THE STATUS OF SEABIRDS AND SHOREBIRDS AT ASHMORE REEF, CARTIER ISLAND & BROWSE ISLAND

MONITORING PROGRAM FOR THE MONTARA WELL RELEASE

PRE-IMPACT ASSESSMENT AND FIRST POST-IMPACT FIELD SURVEY

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Final report: June 2010

Figure 1 Mixed colony of seabirds, predominantly Brown Boobies and Common Noddies, East Island, Ashmore Reef, April 2010

Recommended citation: Clarke, R.H. 2010. The Status of Seabirds and Shorebirds at Ashmore Reef and Cartier and Browse Islands: Monitoring program for the Montara Well release - Pre-impact Assessment and First Post-impact Field Survey. Prepared on behalf of PTTEP Australasia and the Department of the Environment, Water, Heritage and the Arts, Australia (now the Department of Sustainability, Environment, Water, Population and Communities).

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ABBREVIATIONS

ROKAMBA - Republic of Korea-Australia Migratory Bird Agreement

JAMBA - Japan-Australia Migratory Bird Agreement

CAMBA - China-Australia Migratory Bird Agreement

DEC - Western Australian Department of Environment and Conservation

DEWHA – Australian Federal Department of the Environment, Water, Heritage and the Arts

DSEWPaC - Australian Federal Department of Sustainability, Environment, Water, Population and Communities

ACKNOWLEDGEMENTS

Michael (Mike) Carter and George Swann are thanked for their expert assistance and attention to detail during the April 2010 field survey of Ashmore Reef, Cartier Island and Browse Island. A field survey of this nature would not have been possible without their assistance. As Study team members both George and Mike also made freely available data arising from numerous previous visits to all the islands of interest. The author is grateful to Chantal Simakoff-Ellims (DSEWPaC) for provision of historic bird data (1979-1992) collected by staff of DSEWPaC and its predecessors and for access to mapping data for the Ashmore region. David Milton (CSIRO Marine) responded to requests for information regarding bird records at Ashmore Reef and also graciously provided access to data. Andrew Burbidge (DEC) interrogated the ‘Western Australian breeding seabird islands database’ managed by DEC. The April 2010 survey was undertaken on the MV King Tide. The skipper Bruce Hartley and crew are thanked for their professional conduct and assistance during this voyage.

EXECUTIVE SUMMARY

- Ashmore Reef, Cartier and Browse Islands are situated on or near the Sahul Shelf, off the coast of north west Australia. These reserves support internationally significant numbers of breeding seabirds and migratory shorebirds with all species variously listed under the *EPBC Act 1999*. Ashmore Reef is also a Ramsar wetland of international importance.
- Twenty breeding species of seabird and heron indicate exceptional high diversity, and numbers of breeding seabirds may exceed 100,000 individuals during a single year. Up to 33 migratory shorebirds species and 18,000 individuals have also been documented using the reserves.
- An uncontrolled well release on the Sahul Shelf off the coast of north west Australia occurred in August 2009 and continued until early November 2009. During this event an oil slick formed, petroleum-based products were reported in the vicinity of Ashmore Reef and Cartier Island and small numbers of oiled seabirds were recovered with limited search effort.
- In an MOU between PTTEP Australasia and the (then) Department of the Environment, Water, Heritage and the Arts (DEWHA) - now Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), a monitoring plan for the Montara Well release was developed. This included a requirement to quantify potential damage and adverse affects on fauna. Subsequently, triggers for monitoring of shoreline impacts on birds were met.
- All available literature and data relating to seabirds and shorebirds within the reserves has been reviewed. The review confirms the international significance of these reserves and provides new evidence that recent estimates of seabird and shorebird numbers within the reserves should be revised upwards.
- An initial ground survey of all three reserves was conducted in April 2010. In excess of 75,000 breeding seabirds and 4200 shorebirds were documented. This survey provides a baseline for subsequent post-impact assessments.
- A monitoring protocol for seabirds and shorebirds, terrestrial habitats and vegetation condition has been developed. The protocol seeks to provide robust time-series data that will permit the detection of significant impacts (if any) on birds and terrestrial habitats within the reserves.
- Post-impact monitoring is to be undertaken on a twice annual basis for a period of five years with April to May and November being identified as the most appropriate times for survey.
- Data gathered during the post-impact monitoring period will be compared with pre-impact data extending back to at least 1998. Control data for migratory shorebirds collected from nearby mainland sites will be incorporated into analyses.
- Statistical analyses will focus on identifying and quantifying changes in the temporal patterns of species counts within the reserves following the Montara Well release. To meet these objectives Bayesian change-point models will be employed.
- This review does not seek to provide comment on whether the Montara Well release has led to significant adverse impacts on bird populations. Rather, it seeks to concatenate knowledge concerning population status prior to any potential impact, refine a post-impact monitoring program for seabirds and shorebirds and assess existing data to identify analyses most appropriate to detect potential changes.

INTRODUCTION

Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve lie within Australian Commonwealth waters. Ashmore Reef is situated at 12°20'S, 123°0'E, some 830 km west of Darwin and 630 km north of Broome (Commonwealth of Australia 2002). Cartier Island lies approximately 52 km to the south-east of Ashmore Reef National Nature Reserve at 12°32'S, 123°33'E (Commonwealth of Australia 2002). The Federal Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) is the managing authority for the reserves. Browse Island Nature Reserve is situated at 14°06'S 123°32'E and is 172 km south of Cartier Island and approximately 450 km north, north east of Broome. The reserve is managed by the Western Australian Department of Environment and Conservation (DEC) (Figure 2).

Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve serve to protect marine ecosystems with high biological diversity (Commonwealth of Australia 2002). Ashmore Reef contains three lightly vegetated islands (total land area ~54 ha), and several additional sandbanks that rise above the high water mark. In recent years, grasses have established on one of these sandbanks to the east of East Island (R. Clarke pers. obs., Figure 3). Within its fringing reef, Cartier Island Marine Reserve contains a single sand cay (~2 ha) devoid of vegetation (Pike & Leach 1997, R. Clarke pers. obs., Figure 4). Browse Island is also situated within a relatively small fringing reef. Northern and eastern shores of Browse Island consist of low lying sparsely vegetated eroded coral rubble, while the remainder of the island is more elevated (5-10 m asl) and vegetated with herbs and low shrubs (R. Clarke pers. obs., see Figure 27).

Ashmore Reef supports a large population of seabirds, including some of the most important seabird rookeries on the North West Shelf (Commonwealth of Australia 2002, Milton 2005). Many of these seabirds are breeding visitors and are thus present in large numbers on a seasonal basis. Large colonies of Sooty Terns[1], Crested Terns, Common Noddies, Lesser Frigatebirds and Brown Boobies breed on East and Middle Islands. Smaller breeding colonies of Wedge-tailed Shearwaters, Masked and Red-footed Boobies, Great Frigatebirds, Little Egrets, Eastern Reef Egrets and Black Noddies also occur (Australian National Parks and Wildlife Service 1989, Milton 2005). Many of the bird species present in the region are listed under international treaties for migratory birds (JAMBA, CAMBA and ROKAMBA) and breeding seabirds that are present are listed marine species under the *EPBC Act 1999*. Ashmore Reef is also recognised as a Ramsar wetland of international significance with 58,300 ha being designated in 2002 (Ramsar Convention Bureau 2009). Ashmore Reef has also been designated an important bird area by BirdLife International on the grounds that it supports exceptionally large numbers of migratory or congregatory species (BirdLife International 2010). There is limited information available concerning seabird populations present at Cartier Island and Browse Island, though Crested Terns have previously been reported to nest at Browse Island (Smith *et al.* 1978), and prior to guano extraction in the 19th century this island likely supported significant numbers of other tropical seabirds (see Serventy 1952).

[1] Scientific names for all vertebrates mentioned in the text are presented in Appendix A

Ashmore Reef, Cartier and Browse Islands (hereafter the 'Reserves') are also important foraging areas for migratory shorebirds that visit the region from the northern hemisphere. Numbers of shorebirds are highest between October and April, though large numbers of shorebirds are present year round as many species 'over winter' in their first years of life (Australian National Parks and Wildlife Service 1989, Higgins & Davis 1996). The extensive sand flats exposed at low tide provide foraging opportunities for internationally significant numbers of some species including Grey Plover and Sanderling (Swann 2005a; 2005b).

