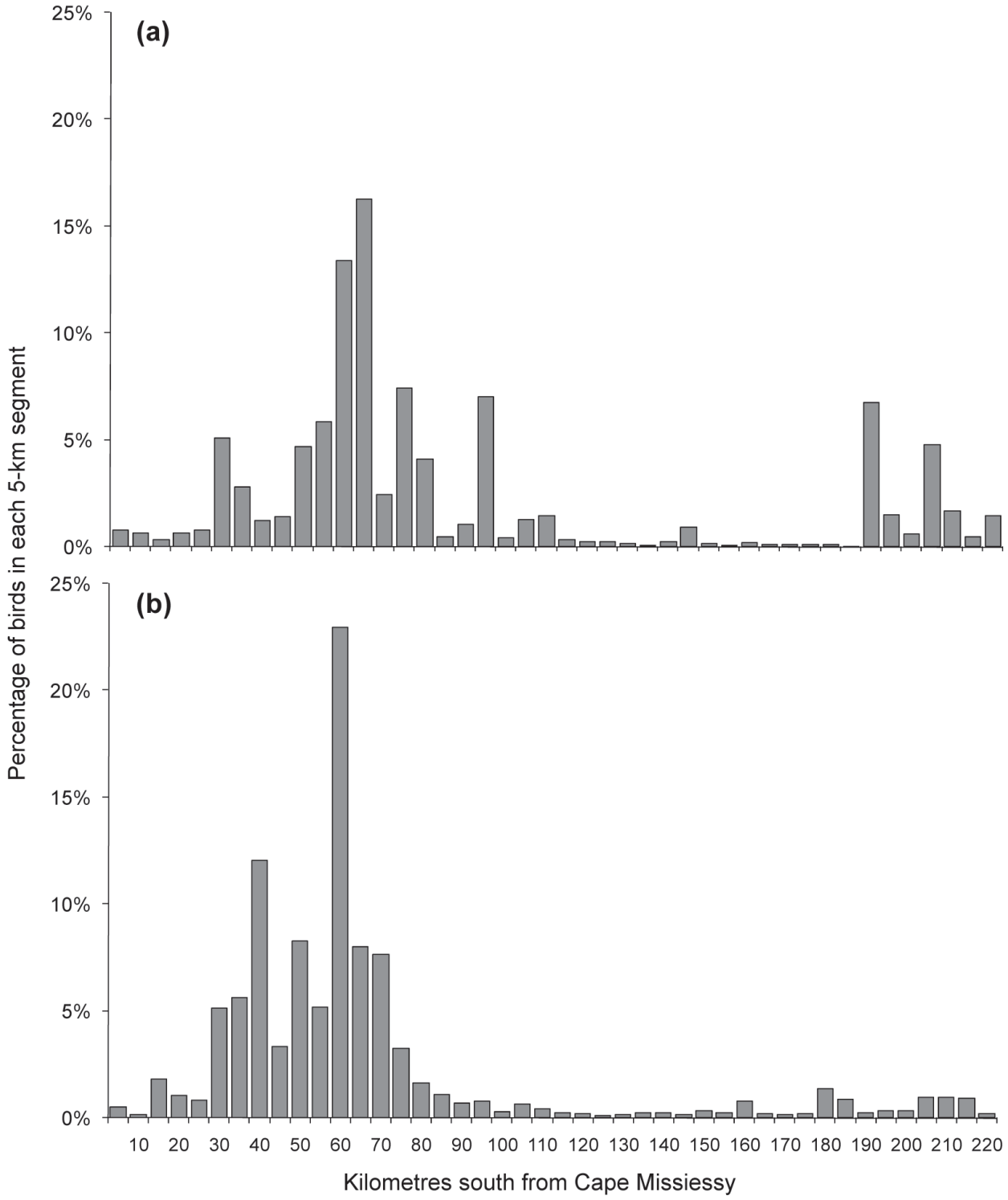


*Figure 9. Percentage of total wader numbers in each 5-km segment along the full 220 km length of Eighty Mile Beach: (a) July 2003; and (b) average of counts in October 1998 and November 2001. Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy. For clarity, only the unit for every second interval is shown.*

found that, except on the highest tides, there is generally a good correlation between the distribution of waders feeding at low tide on the mudflats and their distribution at high tide roosts on the adjacent shoreline. However, some of the waders that feed on tidal flats in the northernmost section (0–25 km) have been observed moving along the beach as the tide advances and end up roosting further south, although the number of birds involved is small. The number of waders roosting along each 5-km segment of beach therefore appears generally representative of the numbers feeding in that segment, which implies that the intertidal zones along the 55–60 km segment are the most heavily used feeding areas along Eighty Mile Beach.

In the 40–45 km segment, wader numbers were anomalously low in both the October 1998 and November 2001 counts (Fig. 8). There was then a regularly used fisherman's campsite in this segment at the 41 km mark, and adjacent beach areas were subject to more sustained human disturbance than any other part of the Anna Plains section of beach. Counts undertaken since the campsite was abandoned in the mid-2000s showed that wader numbers in this segment have risen substantially (unpublished AWSG data), suggesting that even low levels of disturbance are enough to modify wader roosting patterns.

Data from the four counts made in 1998 (Table 1) were used to determine how wader distribution patterns change as numbers build up over the August to October arrival period. Wader distributions along the northernmost 70 to 100 km of Eighty Mile Beach, where the bulk of the wader population is concentrated, indicate that arriving birds distribute themselves along this section of beach as they do when peak numbers are present (Fig. 10). The preference birds have for the 55–60 km segment is evident throughout the arrival period.

