

Importance of Lake MacLeod, northwestern Australia, to shorebirds: a review and update

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A number of surveys have been undertaken to determine Lake MacLeod's significance for shorebirds (also called waders). Given the recent global declines in shorebird populations, a current understanding of the significance of Lake MacLeod to shorebirds is timely. We review all survey data in the context of the following criteria: presence of significant national, international and staging populations in the East Asia–Australasian Flyway; species covered by international agreements; and species listed as being of conservation concern in the Action Plan for Australian Birds 2011. Lake MacLeod hosts significant populations of 10 shorebird species. Of these, three species occurred in internationally significant numbers (red knot *Calidris canutus*, red-necked stint *Calidris ruficollis* and curlew sandpiper *Calidris ferruginea*), five species occurred in numbers representing significant proportions of the Australian populations (common greenshank *Tringa nebularia*, black-winged stilt *Himantopus leucocephalus*, banded stilt *Cladorhynchus leucocephalus*, red-necked avocet *Recurvirostra novaehollandiae* and red-capped plover *Charadrius ruficapillus*) and two species (sharp-tailed sandpiper *Calidris acuminata* and greater sand plover *Charadrius leschenaultii*) had populations that met the significant population staging criterion. The most notable of these populations were those of the curlew sandpiper and banded stilt that accounted for up to 31% and 47% of their Flyway and Australian populations, respectively. Lake MacLeod is of great importance to shorebird conservation both in Western Australia and internationally. We recommend that future management strategies focus on maintaining and enhancing shorebird habitats at Lake MacLeod.

KEYWORDS: East Asian–Australasian Flyway, Lake MacLeod, monitoring, shorebirds.

INTRODUCTION

Lake MacLeod is a large salt lake (2200 km²) located between 23°30'S and 24°40'S and 113°30'E and 114°00'E, on the northwestern coast of Australia, north of Carnarvon (Davis *et al.* 2001; Ellison & Simmonds 2003). The northern sections of the lake are fed seawater via a karst system that connects the lake bed to the Indian Ocean and results in 2000 km² of the lake being permanently inundated (Logan 1987; Davis *et al.* 2001; Russel 2004). This results in a unique, permanent, inland saline wetland that is of national and international importance to migrant and resident bird species as a stopover, wintering and drought refuge area (Rio Tinto Minerals 2008; George 2009).

Currently, 37 species of shorebirds have been recorded at the lake (Jaensch & Vervest 1990; George 2009). Of these, many are trans-equatorial migrants that use the East Asian–Australasian Flyway to spend the austral summer (their non-breeding season) in Australia, with the remaining nine species being nomadic residents that move around the continent in response to rainfall (Jaensch & Vervest 1990; Geering *et al.* 2007; George 2009). Lake MacLeod has held more than 1% of the Flyway populations of three migrant species: red knot (*Calidris canutus*), red-necked stint (*Calidris ruficollis*) and curlew sandpiper (*Calidris ferruginea*); and has held more than 1% of the national population of three endemic species: red-necked avocet (*Recurvirostra novaehollandiae*), banded stilt (*Cladorhynchus leucocephalus*) and red-capped

plover (*Charadrius ruficapillus*) (Rio Tinto Minerals 2008; George 2009). In 2003, it was determined that, at a single point in time, up to 16% of the Flyway population of the curlew sandpiper and up to 26% of the world population of the banded stilt may be present at Lake MacLeod (Rio Tinto Minerals 2008). Consequently, Lake MacLeod is included in *A Directory of Important Wetlands in Australia* (Environment Australia 2001) and is eligible for listing as a Wetland of International Importance under the Ramsar Convention on Wetlands (Rio Tinto Minerals 2008; George 2009).

Globally, 52% of shorebird populations are declining, while only 8% are increasing (Delany & Scott 2006). Reclamation projects at stop-over sites such as Bohai Bay in China and Saemangeum in South Korea pose significant threats to shorebirds as they restrict feeding habitat available to the birds during this critical period and can cause significant population declines (Moore 2006; Rogers *et al.* 2006, 2010; Pain *et al.* 2011; Yang *et al.* 2011). In Australia, development, agricultural pressures on water-tables and human disturbance have contributed to population declines and at some local sites, monitoring has detected decreases of those populations by up to 99% for species such as the red-necked stint and curlew sandpiper (Gosbell & Clemens 2006; Nebel *et al.* 2008; Wainwright & Christie 2008; Creed & Bailey 2009; Singor 2009).