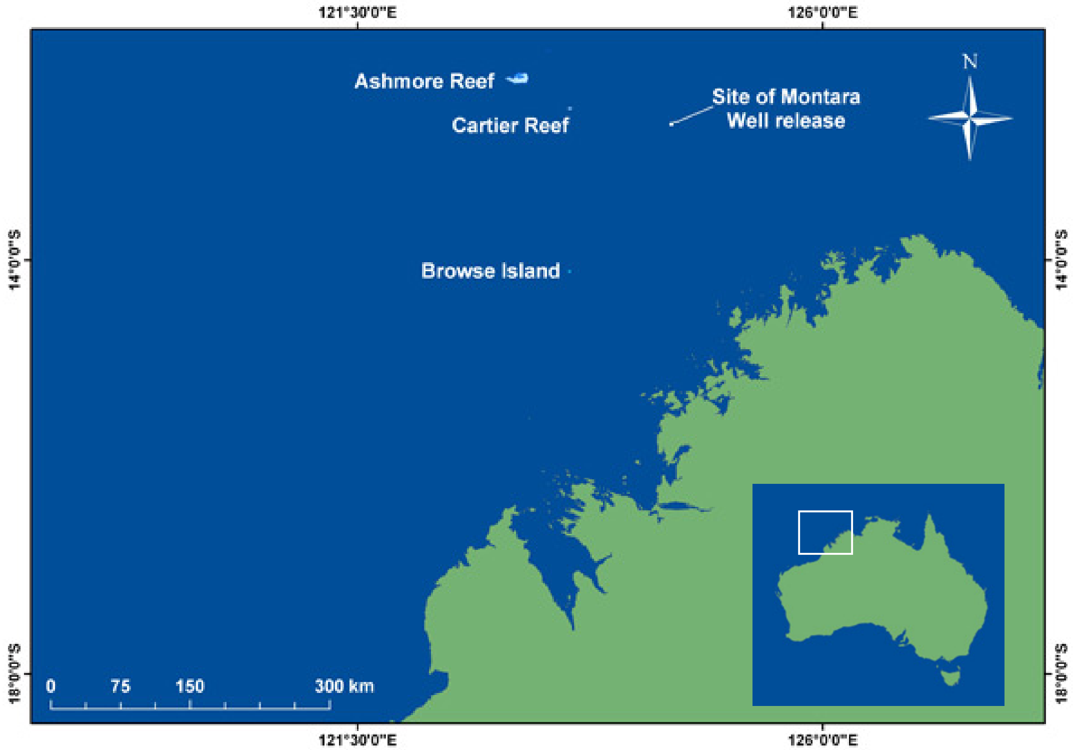

Figure 2 Location of Ashmore Reef, Cartier Reef and Browse Island relative to the site of the Montara Well release and the Kimberley coastline Australia.

An uncontrolled well release from the Montara H1-ST1 Development Well (hereafter the 'Montara Well') situated at 12°40'20"S 124°32'22"E on the Sahul Shelf in the Timor Sea occurred on 21st August 2009 (see Figure 2). The release of gas, condensate and crude oil continued from the well head until the well was successfully intercepted and subsequently plugged on 3rd November 2009. By the end of October 2009, evidence of petroleum-based products had been reported at or in the vicinity of Ashmore Reef, Cartier Reef located to the west and Browse Island to the south west of the Montara Well. Small numbers of oiled birds were recovered both at sea and on the islands at Ashmore Reef (Watson *et al.* 2009, R. Clarke pers. obs.). The extent of the resultant oil slick has been variously reported (AES 2009, Watson *et al.* 2009, submissions to Montara Commission of Inquiry), with satellite imagery demonstrating that it covered many thousands of square kilometres surrounding the Montara Well. The closest terrestrial habitats to the Montara Well are Cartier Island, situated 105 km to the west, and Ashmore Reef, situated 157 km to the west-north-west. Browse Island lies 195 km to the south west of the Montara Well.

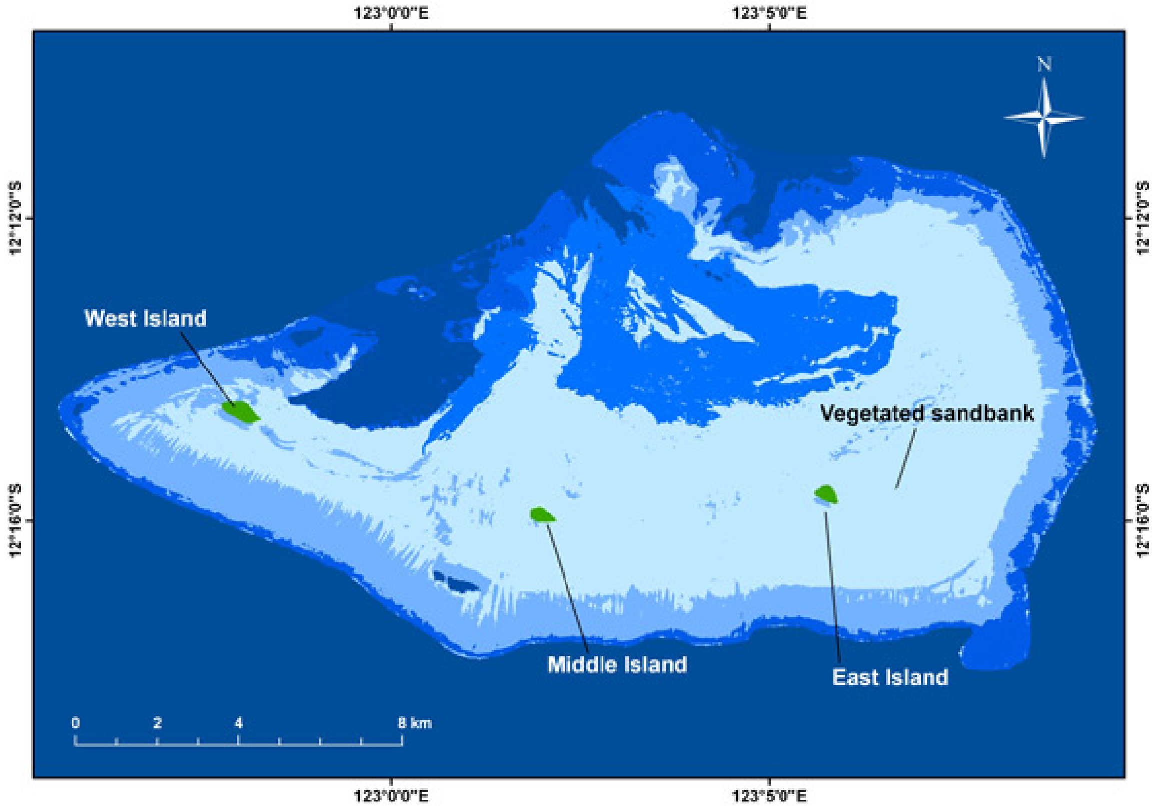

Figure 3 Overview of Ashmore Reef showing the locations and relative sizes of West Island, Middle Island, East Island and the vegetated sandbank discussed in the text. Darker shades of blue indicate deeper water.

Breeding seabirds at the Reserves may be directly exposed to oil via a number of potential pathways. Birds foraging at sea have the potential to directly interact with oil on the sea surface some considerable distance from the marine reserve in the course of normal foraging activities. Surface plunging species such as terns and boobies and species that readily rest on the sea surface such as shearwaters are most at risk. As seabirds are top-order predators any impact on other marine life (e.g. fish kills) may disrupt and limit food supply both for the maintenance of adults and the provisioning of young. Any direct impact of oil on terrestrial habitats within the Reserves, including the shorelines of islands and sandbanks has the potential to contaminate birds present at the breeding sites. As such, the monitoring of trends in breeding population size for a suite of seabird species is considered a minimum requirement to assess potential impacts from the Montara Well release on seabirds that breed within the Reserves.

