Waterbird and shorebird surveys of the Bowling Green Bay Ramsar Site

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1. EXECUTIVE SUMMARY

Bowling Green Bay was declared a Ramsar site in 1996 as it met several of the criteria for a wetland of international importance. Two of the criteria that it met were:

(5) the provision of habitat to support over 20,000 waterbirds, including large populations of Magpie Geese and Brolga; and

(6) supported 1% of the East Asian -Australasian Flyway population of one species of shorebird: Black-tailed Godwit.

The Australian Government has commissioned the development of ecological character descriptions (ECDs) for Australian Ramsar sites, to establish the critical components, processes and services that underpin the Ramsar criteria and to assist with establishing limits of acceptable change (LAC) for the sites.

During the preparation of the draft ECD for the Bowling Green Bay Ramsar site (BGBRS) (Kelly and Lee Long 2011), a lack of sufficient data meant that it was not possible to demonstrate that the BGBRs supported Ramsar criterion (5). Furthermore, the available data on shorebird numbers were considered inadequate for setting a LAC for their populations.

The lack of sufficient data relating to the two Ramsar criteria relevant to the BGBRS resulted in a year-long study of the numbers of shorebirds and waterbirds at the site. The study began in May 2011 with funding provided by the Australian Government Department of Sustainability, Environment, Water, Population and Communities. The study comprised four surveys of the coastal high tide roosts in the BGBRS for shorebirds and additional aerial and ground surveys of nearby wetlands (north of Ayr). The aim of the study was to provide a detailed assessment of the distribution and abundance of shorebirds and waterbirds in the BGBRS. It was anticipated that these data would provide sufficient information to develop LACs for shorebirds and waterbirds.

Key findings of the study include:

- Confirmation of the regional importance of the BGBRS for migratory shorebirds and resident and transient waterbirds.

- The Black-tailed Godwit does not appear to regularly occur at the Ramsar site in internationally significant numbers. However, there is evidence that the Great Knot more regularly occurs in internationally significant numbers.

- The most abundant waterbird species in the survey area were the Magpie Geese and the Pacific Black Duck.

- Over the course of the study, the majority of the waterbirds occurred outside, but adjacent to, the Ramsar site, where the numbers of four species were in internationally significant numbers. This demonstrated the importance of neighbouring wetland habitat, particularly at locations south and south-west of the site, which are extensively used by waterbirds.

- While parts of the BGBRS have been extensively surveyed since the mid-1990s, a systematic and coordinated program of surveys has been lacking. This has made it difficult to identify trends in shorebird populations and then provide quantitative LACs.

- It will be difficult to identify LACs for shorebirds and waterbirds at the site, given the mobility of the bird species, their use of habitats outside the Ramsar site and the difficulty in quantifying change in population numbers. Suggestions are made as to potential monitoring approaches.

Shorebirds

Shorebirds were distributed coastally among 19 high tide roosts, including four at Cape Bowling Green and several around the mouth of the Haughton River and Cungulla in the south western part of the bay. Many of these roosts have been used by shorebirds for a long period of time, as indicated by counts that were made of these high tide roosts in the mid-1990s.

Four aerial and three ground surveys of the coastal high tide roost sites in BGBRS were made on a spring high tide in August 2011, October 2011, January 2012 and March 2012. The March 2012 survey was severely compromised by the cyclonic weather conditions that restricted boat surveys to the more sheltered south western part of the bay. Logistical constraints and the availability of vessel support from the Queensland Department of Environment and Resource Management meant that Cape Bowling Green was only surveyed in January 2012. This has meant that only one complete ground survey of the coast of Bowling Green Bay was made. A total of 5,483 shorebirds, terns and other waterbirds were counted during the January survey, including internationally significant numbers of Great Knot. A total of 3,800 birds were counted in the October 2011 ground survey of the southern and western parts of Bowling Green Bay.

During all surveys counts were made of Little Terns and evidence of breeding was noted. We found no evidence of Little Tern breeding at either Cape Bowling Green or around Cungulla. The largest count of Little Tern was made in October, from the western part of Bowling Green Bay, including Cungulla. Few Little Terns were counted at Cape Bowling Green despite the habitat being ideal for nesting. Disturbance was widespread and frequent at Cungulla and is likely to be deterring Little Tern from nesting in this area. A similar problem may exist on the Cape. In other parts of Queensland, Little Tern nesting occurs from November to early January. We did not survey either Cape Bowling Green or Cungulla during this period. However, a member of Birdlife Townsville (George Baker) made two surveys of Cape Bowing Green at that time (November and early January) and he failed to record any evidence of nesting. We could also not find any historical data on Little Tern nesting in BGBRS. This would make it extremely difficult to develop a suitable LAC for nesting by this species in BGBRS.

We compiled historical shorebird count data from Birdlife Townsville (BLT) and the Queensland Wader Study Group (QWSG) to examine trends in the abundance of shorebirds in the BGBRS. A total of 152 surveys have been made at high tide roosts in the BGBRS since 1996. The BLT surveys included recent counts of over 6,000 Red-necked Stint at Cape Bowling Green in January – February 2011. These counts represent almost 3% of the Flyway population of this species. Of the 152 surveys, 52 have detected Black-tailed Godwit since the internationally significant count in 1996, none have approached 1% of the Flyway population. This large number of Black-tailed Godwit at Cape Bowling Green appears to have been an exceptional occurrence, possibly under unusual weather conditions during migration. The population of Black-tailed Godwit do not appear to regularly occur in the BGBRS in internationally significant numbers in accordance with the Ramsar criterion (every 5 years).

Similarly, the recent large counts of Red-necked Stint appear to be unusual, although this species is generally more abundant. The next highest count record of Red-necked Stint in the QWSG database is less than 4,500 (out of > 21,000 separate surveys). The high variability and infrequency of the occurrence of these internationally significant numbers makes quantifying a LAC for their populations impractical. Large numbers of Red-necked Stint may not occur with sufficient frequency to meet the Ramsar criterion.

There had been no comprehensive survey of all high tide roosts in Bowling Green Bay prior to this study. During the January survey, we counted internationally significant numbers of Great Knot at coastal high tide roosts within BGBRS. Prior surveys of parts of the Bay taken in context of results from this study suggest that internationally significant numbers of Great Knot occur regularly within the BGBRS. The existing data demonstrates that Great Knot move regularly between the western, southern and eastern parts of the bay. Because of this pattern of usage of the area by Great Knot, sampling their numbers would necessitate visiting a range of roost sites from both sides of Bowling Green Bay. Thus, a survey of Great Knot may be a reasonable proxy of change in the Ecological Character of the BGBRS.

We suggest that fixed point habitat images of each high tide roost could be collected at the same time as any surveys to aid in interpreting any change in shorebird numbers. The images can be qualitatively compared to ascertain differences in habitat quantity or quality. This will help inform the interpretation of the results of the surveys of each high tide roost.

In order to adequately monitor shorebird numbers and gather biologically meaningful results, surveys should be made at a maximum interval of every two years (in October – December). Additional ground or aerial surveys of the large sub-coastal claypans to the south east of the BGBRS should occur at the same time. These claypans held substantial populations of Red-necked Stint under favourable conditions and improved understanding of their importance for shorebirds would be highly desirable.

Waterbirds

Four aerial surveys were undertaken of the freshwater wetlands in the BGBRS and adjacent areas south to the latitude of Ayr and east of the Pacific Highway. These surveys focussed on Magpie Geese and Brolga. All other waterbirds and shorebirds seen were also identified and recorded. Aerial counts of each species were linked with their location by recording the time for each record. The times were later linked to position records from a GPS track of each flight. In general, aerial surveys usually under-estimate the abundance of many waterbird species. In order to calibrate the aerial surveys, ground surveys were made of four large, accessible wetlands on the same day as they were surveyed from the air. The habitats in each of these four wetlands varied. However, between them, they contained the range of habitats occupied by waterbirds in the study area.

The first aerial survey was made in August 2011 and was the most comprehensive, with two planes and three observers. At the time of the October 2011 survey, most of the freshwater wetlands surveyed in August had dried out. Some heavy wet season rain fell between the October 2011 and the January 2012 surveys. These rains had partially filled most wetlands in the study area. Torrential rain occurred prior to and during the final survey in March 2012. This caused extensive flooding of most wetlands and made them too deep to be attractive to many waterbird species.

The surveys showed that almost 60,000 waterbirds occurred in the survey area in August 2011. This number declined to about 20,000 in October 2011 and remained at similar numbers during the subsequent surveys. Almost 90% of all waterbirds surveyed in August 2011 were found in wetlands outside the BGBRS. The two most abundant species were Magpie Geese and Pacific Black Duck. Each species accounted for about 15,000 birds or 25% of all the waterbirds counted. A total of 41 species of bird were counted on freshwater wetlands during the four surveys. Of these, four species were found in internationally significant numbers: Cotton Pygmy Goose 1.1%, Eastern Great Egret 1.7%, Pacific Black Duck 1.5% and Royal Spoonbill 2.5% (of their estimated flyway population). These numbers are high relative to many other locations sampled during extensive aerial waterbird surveys of eastern Australia by Richard Kingsford and colleagues from 1982 to 2007.

Although the wetlands that held the majority of the waterbirds were outside the BGBRS, they form a continuous wetland complex with the Ramsar site wetlands. Waterbirds moved regularly between the wetlands outside and inside the BGBRS. The entire system needs to be maintained if the study area is to retain its Ecological Character for waterbirds. A quantitative abundance criterion for a LAC for these waterbird species is impractical, given their dispersed distribution across a large number of wetlands. Thus, a possible LAC could be based on the quantity of each type of habitat occupied by birds and measurements of how this changes between surveys.

The waterbird records mapping and associated wetlands identified in this study could be used as a basis of an ongoing monitoring program. Such an approach could combine aerial survey of waterbirds every two years with evaluation of simultaneous satellite imagery of wetland habitat type and extent. The feasibility of this strategy would depend upon being able to a) classify and map wetland habitats using satellite imagery, b) undertake the aerial survey around the time the image is captured (preferably mid to late dry season) and, c) appropriate ground truthing of the aerial surveys. Changes in the extent of any habitats used by the waterbirds greater than an agreed nominal amount (e.g. 30%) might be used to trigger additional ground-truthing and surveys. Over time, the number of waterbirds counted in the aerial surveys can also be used to measure trends in the abundance of the more common species.

Another or complementary approach may be to monitor waterbird numbers on several occasions during each dry season at the four wetlands that were surveyed from the ground during the current study. It should be feasible for local BLT members or Queensland government staff to undertake these tasks at regular intervals.

2. BACKGROUND

The project was undertaken in collaboration with the Australasian Wader Studies Group (AWSG) and Birdlife Townsville (BLT) (formerly Townsville Regional Bird Observers Club (TRBOC)), funded by the Australian Government as part of the Queensland Wetlands Program[1]. Peter Driscoll and David Milton (AWSG) had the primary responsibility for the project and George Baker (BLT) coordinated local assistance, including participation in fieldwork by members of BLT and logistical support through the Qld Department of Environment and Resource Management (DERM).

The project addressed knowledge gaps relating to waterbirds and shorebirds identified in the draft Ecological Character Description for the Bowling Green Bay Ramsar site as follows:.

1. Specifically, before April 2012, up to three (in this case four) ground count surveys of shorebirds will be undertaken that will build on existing shorebird ground counts at important roost sites in the Bowling Green Bay Ramsar site and contribute to improved understanding of year to year variation in shorebird numbers.
2. Also, counts of Brolgas and Magpie Geese in the Bowling Green Bay Ramsar site must be made during the dry season to establish baseline counts for these species and an estimate of natural variability.
3. A report after each survey is required as well as a final report on the whole project.
4. Surveys of the Little Tern nesting populations on Cape Bowling Green sand spit and Cungulla beach ridges are a recommended outcome of the surveys.

This report outlines the results of all four surveys of the Bowling Green Bay Ramsar site (BGBRS) that were undertaken between 27 – 31 August, 2011 and 17 – 23 March 2012. Each survey was timed to coincide with the spring high tide for that month.

3. SURVEY METHODS

Shorebirds

Shorebirds were surveyed during the four field visits to the BGBRS and adjacent coastal habitats by a combination of aerial and ground counts (Table 1). Ground counts of shorebirds were made during the last three field trips, when their populations were highest. This period corresponds with the non-breeding season when shorebird abundance is highest in Australia. Aerial surveys were made of the BGBRS coastal habitats at high tide during each field trip (refer next Section). These surveys were undertaken prior to making counts of shorebirds from the land or boat. The aerial surveys identified the location of shorebird high tide roosts and birds were counted in size-related groups that each probably contained more than one species. Distinctive species such as Black-winged Stilt, Eastern Curlew, Common Greenshank, Great Knot, Pied Oystercatcher and Whimbrel were separated where feasible. Aerial surveys were by either Peter Driscoll (October 2011, January 2012, March 2012) or David Milton (August 2011, October 2011) with a Carbon Cub, Pelican or Foxbat light plane.

[1] Commencing in 2003, the Queensland Wetlands Program was a joint initiative of the Australian Government and Queensland Government. It was established to support projects or activities that result in long-term benefits to the sustainable management, wise use and protection of wetlands in Queensland, particularly the Great Barrier Reef catchments. Australian Government priorities for phase II of the Program included addressing Ramsar site data needs and gaps, identified in ECDs.

Most high tide roosts of shorebirds were accessed by boat, depending on the tide height and their proximity. Some roosts on the western foreshore of Bowling Green Bay could be accessed from the land (Table 2). Counts were made of these roosts from the land when boat access was difficult due to strong winds.

Shorebird roosts in the Burdekin River delta were also surveyed twice from the air and by boat (October 2011; January 2012). These roosts were outside the BGBRS, but some regular movement of shorebirds between the two regions would be expected at least seasonally. Four high tide roosts known from previous surveys by QWSG were confirmed to still occur in the mouth of the Burdekin River. Several new roosts were also identified. The results for work on the Burdekin River delta are in Appendix A and do not contribute to the main body of this report. Similarly, an aerial survey of the Ross River Dam was undertaken in August. Although the results are not presented, they are available upon request.

Waterbirds

Magpie Geese and Brolga vary in their seasonal habitat use, being more concentrated and thus more detectable during the dry season (Bayliss and Yeomans 1990). The first survey of the BGBRS was scheduled for late August to coincide with the mid-late dry season during the period when the birds should be more concentrated. Due to problems of access, land tenure and extent of the BGBRS and adjacent lands, the abundance of Magpie Geese and Brolga within the survey area could not be estimated effectively from the ground. Consequently, the first survey was planned to include an extensive aerial survey of the region by light plane with subsequent ground checking of aerial counts at selected sites. Emphasis was placed on Magpie Geese and Brolga but waterbirds in general and shorebirds were surveyed. Aerial surveying was less intense for the remaining field trips, but counts were made from the air where birds were found to have high numbers and a seasonal comparison of counts is possible.

Figure 1. Intended systematic flight paths over the study area for August 2011.
The Bowling Green Bay Ramsar site boundary is shown in red. The actual flights were not flown strictly as shown and specific areas were targeted once a general coverage was achieved.