As a result of these threats, 16 species of shorebird are listed as threatened in Australia in the *Action Plan for Australian Birds* (Garnett *et al.* 2010). International agreements between the government of Australia and those of the People's Republic of China (CAMBA), Japan

(JAMBA) and, most recently, the Republic of Korea (ROKAMBA) have been signed for the protection of migratory birds (JAMBA 1974; CAMBA 1986; ROKAMBA 2006). These listings and agreements bind the Federal Government (and thereby other levels of government in Australia) to the conservation of shorebirds and their habitats and encourage scientific research at the national and international level.

The broad objective of this paper is to evaluate the importance of Lake MacLeod to shorebirds. Specifically, we aim to: (i) identify instances where the lake supports more than 1% of the global or national populations of a species; (ii) determine if the lake is an important stopover site for a species (i.e. counts of 0.25% or more of the flyway population); (iii) evaluate the importance of the lake for listed declining shorebird species; and (iv) establish the significance of the lake for those species protected under international conventions.

METHODS

Data collection and interrogation

We were interested in all bird count data from Lake MacLeod. The methodology for our data collection was adapted from Horwitz *et al.* (2010). Online database engines such as Google Scholar™, ISI Web of Knowledge™, BioOne™ and others, were used for a desktop literature search. The key words used were 'Lake MacLeod' and 'Carnarvon Basin' in conjunction with the following secondary key words: Fauna Survey of, Avian Survey of, Fauna Report of, Avian Report of, Birdwatching Event of, Shorebirds of, Waders of, Rio Tinto, Dampier Salt and others. Organisations included in the search were Dampier Salt Ltd, Western Australian Department of Environment and Conservation, Commonwealth Department of Environment, Water, Heritage and the Arts (now DSEWPac), Commonwealth

Department of Agriculture Fisheries and Forestry, CSIRO, Museum of Western Australia, Birds Australia (now Birdlife Australia), Shorebirds 2020 and BirdLife International. The domestic databases and publications of some of these organizations were also searched with the same keywords. Where appropriate, interviews with key personnel were sought.

All relevant records received were stored in Excel™ files. Data manipulation was focused on summarising total species counts in relation to survey periods, and assessing counts against the various criteria (e.g. 1% criterion) as previously outlined.

Evaluating Lake MacLeod's significance for shorebirds

From the database search, 15 reports and journal publications were discovered that contained information on the shorebirds of Lake MacLeod (Appendix 1). Only 12 of these can be described as surveys, or contained enough information to be used for the purposes of this study. These surveys also identified areas within the lake that were of the most importance to shorebirds (Table 1).

The Shorebirds 2020 database included 18 counts from Lake MacLeod. Of these, 11 represent the counts from the above surveys whilst the remaining seven only cover part of the lake and due to uncertainty as to methods and coverage, were excluded from this study.

Shorebird counts for Lake MacLeod were consequently available from the following surveys: Jaensch & Vervest (1990), Davis *et al.* (2001), Davis (2002, 2003a, 2003b, 2004) and Hassell (2004, 2005, 2006). For more information see Appendix 1. All counts from all surveys are available in George (2009).

East Asian–Australasian Flyway population estimates of trans-equatorial migrant species were acquired from Bamford *et al.* (2008). Australian population estimates for migrant species (that is the number of individuals of a migrant species visiting Australia) and for species

Table 1 Areas of importance to shorebirds in Lake MacLeod.

Site	Coordinates	Habitat	Important for:	Use
1. Jack's Vent (and surrounding channels and vents)	23°57'40"S 113°38'25"E	Mangrove-lined channels between the vents and open-water areas	Bar-tailed godwit, great knot, common greenshank, black-winged stilt, banded stilt	Feeding
2. 'Roost Site'	23°55'40"S 113°38'10"E	Dry samphire cover	Various shorebird species	Roosting
3, 4. Godwit Beach to Linda's Creek	23°57'07"S 113°38'48"E	Extensive shallow mudflats, stands of stunted dead mangroves	Red-necked stint, curlew sandpiper, other trans-equatorial migrant shorebird species.	Feeding
5. Stilt Lagoon	23°58'20"S 113°38'34"E	Shallow expanse of water	Red-necked avocet, banded stilt	Feeding
6. Oystercatcher Flat	23°58'43"S 113°38'24"E	Large mud-bank barrier, no mangrove background	Banded stilt, red-necked avocet	Feeding
7. Stilt Flat	23°58'59"S 113°38'24"E	Inundated mud flat	Banded stilt, black-winged stilt, other trans-equatorial migrant shorebird species.	Feeding
8. Dogleg Channel	23°59'36"S 113°36'47"E	Shallow mud channel	Red-necked stint, curlew sandpiper, sharp-tailed sandpiper, other trans-equatorial migrant shorebird species.	Feeding
9. Phalarope Flat	24°00'27"S 113°37'57"E	Shallow water over sandy mudflats	Red-necked stint, curlew sandpiper, banded stilt	Feeding, roosting.