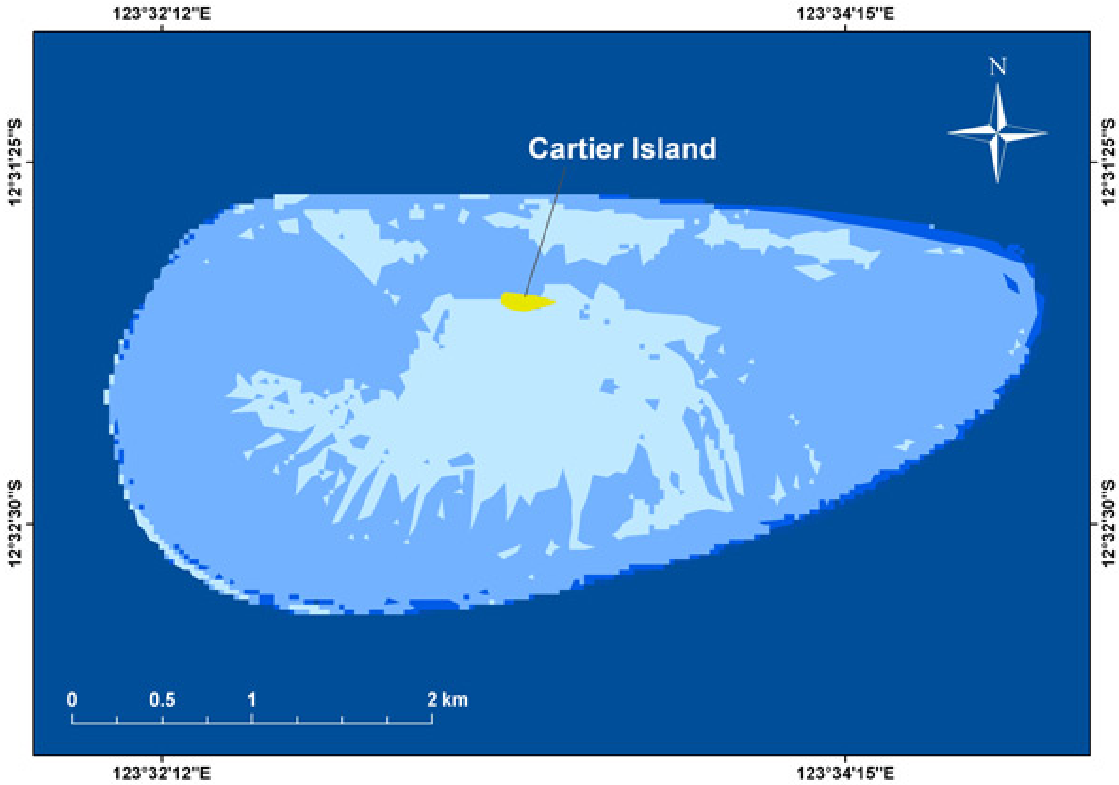

Figure 4 Overview of Cartier Reef showing the location of Cartier Island towards the centre of the reef. Darker shades of blue indicate deeper water.

Shorebirds are likely to be exposed to oil when it directly impacts the reef, associated sand flats and shorelines within the Reserves. As shorebird species present in the Reserves forage for invertebrates (e.g. sand worms *Polychaeta* spp., crabs) on exposed flats at lower tides (Higgins & Davis 1996), there is the potential for both direct impacts through contamination of individual birds (ingestion or soiling of feathers) and indirect impacts through the contamination of foraging areas that may result in a reduction in available prey items. The monitoring of trends in shorebird population sizes would be a minimum requirement to assess potential impacts from the Montara Well release on those shorebird species that regularly occur within the Reserves.

In an agreement between PTTEP Australasia and DEWHA (now DSEWPaC) a monitoring plan for the Montara Well release in the Timor Sea was developed (9th October 2009). As part of that plan it was stated that:

"If shoreline impact, and subsequent harm, is anticipated it is useful to obtain baseline information relating to the fitness of coastal species and habitats prior to impact. This information assists in determining whether damage observed after an impact is due to the oil, cleanup or was pre-existing.

If impacted, shoreline biota and habitats can continue to be monitored to assess the extent and duration of any damage. Quantifying damage to species may require ground survey; aerial surveys will not allow detailed assessments of fauna, flora or habitats."

Triggers

Under the Montara Monitoring Plan (PTTEP Australasia 2009), it is stated *"If shoreline impact is anticipated (either reefs, islands or mainland) and adverse effects are anticipated on associated fauna, flora, habitats or communities, then both baseline (pre-impact) and post impact data is required."*

The following observations dictate that triggers for both pre-impact and post impact monitoring were met during the period of uncontrolled release.

- The source of the Montara Well release was located approximately 105 km from Cartier Island Marine Reserve, 157 km from Ashmore Reef National Nature Reserve and 195 km from Browse Island. The source location was thus well within foraging and dispersal distances for many seabirds that breed within the Reserves (Study team[1] unpubl. data).
- Hydrocarbon products believed to have originated from the Montara Well release were detected at or in the vicinity of Ashmore Reef (DEWHA (now DSEWPaC) website accessed 25 Nov. 2009, R. Clarke pers. obs.), Cartier Island (Watson *et al.* 2009) and Browse Island (DSEWPaC communication).
- Oiled seabirds (notably Common Noddies) were detected both at sea and on islands within the Reserves, indicating direct impact (DEWHA (now DSEWPaC) website accessed 25 Nov. 2009, Watson *et al.* 2009).

Study Objectives

This pre-impact assessment seeks to utilize targeted investigations to identify and quantify the pre-impact status of seabirds and shorebirds and health of flora in the Ashmore Reef, Cartier Island and Browse Island areas.

More specifically the pre-impact assessment seeks to:

- Collate and interpret existing data on seabird and shorebird numbers as they relate to terrestrial environments at Ashmore Reef, Cartier Island and Browse Island;
- Undertake a targeted field survey of breeding seabirds and migratory shorebirds utilising standard methods to provide a measure of seabird and shorebird status within the reserves as soon as possible after the Montara Well release;
- Explore existing long-term data sets to identify statistical analyses most appropriate to detect changes in breeding seabird and migratory shorebird numbers due to the Montara Well release;
- Utilize the above information and knowledge to develop and refine a post-impact monitoring program for seabirds and shorebirds that occur within the Ashmore Reef, Cartier Island and Browse Island reserves.

[1] The Study team consists of G. Swann, M. J. Carter, A. Boyle and R.H. Clarke

This approach is consistent with the objectives agreed upon by PTTEP Australasia and DEWHA (now DSEWPaC) (PTTEP Australasia 2009). As the Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve are Commonwealth reserves managed under the *EPBC Act 1999*, any monitoring activities must also be conducted in accordance with the requirements of the *EPBC Act 1999* and under the guidance of the existing management plan (Commonwealth of Australia 2002).

APPROACH AND METHODS

Pre-impact Assessment

Collation, analysis & review of existing data

Ashmore Reef has been visited by observers with bird identification skills since at least 1949 (Serventy 1952). Subsequent to that single visit, during a 19 year period commencing in 1979 bird observations, including counts of variable intensity, were documented on 68 occasions, principally by Australian National Parks and Wildlife Service (now DSEWPaC) staff. These visits occurred in all months, with at least two visits taking place in any calendar year (Milton 2005, DSEWPaC unpubl. data). A summary of this data has been presented by Milton (2005). Since 1996 members of the Study team have collectively visited Ashmore Reef on 13 occasions with visits being made in all years since 2000, principally in October and November (nine visits) and January and February (three visits). Bellio *et al.* (2007) report on an additional visit (November 2004), when efforts were made to quantify seabirds breeding on the islands in relation to potential impacts of tropical fire ants *Solenopsis geminata*.

Counts during the period 1979 to 1998 were of variable intensity and were conducted by observers with a range of skills (Milton 2005). Further, data held by the author for this period (NOW DSEWPAC unpubl. data) does not quantify effort beyond specifying the island and the month and year of the visit (e.g. total time ashore and whether a count was complete or partial is not specified). In contrast, observations by Milton (1999; 2005), Bellio *et al.* (2007) and the Study team (Swann 2005a; 2005b; 2005c, Study team unpubl. data) do quantify effort. For this reason, pre-impact assessment largely focuses on records gathered since 1996, with reference to pre-1996 observations where counts are considered both reliable and notable. The methods employed by the Study team to record birds have remained largely consistent between expeditions, with all species encountered either being individually counted or in the case of larger aggregations of seabirds, estimated. Importantly, all of these surveys have involved one or more experienced observers competent in the identification of seabirds and shorebirds in north west Australia and experienced with counting techniques for large aggregations of birds. Whilst these data were gathered with a level of consistency, it should be noted that they were not collected with the explicit intention that they form the basis of a pre-impact assessment of an uncontrolled well release. Potential limitations are that the data were principally collected in October and November of each year (and to a lesser extent in January and February); that counts for some species will be incomplete, dependant on the level of island access granted; and that not all islands at Ashmore Reef were visited on every expedition.

Initial Post-Impact Field Survey

In April 2010 an initial ground assessment to count all shorebirds and seabirds present on the islands and sandbanks of Ashmore Reef, Cartier and Browse Islands in a rigorous and repeatable manner was undertaken. As these counts were conducted 7 to 8 months after the uncontrolled well release commenced, and 5 to 6 months after the well release was successfully killed, it is not appropriate to treat these counts as pre-impact assessments. Rather, they provide a measure of total seabird and shorebird abundance within each reserve at the earliest opportunity after the event. These counts also provide opportunity to trial and refine monitoring protocols for ongoing post-impact monitoring purposes and provide an objective baseline for post-impact monitoring, with island-wide census and complete shorebird counts facilitating the identification of trends in population size during any post-impact assessment period. Study team members present during this survey were Mike Carter, George Swann and the author.

Detailed census methods

Breeding seabirds

Complete island wide counts of breeding seabirds were undertaken on all islands visited (West, Middle and East Islands, Ashmore Reef, Cartier Island and Browse Island) during April 2010. Counts were systematic with the observer recording the number of adults and the number of active nests for each species that was encountered.