Prior to the commencement of the first field survey, a systematic plan was designed to cover the BGBRS and adjacent lands from the air (Figure 1). The spacing of the aerial transects was designed to obtain a better than 60% coverage within the BGBRS from a height of 480 ft (146 m) at a speed of 110 $km.h^{-1}$. This equated to a transect width of 600 m. Previous survey experience suggested that Brolgas and Magpie Geese could be detected effectively at this distance at this speed. Generally, two observers made simultaneous counts of Magpie Geese, Brolgas and other waterbirds on separate sides of the plane. One observer, Peter Driscoll (PD), who piloted the plane, was present during most aerial surveys and the second observer alternated between David Milton (DM) and Sandra Harding (SH). Details of all flights can be found in Table 1.

Flights were made in early to mid-morning and later in the afternoon when Magpie Geese were most likely to be roosting and thus concentrated around freshwater wetlands and not dispersed to feed. On the first field trip, two planes were used simultaneously (Carbon Cub and Foxbat) to increase the coverage of the freshwater wetlands outside the BGBRS (Figure 1). On subsequent field trips a single plane was used, primarily the Carbon Cub.

During all aerial transects, counts of Magpie Geese, Brolga, shorebirds and other waterbirds seen by each observer were recorded against the time of observation. These observation times were linked post-survey to GPS tracking of the flight routes to give their location. After the aerial surveys, selected wetlands with high counts of Magpie Geese were surveyed from the ground. Ground access was more restricted and so fewer wetlands could be surveyed from the ground. In total, four large freshwater wetlands were counted from the ground on each field trip (Table 1).

The intensive aerial surveying on the first field trip in late August resulted in overlaps of areas and sites that were counted. In many instances the same site was counted as many as two or three times. Therefore, the maximum count of individual taxa from each site was taken as the representative count for the August field trip.

Table 1. Details (where and when) of the aerial surveys and ground counts.
The surveys for shorebirds and waterbirds, especially Magpie Geese and Brolgas, within and adjacent to the Bowling Green Bay Ramsar site (BGBRS) were undertaken between August 2011and March 2012 as detailed in the table (PD = Peter Driscoll, DM = David Milton, SH = Sandra Harding; GB = George Baker; ST = Stephanie Tonkin).

Date	Observers	Time of day	Activity
27 August 2011	PD, SH	AM:	Systematic aerial survey of BGBRS
	PD, SH	PM	Systematic aerial survey of BGBRS
	DM	AM/PM	Targeted ground reconnaissance of accessible freshwater wetlands south of the BGBRS and accessible known shorebird high tide roosts.
28 August 2011	PD, SH	AM/PM	Targeted aerial survey of freshwater wetlands with high concentrations of Magpie Geese within and outside the BGBRS.
	DM	AM	Aerial survey of freshwater wetlands south of the BGBRS and mouth of Burdekin R.
29 August 2011	PD, DM	AM	High tide aerial survey of Cleveland and Bowling Green Bay coast for shorebirds at roosts.
	SH	AM	Ground reconnaissance of accessible freshwater wetlands and shorebird roosts south of BGBRS.

	PD, DM	PM	Targeted aerial survey of freshwater wetlands south of BGBRS with high concentrations of Magpie Geese.
30 August 2011	PD, DM, SH	AM/PM	Ground counts of Magpie Geese, Brolgas and other waterbirds on accessible freshwater wetlands within and outside BGBRS with large concentrations of Magpie Geese.
31 August 2011	PD	AM	Targeted aerial survey of wetlands during departure flight south.
26 October 2011	DM	AM:	Systematic coastal aerial survey
	PD	AM	Selective sub coastal aerial survey
	SH, GB	AM	Ground counts of freshwater wetlands
	SH, GB, DM, PD	PM	Ground counts of freshwater wetlands.
27 October 2011	DM, SH, PD	AM/PM	Ground counts by boat of shorebird roosts within BGBRS
	DM, SH, PD	AM	Ground counts of freshwater wetlands
28 October 2011	PD, SH	AM	Ground counts by boat of shorebird roosts within BGBRS
	DM, GB	AM	Ground counts by boat of shorebird roosts– aborted trip to Cape Bowling Green. ROSS counted.
	PD, DM, SH	PM	Low tide feeding counts of shorebirds in Cleveland Bay
29 October 2011	PD, DM, SH	AM/PM	Ground counts by boat of shorebird roosts at the mouth of the Burdekin River
30 October 2011	PD, DM, SH	AM/PM	Ground counts of shorebird roosts within BGBRS including at Chunda Bay and Alva
21 January 2012	PD, SH, DM	AM	Ground counts (boat) of shorebird roosts: western BGBRS
	SH, DM	AM/PM	Ground counts of freshwater wetlands
	PD	PM	Selective sub coastal aerial survey
22 January 2012	PD, SH, DM	AM	Ground counts (boat) of roosts: eastern BGBRS incl. Cape
	PD, SH, DM	PM	Ground counts of freshwater wetlands
23 January 2012	PD, SH, DM	AM	Ground counts (car & foot) supra-tidal wetlands, near Alva
	PD, SH, DM	AM	Ground counts of freshwater wetlands
24 January 2012	PD, DM, SH	AM/PM	Ground counts (boat) of shorebird roosts: Burdekin River mouth
25 January 2012	PD, DM, SH	PM	Ground counts of shorebird roosts: New Beach, Repulse Bay
17 March 2012	PD, ST	AM	Ground counts (boat) of shorebird on western side of BGBRS
20 March 2012	PD, DM, SH	AM	Ground count of Salmon Ck shorebird roost, western side BGBRS
		PM	Ground counts of Cromarty freshwater wetland
21 March 2012	PD, DM, SH	PM	Ground counts of accessible freshwater wetlands
22 March 2012	PD	AM	Aerial survey of shorebird roosts and selected freshwater wetlands in BGBRS
23 March 2012	DM, SH	AM	Ground counts of accessible freshwater wetlands

4. RESULTS

Distribution of shorebirds and waterbirds within/beyond BGBRS

Shorebirds

The majority of shorebirds in the survey area were found within the BGBRS (Figure 2). There have been 19 roosts identified within the BGBRS (Table 2). Many of the roosts in BGB have been known for a long time. Birdlife Townsville (BLT) has periodically counted at these sites since the mid-1990s (Table 2). A total of 17 roosts within BGBRS were surveyed at least once during the project (Table 2). Of these, seven new roosts were identified and two that had previously been counted that did not hold birds during the survey period. The new roosts were mostly along the southern coast of Bowling Green Bay and only accessible by boat. These roosts did not hold highest numbers of shorebirds in the BGBRS, but had a different species composition to those at Cape Bowling Green (Table 2). We also identified one new roost on Cape Bowling Green that was south of those regularly monitored by BLT with logistical support from marine parks staff.

The shorebirds found beyond the BGBRS were all either on freshwater wetlands or coastal claypans that were seasonally inundated by king tides (Table 2). Many of these birds probably periodically rely on the intertidal flats within the BGBRS for feeding. There were very few non-migratory shorebirds counted on the large number of freshwater wetlands surveyed during the project (see Waterbird section below).

The species composition of the coastal high tide roosts in Bowling Green Bay is typical of similar habitats elsewhere along the adjacent Queensland coast (Driscoll 1997). A total of 19 species of shorebird, seven terns or gull, six other waterbirds and three raptors were counted at high tide roosts in BGBRS during the project. Only one species of shorebird was counted in internationally significant numbers – Great Knot (Table 3). Most other species were counted in much lower numbers than have been periodically recorded in previous surveys by BLT members. The distribution of species also differed, with the Sand Plover, Grey Plover, Eastern Curlew and Whimbrel being mostly confined to the western and south western parts of Bowling Green Bay (Table 3). Black-tailed Godwit were only found at Cape Bowling Green and Sharp-tailed Sandpiper were mostly restricted to southern Bowling Green Bay roosts during the survey period. The numbers of several species, (Black-tailed Godwit, Sharp-tailed Sandpiper and Red-necked Stint) recorded by BLT at Cape Bowling Green during the period of the project were substantially higher than found during our surveys of the entire BGBRS. Our data also suggest that Great Knot are not strongly site-faithful in Bowling Green Bay (Table 3). We counted large numbers of Great Knot in different parts of Bowling Green Bay during each survey. Rogers et al. (1996) and Driscoll (2001) found a similar pattern of shifts in roosting preferences by Great Knot as the tidal cycle changed.

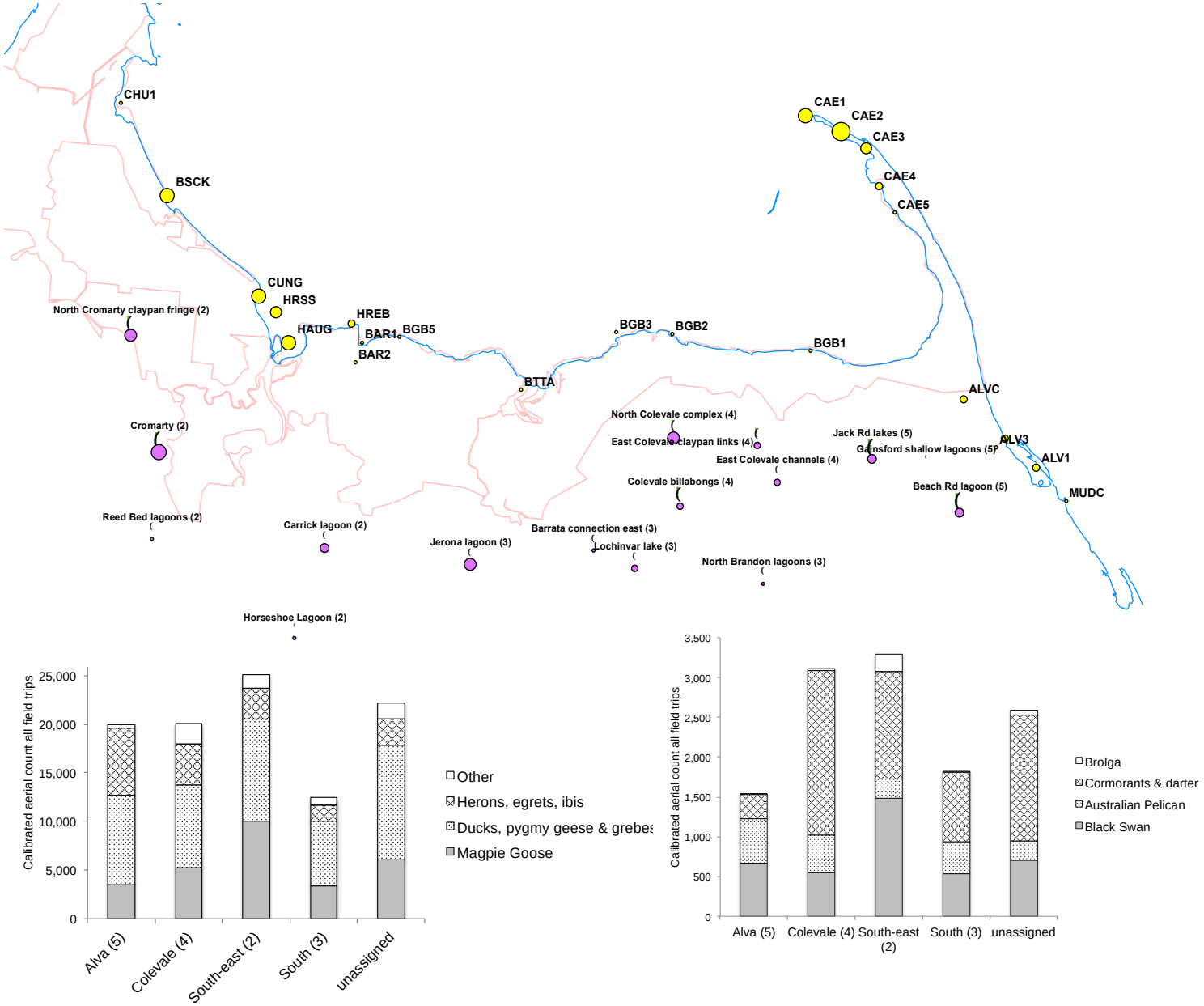

Figure 2. Relative bird numbers and locations for high tide roosts and major wetlands.

Yellow dots with 4 letter codes are roost sites with the size of the dots (not to scale) indicating relative numbers as per Table 2. The named freshwater wetlands are assigned purple (total counts) and green (magpie geese) dots, also indicating relative numbers as per Appendix C. The relative abundance of different species for each of 4 wetland groupings (Alva, Colevale, South-east and South) is shown in the accompanying histograms. Members of the groups are indicated by number references (5, 4, 2 and 3) for each of the wetland groups. BGBRS boundary is shown in pink.

Table 2. List of high tide shorebird roost sites with total bird counts and coordinates.
The sites are in or adjacent to the Bowling Green Bay Ramsar site (BGBRS) and the bird totals are for shorebirds, terns and waterbirds combined. Also indicated in brackets is the number of visits made to each roost by the study team and during previous surveys by QWSG and BLT ("other", includes surveys with DERM logistical support).

Site	BGBRS	Latitude	Longitude	Other surveys	Field Trip				Total
					1	2	3	4	
ALV1 - Alva Creek 1	N	-19.4767	147.5031	1460 (2)	–	–	–	–	1460 (2)
ALV2 - Alva Creek 2	N	-19.4624	147.4874	1062 (4)	1020 (1)	–	39 (1)	–	2121 (6)
ALV3 - Alva Creek 3	N	-19.4667	147.4831	18 (2)	–	–	–	–	18 (2)
ALVC - Alva Beach claypan, Bowling Green Bay	N	-19.4429	147.4668	–	–	344 (1)	1495 (1)	–	1839 (2)
BAR1 - Barramundi Creek sandspit	Y	-19.4150	147.1650	54 (1)	–	29 (1)	210 (1)	–	293 (3)
BAR2 - Barramundi Creek 2	Y	-19.4247	147.1617	13 (1)	–	–	–	–	13 (1)
BGB1 - Bowling Green Bay South 1	Y	-19.4190	147.3900	–	–	263 (1)	180 (1)	–	443 (2)
BGB2 - Bowling Green Bay South 2	Y	-19.4108	147.3205	–	–	806 (1)	143 (1)	–	949 (2)
BGB3 - Bowling Green Bay South 3	Y	-19.4098	147.2926	–	400 (1)	164 (1)	41 (1)	–	605 (3)
BGB5 - Bowling Green Bay south 5	Y	-19.4122	147.1837	–	–	–	270 (1)	–	270 (1)
BSCK - Salmon Ck Bowling Green Bay	Y	-19.3424	147.0672	7356 (32)	–	91 (1)	1521 (1)	189 (1)	9157 (35)
BTTA - Barratta Creek	Y	-19.4381	147.2447	278 (2)	–	–	15 (1)	–	293 (3)
CAE1 - Cape Bowling Green tip	Y	-19.3028	147.3874	13622 (11)	–	–	457 (1)	–	14079 (12)
CAE2 - Cape Bowling Green inner tip	Y	-19.3108	147.4052	65213 (29)	–	–	30 (1)	–	65243 (30)
CAE3 - Cape Bowling Green radio tower beach	Y	-19.3190	147.4179	6944 (7)	717 (1)	–	312 (1)	–	7973 (9)
CAE4 - Cape Bowling Green southern beach	Y	-19.3377	147.4244	996 (2)	–	–	370 (1)	–	1366 (3)
CAE5 - Cape Bowling Green south	Y	-19.3506	147.4321	–	–	–	183 (1)	–	183 (1)
CHU1 - Black Soil Ck, Bowling Green Bay	Y	-19.2965	147.0440	300 (2)	–	210 (1)	71 (1)	–	581 (4)
CUNG - Cungulla, Bowling Green Bay	Y	-19.3921	147.1132	11094 (7)	–	6 (1)	940 (1)	153 (1)	12193 (10)
HAUG - Haughton River staging roost	Y	-19.4150	147.1281	10416 (11)	–	–	–	–	10416 (11)
HREB - Haughton R mouth east beach	Y	-19.4056	147.1597	–	–	1150 (1)	–	–	1150 (1)
HRSS - Haughton River mouth sandspit	Y	-19.3998	147.1219	3267 (3)	–	973 (1)	688 (1)	75 (1)	5003 (6)
MCEB - Barramundi Ck mouth east beach	Y	-19.4094	147.1722	–	–	98 (1)	80 (1)	–	178 (2)
MUDC - Mud Creek	N	-19.4931	147.5181	133 (1)	–	–	–	–	133 (1)
Grand Total				122226 (117)	2137 (3)	4134 (11)	7045 (18)	417 (3)	135959 (152)

Table 3. Total species counts at high tide shorebird roosts within the BGBRS.
Included are shorebirds raptors & waterbirds counted during the project. Counts from each fieldtrip are grouped for western or southern Bowling Green Bay, and for Cape Bowling Green. Shaded cells are counts that were not statistically different from zero with 95% confidence. Totals are for just two field trips. * = Only Cungulla and Salmon Ck roosts were surveyed due to cyclonic winds and heavy rain; † = BLT surveys: 30 September 2011; 28 November 2011; 12 January 2012. ¶ No survey of Cape Bowling Green was made in Oct 11.