Adapted from Davis *et al.* 2001; Davis 2002, 2003a, 2004; Hassell 2004, 2005, 2006.

endemic to or resident in Australia were acquired from Geering *et al.* (2007).

To determine the importance of Lake MacLeod to shorebirds, five criteria were used.

1. To examine if a locality was internationally significant, Criterion Six of the Ramsar Convention was used. This criterion states: 'a wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or sub-species of water bird' (Ramsar Convention Bureau 2000). A site is determined to 'regularly support' 1% of a population if the 1% threshold is achieved in two out of three seasons, or is met by the mean of at least five maximum annual counts (Ramsar Convention Bureau 2000).

2. To determine if a locality is important during migration as a stopover site, the guidelines present in the Ramsar convention were used. These state that a locality is significant as a stopover site if counts are equal to, or greater than 0.25% of the flyway population, at least once (Ramsar Convention Bureau 2000). Non-migratory species were not assessed under this criterion.

3. To investigate if Lake MacLeod is significant on an Australian-only level, the two criteria proposed in Watkins (1993) were examined. These criteria signify that a site is of national importance for shorebirds if at least 1% of the Australian population or 10 000 or more individuals have at any one time been recorded at the site (Watkins 1993). Furthermore under this plan, any counts that are internationally important are automatically considered to be of national importance (Watkins 1993).

4. To examine if Lake MacLeod was a significant locality for shorebirds under threat of extinction, the conservation status (IUCN rankings) of the shorebird species occurring at Lake MacLeod was acquired from Garnett *et al.* (2010) which has the following rankings: Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CE), Extinct in the Wild (EW) and Extinct (EX).

5. Lastly it was checked to see if these species were also covered by the three international agreements (CAMBA, JAMBA and ROKAMBA). Although this was also done for the *Lake MacLeod Management Plan* (Rio Tinto Minerals 2008), it was discovered that this plan did not list all the species present in these agreements and thus a repeat of the procedure was deemed necessary. Since the three agreements largely cover all migrant shorebird species occurring at Lake MacLeod (JAMBA 1974; CAMBA 1986; ROKAMBA 2006), they can be considered collectively for this criterion.

The above analysis was undertaken for all 37 species of shorebird recorded at the lake. For species meeting the 1% criterion either globally or for Australia, the average number of birds was calculated as well. This was done to determine if the site holds significant numbers of these species on average. The number of times that surveys met the 1% criterion was also noted, to determine how frequently the lake holds significant numbers of the particular species. Finally maximum counts for these species were used to specify the maximum percentage of the population, Flyway and Australian, using Lake MacLeod.

RESULTS

Lake MacLeod's significance to shorebirds

Using the Ramsar criteria (Ramsar Convention Bureau 2000) and Watkins (1993), 10 shorebird species were found to have significant counts at Lake MacLeod. Internationally, the lake holds significant numbers of red knot, red-necked stint and curlew sandpiper (Appendix 2). Nationally, the counts for these three species are also significant. The area also holds nationally important populations of an additional five species: common greenshank, black-winged stilt (*Himantopus leucocephalus*), banded stilt, red-necked avocet and red-capped plover (Table 2).

For migrant taxa, the 0.25 % staging criterion was reached for six species: the common greenshank, red knot, red-necked stint, sharp-tailed sandpiper (*Calidris acuminata*), curlew sandpiper and greater sand plover (*Ch. leschenaultii*) (Table 2).

The average numbers of these species present on the lake, the frequency with which these numbers meet the various criteria and the percentages of the East Asian-Australasian Flyway populations (Bamford *et al.* 2008) that these numbers represent are shown in Table 2. Detailed counts for all 37 species are in Appendix 2.

Lake MacLeod hosts 12 species that are listed in the Near Threatened or more severe categories (Appendix 2). Of these, the Asian dowitcher (*Limnodromus semipalmatus*), ruddy turnstone (*Arenaria interpres*), grey-tailed tattler (*Heteroscelus brevipes*) and black-tailed godwit (*Limosa limosa*) are listed as Near Threatened, the great knot (*C. tenuirostris*), red knot, curlew sandpiper, eastern curlew (*Numenius madagascariensis*), bar-tailed godwit (*L. lapponica*), greater sand plover and grey plover (*Pluvialis squatarola*) as Vulnerable and the lesser sand plover (*Ch. mongolus*) as Endangered. All 28 migratory species occurring on the lake are protected under the three international agreements (Appendix 2).