Active nests provide a more objective measure of seabird colony size (number of breeding pairs) than do counts of adults, as presence by one or both adults at a colony is dependant on breeding stage and time of day. Nevertheless, counts of adults are appropriate when counts of nests are unachievable. For most species two separate counts were made – all active nests and all adults present (Great Frigatebird, Brown, Red-footed and Masked Boobies, Crested Tern and Lesser Noddy). As anticipated, Sooty and Bridled Tern, Common and Black Noddy were nesting amongst herbaceous vegetation and in aggregations that precluded counts of individual nests. In this instance it had been proposed that estimates of breeding population would be obtained by counting sub samples within fixed areas, then extrapolating these to the total area occupied by the colony. As it eventuated this was not possible as many individuals of the above species, as well as Lesser Frigatebird, were yet to lay eggs and individual nests were not discernible. As a consequence, a count of all adults[1] of each of these species was made on each island.

All birds, and where appropriate nest contents, were visually assessed for evidence of oil with the intention that any oiled birds and/or oiled eggs be thoroughly documented (including a photographic record) following standard protocols.

Middle and East Island, Ashmore Reef, were each visited on at least three separate dates during the course of surveys. For the three booby species, Great Frigatebirds and the less abundant tern species (e.g. Bridled Terns) a single count of nests and adults was made. For

[1] As many seabirds are difficult to age once they have left the nest here adults are defined as all free-flying individuals

abundant species, or species that occur at very high local densities (e.g. Crested Terns within breeding colonies) multiple counts by at least two observers were undertaken to ensure a degree of consistency was achieved.

West Island, Ashmore Reef, was visited on a number of occasions to document vegetation and count seabirds and shorebirds. Coordinates for all tropicbird nests were recorded so that any change in breeding distribution on West Island may be tracked in future seasons. The Wedge-tailed Shearwater colony on West Island was inactive during the April visit; opportunity was therefore taken to map the boundaries of the colony (vacant burrows) at a time when disturbance was likely to be negligible.

Seabirds at Cartier Island were counted over a single day, whilst those on Browse Island (including a large colony of nesting Crested Terns) were counted over two consecutive days.

Shorebirds

Complete counts of shorebirds on Ashmore Reef, Cartier Island and Browse Island were conducted by visiting all high tide roosts. Shorebirds rest (roost) in dense flocks during higher tides on remaining exposed sandbanks, and on the vegetated islands. These sites were visited with the use of tenders. All birds were identified to species and counted with the aid of spotting scopes. At Ashmore Reef, all shorebird sites were counted over a four day period, with larger roosts being counted at least twice. On the final day of shorebird counts all shorebird roost sites that had previously been located and individually assessed were counted over a single high tide phase. When assessed against counts on previous days, this approach provides opportunity to determine the total number of shorebirds of each species present within Ashmore Reef with a degree of confidence. A single day of shorebird counts was conducted at both Cartier Island and Browse Island.

A program of marking shorebirds by fitting a small coloured plastic band with a tab to the leg(s) of shorebirds commenced in Australia in 1990. This marking technique is known as leg flagging. Subsequently, a flagging protocol has been developed for the East Asian – Australasian Flyway, which enables the marking of shorebirds with colour combinations unique to individual countries, and in some cases regions within a country (Commonwealth of Australia 2001). Resightings of leg flagged shorebirds provides valuable information on migration routes, delineation of sub-populations of shorebirds and the identification of important ‘stop-over’ areas for migratory shorebirds. During shorebird counts at Ashmore Reef, Cartier Island and Browse Island, shorebird flocks were routinely scanned for the presence of leg flagged individuals. The colour combinations of any flagged individuals were recorded and these were subsequently submitted to the Australian Wader Study Group flag database so that the origin of the flagged bird(s) could be determined.

Vegetation condition

As most plant species present at Ashmore Reef display an *annual* life history and many of the remaining species die back considerably during the dry season, there are relatively few plant species that are suitable for monitoring purposes. Two exceptions are Coconut Palms *Cocos nucifera* and Octopus Bush *Argusia argentea* on West Island.

Photo monitoring points serve to provide a visual record of the vegetation condition on each island. These are also intended to provide opportunities to more specifically monitor changes in gross health of the two remaining Coconut Palms and *Argusia argentea* on West Island, Ashmore Reef. Photo monitoring points were established using standard procedures on all islands and significant sandbanks at Ashmore Reef (15 photo points), Cartier Island (2 photo points) and Browse Island (6 photo points) during the initial ground assessment (April 2010) (see Clarke 2009). Images were taken using a 17 mm lens and Canon 1D camera. As the camera has a 1.3 x reduced frame sensor, all images were captured using the equivalent of a 22 mm lens on a standard SLR camera. Images were taken with the camera positioned directly over the photo monitoring point marker and held at a height of 1.6 m. Orientation of the camera has been documented for each photo monitoring point as a compass bearing. When gathering future images at photo monitoring points the original image should be on hand to assist with orientation and framing relative to recognisable landmarks.

Leaf fitness measures were developed for *Argusia argentea* on West Island in accordance with PTTEP Australasia (2009). The protocol involves selecting the nearest *Argusia argentea* shrub to each photo monitoring point, then randomly selecting two clumps of leaves at a height of 1.5 m. The first 10 leaves in each clump are then assessed on a scale of 1 to 5 for damage (1 being 100% intact, 5 representing a leaf with less than 20% total surface area remaining) and on a scale of 1 to 5 for leaf colour (1 being bright green and indicating a healthy vigorous leaf, 5 being brown and indicating a recently dead leaf).

Data collection and management

A GPS was routinely employed to record various waypoints of interest. This included significant landscape features (Coconut Palms, fresh water wells, trig points etc), nests of selected seabird species and all photo monitoring points. These waypoints, downloaded from the GPS, are maintained as an electronic spreadsheet. The high tide line for all islands visited (West, Middle, East Islands, Ashmore Reef, Cartier Island and Browse Island) was also plotted with the aid of a handheld GPS. Delineation of the high tide line was straightforward in this instance as peak tides of 4.0 m and calm conditions occurred during the survey period. These tracks have been converted to GIS layers (Shape files in ArcView) and are presented in Figures 9-11 and Figure 27.

RESULTS

Ashmore Reef

Terrestrial environments

The vegetation at Ashmore Reef has been well documented by Pike & Leach (1997) (Figures 5-7). As one would expect for islands that are relatively isolated, vegetation communities are rather simplified. On West Island there is a single dominant shrub species, *Argusia argentea*, two Coconut Palms, several other shrubs represented by very small numbers of individuals and a range of creepers, annual herbs and grasses (Pike & Leach 1997, Figure 5). A dense patch of Beach Spinifex *Spinifex longifolius* adjacent to the

northern shore has at least doubled in size since the publication of Pike and Leach (1997). (Figure 5 c.f. Figure 9). Recent inspection of Middle and East Islands revealed two living *Argusia argentea* shrubs less than 50 cm in height on Middle Island and no apparent shrubs on East Island (October 2009; R. Clarke pers. obs.). All other vegetation on these two islands is characterised by ground creepers, annual herbs and grasses. Current vegetation on East and Middle Island reflects considerable change to shrubs and palms since the publication of Pike & Leach (1997). All three Coconut Palms on Middle Island have now died, with a single palm stem remaining near the well. Similarly, shrubs reported by Pike & Leach (1997) that occurred on Middle and East Island have also since died. This is presumably due to damage caused by nesting seabirds (especially Red-footed Boobies and Great Frigatebirds) and roosting Common Noddy. Shrubs that are no longer present include a single *Cordia subcordata* previously reported on East Island and a number of mature *Scaevola taccada* and several larger *Argusia argentea* shrubs previously reported on Middle Island. The dead remnants of *Scaevola taccada* shrubs now serve as the principal nesting sites for both Red-footed Boobies and Great Frigatebirds (see Figure 18).

A sandbank to the east of East Island is now vegetated (first noted October 2009; Study team unpubl. data; Figure 8). Three grass species were present on this 'new' island in April 2010, when the total vegetated area was measured at 1150 m^2. The dominate grass species was Stalky Grass *Lepturus repens* (~90% of total cover); Cuming's Lovegrass *Eragrostis cumingii* (~10% of total cover) and a single specimen of Finger grass *Digitaria mariannensis* were also present.