Species	Western BGB (5 roosts)			Southern BGB (7 roosts)		Cape Bowling Green (5 roosts)			TOTAL		
	Oct 11	Jan 12	Mar12*	Oct 11	Jan 12	Sep11†	Nov11†	Jan 12	Jan12†	Oct11¶	Jan 12
Australian Darter	–	–	–	–	–	–	1	–	–	–	–
Australian Pelican	–		8	–	2		5	6	6	–	8
Bar-tailed Godwit	314	70	117	146	132	62	166	286	26	460	488
Beach Stone-curlew	1	1	2	–	–	–	–	1	–	1	2
Black-tailed Godwit	–	–	–	–	–	70	1047	450	800	–	450
Brahminy Kite	–	–	1	1	–	–	–	–	–	1	–
Caspian Tern	4	4	–	6	7	7	–	10	5	10	21
Common Greenshank	15	1	–	–	–	5	–	2	–	15	3
Common Tern	–	–	9	–	–	–	710	300	55	–	300
Crested Tern	102	5	2	–	–	710	100	–	10	102	5
Curlew Sandpiper	–	–	–	–	4	12	65	–	76	–	4
Eastern Curlew	80	41	–	4	4	6	6	13	7	84	58
Eastern Reef Heron	4		–	–	–	–	–	–	–	4	–
Great Knot	–	2850	90	800	25	120	1443	50	400	800	2925
Greater Sand Plover	750	40	56	10	398	–	124	100	143	760	538
Grey Plover	50	95	25	1	–	–	–	–	–	50	95
Grey-tailed Tattler	10	–	–	–	–	–	–	13	–	10	13
Gull-billed Tern	30	1	–	1	–	–	–	–	–	31	1
Least Frigatebird	–	–	22	–	–	–	–	–	–	–	–
Lesser Crested Tern	–	–	4			330	–	–	–	–	–
Lesser Sand Plover	300	20	14	30	2	–	–	–	–	330	22
Little Egret	2	–	–	–	–	–	–	–	–	2	–
Little Tern	542	38	–	37	14	14	75	14	250	579	66
Osprey	–	–	–	–	–	–	–	1	1	–	1
Pacific Golden Plover	–	–	–	1	–	–	2	–	25	1	–
Pied Oystercatcher	5	8	4	9	2	2	–	6	4	14	16
Red Knot	–	–	4			–	–	–	–	–	–
Red-capped Plover	–	–	28	42	42	10	–	16	–	42	58
Red-necked Stint	–	12	–	105	214	210	–	15	658	105	241
Sharp-tailed Sandpiper	141	–	–	170	62	140	1448	28	95	311	90
Silver Gull	13	8	1	9	2	10	16	10	–	22	20
Terek Sandpiper	–	–	–	–	–	–	–	25	–	–	25
Whimbrel	66	26	29	1	–	16	–	6	–	67	32
White-bell. Sea-eagle	–	–	1	–	1	–	–	–	–	–	1
White-faced Heron	1	–	–	–	–	–	–	–	–	1	–
Species detectable (%)	14 (74)	12 (75)	10 (56)	10 (59)	7 (47)	15 (94)	12 (86)	17 (85)	14 (88)	18 (75)	19 (76)
Total Species	19	16	18	17	15	16	14	20	16	24	25
Total Count	2430	3220	417	1373	911	1724	5208	1352	2561	3802	5483

Waterbirds

Comparison of aerial and ground counts

Aerial counts were referenced in the field with individual sighting coordinates and were not initially allocated to a particular wetland. In contrast, all ground-based waterbird surveys were at wetlands that had known locations and extent. To reconcile aerial and ground counts from wetlands, some natural

grouping of aerial counts had to be made that would relate to particular, known wetland sites. This was not required for shorebird roost sites, because aerial observations were primarily done for reconnaissance, not to achieve a population estimate.

In contrast, because of the extent and mostly inaccessible nature of most of the wetland area in and adjoining the BGBRS, we were to rely primarily on aerial records to estimate numbers of birds. To do so required calibration of counts of birds from the air with those from the ground (Appendix C). Four wetlands (Table 4, Figure 2) were counted from the ground on every field trip, even though on one occasion a wetland was completely dry. Similarly, aerial counts over these four wetlands and throughout the study area were undertaken on each trip, allowing for a seasonal comparison of waterbird numbers (next section).

Table 4. Comparison of aerial and ground counts of waterbirds at four wetlands.
The table gives the totals for species counted throughout the study at four sites that were sampled on each field trip from both the air (A) and from the ground (G). The sites were CROM = Cromarty; HORL = Horseshoe Lagoon; CARR = Carrick Lagoon; and JERL = Jerona Road Lagoon. Site locations are in Figure 2. The calibration codes are defined in the text and discussed in Appendix B.

Species	CROM		HORL		CARR		JERL		Total		Calibration code
	A	G	A	G	A	G	A	G	A	G	
Australasian Darter	–	10	8	69	–	5	–	6	8	90	C
Australasian Grebe	–	–	–	207	–	28	–	22	–	257	C
Australian Pelican	40	9	17	12	90	33	6	18	153	72	A
Australian Pratincole	–	–	–	–	–	2	–	–	–	2	C
Australian White Ibis	–	22	–	2	–	–	–	11	–	35	B eg
Australian Wood Duck	–	–	–	–	–	53	–	–	–	53	B dk
Black Kite	–	5	–	–	–	–	–	–	–	5	C
Black Swan	755	557	429	324	112	73	3	40	1299	994	A
Black-fronted Dotterel	–	1	–	–	–	–	–	11	–	12	C
Black-necked Stork	–	5	–	1	2	1	–	6	2	13	C
Black-winged Stilt	10	300	–	–	25	1	95	117	130	418	A
Brolga	162	41	–	–	–	3	–	38	162	82	A
Cattle Egret	810	64	–	4	–	36	150	24	960	128	B eg
Comb-crested Jacana	–	49	–	82	–	15	–	1	–	147	C
Common Greenshank	–	1	–	–	–	–	–	2	–	3	C
Common Tern	–	34	–	–	–	–	–	94	–	128	B te
Cotton Pygmy-goose	75	7	60	60	–	–	30	–	165	67	B pg
Dusky Moorhen	–	–	–	1	–	–	–	–	–	1	C
Eastern Great Egret	–	114	–	6	–	17	–	215	–	352	B eg
Glossy Ibis	20	16	10	1	–	17	–	3	30	37	A
Green Pygmy-goose	–	101	120	19	20	–	–	–	140	120	B pg
Grey Teal	–	71	–	4	–	4	–	90	–	169	B dk
Gull-billed Tern	–	6	–	10	–	–	–	–	–	16	B te
Hardhead	–	–	30	490	–	16	–	35	30	541	B dk
Intermediate Egret	–	551	–	5	–	31	–	47	–	634	B eg
Little Black Cormorant	60	69	106	110	10	19	1	4	177	381	A
Little Egret	–	19	–	3	–	5	–	29	–	56	B eg
Little Pied Cormorant	65	10	2	25	–	12	–	16	67	63	A
Magpie Goose	434	326	240	763	157	20	198	324	8135	9330	A
Marsh Sandpiper	–	65	–	–	–	–	–	–	–	65	C
Masked Lapwing	–	104	–	5	2	29	–	35	2	173	C
Pacific Black Duck	100	112	130	258	220	29	–	104	450	2717	B dk
Pacific Golden Plover	–	7	–	–	–	–	–	–	–	7	C
Pied Cormorant	–	1	–	–	–	–	–	–	–	1	C
Plumed Whistling-Duck	–	131	–	–	–	–	–	96	–	227	B dk
Purple Swamphen	–	21	–	–	–	–	–	–	–	21	C
Royal Spoonbill	60	199	–	5	–	59	100	246	160	509	B eg
Sharp-tailed Sandpiper	–	89	–	–	–	–	–	3	–	92	C
Straw-necked Ibis	–	3	–	–	1	1	–	–	1	4	C
Unidentified Duck	974	–	180	–	152	–	130	–	1436	–	B dk

Species	CROM		HORL		CARR		JERL		Total		Calibration code
	A	G	A	G	A	G	A	G	A	G	
Unidentified Egret	780	–	70	–	592	–	374	–	1816	–	B eg
Unidentified Tern	–	–	137	–	94	–	–	–	231	–	B te
Wandering Whistling-	–	648	10	2	200	3	–	67	210	720	B dk
Whiskered Tern	–	108	–	256	–	4	–	–	–	368	B te
Whistling Kite	–	6	–	4	1	2	–	–	1	12	C
White-bellied Sea-Eagle	–	1	–	–	–	1	–	–	–	2	C
White-faced Heron	4	24	–	–	4	–	3	4	11	28	A
White-necked Heron	–	11	–	–	–	–	–	16	–	27	C
White-winged Black	–	–	–	3	–	–	–	–	–	3	B te
Yellow-billed Spoonbill	–	9	–	–	–	–	–	–	–	9	B eg
Grand Total	8255	7881	1549	2731	3100	2998	2872	5581	15776	19191	

A total of 47 species of bird associated with freshwater wetlands were counted during the project at the four calibration wetlands (Table 4). No additional species were seen during aerial surveys of other wetlands. Total ground counts were generally 20% higher than aerial counts at these wetlands. The total ground count of the most abundant species, the Magpie Goose, was 15% higher than the aerial count but the pattern was different for other species. Low numbers of Brolga were recorded but about twice as many were seen from the air (Table 4) as from the ground. Pacific Black Duck were counted from the air more than from the ground however, for all species of duck combined, the number counted from the ground was much higher. In this instance, many duck have either not been seen from the air and/or they have often been misidentified as Pacific Black Duck.

Ducks of all species were the most abundant group of waterbirds across the four wetlands. In contrast, shorebird numbers were low, reflecting their preference for feeding on coastal intertidal flats or at the margins of drying freshwater wetlands. Shorebirds accounted for less than 5% of the total number of birds counted from the ground and less than 1% of the aerial count. This difference is not surprising, given shorebirds are generally smaller than waterbirds and therefore more difficult to see from the air on freshwater wetlands.

For most species, there was no statistically significant relationship between aerial and ground counts. The exceptions were for two abundant and easily seen species, the Black Swan and Magpie Goose ($P< 0.001$). Both species showed a correlation that was statistically no different from a 1:1 relationship between aerial and ground counts, although the best line of fit has the aerial count at 73% of the ground count for Magpie Geese (Figure 3). The lack of statistical significance for other species was perhaps mainly because of high variability in the data due to a number of factors including low sample size (16 paired values) poor visibility from the air, diurnal and seasonal movements of birds and the difficulty of a clear definition of the areas being counted.

A previous comparison of aerial and ground counts of Magpie Geese in the Northern Territory (Bayliss and Yeomans 1990) showed that as little as half of the Geese counted from the ground were counted from the air. The differences in our counts of Magpie Geese were not as large overall and not statistically significant, although there was considerable variation, indicated by the spread values in Figure 3. For example in some wetlands, such as Cromarty, many Magpie Geese were difficult to detect from the air due to tree-cover around the margins. In almost all other wetlands in the region, trees rarely obscured the wetland margin. Overall, the aerial surveys are likely to provide a reasonable estimate of Magpie Geese abundance at most wetlands (Figure 2).

As noted earlier, aerial surveys detected more Brolga than counted from the ground (Table 4). This is not surprising as Brolgas were rarely seen feeding in open situations within the wetlands. Thus, they were not

as readily visible from the ground as the air. For this species, aerial surveys would appear to be the more accurate method of counting.

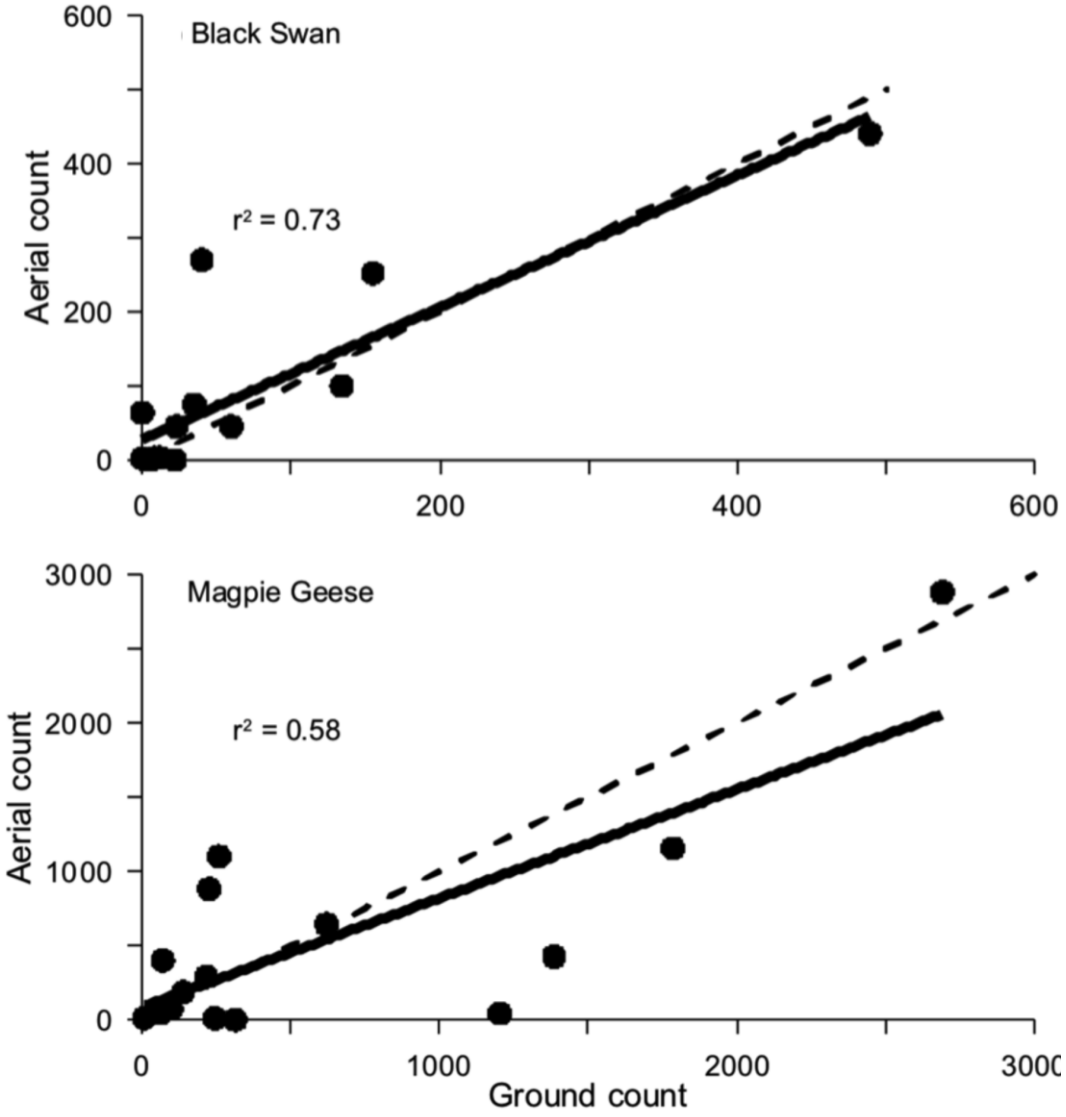

Figure 3. Ground counts plotted against aerial counts for Black Swan and Magpie Geese.
The counts for each species at four wetlands for each of the four field trips are plotted together with the line of best fit between aerial and ground counts, which is statistically significant (P< 0.001) for both species.