Analysis of the count data for August to October 1998 for a number of wader species showed that their preferred locations along the Anna Plains section of beach changed little over the three-month period. Hence, species' distributions recorded in October 1998 and November 2001 can be assumed to reflect reliably their preferred roosting (and feeding; see Rogers 2005) sites. To determine each species' preferred locations, data from the October 1998 and November 2001 counts were combined. Most species show a marked preference for locations along the northern parts of Eighty Mile Beach (Figs. 11–16); however, the specific segments preferred by particular species differed quite markedly. Three species—whimbrel, sanderling and grey plover—were more generally distributed, while two others—pied oystercatcher and ruddy turnstone—were atypical, showing a distinct preference for the southern section of Eighty Mile Beach. Twelve species were present predominantly on the northern section of Eighty Mile Beach (Figs. 11–14):

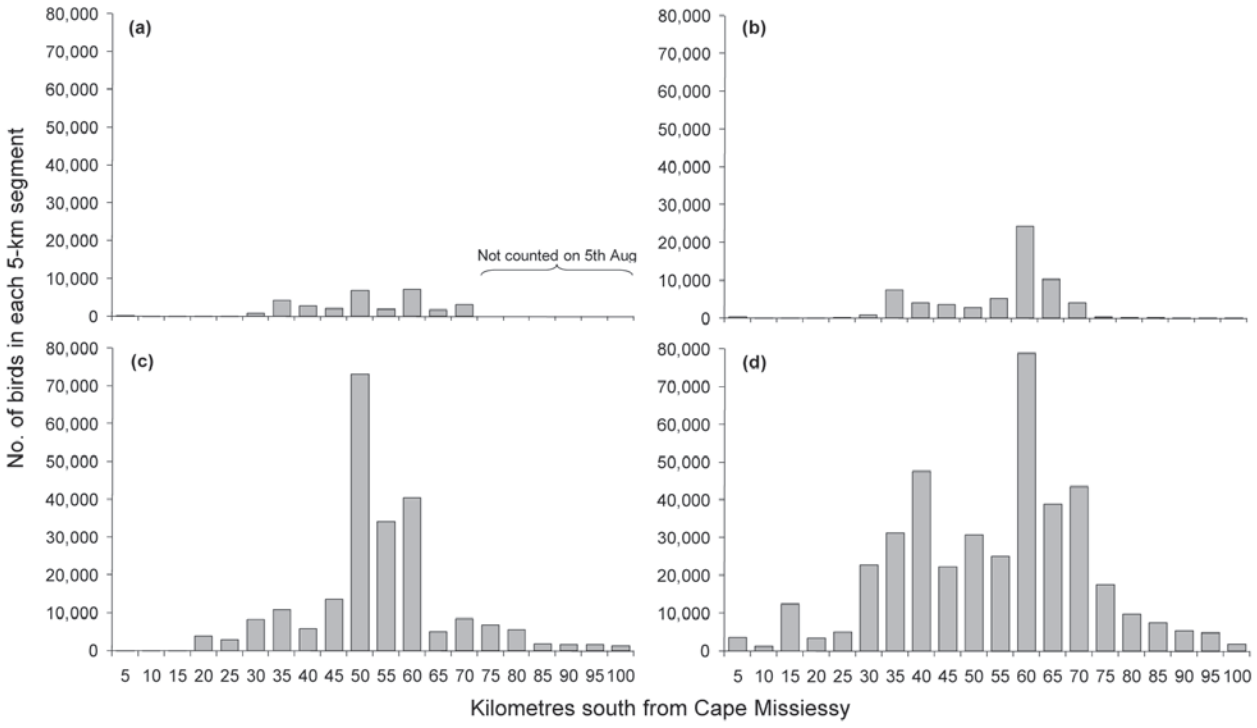


*Figure 10. Distribution of all waders (total number of waders in each 5-km segment) along the 0–100 km section of Eighty Mile Beach during August–October 1998: (a) 5 August (total = c. 31,000); (b) 19 August (total = c. 65,000); (c) 14 September (total = c. 226,000); and (d) 17–18 October (total = c. 415,000). Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy.*