DISCUSSION

Apart from George (2009), this is the first study to use all the survey data collected from Lake MacLeod to examine the lake's importance both on a national level and as a staging area during shorebird migration. Consequently, we were also able to provide an update on the lake's international importance, against the latest East Asia-Australasian Flyway population estimates (Bamford *et al.* 2008).

Ten species of shorebird were found to have significant numbers at Lake MacLeod. Of these, eight have had international and nationally significant numbers, while for the other two species, the area may be important as a staging area.

International and national significance for shorebirds

The internationally significant numbers of red knot, red-necked stint and curlew sandpiper have been previously highlighted (Hassell 2006; Rio Tinto Minerals 2008; George 2009). The counts for these species are also nationally significant. Lake MacLeod also held 1% of the Australian populations of an additional five species:

Table 2 Shorebird species for which Lake MacLeod holds significant numbers.

Species	1%F/W ^a	1%Aust. ^a	0.25% ^b	Average ^c	%F/W ^c	%Aust. ^c	Max ^d	%F/W ^d	%Aust. ^d
Common greenshank	0	2	2	128	0.21	0.67	300	0.5	1.58
Red knot	1	1	3	452	0.21	0.34	2566	1.17	1.90
Red-necked stint	8	8	9	5418	1.67	2.01	25000	7.69	9.26
Sharp-tailed sandpiper	0	0	2	155	0.10	0.11	850	0.53	0.61
Curlew Sandpiper	9	9	10	21216	11.79	17.98	55000	30.56	46.61
Black-winged stilt	N/A	1	N/A	645	N/A	0.22	3008	N/A	1.00
Banded stilt	N/A	9	N/A	19691	N/A	9.56	100000	N/A	46.61
Red-necked avocet	N/A	3	N/A	700	N/A	0.65	2401	N/A	3.30
Red-capped plover	N/A	3	N/A	830	N/A	0.87	3125	N/A	3.30
Greater sand plover	0	0	1	61	0.05	0.08	515	0.46	0.69

^a The 1% F/W and 1% Aust. represent the number of surveys (out of 12 total) for which Lake MacLeod was found to hold at least 1% of the East Asia-Australasian Flyway (EAAF) and Australian populations of these species in accordance with the Ramsar (Ramsar Convention Bureau 2000) and A National Plan for Shorebird Conservation in Australia (Watkins 1993) criteria.

^b For migrant taxa, the 0.25% column represents the number of surveys for which the 0.25% staging criterion was met (Ramsar Convention Bureau 2000).

^c The average number of individuals recorded from the surveys together with the percentages these represent of the flyway and Australian populations.

^d The 'Max' column lists the highest counts of these species recorded at the lake and the proportions of the flyway and Australian populations these represent.

N/A (Not Applicable) entries are for species that are resident and/or endemic to Australia and thus do not use stopover sites or the flyway. EAAF population estimates adapted from Bamford *et al.* 2008, Australian population estimates adapted from Geering *et al.* 2007.

common greenshank, black-winged stilt, banded stilt, red-necked avocet and red-capped plover. The site's national significance for the last three species is already known (Hassell 2006; Rio Tinto Minerals 2008; George 2009), however, it is the first time that it has been realised for the common greenshank and black-winged stilt.

Of these eight species occurring at Lake MacLeod at nationally and internationally significant levels, only three (red-necked stint, curlew sandpiper and banded stilt) have had significant counts in most of the surveys, and the proportions of the populations that occur are also high. For the curlew sandpiper and banded stilt, the maximum proportions of the East Asian-Australasian Flyway and Australian populations recorded in the area are double those presented in the *Lake MacLeod Management Plan* (Rio Tinto Minerals 2008); 16% then versus 31% now of the flyway population for the curlew sandpiper and 26% versus 47% for the endemic banded stilt. The high frequency with which these large numbers occur at Lake MacLeod suggests that for the curlew sandpiper the area may be a non-breeding site of major importance. Likewise for the non-migratory banded stilt, the area appears to be an important drought refuge area. The species has not been recorded breeding in the area and departs when suitable conditions present themselves elsewhere (Hassell 2006).

For the other five species, the number of significant counts and the populations using Lake MacLeod, are much lower. These suggest that for these species the lake is of lesser significance or that significant counts are unusual events, for example, when regional weather conditions make the lake attractive to these species. Conversely, regional weather conditions may result in Lake MacLeod being the only water source present away from the coast (due to its karst link and permanent

inundation), meaning that high counts may coincide with conditions where other inland wetlands are dry.