Calibrated aerial counts of all wetlands

The four sites where both ground and aerial counts were made can be used to calibrate aerial counts from elsewhere, to give a better representation of actual numbers of birds overall. As shown in the preceding section, aerial and ground counts of particular species are correlated. The best measure we have of this relationship is the ratio of ground to aerial counts from Table 4, which is the basis of the calibration that has been made to aerial counts generally. However, three different approaches were used depending upon the taxa.

These different categories of taxa are coded in Table 4 as follows and an explanation of the different calibration measures that are applied is given in Appendix C.

- Group “A” taxa:
  Species where considerable numbers were counted from both the air and the ground.

- Group “B” taxa, which includes subgroups:
  “dk” as ducks and grebes
  “eg” as herons, egrets, ibises
  “te” as terns and
  “pg” as the two species of pygmy geese
  Three of these species groups also includes counts of the respective “unidentified” category which applied only to aerial counts, that is unidentified duck, egret, or tern.

- Group “C” taxa
  Species that were very poorly represented in the aerial counts, usually because of their small size or cryptic nature, whereby they were difficult to see from the air.

A reasonable coverage of the extent of all wetlands was made from the air on each field trip and both spatial and seasonal comparisons have been made with the calibrated aerial counts.

Major wetlands

How aerial counts were grouped spatially to represent different wetland sites, and groups of sites is illustrated in Appendix B and tabulated in Appendix C. Thirty sites were used in seven site groupings. The four, principal groupings are indicated in Figure 2. Counts from these four groups together with the “unassigned” count category represent the vast majority of aerial counts over freshwater wetlands and the selected calibrated counts and subtotals are given in Figure 2. The “unassigned” are simply those records that could not be readily assigned on the basis of their locations to a particular wetland site (refer to Appendix B).

Almost all concentrations of waterbirds (including Magpie Geese) counted during this study were found outside the BGBRS (Figure 2, Figure 4 and Appendices B & C). A maximum of around 6,000 waterbirds were counted inside the BGBRS boundary in August compared to about 50,000 outside the boundary. This shows that the BGBRS is not supporting sufficient waterbird populations to meet the Ramsar criterion of 20,000 waterbirds. However, within 10 km there are about tenfold the number of waterbirds as are occurred within the BGBRS. These waterbirds are in the expansive freshwater systems of the subcoastal plains amongst agriculture lands.

The placement of these significant wetland sites is shown in Figure 2. As well, there is considerable widespread occurrence of waterbirds throughout the area with about 20% of counts not being assigned to specific sites. The area to the south west of the BGBRS, including the Cromarty wetlands, holds particularly large numbers of waterbirds including a high count of 17,000 waterbirds in August, 44% of which were at Cromarty. (Figure 2)

Waterbirds in the Colevale area were almost as abundant as in the south west but were not as consistently high on field trips after August. Significant numbers occur at a number of other locations, as shown in Figure 2.

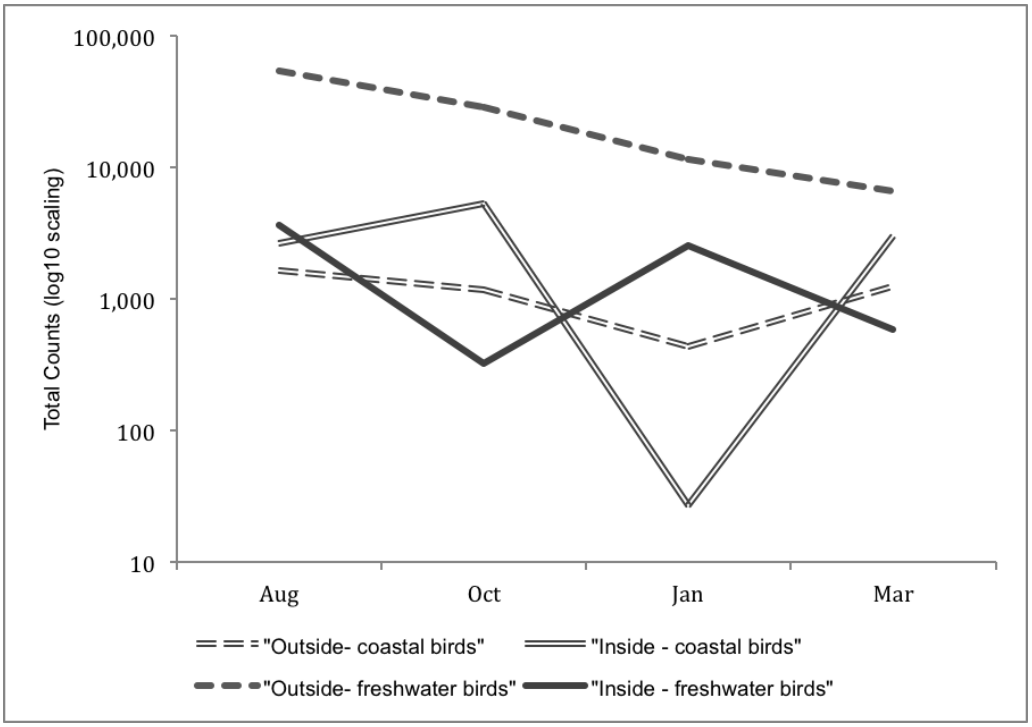

Figure 4. Total aerial counts of birds inside and outside the BGBRS for each survey.
Note the log scale on total counts and Refer to Appendix C for a species breakdown of the totals counts for each field trip between August 2011 and March 2012.

Seasonal changes in wetlands

The August aerial survey was more thorough than subsequent surveys. As a consequence, there is bias in the methods that would tend towards estimating larger numbers of birds in August. Nevertheless, a seasonal comparison of waterbird counts is useful because there were obviously dramatic changes occurring with a decline in numbers of most waterbird groups as the dry season advanced and the wet began (Figures 4 & 5). The number of Magpie Geese declined dramatically after the August survey, but stabilised and the total was similar for the remaining surveys. By comparison, the number of ducks showed a more dramatic decline that continued as wetlands dried and the wet season advanced (Figure 5).

There were few Brolgas in the region, compared to previous estimates made in the 1980s and early 1990s (Kelly and Lee Long 2011). The largest counts of Brolga were made in the northern Cromarty claypan and nearby grasslands (Figure 2). Elsewhere in the study area, Brolgas were present in pairs or small family groups. The total count in August was < 300 birds, suggesting that the previous estimates of 8,000 Brolga are unlikely to still occur in the region. Rainfall in northern Australia during both 2010 and 2011 was above the long-term average. Thus, there were large areas of suitable wetland and adjacent feeding habitat elsewhere that Brolga may have been using. Further aerial surveys in drier years are needed in order to be confident that this is the case. Ground surveys counted about half the number identified from the air. This suggests that aerial surveys were much more efficient at detecting and counting this species.

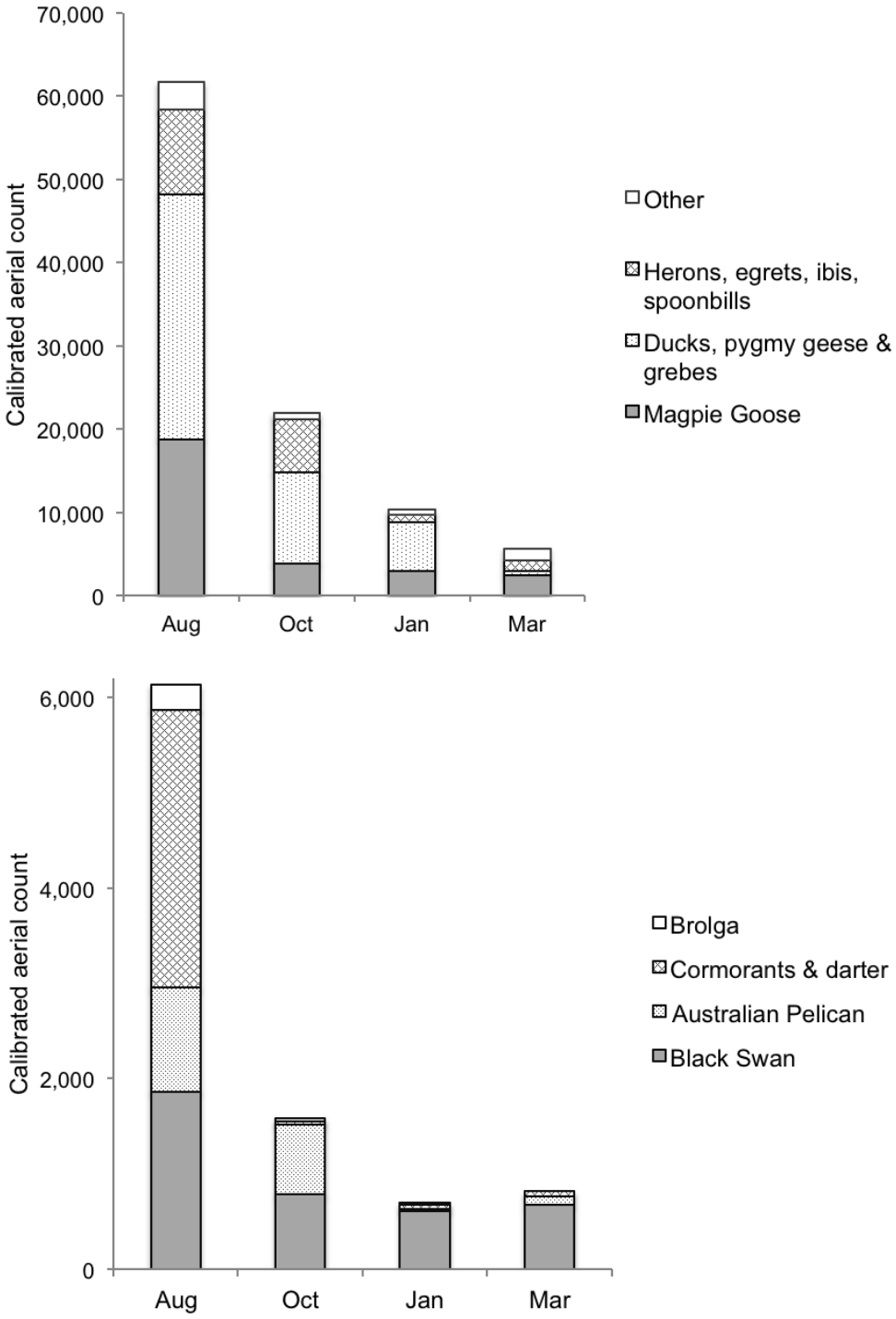

Figure 5. Seasonal aerial counts of different waterbirds groups.
Counts are from the four main areas and the "unassigned category" as given in Appendix C and depicted in Figure 2.

National and international significance of BGBRS

Shorebirds

There were 24 species of migratory and five species of resident shorebird seen within the BGBRS during coastal high tide roost surveys (Table 6). The maximum count of each species of migratory shorebird seen within the BGBRS and the number of locations each were seen during each survey varied widely. Only the Great Knot was counted in internationally significant numbers (> 1% of their Flyway Population Estimate (FPE)) within BGBRS during the four surveys for the current project. Two species (Black-tailed Godwit and

Red-necked Stint) were counted in internationally significant numbers during previous surveys of BGBRS (Table 6). These surveys were undertaken either by George Baker or other observers from BLT. On each occasion, the birds were observed at Cape Bowling Green during counts made with the assistance of DERM. Red-necked Stints were counted in internationally significant numbers on three occasions, including twice during 2011 (January and February).

During the actual study, three migratory and two species of resident shorebird were counted in nationally significant numbers at high tide roosts within BGBRS (>0.1% of FPE). Besides the internationally significant count records, a total of 13 species of migratory shorebird and two species of resident shorebird have been counted at least once, some on several occasions, in nationally significant numbers (Table 6). This confirms the regional importance of the BGBRS for migratory shorebirds, especially during both southward and northward migration.

Waterbirds

The best estimate of the maximum number of waterbirds in the study area at any one time (Figure 1) was 56,335 (Table 5). Pacific Black Duck were the most abundant waterbird counted during surveys, followed by Magpie Geese. Counts of Pacific Black Duck, Cotton Pygmy-goose, Eastern Great Egret and Royal Spoonbill exceed the 1% FPE (Delany and Scott 2006) and were internationally significant. All counts of waterbird species in internationally significant numbers only occurred outside the BGRS in nearby palustrine wetlands (Figure 2).

Table 5. The estimated maximum count of each species of waterbird.
The values are from the calibrated aerial counts for each field trip for the whole survey area (Appendix C) and the 1% FPE for each species is based on current waterbird population estimates (Delany and Scott 2006).