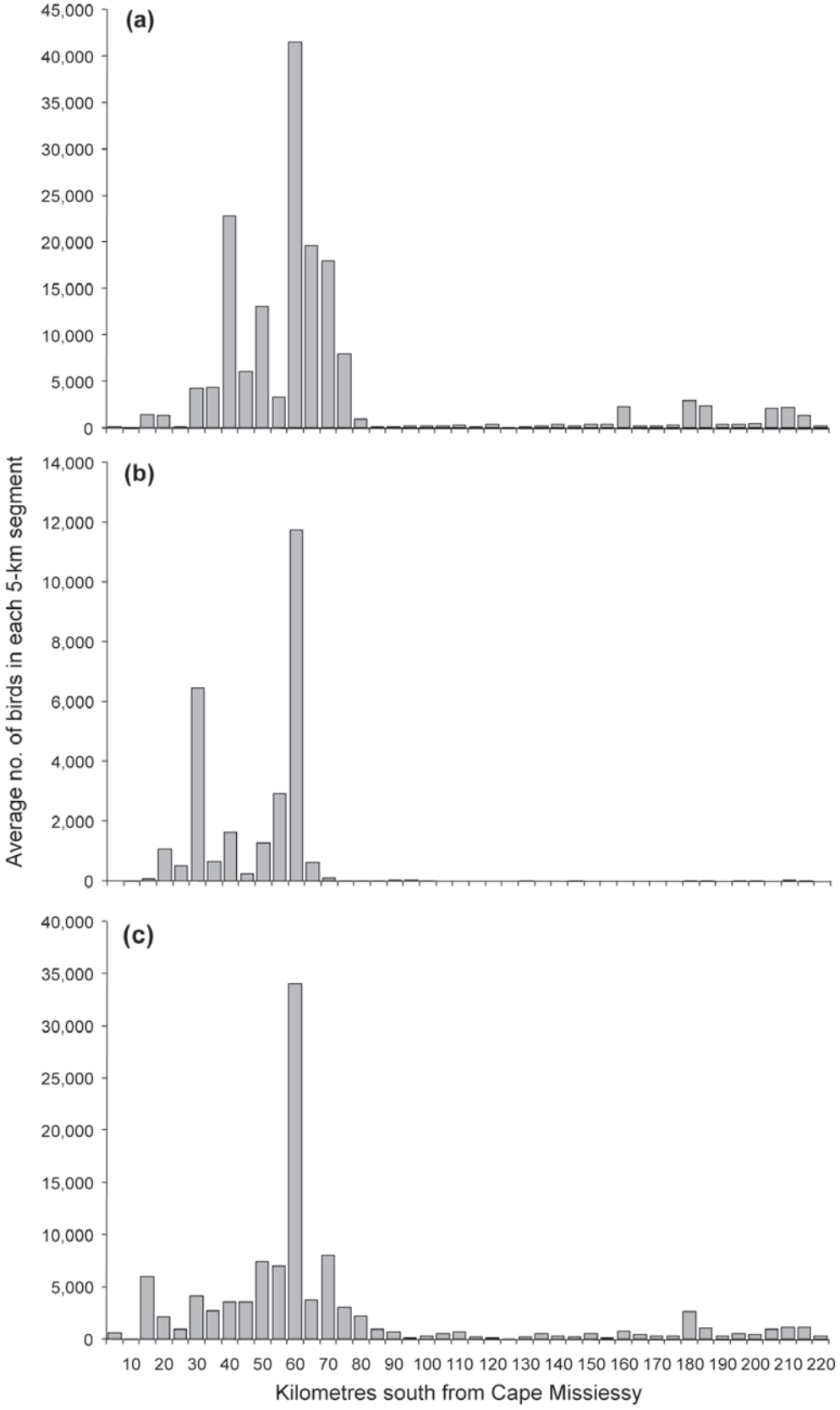


*Figure 11. Distribution of wader species (average number of waders in each 5-km segment) occurring predominantly on the northern sections of Eighty Mile Beach—average of counts in October 1998 and November 2001: (a) great knot; (b)red knot; (c) bar-tailed godwit. Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy. For clarity, only the unit for every second interval is shown.*

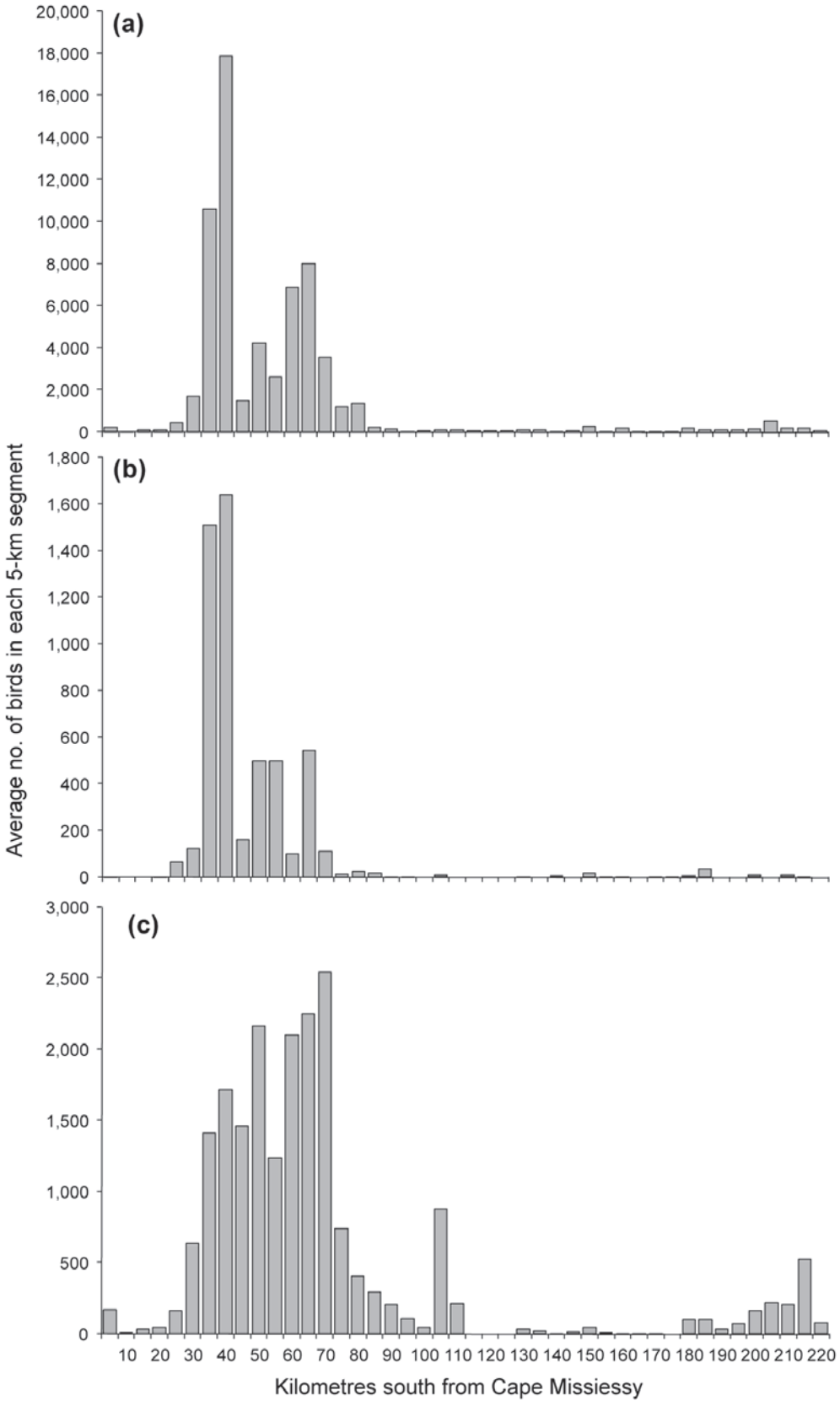


*Figure 12. Distribution of wader species (average number of waders in each 5-km segment) occurring predominantly on the northern sections of Eighty Mile Beach—average of counts in October 1998 and November 2001: (a) greater sand plover; (b)curlew sandpiper; (c) red-necked stint. Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy. For clarity, only the unit for every second interval is shown.*

a) Great knot. This, the most numerous species, was concentrated within the 35–75 km stretch of beach (Fig. 11). The 35–40 km and 55–75 km sections held 67% of the total population, with particularly high numbers in the 55–60 km segment. Several flocks totalling around 3000 birds were present in the 0–20 km section and a further 2000 to 3000 birds were present in sections nearer Cape Keraudren. Though few birds were recorded on the 80–150 km section, great knot were present on every 5-km segment along the entire beach.