Staging area, species threat status and coverage by international treaties

As a staging area, Lake MacLeod may be important for six migrant shorebird species as some counts for these species equaled or exceeded the 0.25% of their estimated Flyway populations. These are the common greenshank, red knot, red-necked stint, sharp-tailed sandpiper, curlew sandpiper and greater sand plover. This is also supported by observations during the start of the northbound migration of fat birds (curlew sandpipers and red-necked stints) in partial or complete breeding plumage at Lake MacLeod (Davis 2003a). However, this is complicated by the fact that Australia is a non-breeding season destination making it difficult to distinguish between non-breeding and stop-over birds (Geering *et al.* 2007; Bamford *et al.* 2008). In order to fully understand the use of the lake as a staging area one would have to calculate the 'turnover rate' of birds that are in transit using the lake (Colwell 2010). This would be best achieved by colour-marking or radio-tagging individuals (Iverson *et al.* 1996; Warnock and Bishop 1998; Battley & Rogers 2007; Colwell 2010).

All 28 migratory species occurring at Lake MacLeod are protected by international treaties (JAMBA 1974; CAMBA 1986; ROKAMBA 2006) (Appendix 2). This includes the 12 species at risk of extinction that occur in the area (Appendix 2) (Garnett *et al.* 2010). However, only the red knot, curlew sandpiper and greater sand plover have been recorded as having internationally significant populations there and, of these three, only the curlew sandpiper has occurred in significant numbers for the majority of the surveys. Based on this and the large

numbers using the site, Lake MacLeod is considered to be of vital conservation importance to at least the curlew sandpiper.

Lake MacLeod's importance for shorebirds compared with other sites in Australia

Unlike wetland areas in the southeast and southwest of the continent where some shorebird populations have declined, the numbers of shorebirds at Lake MacLeod appear to have remained high. This is especially true for the curlew sandpiper where the number of birds utilising sites in Victoria, for example, has declined by 80% from 30 000 birds in the early 1980s to about 5000 between 2004 and 2006 (Gosbell & Clemens 2006). The species has a negative trend of 3% per year and similar declines have been observed in bar-tailed godwit, red-necked stint, sharp-tailed sandpiper and the Australian populations of other species in Victoria (Gosbell & Clemens 2006; Nebel et al. 2008; Wainwright & Christie 2008; Creed & Bailey 2009; Singor 2009; Garnett et al. 2010; Wilson et al. 2011). In addition to habitat destruction along the Flyway, these declines are also caused by local habitat loss and human disturbance (Gosbell & Clemens 2006; Nebel et al. 2008; Wainwright & Christie 2008; Creed & Bailey 2009; Singor 2009). Thus, the isolated and disturbance-free nature of Lake MacLeod may contribute to its importance for these species (Hassell 2006). However, ensuring that Lake MacLeod's ecosystems remain well-managed will, on its own, not stem ongoing shorebird declines if the threats outside Australia are not addressed.

Important areas within the lake

Survey work has identified nine sites of particular importance to shorebirds within Lake MacLeod (Table 1) (Hassell 2006). Large numbers of shorebirds congregate in these areas and it is for this reason that these have been used as the focal points for bird counts (Hassell 2006). However, no work performed in the area to date has investigated why these areas are so attractive to shorebirds. A number of abiotic and biotic factors can make an area attractive to shorebirds (Colwell 2010) and an investigation of these is planned in an Edith Cowan University and Dampier Salt Ltd research partnership scheduled for 2012–2014.

CONCLUSIONS

Survey work has recognised Lake MacLeod's importance to shorebirds, particularly for red-necked stint, curlew sandpiper and banded stilt. Numbers of these species at this site have remained high, despite ongoing habitat loss and degradation in southern Australia and at the Yellow Sea staging areas. Ensuring that the shorebird habitats of Lake MacLeod are managed appropriately into the future has national and international importance for shorebirds.

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Appendix 1 Survey effort and methodology at Lake MacLeod.