Species	Maximum	1% population estimate
Australasian Darter	141	1 000
Australasian Grebe	405	No est.
Australian Pelican	995	10 000
Australian White Ibis	176	10 000
Australian Wood Duck	302	10 000
Black Swan	1 333	10 000
Black-necked Stork	21	300
Brolga	258	1 000
Cattle Egret	636	10 000
Comb-crested Jacana	233	No est.
Common Tern	205	No est.
Cotton Pygmy-goose	113	100
Dusky Moorhen	40	No est.
Eastern Great Egret	1 748	1 000
Glossy Ibis	230	10 000
Green Pygmy-goose	204	1 000
Grey Teal	967	20 000
Gull-billed Tern	27	1 000
Hardhead	3 095	10 000
Intermediate Egret	3 149	10 000
Little Black Cormorant	2 351	10 000
Little Egret	278	1 000
Little Pied Cormorant	360	No est.
Magpie Goose	14 739	20 000
Pacific Black Duck	15 546	10 000
Pied Cormorant	7	No est.
Plumed Whistling-Duck	1 298	10 000
Purple Swamphen	32	1 000
Royal Spoonbill	2 529	1 000
Straw-necked Ibis	3	10 000
Wandering Whistling-Duck	4 119	10 000
Whiskered Tern	573	10 000

Species	Maximum	1% population estimate
White-faced Heron	135	No est.
White-necked Heron	42	1 000
White-winged Black Tern	4	No est.
Yellow-billed Spoonbill	41	1 000
Grand Total	56 335	

Counts of six waterbird species would qualify for national significance under the same criterion (0.1 % FPE). These species were Black Swan, Hardhead, Plumed and Wandering Whistling Ducks, Intermediate Egret and Little Black Cormorant). This clearly demonstrates the critical importance of these wetlands to at least 10 species of waterbird. Sustainable management of these wetlands on freehold and leasehold lands within 10 km of the BGBRS southern boundary is necessary to maintain the habitats necessary for these waterbird species. Our aerial survey methods were biased towards obtaining precise and accurate estimates of Magpie Geese and Brolga as requested in the contract. Thus, these estimates are highly likely to have under-estimated the populations of many of the other waterbirds, given the assumptions and potential biases in our approach (Kingsford 1999). These practical difficulties in obtaining more accurate and precise estimates merely further emphasize the importance of this region for at least 41 species of freshwater-inhabiting waterbirds (Table C1). The total abundance of waterbirds compares favourably with other similar sized wetlands in eastern Australia (Kingsford and Porter 2009). Indeed, the study area had one of the largest waterbird counts of eastern Australian wetlands after Lake Galilee and Currawinya Lakes. Additional surveys would confirm the relative importance of this region for waterbirds, or show that the survey counts were merely a result of recent above average rainfall.

Table 6. Shorebird counts from BGBRS from all known sources and their timing.
The status and flyway population estimate (FPE) of each species is shown. The estimated percentage of the FPE counted within BGBRS is shown for counts that were internationally (>1% FPE: bold) or nationally significant (> 0.1% FPE). The flyway population estimates are based on the draft IUCN Waterbird Population Estimates 5 (2012). The criterion for National significance was taken from the *EPBC* Act Draft Guidelines (2009). Sum = combined counts from one or more roosts made at the same time; Max = maximum count from any single roost; N = number of roosts counted during surveys made at the same time. (Mig: Migratory; Res: Resident)

Common name	Source	Observer	Month	Year	Sum	Max	N	Status	Flyway Popn estimate (FPE)	Percentage of FPE
Bar-tailed Godwit	Other	TRBOC	12	1996	2103	2103	1	Mig	325 000	0.65
	Survey	David Milton	8	2011	900	500	2			0.28
	Survey	Peter Driscoll	10	2011	432	300	3			0.13
	Other	George Baker	10	2010	400	400	1			0.12
	Survey	David Milton	1	2012	387	173	9			0.12
Beach Thick-knee	Other	Dez Wells	1	2001	4	2	2	Res	25 000	0.0002
Black-tailed Godwit	Other	TRBOC	12	1996	2058	2058	1	Mig	160 000	**1.29**
	Other	George Baker	11	2011	1047	1047	1			0.65
	Other	George Baker	1	2012	800	800	1			0.50
	Other	George Baker	12	2010	633	633	1			0.50
	Other	George Baker	10	2010	600	600	1			0.38
	Survey	David Milton	1	2012	450	300	2			0.28
Broad-billed Sandpiper	Other	Stuart Pell	10	1995	22	19	2	Mig	10 000	0.22
Common Greenshank	Other	Len & Chris Ezzy	6	2009	39	39	1	Mig	100 000	0.0004
Common Sandpiper	Other	Stuart Pell	11	1995	5	3	3	Mig	50 000	0.01
Curlew Sandpiper	Other	TRBOC	8	1999	660	660	1	Mig	180 000	0.37
	Other	George Baker	1	2011	573	572	2	Mig		0.32
Eastern Curlew	Other	George Baker	12	2009	97	96	2	Mig	38 000	0.26
	Other	George Baker	10	2010	92	89	2			0.24
	Other	Stuart Pell	11	1995	92	34	6			0.24
	Other	TRBOC	2	2008	76	64	2			0.20
	Survey	David Milton	10	2011	60	60	1			0.16
	Survey	David Milton	1	2012	58	40	6			0.15
Great Knot	Survey	Sandra Harding	1	2012	2925	1500	5	Mig	290 000	**1.01**
	Other	TRBOC	2	2008	2225	1690	2			0.77

Common name	Source	Observer	Month	Year	Sum	Max	N	Status	Flyway Popn estimate (FPE)	Percentage of FPE
	Other	TRBOC	3	2008	1933	1933	1			0.67
	Other	Len Ezzy	12	2010	1700	1700	1			0.59
	Other	TRBOC	12	1996	1516	1516	1			0.52
	Other	George Baker	11	2011	1443	1295	2			0.50
	Survey	David Milton	1	2012	1400	750	3			0.48
	Other	Stuart Pell	10	1995	1183	702	3			0.41
	Other	Len& Chris Ezzy	2	2009	1100	1100	1			0.38
	Other	George Baker	12	2009	1050	850	2			0.36
	Other	Len Ezzy	3	2009	1020	1020	1			0.35
	Other	TRBOC	3	1999	1000	1000	1			0.34
	Survey	Peter Driscoll	10	2011	800	800	1			0.28
	Other	Len Ezzy	3	2011	710	710	1			0.24
	Other	TRBOC	10	1998	700	700	1			0.24
	Other	Dez Wells	3	2001	650	650	1			0.22
	Other	TRBOC	4	2008	532	532	1			0.18
	Other	Len & Chris Ezzy	1	2010	524	524	1			0.18
	Other	TRBOC	12	1997	448	448	1			0.15
	Other	George Baker	12	2010	402	402	1			0.14
	Other	George Baker	1	2012	400	400	1			0.14
	Other	George Baker	10	2010	400	400	1			0.14
	Other	Stuart Pell	11	1995	355	345	3			0.12
Greater Sand Plover	Other	George Baker	1	2011	670	545	2	Mig	100 000	0.07
Grey Plover	Other	Dez Wells	3	2001	116	116	1	Mig	125 000	0.09
Grey-tailed Tattler	Other	TRBOC	11	1998	125	125	1	Mig	50 000	0.25
Lesser Sand Plover	Other	TRBOC	9	2001	368	368	1	Mig	60 000	0.61
	Other	Dez Wells	1	2000	320	320	1			0.53
	Other	TRBOC	8	1999	222	222	1			0.37
	Other	Dez Wells	10	1999	205	205	1			0.34
	Survey	Sandra Harding	10	2011	180	150	2			0.30

Common name	Source	Observer	Month	Year	Sum	Max	N	Status	Flyway Popn estimate (FPE)	Percentage of FPE
	Other	TRBOC	11	1997	150	150	1			0.25
	Other	TRBOC	12	1998	150	150	1			0.25
	Survey	Peter Driscoll	10	2011	150	150	1			0.25
	Other	George Baker	1	2011	135	135	1			0.23
	Other	Len Ezzy	12	2010	120	120	1			0.20
	Other	Dez Wells	12	1999	114	114	1			0.19
	Other	Dez Wells	5	2000	111	101	2			0.19
	Other	Dez Wells	12	2000	102	102	1			0.17
	Other	TRBOC	12	1996	98	98	1			0.16
	Other	TRBOC	1	2000	96	96	1			0.16
	Other	Len & Chris Ezzy	1	2010	79	79	1			0.13
	Other	TRBOC	7	1999	69	69	1			0.12
Little Curlew	Other	Stuart Pell	11	1995	6	5	2	Mig	180 000	0.003
Marsh Sandpiper	Survey	Peter Driscoll	10	2011	65	65	1	Mig	100 000	0.06
Masked Lapwing	Survey	Peter Driscoll	3	2012	38	38	1	Res	100 000	0.04
Pacific Golden Plover	Other	Dez Wells	1	2000	38	29	2	Mig	100 000	0.04
Pied Oystercatcher	Other	TRBOC	2	2008	61	42	2	Res	11 000	0.55
	Other	Len Ezzy	3	2011	32	32	1			0.29
	Other	Len Ezzy	1	2011	25	25	1			0.23
	Other	TRBOC	3	2008	21	21	1			0.19
	Survey	David Milton	1	2012	14	4	6			0.13
Red Knot	Other	Len Ezzy	12	2010	251	251	1	Mig	105 000	0.24
	Other	TRBOC	2	2008	189	169	2			0.18
	Other	TRBOC	12	1996	180	180	1			0.17
	Other	TRBOC	3	2008	175	175	1			0.17
	Other	Len Ezzy	3	2009	160	160	1			0.15
Red-capped Plover	Other	TRBOC	2	2008	226	208	2	Res	35 000	0.65
	Other	TRBOC	8	1999	200	200	1			0.57
	Other	Dez Wells	8	2000	108	77	3			0.31

Common name	Source	Observer	Month	Year	Sum	Max	N	Status	Flyway Popn estimate (FPE)	Percentage of FPE
	Other	Stuart Pell	10	1995	105	80	2			0.30
	Other	Dez Wells	1	2000	91	50	3			0.26
	Other	George Baker	12	2009	81	80	2			0.23
	Other	TRBOC	12	1996	71	71	1			0.20
	Other	Stuart Pell	11	1995	66	29	4			0.19
	Other	Dez Wells	10	1999	58	58	1			0.17
	Survey	David Milton	1	2012	58	20	5			0.17
	Other	Dez Wells	3	2001	50	50	1			0.14
	Other	Dez Wells	12	1999	50	50	1			0.14
	Other	Dez Wells	12	2002	45	45	1			0.13
	Survey	Sandra Harding	10	2011	42	22	2			0.12
	Other	TRBOC	9	2001	37	37	1			0.11
Red-necked Stint	Other	George Baker	1	2011	6403	6278	2	Mig	315 000	**2.03**
	Other	George Baker	2	2011	6280	3360	2			**1.99**
	Other	TRBOC	8	1999	4598	4598	1			**1.46**
	Other	George Baker	2	2010	1980	1980	1			0.63
	Other	TRBOC	7	1999	1862	1862	1			0.59
	Other	TRBOC	12	1998	1840	1840	1			0.58
	Other	TRBOC	2	1998	1655	1655	1			0.53
	Other	George Baker	10	2010	1560	660	3			0.50
	Other	Ian Clayton	2	1998	1455	1455	1			0.46
	Other	TRBOC	2	2000	1398	1398	1			0.44
	Other	Rosemary Payet	2	1999	728	728	1			0.23
	Other	TRBOC	2	1999	728	728	1			0.23
	Other	George Baker	1	2012	658	333	2			0.21
	Other	TRBOC	12	1997	638	638	1			0.20
	Other	TRBOC	3	2008	545	545	1			0.17
	Other	George Baker	8	2010	510	255	2			0.16
	Other	TRBOC	10	1998	470	470	1			0.15

Common name	Source	Observer	Month	Year	Sum	Max	N	Status	Flyway Popn estimate (FPE)	Percentage of FPE
	Other	TRBOC	9	2001	430	430	1			0.14
	Other	TRBOC	10	1996	413	413	1			0.13
Ruddy Turnstone	Other	TRBOC	10	1996	4	4	1	Mig	35 000	0.01
Sanderling	Other	TRBOC	12	1998	15	15	1	Mig	22 000	0.07
Sharp-tailed Sandpiper	Other	George Baker	11	2011	1488	1384	2	Mig	160 000	0.93
	Other	TRBOC	8	1999	1150	1150	1			0.72
	Survey	Peter Driscoll	10	2011	400	155	4			0.25
	Other	TRBOC	9	2001	397	397	1			0.25
	Other	George Baker	10	2010	300	300	1			0.19
	Other	Len & Chris Ezzy	1	2010	234	234	1			0.15
Sooty Oystercatcher	Other	Dez Wells	8	2000	2	2	1	Res	4 000	0.05
Terek Sandpiper	Other	TRBOC	2	2008	179	177	2	Mig	50 000	0.36
Whimbrel	Other	TRBOC	2	2008	76	62	2	Mig	55 000	0.13
	Other	Stuart Pell	11	1995	61	25	6	Mig		0.11

Defining Limits of Acceptable Change (LACs) for shorebirds and waterbirds in BGBRS

Background

The ecological character description (ECD) of the BGBRS identified avifauna (waterbirds and shorebirds) as one of the critical components of the ecological character of the BGBRS (Kelly and Lee Long 2011). The relevant criteria for the shorebirds and waterbirds are criteria 5 and 6.

Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

Criterion 6: A wetland should be considered internationally important if it regularly supports one or more percent of the individuals in a population of one species or subspecies of waterbird.

In order to define the Limits of Acceptable Change (LAC) for these criteria, some definitions of the wording is needed. Under Criterion 6, the term "regularly" can refer to as infrequently as once every five years (Kelly and Lee Long 2011). This presumably also holds for the same term in Criterion 5.

The ECD requires the best indicators of the critical ecosystem services components and processes within BGBRS to be identified. Kelly and Lee Long (2011) recognised that some of the most appropriate indicators may be difficult to quantify and that surrogate indicators may be needed. Where data exist, they identified three types of indicators that may be used.

1. Related to the natural range of variation around a baseline mean value; e.g., acceptable variation in a population or a water quality parameter;
2. Known ecological tolerance or thresholds; e.g., threshold breeding population sizes required to maintain or recover stocks; physiological tolerance limits of species; toxicity thresholds; or
3. Qualitative descriptions of ecosystem function or ecological state; e.g., particularly where empirical data is insufficient yet expert agreement asserts that ecological character has changed from one state to another.

For shorebirds, the first indicator would seem the most relevant as the majority of shorebird populations within the BGBRS do not breed there. The use of expert opinion alone (indicator type 3) should only be used as a last resort. For waterbirds, LAC indicators may include both the first and second type of indicator or a surrogate of them.

Limits of Acceptable Change may be determined to be 'the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland' (DEWHA 2008). Thus, Kelly and Lee Long (2011) state "The Limits of Acceptable Change may equal the natural variability or may be set at some other value" and be based on quantitative data collected by a monitoring program. For shorebirds and waterbirds, this can be feasibly achieved through a combination of aerial and ground surveys, such as undertaken in this project.

The ECD report provides some suggested indicators for monitoring the state of the shorebird and waterbird populations. For shorebirds and waterbirds they recommend two related indicators – presence and numbers of shorebirds at Cape Bowling Green; presence and numbers of Magpie Geese and Brolga within BGBRS and maintenance of critical wetland habitats.

Shorebirds

A total of 152 surveys of at least one high tide roost have been made within BGBRS since the mid-1990s (Table 2). As noted in the ECD, these counts have not been made in any systematic way and no effort was made to undertake coordinated counts of multiple roosts within a short period of time. This makes these data difficult to use to identify trends in counts that might be the basis of quantitative, ecologically relevant LACs for shorebirds

The simplest LAC that could be applied would be to confirm that each species continue to use the site. This would be easily feasible if regular (at least annual) surveys were made during the main non-breeding period for migratory shorebirds, including those species present in nationally and internationally significant numbers. If a species was not detected during a survey, then we can estimate the confidence we can have that the species was not present (Table 3). The analysis shows that for about 75% of the 35 species seen during the project, a failure to detect them would signal a real absence from BGB. Only one migratory shorebird (Red Knot) and the threatened Beach Stone Curlew were present in small numbers. Failure to detect these species during a survey may not mean they do not still occur in BGB.