b) Red knot. Unlike great knot, this species was confined to certain favoured stretches (Fig. 11), and usually occurred in tight flocks. The 55–60 km segment was again the preferred stretch of beach, with a secondary peak in the 25–30 km segment. The beach south of the 65–70 km segment held virtually no red knot. Distribution patterns in November 2001 and October 1998 were very similar.

c) Bar-tailed godwit. This species was fairly evenly distributed across the 10–90 km section, with typically 3000–6000 birds in each 5-km segment (Fig. 11). The 55–60 km segment was a notable exception, however, holding 21,350 birds in October 1998 and 46,620 in November 2001—this latter figure represented almost half the bar-tailed godwits on the entire beach. This species was present in almost all other segments, generally in small numbers, although over 1000 birds were present in several 5-km segments towards Cape Keraudren in the south.

d) Greater sand plover. Like other common species, these birds occurred mainly on the northernmost 70 km of beach; however, within this section their preferences for specific segments were slightly different (Fig. 12). The main concentration (44% of all birds) occurred in the 30–40 km section, although numbers were still high in the 55–65 km section. Though also present in every segment south of the 70 km mark, many of these held less than a hundred birds.

e) Curlew sandpiper. The overall distribution pattern for this species was most similar to the greater sand plover. Like this species, they favoured the 30–40 km section of beach (Fig. 12) and largely avoided sections of beach south of the 80 km mark.

f) Red-necked stint. This species differs from the previous five species in having a more pronounced bimodal distribution (Fig. 12). Whilst the northern (25–110 km) sections of beach still held the most birds, small flocks totalling just over 1500 birds were present at the southern end of the beach between the 175 km mark and Cape Keraudren. This species' distribution across the 25–110 km section lacked the peaks and troughs evident in the distributions of the previous five, larger, species.

g) Terek sandpiper and grey-tailed tattler. These species had very similar distributions, both being concentrated in the 20–70 km section, and favouring the 35–40 km segment (Fig. 13). Except in November 2001, when 500 tattlers roosted near Cape Missiessy, very few birds of either species were present in the 0–20 km and 100–220 km sections.

h) Common greenshank. This species had a more northerly distribution distinctly different from those of the species discussed above (Fig. 13). Most birds occurred in the 25–40 km section and few in the 55–65 km section favoured by most other species. Except for a small concentration around Wallal (135–155 km), very few birds were present in sections south of the 65 km mark.

i) Eastern curlew. This species favoured a more southerly group of segments in the Anna Plains section than most other waders (Fig. 14). The main flocks occurred in the 45–90 km section; nevertheless some birds were present in each segment north of this. Small numbers were also present on the southernmost 50 km of beach.

j) Red-capped plover. This species occurred along the entire length of Eighty Mile Beach, but was most common in the northern half, with a peak in the 20–30 km section (Fig. 14). This non-uniform distribution was consistent with the fact that few birds were on breeding territories when counts were undertaken.

k) Oriental plover. As already noted, oriental plover typically feed inland, moving to the beach in hot weather. Therefore their distribution along the beaches (Fig. 14) was probably largely determined by conditions immediately inland; for example, the species' prevalence in the 20–95 km section is most probably due to the presence of extensive grasslands on Anna Plains Station, which abuts this section of coast.

Three species had a much more uniform pattern of distribution than the species discussed above (Fig. 15):

a) Whimbrel. Even though this species and the eastern curlew are the two largest waders on Eighty Mile Beach, their distribution patterns were distinctly different. Like many other waders, the latter has a northerly distribution whereas whimbrels were much more uniformly distributed: the only significant peak in concentration occurred close to Cape Missiessy (Fig. 15).

b) Sanderling. Although found right along the beach, this species occurred mainly south of the 70 km mark, with most records from the 85–115 km section and the southernmost 30 km of beach (Fig. 15). As discussed earlier, the substrates in the above areas are much sandier than substrates further north and better suit the sanderling's distinctive feeding technique.

c) Grey plover. This species showed the most uniform distribution, with all segments containing at least a few birds (Fig. 15). The main concentrations were in the north, with peaks in the 25–30 and 55–60 km segments, and towards Cape Keraudren in the south, with a peak in the 200–205 km segment.