Title	Author(s) and year	Available in public literature?	Survey dates	Duration in days	No. of participants	Aerial survey?	No. of areas visited	Notes
The birds of Lake MacLeod, upper west coast, Western Australia.	Smith L A Johnstone R E 1985	Yes	13-14/5/1977 17-18/10/1980 10-11/11/1981	2 (all)	2 and 1	No	2 areas referred to as North and South Cygnet Marsh	Precise numbers not given. Surveys did not cover entirety of the lake and report also includes reports from Dampier Salt-works.
Waterbirds at remote wetlands in Western Australia, 1986-8 Part 2: Lake MacLeod, Shark Bay, Camballin Floodplain and Parry Floodplain.	Jaensch R P Vervest M R 1990	Yes	28/9/1987 to 3/10/1987	5	15	Yes (2)	All of lake surveyed. Aerial survey estimates similar to ground based ones. Large portion of Southern basin not visited	Flocks dense and flighty. May have missed some birds. Estimated count errors at 5-10% for curlew sandpipers and banded stilts.
Aquatic invertebrates and waterbirds of wetlands and rivers of the southern Camarvon Basin, Western Australia.	Halse S A Shiel R J Storey A W Edward D H D Cale D J Harvey M S 2000	Yes	Winter and summer during 1994-1995	Duration of visits not specified	Not specified, but likely to be equal to the no. of authors: 6	Yes, on 12/10/1994	4	Areas visited either visited twice or once. Count entries are a summation of all visits. Invertebrate samples also collected during these. Aerial survey happened solely for the estimation of bird numbers, but large numbers not identified to species level.
Birds of the southern Camarvon Basin, Western Australia: distribution, status and historical changes.	Johnstone R E Burbidge A H Stone P 2000	Yes	N/A	N/A	N/A	N/A	N/A	Not a survey, but a status report on bird distributions and abundances between the years 1970-1996 and more modern ones.
Wader study group surveys at Lake MacLeod, 1999-2000	Davis C Kirkby T Singor M 2001	Yes	8-12/11/1999	4	2+	Yes	No areas GPS listed	No complications listed
Wader study group surveys at Lake MacLeod, 1999-2000	Davis C Kirkby T Singor M 2001	Yes	17-22/9/2000	6	3+	No	5 areas GPS listed. Probably more areas visited but not noted.	Lake flooded (Cyclone Steve). Some areas inaccessible and/or dangerous. Proximity to study site equated to three hours of extra work daily when compared to Nov-99 survey.
October 2001 Survey ^a	Unknown	Unknown	Oct. 2001	-	-	-	-	-
January 2002 Survey ^a	Unknown	Unknown	18-21/1/2002	4	-	-	-	Water levels low, access difficult. Southern basin not visited. Low numbers of birds recorded. I do not have access to the original report. Information from Davis 2003

Appendix 1 (cont.)

Title	Author(s) and year	Available in public literature?	Survey dates	Duration in days	No. of participants	Aerial survey?	No. of areas visited	Notes
Pilbara Wader Surveys Lake MacLeod Sept 2002.	Davis C 2002	No	20-23/9/2002	4	6	Yes	22 areas GPS listed plus 2 more locations for which no GPS information is given	Loss of cover due to mangrove deaths (Cyclone Steve) may have led to some species abandoning the lake.
Lake MacLeod surveys 2002-2003.	Davis C 2003	Yes	14-18/3/2003	5	-	No	Likely to be as Sep-02	Fat birds in partial/full breeding plumage observed suggest that lake is a staging area. Mangroves recovering
Avian Survey of Lake MacLeod October 10-14 2003.	Davis C 2003	No	10-14/10/2003	4	-	No	6	Tern Bay could not be visited. Canoes used for the first time to explore areas around Night Heron Point
Wader Study Group Surveys at Lake MacLeod, March 2004.	Davis C 2004	Yes	18-24/3/2004	6	8	No	7 sites surveyed daily, 2 once (GPS locations for these 9 sites), monitoring trip to north ponds (No GPS information). ~10 locations	Cyclones caused widespread floods around lake, however the lake itself received little rainfall. Conditions allowed access to additional areas.
Lake MacLeod Survey 2004.	Hassell C 2004	No	9-11/11/2004	3	3	No	8 areas visited, North Ponds visited once	Conditions allowed two new areas to be visited Stilt Lagoon and Stilt Flat. Heat haze made identifying birds difficult
Bird Survey Reports for Dampier Salt Limited. Lake MacLeod- September 27-30 2005, Port Headland- November 2 2005, Dampier- November 3 & 4 2005	Hassell C 2005	No	27-30/9/2005	3	3	No	8 areas visited	Flooding of favoured feeding areas caused birds to be distant. Flooding made access more difficult than normal. No rains in other areas so likely to have attracted large numbers of birds.
Bird Survey Reports for Rio Tinto Minerals, Lake MacLeod- October 3-5 2006, Port Headland- November 7 2006, Dampier- November 8 & 9 2006.	Hassell C 2006	No	3-5/10/2006	3	3	Yes	9 areas visited	Drier conditions made access difficult, bad lighting conditions made counts harder.
Shorebirds and their known habitat/status in the Gascoyne Region, Western Australia	George L 2009	Yes	N/A	N/A	N/A	N/A	N/A	Summary of all the DSL surveys. Covers entire Gascoyne region.