A better index of population status, from which to determine the LAC of the shorebirds that occur in internationally significant numbers (Black-tailed Godwit, Great Knot and Red-necked Stint) would be the plots in their counts (Figure 6). The first thing that is apparent from the trends in these counts is that they are highly variable between years. This would make detecting a declining trend almost impossible without substantially increased sampling effort.

The temporal patterns in the count records varied among species – the numbers of Black-tailed Godwit counted most years were relatively small. For the 23 records of Black-tailed Godwit made since 1995, there has only been one of internationally significant numbers. This occurred in 1996, which indicates that the Ramsar definition of the BGBRS “regularly” holding these numbers of Godwit is not being met as “regularly” is defined to be once every five years (Kelly and Lee Long 2011). Given the apparently low frequency of these large counts, it will be impossible to measure a change in Black-tailed Godwit numbers that could be attributed to a change in the Ecological Character of the BGBRS. Indeed, it is questionable whether Black-tailed Godwit should be recorded as being present in internationally significant numbers.

The data for Great Knot suggests that there is greater potential to be able to measure and detect a change in their abundance that may be related to a change in the Ecological Character of the BGBRS (Figure 6). Unlike Black-tailed Godwits, Great Knot were distributed throughout the coastal region of the BGBRS. They can occur in substantial numbers on either side of BGB within the same season (Table 3). A complete survey of BGB would be needed during any monitoring in order to have confidence that the entire BGB population of Great Knot was being counted. Surveys of only part of BGB are unlikely to count the entire population. These regular movements within BGB may also include flights to foraging habitats outside BGB. We have limited data with which to understand the regional and seasonal movements of Great Knot. Large numbers of Great Knot are regularly counted at high tide roosts both north of BGB at the Ross River mouth in Cleveland Bay (Driscoll 1997) and south in the Burdekin River delta (Table A2). The frequency, timing and extent of any movements between these regions by Great Knot are unknown. Improved understanding of the distribution and abundance of Great Knot in BGBRS through more comprehensive surveys could provide sufficient data to develop an LAC for shorebirds. Information on shorebird numbers including the Great Knot could be evaluated within the context of the condition of high tide roosts, as evidenced by regular fixed-point photographic records.

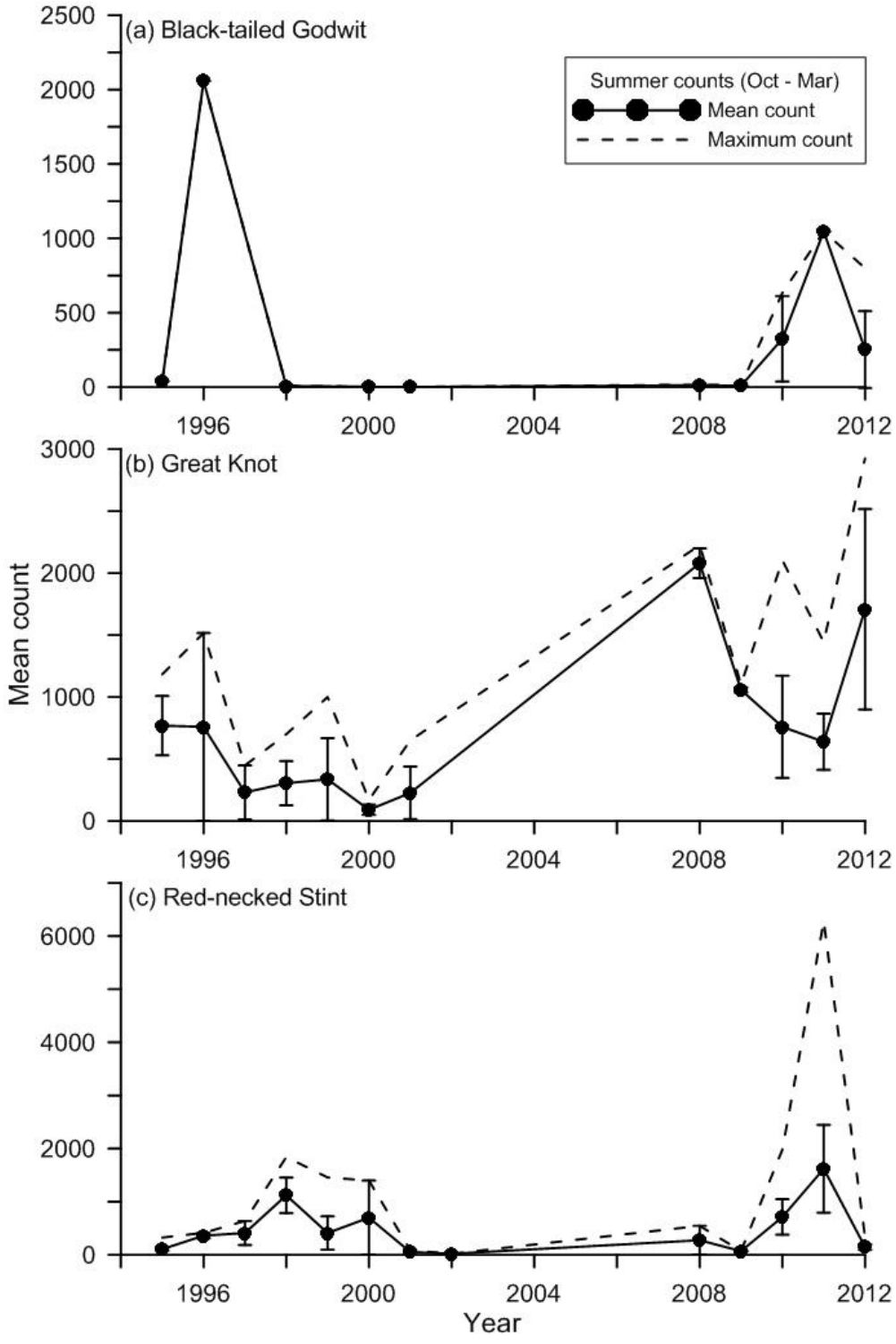

Figure 6. Plot of mean annual counts of Black-tailed Godwit, Great Knot and Red-necked Stint.
The means are shown with ± se and maximums (dashed) for non-breeding season counts (Oct – Mar). All three species have been counted in internationally significant numbers within the BGBRS.

The pattern of use of coastal high tide roosts in the BGBRS by Red-necked Stint is also highly variable (Figure 6). There have been 57 records of Red-necked Stint at coastal high tide roosts within BGBRS, which includes internationally significant numbers during two periods, Aug 1999 and Jan – Feb 2011. Some concerns have been raised about the methods used for these observations and there is some doubt that such numbers have truly been a reflection of number on the ground. This is mostly due to the total numbers being an extrapolation of counts from images taken at sea level.

During our fieldwork in the region, we identified several seasonally inundated saline wetlands, such as Alva Beach claypan (ALVC) that were used by large numbers of Red-necked Stint (Table 2). Our counts of ALVC from the ground only sub-sampled the available habitat in this wetland (approximately 23%). Thus, it does not provide an estimate of the total number of Red-necked Stint that were present. We counted 266 Red-necked Stint, which suggests that the total Red-necked Stint count would have been about 1100 birds. Adding this estimate to the Red-necked Stint counts from other roosts would have still not made the total more than 1500 birds for that survey period (October 2011). This is well short of the 3100 birds needed to qualify for 1% of the flyway population. However, it suggests that there may be periods when the region attracts substantial numbers of Red-necked Stint. These birds could congregate at high tide roosts on Cape Bowling Green under ideal conditions. Thus, the large counts made by previous observers are feasible but require further confirmation. Regular aerial surveys of the sub-coastal wetlands between Alva and the BGBRS during the non-breeding season would be needed to better understand the extent and timing of the use of these habitats by Red-necked Stint. Thus, it would appear to be almost impossible to monitor Red-necked Stint numbers in the BGBRS with sufficient precision to detect a change in numbers attributable to a modification of the Ecological Character of the BGBRS.

The Great Knot was identified in internationally significant numbers in BGBRS for the first time during the current survey. We also found that the Great Knot population was very mobile within the BGBRS. The main concentrations moved between the western and eastern parts of the BGBRS on sequential surveys. BLT members do not currently monitor most of the high tide roosts occupied by Great Knot in the BGBRS. This is because they are only accessible by boat or by lengthy walks along the western foreshore. For this reason, no formal assessment was made of the trend in the numbers of Great Knot from existing data.

Given the inherent difficulties in quantifying changes in the numbers of the three internationally-significant populations of shorebirds, less robust measures of changes in the Ecological Character (as they affect shorebirds and waterbirds) need to be considered but possibly as management options rather than LAC's. One option could be to combine regular monitoring surveys for shorebirds and waterbirds with fixed photographic positions from which annual images could be taken from the same aspect and direction. This approach has been used elsewhere in wetland condition monitoring. It can provide some insight from which to examine habitat changes in detail, should counts of shorebirds change dramatically (> 50%) between surveys. In many cases, these images will be able to quickly show that dynamic coastal processes such as erosion and deposition have been the most likely cause of changes in coastal high tide roost use. Similar fixed position photographs could be considered for intertidal habitats if land use or water practices change in the catchments of the BGBRS.

Waterbirds

Identifying quantitative indices for LACs to the Ecological Character of the BGBRS that is relevant to waterbirds is even more challenging than for shorebirds. As noted above, about 90% of the waterbirds surveyed during the study were found outside the BGBRS (Table C1). Thus, management of the BGBRS alone will potentially have limited measurable effect on the relevant Ecological Characters important to waterbirds.

The important wetlands for waterbirds are all within 10 km of the BGBRS and the waterbirds are likely to use wetlands in the BGBRS at different times and under different environmental conditions (Ma et al. 2010). Thus, management of the entire wetland complex is needed to sustain the current waterbird population. During this study, we saw regular and widespread movements by large flocks of Magpie Geese on a daily basis from freshwater wetlands onto other suitable habitats including agricultural areas (Bayliss and Yeomans 1990a). Wetlands in the BGBRS were used as part of these movements. This highlights the integrated nature of the system and the importance of managing it holistically.

Given the need to manage the BGBRS and adjacent wetlands as a single system, identifying LACs for waterbirds is severely hampered by a lack of data. The current study has provided a baseline population count for the species of waterbird detected. In order to develop relevant LACs for waterbirds, further surveys are needed in years with different rainfall regimes in order to identify the critical waterbird habitats and wetlands. These surveys need to be timed for later in the dry season (August – September) prior to many wetlands drying completely. A suitable water depth is one of the main determinants of waterbird use of a wetland (Ma et al. 2010). In dry years, surveys may need to be undertaken in July to ensure there is sufficient water to support the maximum waterbird population.

The data collected in this study will provide a sound basis by which to identify the critical habitats for waterbirds in the region. Waterbird nesting and refugial habitats were surveyed during the project, with waterbird numbers being much higher at the time when wetlands were generally contracting (mid-late dry season). High resolution, remotely-sensed images can be classified into vegetation types and overlaid with the location fixes for the waterbirds counted in this study. One feasible measure of the Ecological Character would be the area of each habitat type present. The analysis could focus on the numerically abundant species, those in internationally significant numbers or of conservation concern. Taking the satellite images at the same time as undertaking a complete aerial waterbird survey would strengthen the utility of the approach and help verify that the more important habitats have been identified and measured. Changes in the quantity of these habitat types by more than an agreed nominal amount (e.g. 30%) could trigger further on-ground surveys in the areas where the habitat has been lost. This would determine the attributes of that habitat that had been lost and the cause. In many cases, remedial works could be undertaken quickly to restore the wetland values.

Monitoring shorebirds and waterbirds in the BGBRS

Shorebirds

The monitoring of shorebirds to detect a measurable LAC for at least Black-tailed Godwit and Red-necked Stint in internationally significant numbers in the BGBRS appears to be logistically impossible with the current or likely level of resourcing. Despite the difficulty in detecting changes in counts, there are clear benefits of undertaking regular surveys of all shorebird roosts within the BGBRS. As shown in Table 3 above, a failure to detect any of the major shorebird species expected to be present can be treated with confidence as a real absence. Continued occurrence of the species identified to be present in internationally or nationally significant numbers would be proven. A complete survey would also verify that all high tide roosts are viable. This would help link the recommended fixed photography of each roost with the counts and increase the understanding of the movement patterns of shorebirds within BGB. Shorebird surveys are inherently variable and have weak power to detect trends (Wilson et al. 2011). However, complete surveys of BGB would reduce the variability that is present in the counts made during the current surveying undertaken by BLT in collaboration with DERM. The current monthly survey routine does have some value, especially for detecting and counting one of the species present in internationally-significant number: Black-tailed Godwit. However, it does not adequately sample the other two species in internationally significant numbers – Great Knot or Red-necked Stint. Boat-based surveys of all BGB coastal roosts are needed for Great Knot as this study has shown they move widely within BGB on a regular basis. Additional comprehensive surveys of BGBRS have the potential to provide sufficient data to develop a suitable LAC for shorebirds by improving understanding of the distribution and abundance of Great Knot. Especially, when evaluated within the context of high tide roost condition, as evidenced by regular fixed point photographic records. For Red-necked Stint, concurrent additional aerial or ground surveys of the sub-coastal wetlands south east of the BGBRS are desirable. The timing of any survey should also be optimised. Pre-wet season surveys (October – December) have the highest probability of detecting the largest Black-tailed Godwit and Great Knot populations, based on the existing data. A

complete survey at this time would also have a high probability of detecting any large populations of Red-necked Stint feeding on the sub-coastal wetlands.

Waterbirds

Monitoring waterbirds at the same time as the shorebirds would be sub-optimal as their numbers in the region vary greatly with water levels in the wetlands. In 2011, the majority of wetlands were dry when we made the October survey. Only about a third of the number of waterbirds counted in August were present (Figure 5). Thus any waterbird survey should be undertaken during the period as the wetlands are drying (July – September). Exact timing would be based on monitoring of the water levels in the four most accessible wetlands (Table 4). Similar to shorebirds, a combination of both aerial and ground surveys are needed to obtain precise and accurate counts of the majority of the waterbird species (Table 7). Regular ground surveys of these four wetlands by DERM staff or BLT members as part of a monitoring program should be encouraged. These data will provide valuable calibration for any aerial surveys of the entire region. They will also contribute greatly to improving the accuracy and precision of any remotely-sensed habitat mapping, as recommended under the LAC section above. A thorough aerial survey with a single plane would need a minimum of six hours flying time (Table 7). Most suitable light aircraft only have a limited range and can remain airborne for about three hours. This coincides well with the concentration span of most observers undertaking surveys of large freshwater wetland complexes.

Table 7. Strategic monitoring program for shorebirds and waterbirds.
Monitoring is within the BGBRS and in adjacent freshwater wetlands to detect LAC in bird populations or habitats.