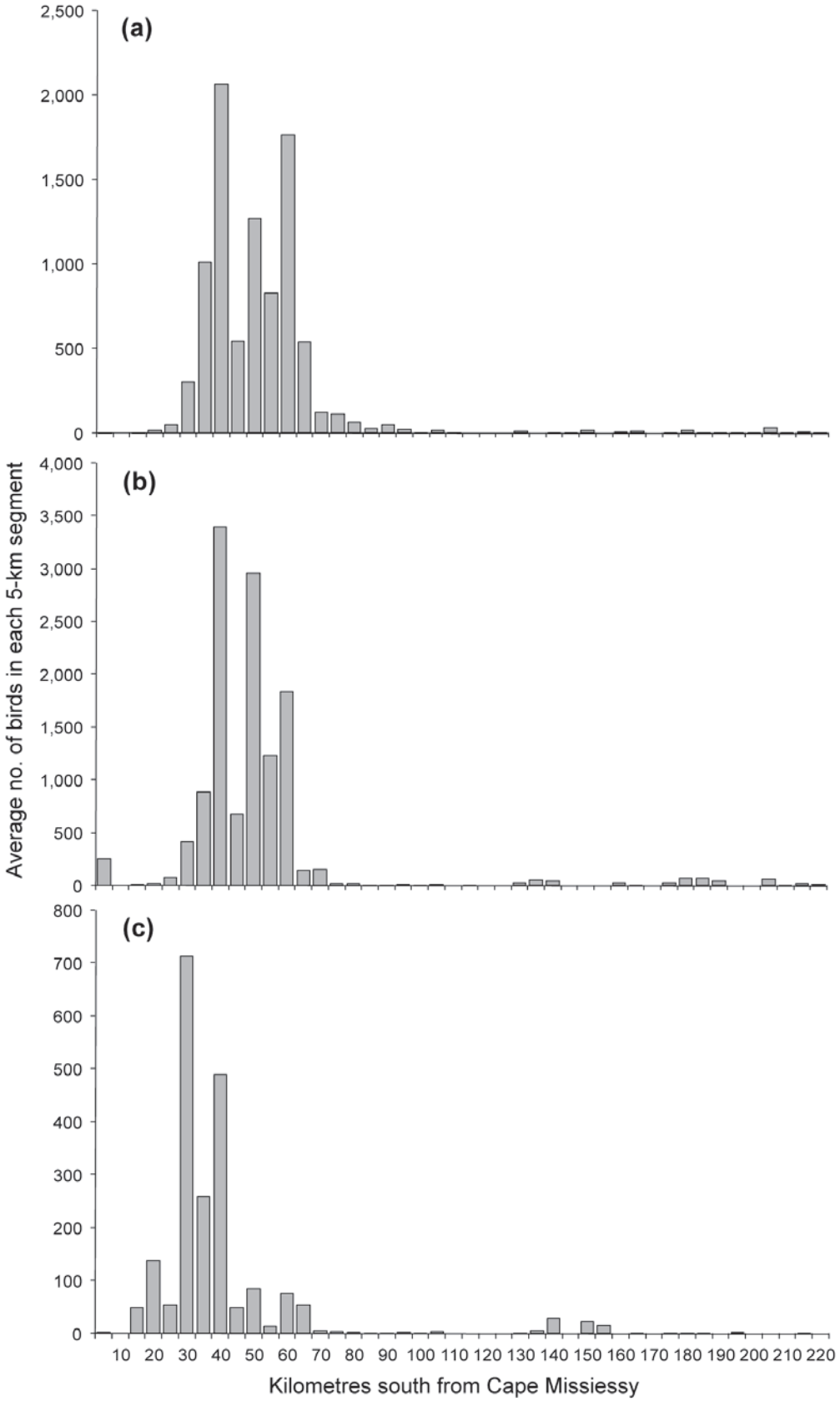


*Figure 13. Distribution of wader species (average number of waders in each 5-km segment) occurring predominantly on the northern sections of Eighty Mile Beach—average of counts in October 1998 and November 2001: (a) Terek sandpiper; (b)grey-tailed tattler; (c) common greenshank. Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy. For clarity, only the unit for every second interval is shown.*