* For the October 2001 and January 2002 surveys the original articles were not available. However, their counts (and the conditions under which they were made) are provided in later surveys.

Appendix 2 Shorebird counts at Lake MacLeod that are of national and international significance and their species conservation status.

Common name ^a	Scientific name	Surveys ^b												Max. pop. ^c	1% ^c	0.25% ^c	Aust. pop. ^c	
		Oct-1987	Nov-1999	Sep-2000	Oct-2001	Jan-2002	Sep-2002	Mar-2003	Oct-2003	Mar-2004	Nov-2004	Sep-2005	Oct-2006					
Scolopacidae																		
Black-tailed godwit NT, A	<i>Limosa limosa</i>	25	14	0	12	0	0	0	0	66	1	0	0	16000	-	1600	400	70000
Bar-tailed godwit VU, A	<i>Limosa lapponica</i>	111	386	18	60	54	160	3	26	65	50	1	26	325000	-	3250	813	185000
Eastern curlew VU, A	<i>Numenius madagascariensis</i>	0	0	1	0	0	0	0	0	0	0	0	0	38000	-	380	95	28000
Little curlew LC, A	<i>Numenius minutus</i>	1	0	0	0	0	0	0	0	0	0	0	0	180000	-	1800	450	175000
Marsh sandpiper LC, A	<i>Tringa stagnatilis</i>	66	3	0	43	0	10	2	1	0	3	0	0	100000	1000000	1000	250	9000
Common greenshank LC, A	<i>Tringa nebularia</i>	92	235	300	120	30	40	72	70	62	270	112	132	60000	-	600	150	19000
Wood sandpiper LC, A	<i>Tringa glareola</i>	0	3	0	0	0	0	0	0	0	2	5	0	100000	1000000	1000	250	6000
Terek sandpiper LC, A	<i>Xenus cinereus</i>	1	0	0	2	0	0	0	0	0	4	0	0	60000	-	600	150	23000
Common sandpiper LC, A	<i>Actitis hypoleucos</i>	5	6	2	5	2	2	7	20	2	11	11	6	25000	100000	250	63	3000
Grey-tailed tattler NT, A	<i>Heteroscelus brevipes</i>	0	2	0	0	0	0	0	0	0	13	0	0	50000	-	500	125	45000
Ruddy turnstone NT, A	<i>Arenaria interpres</i>	18	37	10	50	2	25	2	3	6	38	14	26	35000	-	350	88	20000
Asian dowitcher NT, A	<i>Limnodromus semipalmatus</i>	1	0	0	0	0	0	0	0	0	0	0	0	24000	-	240	60	250
Great knot VU, A	<i>Calidris tenuirostris</i>	135	211	39	38	0	75	10	60	83	260	1	0	375000	-	3750	938	360000
Red knot VU, A	<i>Calidris canutus</i>	2566	137	8	660	0	515	187	668	150	250	2	278	220000	-	2200	550	135000
Sanderling LC, A	<i>Calidris alba</i>	1	1	1	0	0	0	0	0	0	5	3	0	22000	-	220	55	10000
Little stint LC, A	<i>Calidris minuta</i>	0	2	0	0	0	0	0	1	1	0	0	0	-	-	-	-	NA
Red-necked stint LC, A	<i>Calidra ruficollis</i>	8312	2350	6000	4	250	3340	6206	6440	6000	7550	4	25000	325000	-	3250	813	270000
Long-toed stint LC, A	<i>Calidris subminuta</i>	2	0	0	0	0	0	0	0	1	1	1	0	25000	-	250	63	1000
Pectoral sandpiper LC, A	<i>Calidris melanotos</i>	0	0	0	0	0	0	0	0	1	0	0	0	25000	100000	NA	NA	NA
Sharp-tailed sandpiper LC, A	<i>Calidris acuminata</i>	602	214	10	21	3	50	23	205	8	850	295	129	160000	-	1600	400	140000
Curlew sandpiper VU, A	<i>Calidris ferruginea</i>	41606	18392	40000	2000	70	8000	16690	26283	485	45000	1066	55000	180000	-	1800	450	118000
Broad-billed sandpiper LC, A	<i>Limicola falcinellus</i>	1	1	0	0	0	3	0	0	30	0	0	0	25000	-	250	63	10000
Red-necked phalarope LC, A	<i>Phalaropus lobatus</i>	0	0	0	0	0	0	0	0	0	0	0	17	100000	1000000	1000	250	NA

Appendix 2 (cont.)