Bird group	Timing	Survey method & time required	Additional habitat data
Shorebirds	Oct– Dec every 2 years	Boat-based survey on spring high tide (3.2 – 3.4 m) (2 days)	Fixed point digital habitat image of each roost
		Aerial survey of sub-coastal wetlands south-east of BGBRS (2 hrs)	Digital aerial image of wetlands where shorebirds were detected
		Ground counts of sub-coastal wetlands where aerial surveys detected shorebirds (1 day)	
Waterbirds	Jul – Sep every 2 years	Complete aerial survey of freshwater wetlands north of Ayr (approx. 6 hours air time)	High resolution satellite image to be classified and compared with the habitat classification made based on positional fixes obtained from the baseline survey undertaken in this study
	Jul – Sep every year	Multiple ground counts of the four calibration wetlands – Carrick Lagoon, Horseshoe Lagoon, Cromarty wetlands and Jerona Rd Lagoon (1 day)	Fixed point digital habitat image of each wetland on each visit

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6. APPENDICES

Appendix A: Surveys of Burdekin River delta

During the October 2011 and January 2012 surveys, one day was allocated to undertake ground counts of a number of shorebird roosts in the Burdekin River delta. These roosts were either known from the survey by Pell and Lawler (1996) or from an aerial reconnaissance made during the August 2011 field trip. A total of 14 high tide roosts were identified across the four entrances to the Burdekin River delta (Figure A1). Most were found in the vicinity of the two larger southern entrances (Table A1). Only the three northern roosts on Plantation Creek were not visited during the ground surveys. The remaining 11 roosts were visited at least once in either October or January. The species breakdown of counts from the earlier work and from two field trips from this study is given in Table A2.

Large numbers of shorebirds were found at the two main roosts around the southern entrances to the Burdekin River. Almost 10,000 shorebirds were counted during the October 2011 survey (Table A1), with over 6,000 shorebirds counted at one roost. These numbers of shorebirds are much larger than found within the entire BGBRS.

Table A1: Site names, locations, total counts and number of visits for the lower Burdekin River Delta. The table gives the total number of birds seen at each shorebird roost (shorebirds, terns and waterbirds combined) during each field visit and during previous visits. The number of visits (or previous visits) to each shorebird roost is shown in brackets.

Site	Latitude	Longitude	Other	Field Trip		Total
				2	3	
BUA1 - Burdekin Anabranch 1	-19.6017	147.5767	444 (2)	–	31 (1)	475 (3)
BUA2 - Burdekin Anabranch 2	-19.6312	147.5744	2197 (3)	41 (1)	9 (1)	2247 (5)
BUA3 - Burdekin S Anabranch nth bank	-19.6267	147.5797	–	20 (1)	41 (1)	61 (2)
BUR1 - Burdekin River 1	-19.6872	147.6151	1681 (1)	–	322 (1)	2003 (2)
BUR2 - Burdekin River 2	-19.6475	147.6014	4004 (2)	721 (1)	2286 (1)	7017 (4)
BUR4 - Burdekin River 4	-19.7016	147.5976	68 (1)	–	2 (1)	70 (2)
BUR5 - Burdekin River 5	-19.6697	147.6111	622 (1)	6076 (1)	2455 (1)	9183 (3)
BUR6 - Burdekin R N entr.N sandbank	-19.6424	147.5896	–	252 (1)	68 (1)	320 (2)
BUR7 - Burdekin R S anabranch entr. isl. centre	-19.6357	147.5898	–	1618 (1)	41 (1)	1659 (2)
BUR8 - Burdekin R S anabranch entr. isl. N side	-19.6301	147.5886	–	1078 (1)	165 (1)	1243 (2)
BURT - Burdekin mouth tree roost	-19.6480	147.5896	–	45 (1)	1 (1)	46 (2)
PLA1 - Plantation Creek 1	-19.5381	147.5397	655 (2)	–	–	655 (2)
PLA2 - Plantation Creek 2	-19.5431	147.5097	59 (1)	–	–	59 (1)
PLAN - Plantation Creek	-19.5267	147.5467	267 (1)	–	–	267 (1)
Grand Total			9995(14)	9851(8)	5421(11)	25267(33)

Table A2: Total counts for each species and survey for the lower Burdekin River Delta. The total count of shorebirds, waterbirds and raptors during three surveys of the high tide roosts in the Burdekin River delta (refer above). The counts of shorebirds in internationally significant numbers are highlighted in **bold**.

Species	Nov 1995	Oct 2011	Jan 2012
Australian Darter	–	2	–
Australian Pelican	–	17	28
Bar-tailed Godwit	305	241	568
Black-necked Stork	–	2	–
Broad-billed Sandpiper	8	–	–
Black-tailed Godwit	–	20	10
Brahminy Kite	–	1	1
Caspian Tern	–	71	47
Common Greenshank	41	–	7
Common Sandpiper	4	–	–
Common Tern	–	80	750
Crested Tern	–	107	117
Curlew Sandpiper	192	147	1
Eastern Curlew	100	307	155
Great Knot	2302	2052	1145
Greater Sand Plover	490	**1760**	1279
Grey Plover	13	58	36
Grey-tailed Tattler	14	48	–
Gull-billed Tern	–	39	–
Lesser Crested Tern	–	42	–
Lesser Sand Plover	3858	**912**	91
Little Curlew	1	–	–
Little Egret	–	2	–
Little Pied Cormorant	–	2	2
Little Tern	–	526	272
Pacific Golden Plover	125	–	–
Pied Cormorant	–	2	–
Pied Oystercatcher	24	4	21
Red Knot	9	150	100
Red-capped Plover	114	203	19
Red-necked Stint	1381	1334	118
Ruddy Turnstone	17	7	2
Sanderling	15	29	–
Sharp-tailed Sandpiper	757	1557	181
Silver Gull	–	24	12
Terek Sandpiper	114	84	209
Whimbrel	111	21	244
Whistling Kite	–	–	6
TOTAL	9995	9851	5421

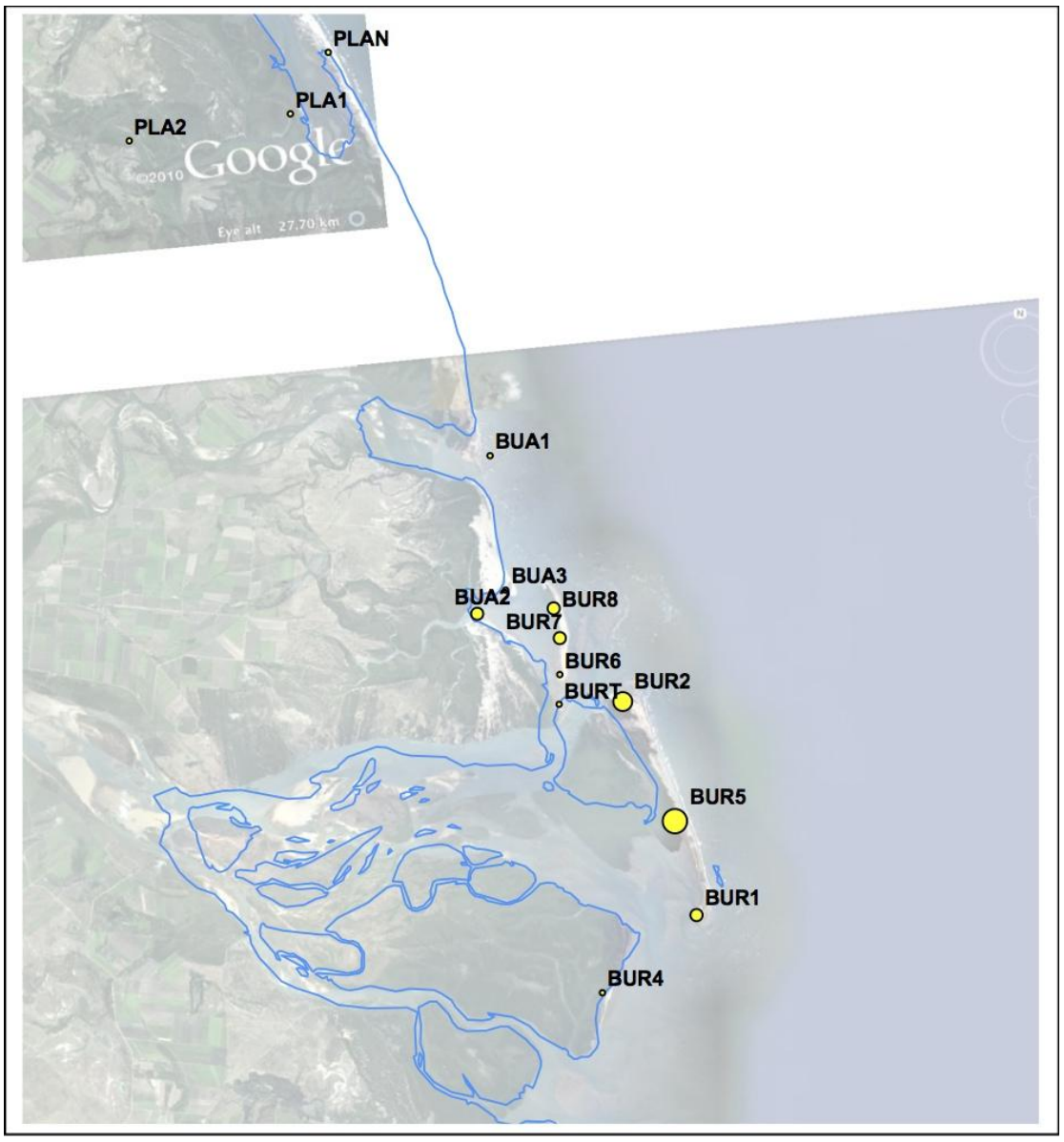

Figure A1: Burdekin roost sites. Refer to previous tables.

Appendix B: Aerial count grouping into sites and site groups

Table B1 below gives names to the sites numbered in Figure B1. It also shows the grouping of the sites that has been the basis of data presentation given in the body of the report and in Appendix C.

The aerial counts were given locations approximate to the position of the plane when taken down in written notes or on tape recorder. Therefore, the positioning will not match precisely where the birds were at the time. Figure B1 shows the spread of count and how they were grouped for analysis. Grouping was done subjectively on later inspection of the counts in relation to one another and known wetland features. All count records that were assigned to sites are given as circles in Figure B1, whereas all other records are indicated with crosses (unassigned counts in Appendix C). The coastline bird count records are indicated with triangles.

Table B1. Place names & reference numbers, group allocation and group names for places shown in Figure B1.

Place Name	Place type	Roost site match	Group	Group Name
unassigned			0	unassigned
Ross River Dam	W		1	Ross River Dam
Cromarty	W	CROM	2	South-eastern Wetlands
Horseshoe Lagoon	W	HORL	2	South-eastern Wetlands
Carrick lagoon	W	CARR	2	South-eastern Wetlands
Alligator Creek lagoons	W		2	South-eastern Wetlands
Reed Bed lagoons	W		2	South-eastern Wetlands
North Cromarty claypan fringe	W		2	South-eastern Wetlands
Jerona lagoon	W	JERL	3	Southern Wetlands
North Brandon lagoons	W		3	Southern Wetlands
Lochinvar lake	W		3	Southern Wetlands
Barrata connection east	W		3	Southern Wetlands
East Colevale claypan links	W		4	Colevale Wetlands
North Colevale complex	W		4	Colevale Wetlands
Colevale billabongs	W		4	Colevale Wetlands
East Colevale channels	W		4	Colevale Wetlands
Beach Rd lagoon	W		5	Alva Wetlands
Jack Rd lakes	W		5	Alva Wetlands
Gainsford shallow lagoons	W		5	Alva Wetlands
Alva Beach Claypan	R	ALVC	6	Coastal strip
Alva Beach Sandspit	R	ALV1	6	Coastal strip
Salmon Creek mouth	R	BSCK	6	Coastal strip
Black Soil Creek mouth	R	CHU1	6	Coastal strip
Haughton River mouth	R	HRSS	6	Coastal strip
Barramundi Ck coast	R	BAR1	6	Coastal strip
Barratta Ck mouth	R	BTTA	6	Coastal strip
Bowling Green Bay mid coast	R	BGB3	6	Coastal strip
Bowling Green Bay east coast	R	BGB1	6	Coastal strip
Cape Bowling Green shorelines	R	CAE2	6	Coastal strip
Mud Creek spit	R	MUDC	6	Coastal strip
Burdekin River mouth	R	BUR1	7	Burdekin River mouth
Out of range			99	out of range

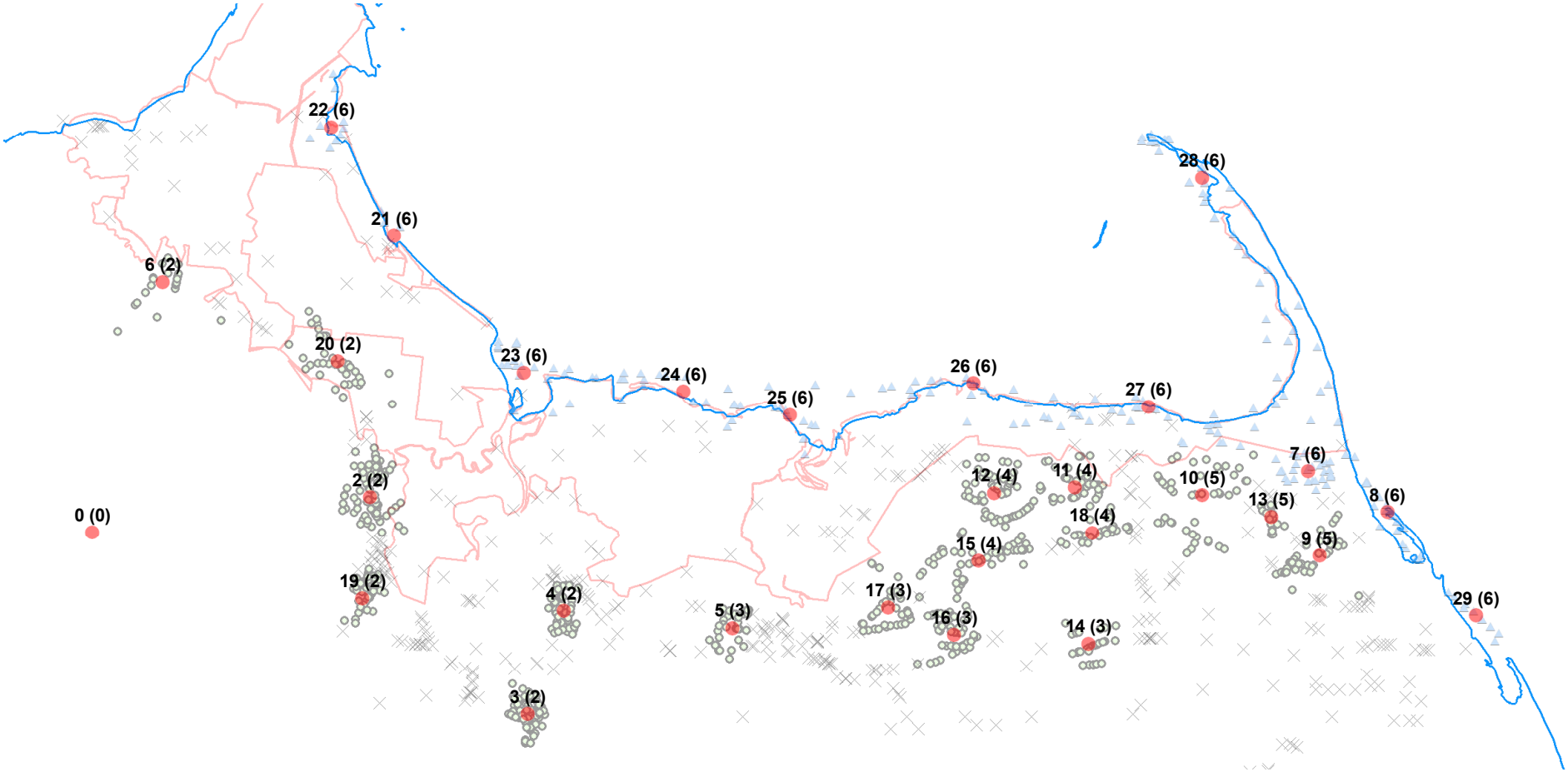

Figure B1: Aerial record locations as positions of the plane when the record was taken. Crosses indicate count records not unassigned to groups. Site (or place) names are indicated beside the red dots and referenced in Table B1. The number in brackets indicates the site grouping to which a site (or place) belongs. Triangles are all group 6 counts and were primarily reconnaissance counts in preparation for on-ground follow-up at high tide roost sites. None of these latter records were calibrated for analysis. All other records shown here have been calibrated.