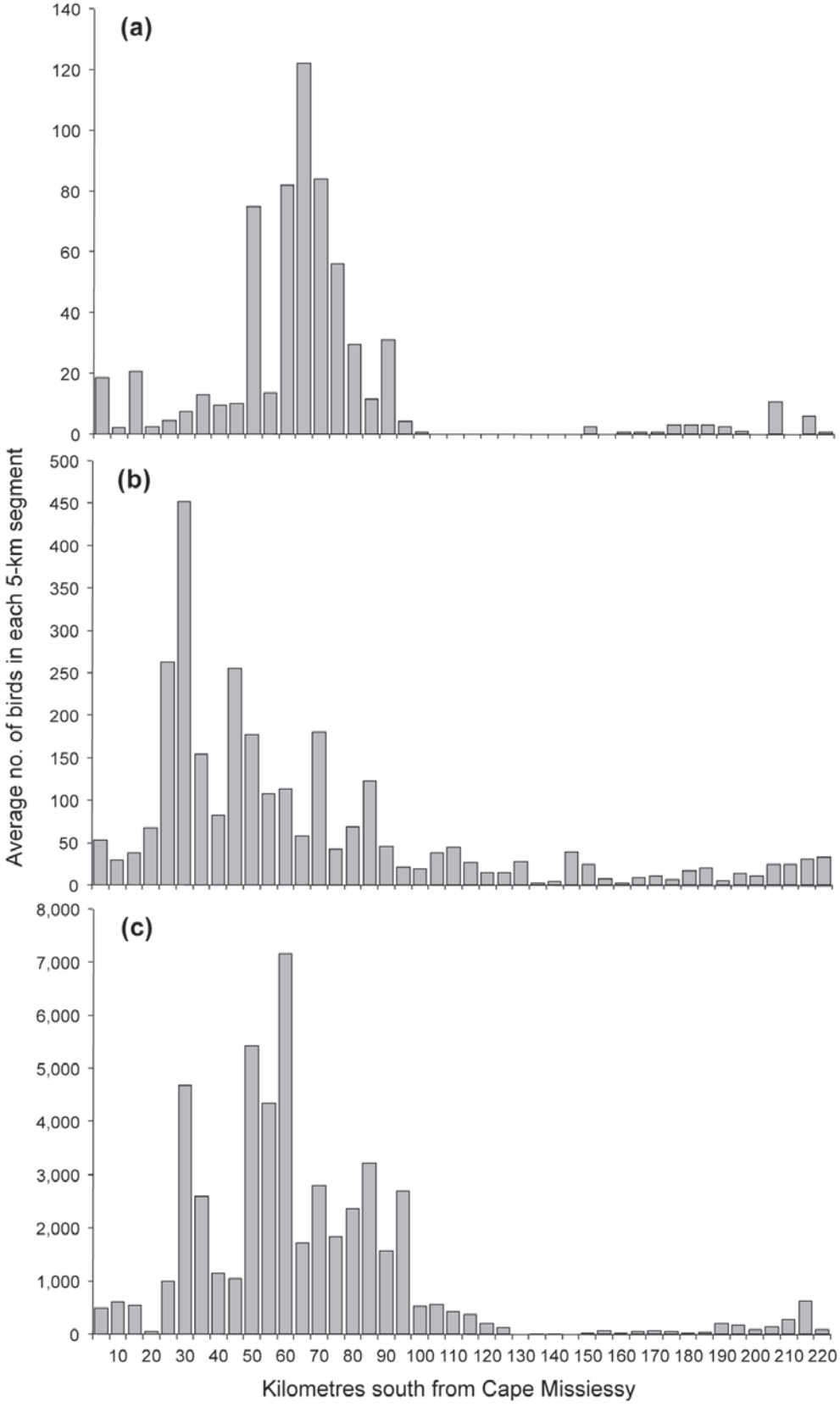


*Figure 14. Distribution of wader species (average number of waders in each 5-km segment) occurring predominantly on the northern sections of Eighty Mile Beach—average of counts in October 1998 and November 2001: (a) eastern curlew; (b)red-capped plover; (c) oriental plover. Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy. For clarity, only the unit for every second interval is shown.*

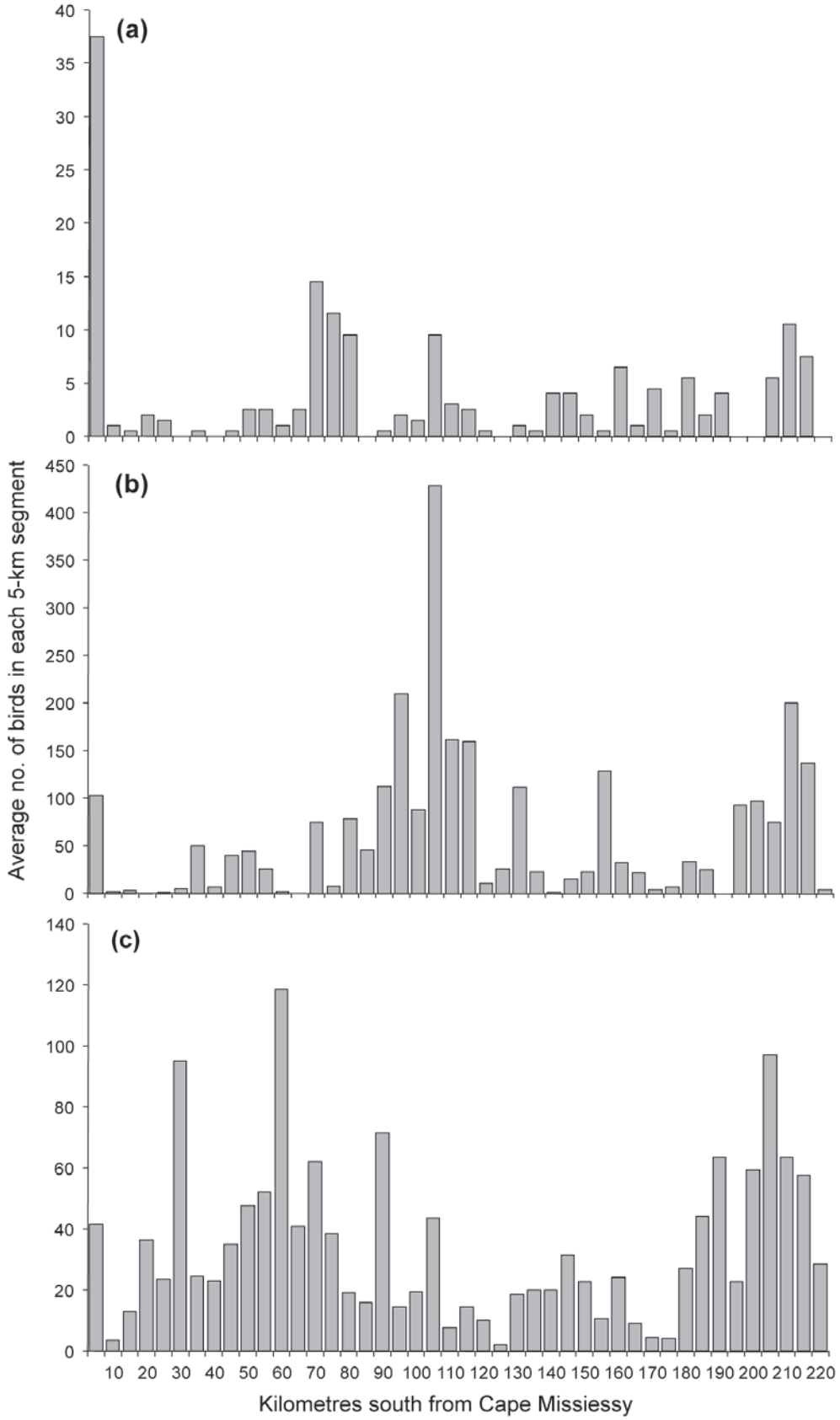


*Figure 15. Species distributed more evenly along Eighty Mile Beach—average number of waders counted in October 1998 and November 2001: (a) whimbrel; (b) sanderling; (c) grey plover. Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy. For clarity, only the unit for every second interval is shown.*