Common name ^a	Scientific name	Surveys ^b												Max. pop. ^c	1% ^c	0.25% ^c	Aust. pop. ^c
		Oct-1987	Nov-1999	Sep-2000	Oct-2001	Jan-2002	Sep-2002	Mar-2003	Oct-2003	Mar-2004	Nov-2004	Sep-2005	Oct-2006				
Haematopodidae																	
Pied oystercatcher LC	<i>Haematopus longirostris</i>	19	6	2	2	2	1	6	6	6	8	2	24	NA	NA	NA	10000
Recurvirostridae																	
Black-winged stilt LC	<i>Himantopus himantopus leucocephalus</i>	310	5	500	284	530	1000	79	885	230	850	3008	60	NA	NA	NA	300000
Banded stilt LC	<i>Cladorynchus leucocephalus</i>	53098	2042	8000	0	600	6000	15645	16204	1	100000	25700	9000	NA	NA	NA	206000
Red-necked avocet LC	<i>Recurvirostra novaehollandiae</i>	2401	0	70	0	402	346	778	214	28	2315	1240	600	NA	NA	NA	107000
Charadriidae																	
Pacific golden plover LC, A	<i>Pluvialis fulva</i>	7	3	0		5	0	1	0	0	4	0	0	100000	100	25	9000
Grey plover VU, A	<i>Pluvialis squatarola</i>	34	31	0	40	0	14	18	5	60	21	10	7	125000	1250	313	12000
Red-capped plover LC	<i>Charadrius ruficapillus</i>	2110	114	500	24	70	300	454	442	400	3125	402	2027	NA	NA	NA	95000
Lesser sand plover EN, A	<i>Charadrius mongolus</i>	1	3	0	0	0	17	0	4	0	0	1	0	140000	1400	350	25000
Greater sand plover VU, A	<i>Charadrius leschenaultii</i>	75	12	0	3	0	35	3	6	0	515	18	68	110000	1100	275	75000
Oriental plover LC, A	<i>Charadrius veredus</i>	0	33	0	12	0	0	0	0	0	3	0	9	700000	700	125	70000
Inland dotterel LC	<i>Charadrius (Peltodytes) australis</i>	0	0	0	0	0	0	0	0	6	0	0	0	NA	NA	NA	14000
Black-fronted dotterel LC	<i>Elseya melanops</i>	1	0	0	0	0	0	0	0	0	0	0	0	17100	NA	NA	15500
Red-kneed dotterel LC	<i>Erythrogonys cinctus</i>	0	0	0	0	0	14	2	5	0	0	1	0	NA	NA	NA	25000-100000
Banded lapwing LC	<i>Vanellus tricolor</i>	0	0	4	0	0	3	0	0	0	0	0	0	NA	NA	NA	25000-100000
Unidentified shorebirds		-	5500	2500	11400	34	40000	7700	8000	0	10000	110000	0	NA	NA	NA	25000-100000

^a The conservation status of the shorebird species is listed next to their common name in the left most column: IUCN status (LC= Least Concern, NT=Near Threatened, VU=Vulnerable, EN=Endangered) in accordance with the Action Plan for Australian Birds (2010) and their protection (A) or lack thereof (blank) in regards to the CAMBA, JAMBA and ROKAMBA agreements is listed next to this.

^b Survey counts from: Jaenich & Vervest 1990; Davis *et al.* 2001; Davis 2002, 2003a, 2004; Hassell 2004, 2005, 2006. East Asia-Australasian flyway population estimates from: Bamford *et al.* 2008. Australian population estimates from: Geering *et al.* 2007. Figures in bold meet the 1% criterion of the Ramsar convention, that is the count represents $\geq 1\%$ of the East-Asian Australasian Flyway population; underlined means that the count represents $\geq 1\%$ of the Australian population; and if italicised that it meets the $\geq 0.25\%$ of the Ramsar convention staging criterion.

^c The East Asian-Australasian Flyway (minimum and maximum population estimates) and Australia population estimates are listed; if there was only one estimated, then that is listed as the minimum population) as are the number of individuals that constitute 1% and 0.25% of the Flyway population.



Bertzeletos, Demetrios., Davis, Robert A, and Horwitz, P. 2012. "Importance of Lake MacLeod, northwestern Australia, to shorebirds: a review and update." *Journal of the Royal Society of Western Australia* 95(2), 115–124.

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