Appendix C: Tables of calibrated aerial counts

The calibrated aerial counts for each species are given below (Table C2) as values for each field trip and wetland site grouping, using four major site groups and the unassigned counts (crosses in Figure B1). The coastline bird counts (primarily near high tide shorebird roost sites Group 6) are not included in this tabulation. However, the data from this table and for the coastline bird counts (Group 6) are included in the assessment of numbers of birds recorded inside and outside of the Ramsar boundary (Table C1). Neither Table C1 nor C2 include aerial counts made from the Ross River Dam or the Burdekin River area.

Calibration was based upon establishing a relationship between aerial counts and ground counts for different groups of species and using this relationship to estimate the actual bird count locations where only aerial counts were available. The sites and approach used for the calibration is described under "Calibrated aerial counts of all wetlands" and Table 4. More details are provided below.

- Group "A" taxa are those species where considerable numbers were counted from both the air and the ground. In this instance the calibration measure simply becomes the ratio of the two count totals from the "calibration sites". That is if this ratio is two so that twice as many birds were counted on the ground then seen from the air then all aerial counts for this species are multiplied by two to better reflect the actual numbers of birds throughout. If more were seen from the air and counted in the ground then the aerial count becomes the best estimate of numbers of the species.
- The same approach is taken for the Group "B" taxa, although in this instance it is the totals of all of the group members for both aerial and ground counts that are used to establish the calibration ratio. Again, if total aerial counts are higher from the "calibration sites" then for other areas, the aerial count is taken as the estimate of numbers. Once the adjusted total for the group is derived from the aerial counts, then the ratio of the species contributions to the group total for the ground counts at the "calibration sites" is used as breakdown of the estimated total aerial count for the group. That is, the assumption was made that for each group, ducks for example, that the relative numbers of the species throughout the whole area was the same as was encountered at the calibration sites.
- Finally, the group "C" species were very poorly represented in the aerial counts, usually because of their small size or cryptic nature, whereby they were difficult to see from the air. Hence, their numbers are represented in the adjusted aerial counts on the following basis. They have been assumed to be as abundant elsewhere as they were found to be from ground counts on the calibration wetlands, and the best indicator of their presence is Magpie Geese numbers. Hence their numbers have been indexed to Magpie Geese counts throughout the study area. That is the ratio of the target species total ground count at the calibration sites to the total aerial count of Magpie Geese at the calibration count is used to predict their number elsewhere on the basis of the number of Magpie Geese counted from the air.

Table C1 Calibrated (for freshwater birds) aerial counts inside and out of (nearby) the Ramsar boundary.

	Outside Ramsar boundary					Inside Ramsar boundary					Total
	Aug	Oct	Jan	Mar	Tot.	Aug	Oct	Jan	Mar	Tot.	
Primarily coastline birds											
Australian Pied Oystercatcher						5	1			6	6
Bar-tailed Godwit						990	66		160	1216	1216
Black-tailed Godwit				10	10						10
Caspian Tern	26				26	11	50			61	87
Common Greenshank				1	1						1
Common Tern	157	135	112	42	446	48	15		7	70	516
Crested Tern	30			20	50	50			20	70	120
Eastern Curlew		6			6	26	25		20	71	77
Great Knot						299	950			1249	1249
Grey-tailed Tattler	2				2	50				50	52
Gull-billed Tern	18	16	13	5	52	9	1			10	62
Little Tern		25		205	230		1500			1500	1730
Pacific Golden Plover	11	3	1	2	17		10	2		12	29
Red-capped Plover	4	15			19						19
Red-necked Stint	969	200			1169		10			10	1179

Sand Plover						4				4	4
Sharp-tailed Sandpiper	140	315	20	34	509	3		25	30	58	567
Silver Gull	14	200			214	82	20		20	122	336
Unidentified large wader				38	38				330	330	368
unidentified medium wader	5			85	90	567	51		1850	2468	2558
Unidentified Small Wader	28	20	110	800	958	69	220		260	549	1507
Unidentified Tern	49		175	24	248	298	94		310	702	950
unidentified wader	200	250			450	68	2200			2268	2718
Whimbrel	5	4			9	53	84		2	139	148
White-winged Black Tern	3	3	2	1	9	1				1	10
Coastline bird subtotal	1661	1192	433	1267	4553	2633	5297	27	3009	10966	15519
Primarily freshwater birds											
Australasian Darter	137	54	20	34	245	4		23		27	272
Australasian Grebe	392	155	57	96	700	13		60	1	74	774
Australian Pelican	944	848	52	116	1960	51	39		20	110	2070
Australian Pratincole	2			1	3						3
Australian White Ibis	164	148	22	20	354	12			9	20	375
Australian Wood Duck	277	150	80	6	513	25	2	1		28	541
Black Kite	7	3	1	1	12			1		1	13
Black Swan	1333	981	766	817	3897				38	38	3935
Black-fronted Dotterel	18	7	3	4	32			3		3	35
Black-necked Stork	21	8	3	4	36			3		3	39
Black-winged Stilt	977		88	29	1094	66			95	161	1255
Brahminy Kite	1			3	4	1				1	5
Brolga	215	28	10		253	43		11		54	307
Cattle Egret	595	547	82	78	1302	41	2	2	27	72	1373
Comb-crested Jacana	225	89	33	54	401	8		34	1	43	444
Cotton Pygmy-goose	113	57	34		204						204
Eastern Great Egret	1636	1503	225	215	3578	112	7	3	75	198	3776
Glossy Ibis	225				225	5				5	230
Green Pygmy-goose	204	103	33		339						339
Grey Teal	886	483	254	20	1643	81	8	5		94	1737
Hardhead	2837	1546	812	67	5262	258	25	16		299	5561
Intermediate Egret	2950	2711	407	389	6456	199	15	5	136	356	6813
Little Black Cormorant	2313		19	40	2372	38				38	2410
Little Egret	261	239	34	34	567	17	2		14	32	600
Little Pied Cormorant	329		10	9	348	31				31	379
Magpie Goose	14275	5646	2232	3500	25653	464		2206	57	2727	28380
Marsh Sandpiper	98	39	14	24	175	3		16		19	194
Masked Lapwing	264	105	39	65	473	9		40	4	53	526
Pacific Black Duck	14251	7764	4081	336	26432	1295	128	77		1500	27932
Plumed Whistling-Duck	1189	648	341	27	2205	109	11	6		126	2331
Purple Swamphen	31	13	4	8	56	1		4		5	61
Royal Spoonbill	2367	2174	327	310	5178	162	12	5	109	288	5466
Straw-necked Ibis	3	2	1	1	7			1		1	8
Striated Heron							3			3	3
Wandering Whistling-Duck	3776	2057	1082	90	7005	343	34	20		397	7402
Whiskered Tern	436	389	323	121	1269	137	27			164	1433
Whistling Kite	18	7	3	4	32			3		3	35
White-bellied Sea-Eagle	1	1		1	3	1				1	4
White-faced Heron	46	11	5	22	84	89	4			93	177
White-necked Heron	41	16	6	10	73	1		6		7	80
Yellow-billed Spoonbill	39	37	5	5	87	2			3	5	92
Freshwater bird subtotal	53897	28569	11508	6561	100532	3621	319	2551	589	7080	107614
Total	55558	29761	11941	7828	105085	6254	5616	2578	3598	18046	123133

Table C2. Calibrated total aerial counts in wetland groups. Refer to Appendix B.

	Alva Wetlands					Colevale Wetlands					South-eastern Wetlands					Southern Wetlands					unassigned					Total
	Aug	*Oct*	*Jan*	*Mar*	*Tot.*	*Aug*	*Oct*	*Jan*	*Mar*	*Tot.*	*Aug*	*Oct*	*Jan*	*Mar*	*Tot.*	*Aug*	*Oct*	*Jan*	*Mar*	*Tot.*	*Aug*	*Oct*	*Jan*	*Mar*	*Tot.*	
Primarily coastline birds																										
Australian Pied Oystercatcher																					2				2	2
Black-winged Stilt	3			6	9	96		48	10	154	176				176	305				305	460			109	569	1213
Caspian Tern																					9				9	9
Common Greenshank									1	1																1
Common Tern	19				19	72			39	111	29	41	77		147	2	84	8		94	99	9	19		127	498
Crested Tern																					30				30	30
Eastern Curlew																					4				4	4
Gull-billed Tern	3				3	9			5	14	3	5	9		17		10	1		11	12	1	2		15	60
Little Tern				5	5				200	200																205
Pacific Golden Plover	2	1			3	4				4	3	2	1	1	7	1				1	3			1	4	19
Red-necked Stint																					19				19	19
Sharp-tailed Sandpiper	24	8	1		33	50		3		53	49	22	14	12	97	16	4	9	5	34	46	4	3	7	60	277
Silver Gull	10				10																22				22	32
unidentified medium wader									5	5											1				1	6
Unidentified Small Wader									800	800																800
unidentified wader						150				150											30				30	180
Whimbrel																					24	6			30	30
White-winged Black Tern						1			1	2	1	1	2		4		2			2	2				2	10
Coastline bird subtotal	61	9	1	11	82	382		51	106	1494	261	71	103	13	448	324	100	18	5	447	763	20	24	117	924	3395
									1																	
Primarily freshwater birds																										
Australasian Darter	24	8	1		33	49		3		52	48	22	13	12	95	16	4	9	4	33	45	4	3	7	59	272
Australasian Grebe	68	24	4	1	97	138		6		144	138	63	38	35	274	45	11	23	13	92	128	11	9	19	167	774
Australian Pelican	508	50			558	83	360	12	20	475	143	33	7	62	245	217	185			402	136	107		4	247	1927
Australian Pratincole						1				1	1				1						1				1	3
Australian White Ibis	34	107			141	68	10	3	3	85	46	2	9	5	61	15	5	2	9	31	36	7	5	7	55	373
Australian Wood Duck	26	25	54	2	107	63	35	1		99	96	13	10	1	120	39	33	2	2	76	117	20			137	539
Black Kite	2				2	2				2	3	2	1		6	1				1	2				2	13
Black Swan	89	150	3	426	668	482	40	4	20	546	599	258	516	111	148	310	183	36	3	532	384	150	51	120	705	3935
Black-fronted Dotterel	3	1			4	7				7	6	3	2	1	12	2		1	1	4	6	1		1	8	35
Black-necked Stork	3	1			4	7				7	7	3	2	1	13	2	1	1	1	5	6	1		1	8	37
Brahminy Kite	1			3	4																					4
Brolga	6		3		9	10	7			17	204	4	6		214		4	3		7	43	10	6		59	306
Cattle Egret	121	392	3		516	252	32	9	14	307	169	3	31	24	227	58	20	9	29	116	128	26	20	22	196	1361
Comb-crested Jacana	39	14	2		55	79		4		83	80	36	22	20	158	26	6	14	7	53	73	6	5	11	95	444

Cotton Pygmy-goose							3			3	83		18		101	11	36			47	18	18			36	188
Eastern Great Egret	329	107	10		141	695	92	22	37	847	462	10	87	65	624	157	55	22	82	315	353	68	55	61	537	3740
Glossy Ibis	5				5	99				99	38				38	62				62	26				26	230
Green Pygmy-goose							7			7	152		33		184	20	64			83	33	33			65	339
Grey Teal	86	79	173	8	346	203	113	2		318	304	42	32	3	381	125	105	9	6	245	374	64			438	1728
Hardhead	275	254	554	25	110	646	361	8		101	974	135	103	10	122	400	336	28	20	784	119	206			140	5534
Intermediate Egret	595	194	19		255	125	165	41	68	152	837	20	155	118	113	281	101	41	147	569	636	123	97	111	966	6748
Little Black Cormorant	87			11	98	293			6	299	511			6	517	105		11		106	435				435	2410
Little Egret	53	172	2		227	111	15	3	5	135	73	2	14	10	99	24	9	3	14	49	56	10	9	10	85	595
Little Pied Cormorant	10			2	12	48			4	52	230		7		237						73				73	374
Magpie Goose	247	860	135	30	350	502	11	241		527	504	227	140	130	100	163	390	869	459	334	465	401	337	684	607	28230
Marsh Sandpiper	17	6	1		24	35		2		37	34	16	10	8	68	11	3	6	3	23	32	3	2	5	42	194
Masked Lapwing	46	16	3		65	94		4		98	93	42	25	24	184	31	7	17	9	64	86	7	6	13	112	523
Pacific Black Duck	138	127	278	128	557	324	181	38		509	488	677	516	51	613	200	168	141	102	393	602	103			705	27794
Plumed Whistling-Duck	116	107	233	11	467	271	151	3		425	407	57	42	4	510	167	141	11	9	328	503	86			589	2319
Purple Swamphen	5	2			7	11				11	10	5	3	3	21	4	1	2	1	8	10	1	1	2	14	61
Royal Spoonbill	477	155	14		205	100	133	32	55	122	671	17	124	94	907	227	80	32	118	457	509	99	78	89	775	5414
Straw-necked Ibis	1				1	1				1	1	1	1		3	1				1	2				2	8
Striated Heron																						3			3	3
Wandering Whistling-Duck	365	339	738	34	147	859	481	10		135	129	180	137	14	162	533	447	37	27	104	159	274			186	7365
Whiskered Tern	55				55	207			112	319	84	118	220		422	5	242	24		271	285	25	56		366	1433
Whistling Kite	3	1			4	7				7	6	3	2	1	12	2		1	1	4	6	1		1	8	35
White-bellied Sea-Eagle						1				1	1				1						1				1	3
White-faced Heron			3	8	11	11				11	8	10		10	28	3		3	3	9	74				74	133
White-necked Heron	7	2			9	15				15	15	7	4	4	30	5	1	2	1	9	13	1	1	2	17	80
Yellow-billed Spoonbill	9	27			36	17	2			19	12		2	2	15	5	2		2	9	9	2	2	2	14	92
Freshwater bird subtotal	7323	8496	4741	689	21249	15392	3834	449	344	20019	17768	4056	3595	2005	27424	7493	4157	1359	1071	14080	18109	2802	743	1172	22825	105596
Total	7384	8505	4742	700	21331	15774	3834	500	1405	21513	18029	4127	3698	2018	27872	7817	4257	1377	1076	14527	18872	2822	767	1289	23749	108991