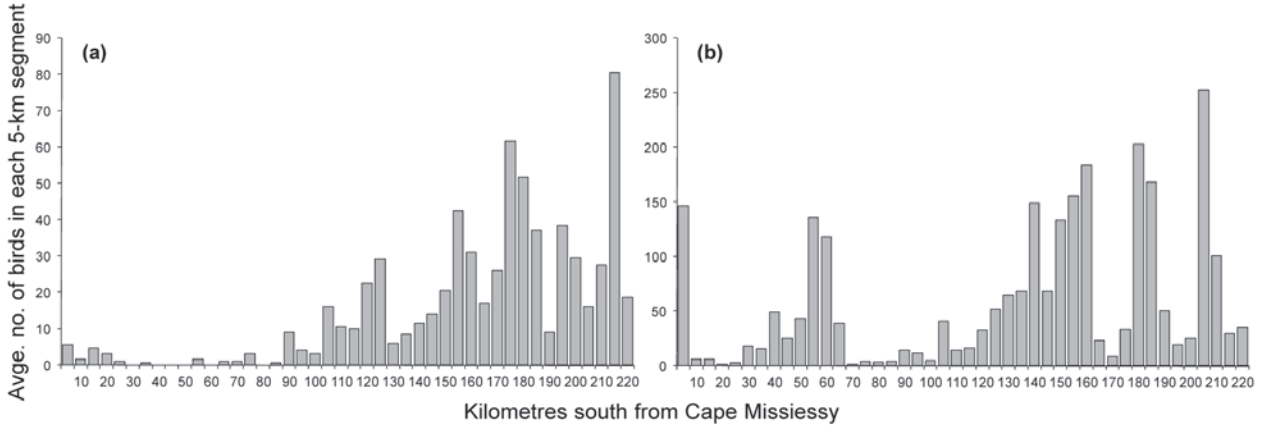


*Figure 16. Distribution of wader species occurring predominantly on the southern sections of Eighty Mile Beach—average numbers of waders counted in October 1998 and November 2001: (a) pied oystercatcher; (b) ruddy turnstone. Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy. For clarity, only the unit for every second interval is shown.*

Two wader species were atypical in that they preferred the more southerly segments of Eighty Mile Beach (Fig. 16):

a) Pied oystercatcher. This species' distribution was the inverse of that for most other species, with most birds occurring in the southern half of the beach (100–220 km). Though most birds were in small flocks, some were still in pairs on breeding territories.

b) Ruddy turnstone. This species was also most numerous along the southern half of Eighty Mile Beach, where there are a number of small rocky outcrops. However, unlike the former species, turnstones were also quite numerous in the 25–65 km section as well as on the rocky outcrop at Cape Missiessy.

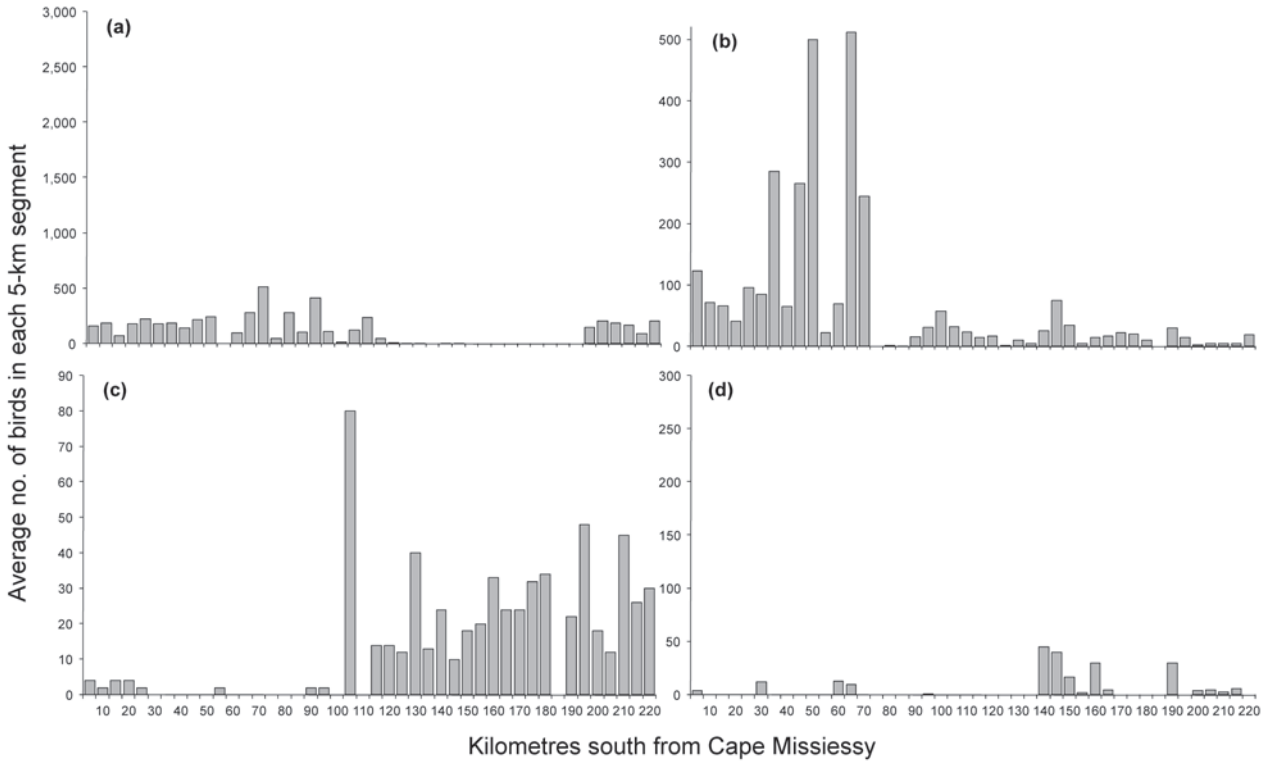


*Figure 17. Distribution of wader species(average number of waders in each 5-km segment) along the full 220 km length of Eighty Mile Beach on 8–9 July 2003: (a) red-necked stint; (b) red-capped plover; (c) pied oystercatcher; (d) ruddy turnstone. Numbers on the x axis represent the upper distance for that segment, e.g. '10' corresponds to data for the segment of Eighty Mile Beach that is 5–10 km from Cape Missiessy. For clarity, only the unit for every second interval is shown.*