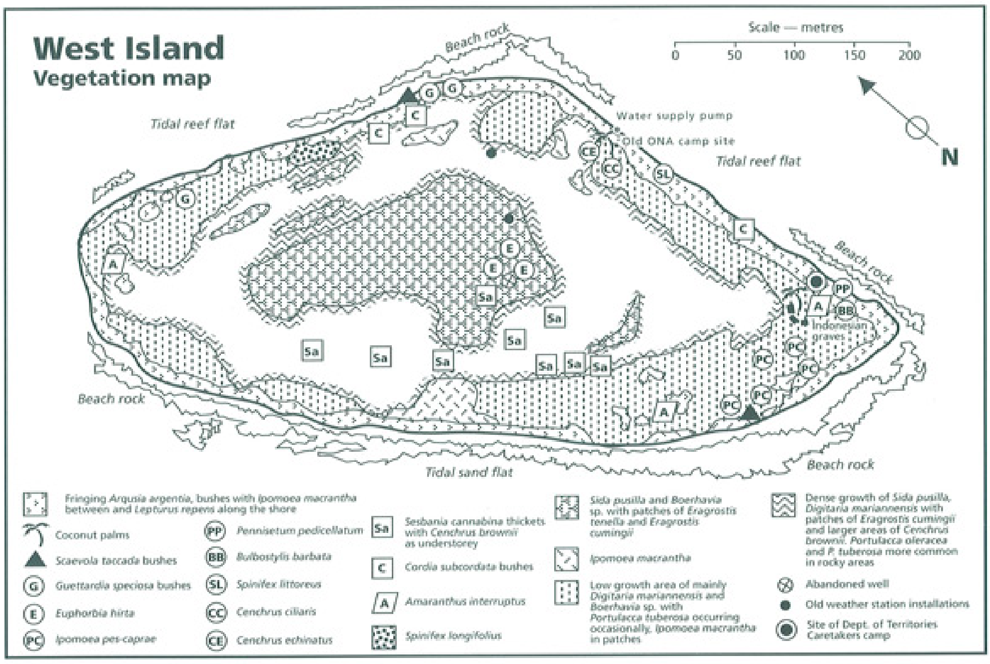

Figure 5 Vegetation communities on West Island Ashmore Reef from Pike & Leach (1997). Note that both the composition of the vegetation and island shape has changed slightly since the production of this map. Note the relatively small size of the *Spinifex longifolius* patch.

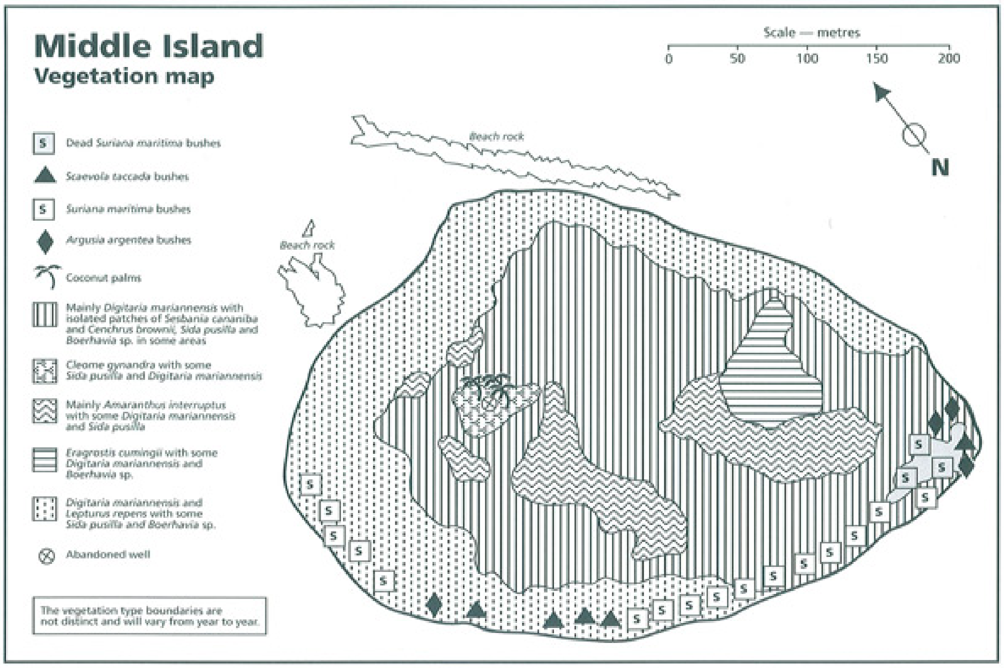

Figure 6 Vegetation communities on Middle Island Ashmore Reef from Pike & Leach (1997). Note that both the composition of the vegetation and island shape has changed since the production of this map; notably all large shrubs and palms have since died.

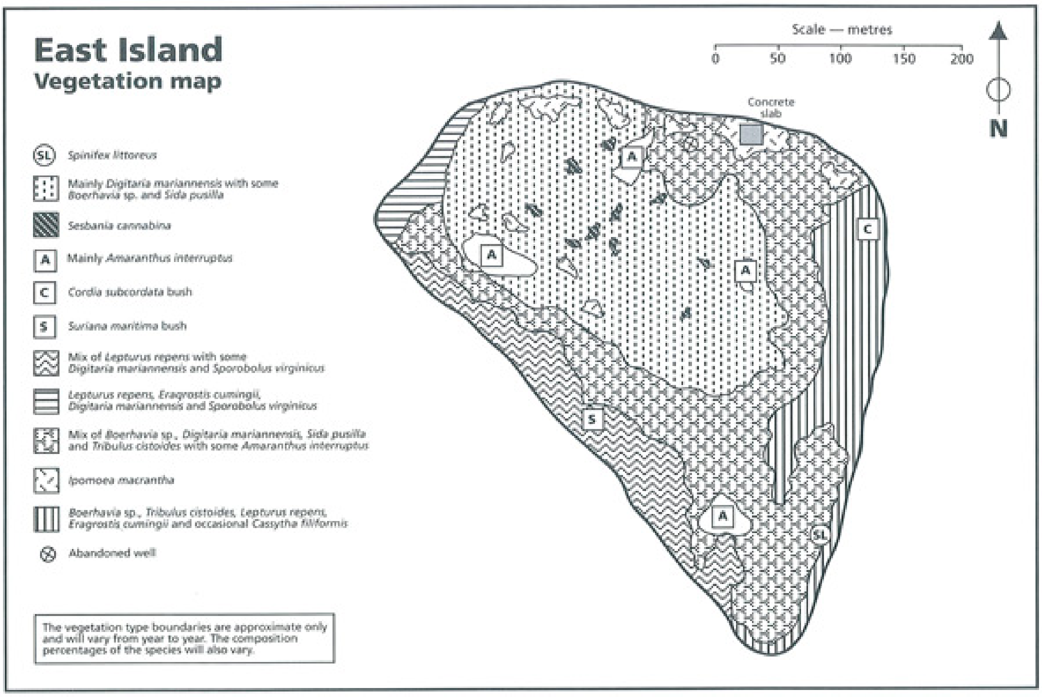

Figure 7 Vegetation communities on East Island Ashmore Reef from Pike & Leach (1997). Note that both the composition of the vegetation and island shape has changed slightly since the production of this map; notably all large shrubs have since died.

The total land area of vegetated islands at Ashmore Reef has been previously been reported (e.g. Carter 2003, Bellio *et al.* 2007, Clarke *et al.* 2009), yet there appears to be considerable variation in the literature as to the actual size of each island. As these islands may be somewhat dynamic, variation may in part be due to real changes following disturbance and deposition events such as cyclones, however it also seems likely that some of the observed variation is due to inaccurate or more likely 'casual' estimates of total land area. During April 2010 the land area for each island was therefore measured at the high tide line, using a handheld GPS, tracking at 10 m intervals. West Island had a total land area of 28.1 ha, Middle Island had a total land area of 12.98 ha and East Island had a total land area of 13.42 ha.

Fifteen photo monitoring points were established during April 2010. Six sites were established on West Island, four sites on Middle Island and three sites on East Island within Ashmore Reef Nature Reserve (Figures 9-11). A further two sites were established on the newly vegetated sandbank to the east of East Island to assist with ongoing monitoring of this new and apparently dynamic site. The disparity in the number of sites established per island reflects both the larger size and more heavily vegetated nature of certain islands (e.g. West Island, Ashmore Reef).

Figure 8 Vegetated sandbank to the east of East Island, Ashmore Reef. The dominant grass visible in this image is *Lepturus repens*. April 2010.

Twenty leaves of *Argusia argentea* were assessed for leaf fitness measures at each of the six photo monitoring points on West Island. The mean leaf damage score was 2.03 (n = 120, range 1-4), whilst the mean leaf colour score was 1.07 (n = 120, range 1-4). These are relative measures of leaf fitness that will continue to be assessed on future visits (see methods), so that trends in vegetation health may be determined. Photo monitoring point 6 had the lowest leaf assessment scores (3.05 leaf damage score, 1.25 leaf colour score), reflecting the deteriorating health of shrubs on the south-eastern dune edge of West Island (see below).

Incidental observations on West Island in April 2010 noted that there has been some die-off of *Argusia argentea* shrubs on the south eastern corner of the island (See Appendix C; West Island #6 photo monitoring point). Whilst still alive, many of these shrubs appeared stressed in late October 2009 and the island generally appeared very dry (R. Clarke pers. obs.). Although the Study team have no data to hand, it is suggested that below average rainfall over recent wet seasons (2008-09 and 2009-10) at Ashmore Reef has contributed to the deaths of these shrubs. Additionally, the Coconut Palm located near the water pump on West Island appeared stressed in April 2010, with most mature fronds 'hanging' from the palm rather than radiating at angles at or above horizontal (See Appendix C; West Island photo monitoring point 2; c.f. apparently healthy Coconut Palm at West Island photo monitoring point 1).

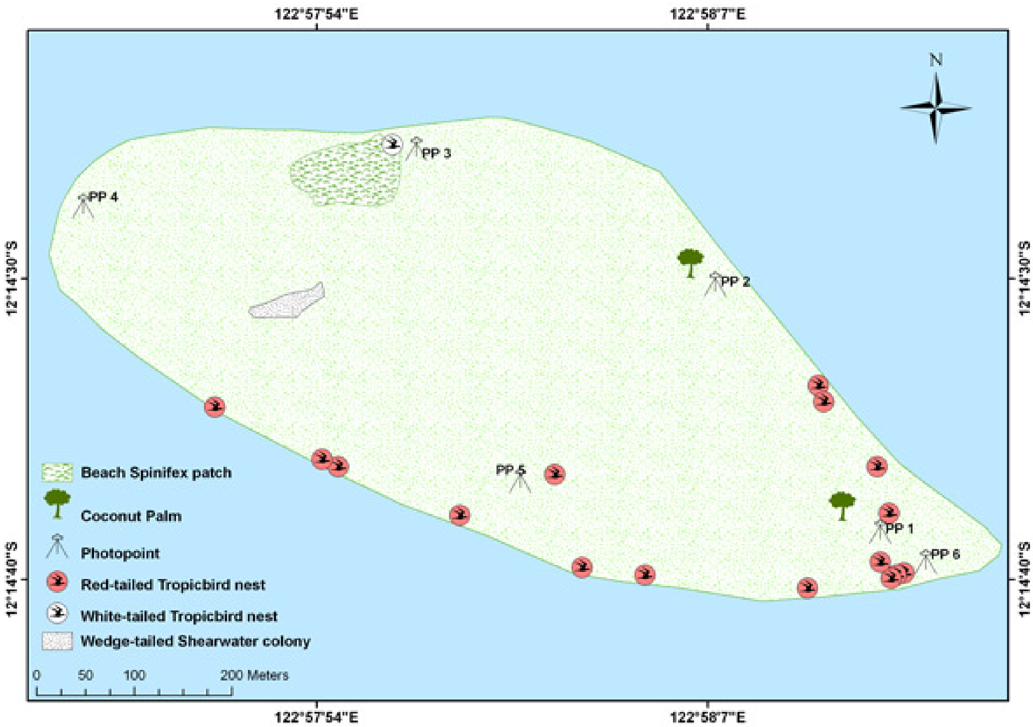

Figure 9 Map of West Island, Ashmore Reef showing the locations of photo monitoring points. The boundary of the Wedge-tailed Shearwater colony and nest sites of tropicbirds, as recorded in April 2010, are also displayed.

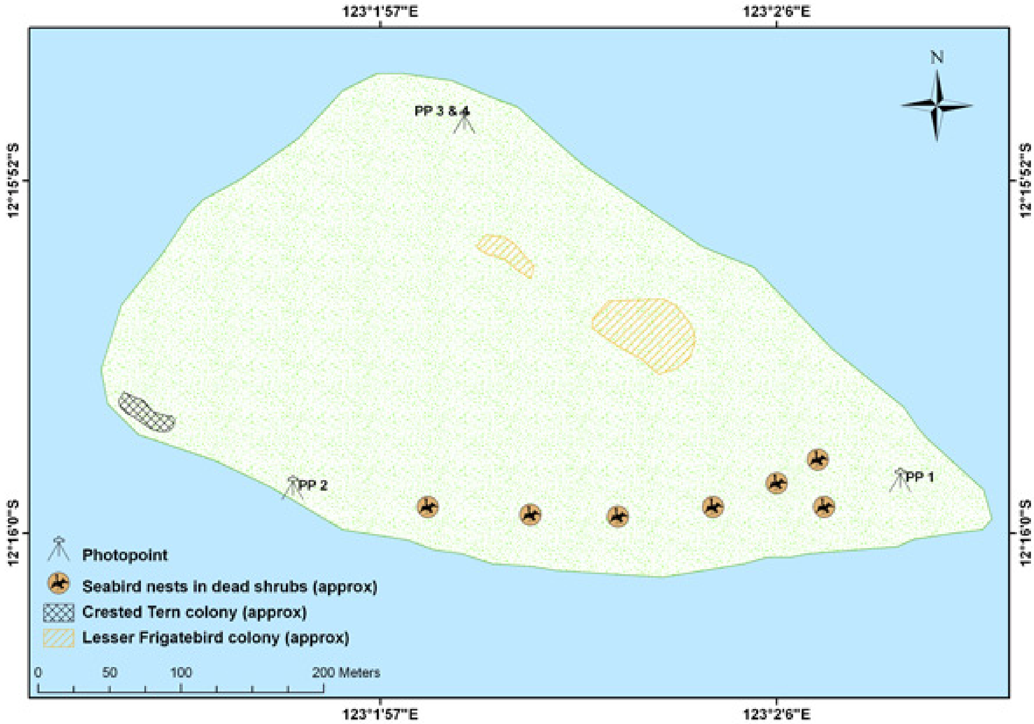

Figure 10 Map of Middle Island, Ashmore Reef showing the locations of photo monitoring points. The boundaries of Crested Tern and Lesser Frigatebird colonies and dead shrubs in which Great Frigatebirds and Red-footed Boobies nest, as recorded in April 2010, are also displayed.

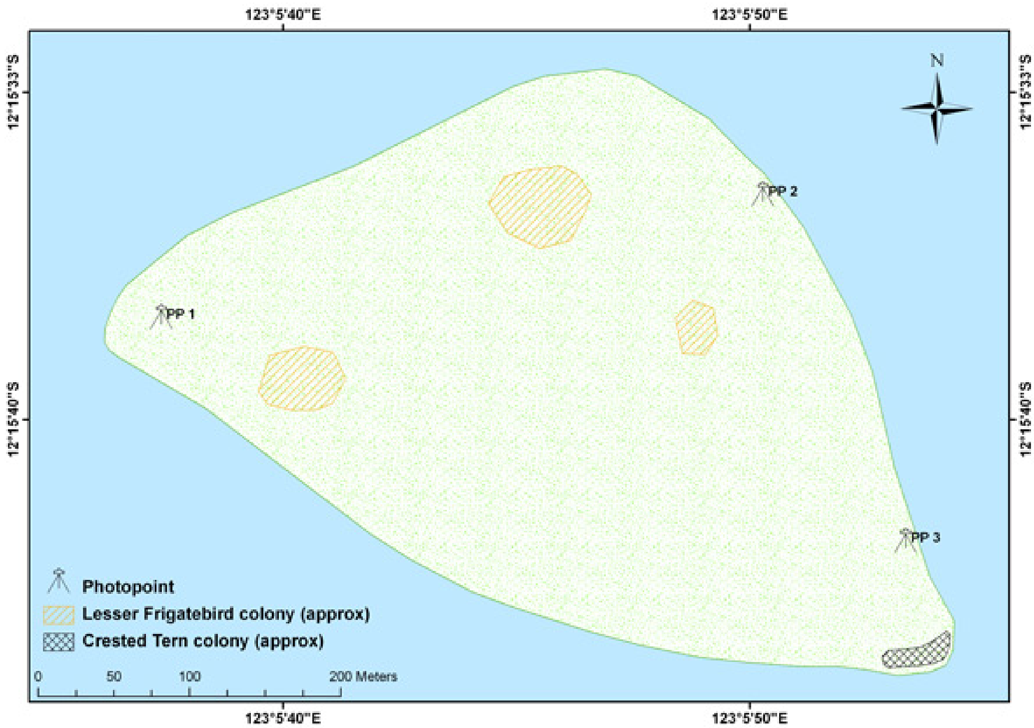

Figure 11 Map of East Island, Ashmore Reef showing the locations of photo monitoring points. The boundaries of Crested Tern and Lesser Frigatebird colonies, as recorded in April 2010, are also displayed.

Seabirds

Sixteen species of seabird and four species of heron have been reported to breed at Ashmore Reef (Commonwealth of Australia 2002, Milton 2005, Study team unpubl. data). The highest diversities and greatest densities of breeding seabirds and herons at Ashmore are found on Middle (16 species) and East Islands (15 species), with West Island hosting the largest colony of Eastern Reef Egret and relatively small numbers of Wedge-tailed Shearwater and tropicbirds on an annual basis (two other heron species and Crested Tern have also bred there on an irregular basis) (Table 1). The diversity of seabirds across these three small islands is exceptional in an Australasian context. It has been speculated that this diversity may have arisen because of the isolated nature of this island group, the diversity of available habitat on the three vegetated islands and the proximity of Ashmore Reef to the Indonesian Through Flow – a potentially nutrient rich current linking the Pacific and the Indian Oceans that is active in the vicinity of the reef (Commonwealth of Australia 2002, Milton 2005, Potemra 2005, Bellio *et al.* 2007).