## Distribution of wader species along the beach in July

For most waders, distributions along Eighty Mile Beach in July 2003 were similar to those in October 1998 and November 2001, though with a less marked peak in the 25–80 km section. Red-necked stints and red-capped plovers were more evenly distributed along the beach than at other times, while ruddy turnstones and pied oystercatchers showed an even more marked preference for the southern half of the beach (Fig. 17). Notable in July 2003 was the presence of 192 breeding pairs of pied oystercatchers, 181 of which were on the southernmost 110 km of beach. Most were nesting at the top of the wide sandy beaches or on the seaward side of sand dunes fringing the beach. Most birds probably had eggs, or were about to lay, though one newly-hatched chick was seen. This was probably the largest concentration of breeding pied oystercatchers outside Victoria and Tasmania.

# CONSERVATION ISSUES

For most migratory waders spending their nonbreeding season on Eighty Mile Beach, northward migration begins with a lengthy, uninterrupted flight to East Asia. There they replenish their fat reserves before moving on to breeding grounds further north (Barter 2003). Extensive reclamation and development is presently occurring in traditional wader staging areas in East Asia and this is having a seriously detrimental effect on wader populations (Barter 2003; Milton et al. 2003). To minimise the adverse impacts of these developments it is important that birds leave Australia in the best condition possible. This implies that birds should be subject to minimal disturbance at their nonbreeding sites in Australia, particularly during the weeks immediately prior to their departure north. Hence the ecological integrity/quality of feeding areas along Eighty Mile Beach needs to be preserved and disturbance of both feeding and roosting birds minimised.

Threats to the ecology of beaches and mudflats along Eighty Mile Beach have been reviewed by Pearson et al. (2005b). The mudflats are subject to disturbance during cyclones; however, whilst these can cause significant localised changes to the benthos (Honkoop et al. 2006), no long-lasting impacts on the mudflats' suitability as wader feeding grounds have been noted. Of potentially more importance are the direct and indirect impacts associated with fishing and the harvesting of shellfish along the beach, particularly on feeding and, more importantly, roosting waders. Even seemingly minor disturbances, such as the presence of the fisherman's campsite at the 41 km mark during the 1998 and 2001 counts, may have significant effects on the number of birds roosting on the beach. Disturbances that lead to waders roosting further than necessary from preferred feeding grounds are energetically unfavourable and therefore undesirable (Rogers et al. 2006a). However, even more detrimental are disturbances that cause waders to take flight in alarm. At Roebuck Bay, the energy expended by great knots and red knots on commuting to roosts and at roosts is 17–28% of the birds' total energy budget, with energy costs of alarm flights being 3–6 times more important than commuting energy costs (Rogers et al. 2006a). Intensified use of roosting beaches for recreational activities could be expected to increase the frequency of alarm flights, a particularly detrimental outcome when birds are trying to build fat reserves prior to departure northward. At present, fishing-related activities are infrequent on Eighty Mile Beach, and the proposed establishment of an Eighty Mile Beach Marine Park, incorporating the main wader feeding grounds along the northern part of Eighty Mile Beach, should further reduce the adverse effects of the harvesting of marine resources.

Realistically it is impossible to totally exclude people from beaches. At present, access to Eighty Mile Beach occurs primarily at Wallal Downs and near Mandora. As the distributional data show, these areas are of less importance to waders than areas further north. However, pressures to access Eighty Mile Beach at other points will undoubtedly increase. Therefore measures need to be introduced to restrict human access to the northern parts of Eighty Mile Beach, particularly the 25–60 km section, especially later in the season when waders are building up fat reserves. Protection is also desirable for pied oystercatcher breeding areas around Wallal and along the southern half of Eighty Mile Beach.

A potentially disastrous threat to Eighty Mile Beach is oil spills. Oil washing ashore detrimentally affects coastal birdlife, including migratory waders. Waders tend to vacate polluted beaches so few succumb to the heavy oiling that kills many diving birds like auks and cormorants (Bourne et al. 1967; Evans et al. 1993). Nevertheless, the plumage of many species, especially those feeding in the surf zone, is susceptible to oiling (Burger 1997), and at least 25,000 partly-oiled waders were recorded along the Arabian Gulf coast after the 1991 Gulf War (Evans et al. 1993). Oiled waders spend more time preening and less time feeding, which can lead to weight loss and kidney damage (Chapman 1984). In pre-migration periods oiled birds show reduced rates of weight gain (Burger 1997; Evans et al. 1993), a major problem for waders trying to build their fat reserves before departing on lengthy migrations. Oil also has a long term impact on intertidal mudflats and their wader carrying capacity, with full recovery in diversity and abundance of intertidal biota generally taking three to five years (Jones et al. 1998; Price 1998).

The Department of Sustainability, Environment, Water, Population and Communities (2012) recognises that oil releases from offshore oil and gas rigs (such as the 2009 well blowout in the Montara Oilfield off northern Australia) pose a potential threat to all north-west Australian beaches. Oil spills from ships are viewed as less of a threat (Department of Sustainability, Environment, Water, Population and Communities 2012) but do occur: in 1991, 20,000 tonnes of light crude spilled from the *Kirki* when it broke in half 40 km off the West Australian coast (Flood 1992). A detailed oil spill response plan has been prepared by the Department of Transport (2010). However, this contains no specific provisions for dealing

with the impact of oil on the birdlife of Eighty Mile Beach. Since wader distributions vary markedly along this beach, and also seasonally, the nature and severity of oil-related impacts on coastal birdlife will depend on where, when and in what quantities oil arrives on the shore. It is strongly recommended that the response to any oil spill impacting Eighty Mile Beach be tailored to local conditions and take into account that clean-up activities can themselves have a pronounced disruptive effect on wader behaviour (Andres 1997; Burger 1997).

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