The seabirds present at Ashmore Reef display a variety of reproductive strategies. Most species breed annually, however several species have been reported to breed at Ashmore only occasionally. For example, Milton (2005) reported that both Roseate Tern and Lesser Crested Tern are breeding species within the reserve, yet the Study team has not observed breeding Roseate Terns in over 10 years of visits[1] and has never recorded Lesser Crested Terns at Ashmore Reef during the same period. This may reflect a seasonal bias in sampling, as many species of seabird have relatively well defined breeding seasons. On present knowledge it would appear that most seabirds at Ashmore Reef are dry season breeders, with the majority of species commencing egg laying and incubation in April (Figure 12). This includes Lesser Frigatebird, three species of Noddy and Brown Booby. Red-footed and Masked Booby also breed through the dry season, however specific months for egg laying are less well defined and documented. Several other species display a more variable response to season. For example, Crested and Sooty Terns have been reported to commence laying at various times including the months of January, April and November. As these species display relatively short breeding cycles (~20-25 day incubation periods, 4-6 week nestling periods; Higgins & Davis 1996), this strategy may allow these species to exploit temporary instances of elevated food availability in the local marine environment. Wedge-tailed Shearwaters appear to be the only obligate wet season breeder, though available data indicates both species of tropicbirds may also be most abundant between the months of January and April (Table 2). Eastern Reef Egrets, which are the only abundant breeding heron present within the reserve system, breed in the late dry season.

The islands of Ashmore Reef support internationally significant numbers of seabirds (Bellio *et al.* 2007). Up to 54,000 Common Noddies, 45,000 Sooty Terns, 5000 Brown Boobies and in excess of 2000 Lesser Frigatebirds have been reported breeding on Middle and East Island prior to the commencement of this study (Milton 2005, DSEWPaC unpubl. data, Study

[1] Although no nesting has been observed by the Study team, in April 2010 there were adults in breeding plumage participating in paired flight displays at both West and Middle Island indicating nesting may have been about to commence.

team unpubl. data; Tables 3 and 4). Some of these colonies are amongst the largest breeding colonies of that species in the Australasian region. For example Bellio *et al.* (2007) report that Ashmore Reef supports the largest colony of Sooty Terns in Western Australia and the second largest colony of Common Noddy in Australia. Although previous authors have concluded that Ashmore Reef may support up to 50,000 breeding seabirds (Milton 2005, Bellio *et al.* 2007), based on recent data, the total number of breeding seabirds may actually exceed 100,000 individuals during a 12 month cycle (Study team unpubl. data; Tables 3 and 4).

Counts conducted in April 2010 were well timed such that the majority of dry season breeding species were present and many of these had commenced incubation. This is some of the first data that identifies April as a key month in the breeding cycle for most species of seabird at Ashmore Reef. Notably, this finding provides valuable guidance for the identification of optimal periods in which annual surveys of seabirds should be conducted in future (see later). Thirteen of the 16 breeding seabirds at Ashmore Reef were attending active nests during the April visit, though surprisingly no herons or egrets were observed breeding[1] (Figure 12). As all seabirds on both East and Middle Islands were counted over consecutive days and because most species were attending nests it is considered appropriate to pool these data to provide total measures of abundance. Approximately 72,000 breeding seabirds were utilizing islands on Ashmore Reef at the time of the survey. Notable counts included 44,805 Common Noddies, 7500 Sooty Terns, 4379 Brown Boobies nests (extrapolated to 8758 breeding adults), 5937 adult Crested Terns within colonies and 2760 nests of Crested Terns and 4277 Lesser Frigatebirds within colonies. Whilst numbers are not as spectacular, the largest ever reported colony sizes at Ashmore Reef for Great Frigatebird (40 nests), Red-footed Booby (101 nests), Masked Booby (33 nests) and Red-tailed Tropicbird (17 nests) were also obtained during the April 2010 survey. Significantly, Lesser Noddy was also confirmed as a breeding species at Ashmore Reef with 13 adults and four nests observed. Questions regarding the identity of Lesser Noddy at Ashmore Reef have previously been raised (Australian National Parks and Wildlife Service 1989, Stokes and Hinchey 1990, Higgins & Davies 1996, Commonwealth of Australia 2002). Observations and photographs of this species carrying nesting material, alighting on newly constructed nest platforms and of a single nest containing an egg serve to confirm the species status as a breeding seabird within the reserve. Breeding by Wedge-tailed Shearwater, Eastern Reef Egret, Little Egret and Nankeen Night-Heron was not recorded during the April visit. Counts of these species will be undertaken, where appropriate, during a late dry season visit.

To ensure all available information is considered when establishing a long term monitoring program for breeding seabirds, more detailed information concerning individual seabird species at Ashmore Reef follows. In these species accounts, emphasis is placed on behavioural ecology as it relates to the potential for interaction with contaminants from the Montara Well release, breeding ecology and known populations sizes of breeding seabirds.

[1] Small numbers of Eastern Reef Egrets and Little Egrets were aggregated in the centre of East Island in April 2010 indicating possible breeding but active nests were not observed.

Table 1 Breeding distribution of seabirds and herons on the three vegetated islands of Ashmore Reef, Australia. 'Not observed' indicates *breeding activity* has not been reported, but adults of these species may have been observed ashore at times.

	West Island	Middle Island	East Island
Wedge-tailed Shearwater	Regular	Not observed	Not observed
Red-tailed Tropicbird	Regular	Occasional?	Occasional?
White-tailed Tropicbird	Regular	Occasional?[1]	Occasional?
Masked Booby	Not observed	Regular	Regular
Red-footed Booby	Not observed	Regular	Regular
Brown Booby	Not observed	Regular	Regular
Great Frigatebird	Not observed[2]	Regular	Occasional?
Lesser Frigatebird	Not observed	Regular	Regular
Crested Tern	Occasional	Regular	Regular
Lesser Crested Tern	Not observed	Unconfirmed	Unconfirmed
Roseate Tern	Not observed	Occasional	Occasional
Bridled Tern	Not observed	Regular	Regular
Sooty Tern	Not observed	Regular	Regular
Common Noddy	Not observed	Regular	Regular
Black Noddy	Not observed	Regular	Regular
Lesser Noddy	Not observed	Occasional?	Occasional?
Great Egret	Not observed	Occasional?	Not observed
Little Egret	Occasional	Occasional?	Occasional?
Eastern Reef Egret	Regular	Regular	Regular
Nankeen Night-Heron	Occasional	Not observed	Not observed

[1] Observed in the past when the Coconut Palms were extant. In the absence of palms the species may no longer breed there.

[2] Has roosted on West Island on occasion and may be prospecting.

Table 2 Count of tropicbirds on West Island, Ashmore Reef during 16 visits between October 1998 and April 2010. In instances where several counts were made over consecutive days the highest count from that period is presented. Tropicbird records from Middle and East Islands are presented in Tables 3 and 4.

	Oct-1998	Oct-2000	Oct-2001	Nov-2001	Jan-2002	Feb-2003	Sep-2003	Oct-2004	Nov-2004	Jan-2005	Oct-2005	Oct-2006	Oct-2007	Oct-2008	Oct-2009	Apr - 2010
Red-tailed Tropicbird																
adults	-	4	2	10	8	10	20	4	4	17	12	4	4	10	3	24
nests	-	2	1	5	2	4	7	2	3	14	3	3	3	8	1	17
White-tailed Tropicbird																
adults	-	-	-	4	2	4	3	3	-	8	-	3	3	4	1	3
nests	-	-	-	2	1	-	-	2	-	2	-	-	-	-	-	1

Sources: Study team unpublished data, Swann (2005a), Swann (2005b), Swann (2005c), Milton (2005), this study

Table 3 The maximum count of seabirds obtained during 48 visits between 1979 and 1998 and counts of seabirds during 11 visits between Jan 2002 and April 2010 at Middle Island, Ashmore Reef. In instances where several counts were made over consecutive days the highest count from that period is presented. Numbers in bold indicate breeding of that species was explicitly reported for that count. n = nests (Brown Booby-April 2010)

Date	Max. count 1979-1998	Jan 2002	Jan 2003	Sep 2003	Oct 2004	Jan 2005	Oct 2005	Oct 2006	Oct 2007	Oct 2008	Oct 2009	Apr 2010
Red-tailed Tropicbird	1	0	1	1	1	0	0	2	0	0	0	0
White-tailed Tropicbird	6	0	3	0	0	2	0	1	1	1	0	0
Masked Booby	3	4	3	**2**	3	**14**	10	**20**	**10**	**20**	**30**	**28**
Red-footed Booby	15	**46**	**42**	**40**	60	220	30	**50**	**80**	**80**	**100**	**101**
Brown Booby	1050	**1530**	**1250**	**1000**	**1000**	**2300**	**1000**	**2000**	**5000**	**1000**	**3000**	**2841n**
Great Frigatebird	24	**8**	**4**	2	3	**20**	20	**30**	**20**	**20**	**20**	**65**
Lesser Frigatebird	1991	**1000**	**300**	**100**	300	300	200	**2000**	**800**	**300**	**1000**	**2504**
Crested Tern	400	**150**	**105**	300	60	325	70	**500**	300	10	**250**	**2814**
Bridled Tern	239	0	0	0	10	0	0	5	8	1	2	**50**
Sooty Tern	40000	**15000**	**5000**	50	**5000**	50	**3000**	**10000**	**15000**	**100**	500	**2500**
Common Noddy	10000	1500	260	**5000**	**15000**	60	200	**3000**	**700**	**2000**	**1800**	**13875**
Black Noddy	120	100	3	2	6	0	10	5	5	0	30	**180**
Lesser Noddy	120	0	0	0	0	0	0	0	0	0	1	**7**

Sources: Study team unpublished data, Swann (2005a), Swann (2005b), Swann (2005c), Milton (2005), this study

Table 4 The maximum count of seabirds obtained during 51 visits between 1979 and 1998 and counts of seabirds during eight visits between Jan 2002 and April 2010 at East Island, Ashmore Reef. In instances where several counts were made over consecutive days the highest count from that period is presented. Numbers in bold indicate breeding of that species was explicitly reported for that count. n = nests (Brown Booby-April 2010)

	Max. count 1979-1998	Jan 2002	Jan 2003	Jan 2005	Oct 2005	Oct 2006	Oct 2007	Oct 2009	Apr 2010
Red-tailed Tropicbird	6	1	1	0	0	0	0	0	0
White-tailed Tropicbird	1	0	0	0	2	2	5	0	0
Masked Booby	9	5	25	**4**	**10**	**5**	**15**	**8**	**10**
Red-footed Booby	0	0	**12**	**8**	**10**	**12**	**40**	**30**	**20**
Brown Booby	500	**1800**	**2000**	**2200**	**1000**	**3000**	**3000**	**1900**	**1538n**
Great Frigatebird	2	0	**4**	0	**5**	2	**10**	0	0
Lesser Frigatebird	140	**800**	**2000**	**600**	**300**	**1000**	**500**	**300**	**1773**
Crested Tern	2700	**310**	**310**	150	10	10	400	85	**2568**
Bridled Tern	2400	0	0	0	**3**	**5**	**6**	5	**300**
Sooty Tern	20000	**25000**	**10000**	350	**10000**	**10000**	**10000**	**7000**	**5000**
Common Noddy	54000	3000	**1800**	530	**3000**	**5000**	400	**1070**	**30930**
Black Noddy	375	1500	5	3	20	10	20	70	**450**
Lesser Noddy	20	0	0	0	0	0	0	0	**6**

Sources: Study team unpublished data, Swann (2005a), Swann (2005b), Swann (2005c), Milton (2005), this study

Table 5 Count of Eastern Reef Egrets on West Island, Ashmore Reef during 16 visits between Oct 1998 and October 2009. In instances where several counts were made over consecutive days the highest count from that period is presented.

	Oct 1998	Oct 2000	Oct 2001	Nov 2001	Jan 2002	Feb 2003	Sep 2003	Oct 2004	Nov 2004	Jan 2005	Oct 2005	Oct 2006	Oct 2007	Oct 2008	Oct 2009	Apr 2010
Count of adults	None reported	100	300	300	191	150	200	400	?	400	200	500	300	700	400	250
Active nests?	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

Sources: Study team unpublished data, Swann (2005a), Swann (2005b), Swann (2005c), Milton (2005), this study

Figure 12 Breeding seasons of seabirds and herons, and wintering period for migratory shorebirds, at Ashmore Reef.
Breeding months (seabirds) and presence of adults (shorebirds) are shaded dark grey, pale grey indicates ‘shoulder’ months. Letters denote reported seabird reproductive stage; E = eggs; SC = small chick; MC = medium chick; LC = large chick or fledgling; B = breeding reported/reproductive stage not specified. Data sourced from Milton (2005), Swann (2005a, 2005b, 2005c), Bellio *et al.* (2007) and Study team unpubl. data. Known breeding stages extrapolated to breeding seasons using data in Marchant & Higgins (1990a, 1990b), Higgins & Davis (1996). Unshaded cells indicate there is no *evidence* of breeding, though for many species breeding may still take place in these months.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Wedge-tailed Shearwater									B	B		
Red-tailed Tropicbird	E, SC - LC			E, MC, LC					B	LC	B	
White-tailed Tropicbird	E			E							E	
Masked Booby				LC					B	LC	B	
Red-footed Booby	B	E, SC		E					B	LC	B	
Brown Booby	E	E		E					B	LC	B	
Great Frigatebird	B	E		E								
Lesser Frigatebird				E					B		Empty nests	
Crested Tern	E, SC			E						E	B	
Lesser Crested Tern								?				
Roseate Tern					?	?	?	?				
Bridled Tern				E						LC		
Sooty Tern	E			E						E, LC	E	
Common Noddy				E						E		
Black Noddy				E						Empty nests		
Lesser Noddy				E						Empty nests		
Great Egret										E		
Little Egret										E, LC		
Eastern Reef Egret	E, SC, MC								B	E, SC - LC	B	
Nankeen Night-Heron										E, LC		
Migratory shorebirds												

Individual Seabird Species Accounts

Wedge-tailed Shearwater

A small colony of Wedge-tailed Shearwaters breed on West Island, Ashmore Reef; there are no reports of breeding colonies on either Middle or East Island. Swann (2005a) estimated that there were 30 active burrows in January 2002, but owing to the fragile nature of burrows, an accurate count was not conducted. In 2010 any young had fledged by mid-April and burrows entrances were assessed as inactive (R. Clarke pers. obs).

Figure 13 Wedge-tailed Shearwater at sea near Ashmore Reef, north west Australia, April 2010.

Although a number *Procellariiformes* (petrels and shearwaters) occur with some frequency in waters surrounding Ashmore Reef, including waters directly affected by the Montara Well release (Watson *et al.* 2009, Study team unpubl. data), the Wedge-tailed Shearwater is the only *Procellariiforme* that breeds locally. Catry *et al.* (2009) demonstrated that breeding Wedge-tailed Shearwaters in the western Indian Ocean can move considerable distances, with core foraging areas extending up to ~500 km from the breeding site and, when not breeding, the species was shown to range up to 1000 km from the breeding site. The foraging areas of Wedge-tailed Shearwater that breed at Ashmore Reef are unknown, but the distances over which this species forages (Catry *et al.* 2009), indicate that the Montara Well release had the potential for at sea impact. That Watson *et al.* (2009) recorded the species within oil affected transects in September and October 2009 further highlights this potential. The species is a listed migratory species under JAMBA and is a listed marine species under the *EPBC Act 1999*.

As the Wedge-tailed Shearwater arrives and departs the breeding grounds in darkness (Marchant & Higgins 1990a), and on West Island, nests within shallow burrows that easily collapse underfoot, there are no accurate counts of the population. To address this, the boundaries of the colony have recently been mapped (April 2010), so that any change in the extent of the colony may be monitored over time.

Red-tailed Tropicbird

Small numbers of Red-tailed Tropicbirds breed at Ashmore Reef. Between 1983 and 1988 Milton (2005) estimated up to three pairs nested there in any year. More recent data suggests five to ten pairs nest on West Island in most years (Table 2). The highest count to date was obtained in April 2010 when a total of 17 active nests were located on West Island. When combined with historic data, these recent counts suggest that this population may be increasing, albeit slowly. Individuals and pairs are occasionally reported from East and Middle Island, but there are few, if any, confirmed nesting attempts on those islands.

Figure 14 Red-tailed Tropicbird adult attending medium-sized chick at base of mature *Argusia argentea* shrub on West Island, Ashmore Reef, April 2010.

The Red-tailed Tropicbird is a shallow diving species that readily alights on the sea surface and typically forages within the first 4 m of the water column (LeCorre 1997). There is limited information concerning foraging range when breeding, but observations at sea in the Ashmore Reef region (Study team unpubl. data) demonstrate they are capable of foraging considerable distances from land. There are also documented instances of transoceanic movements demonstrating that sea surface oil arising from the Montara Well release was within range should the species forage over waters to the east of Ashmore Reef. The Red-tailed Tropicbird is a listed marine species under the *EPBC Act 1999*.

As Red-tailed Tropicbirds nest under fringing *Argusia argentea* shrubs on West Island, it is feasible to accurately count all nests during each survey visit. In April 2010 the position of all nests was accurately recorded so that any changes in nest site distribution can also be monitored. Given peaks in abundance, the optimal period for monitoring appears to be in the months of April and May.

White-tailed Tropicbird

The White-tailed Tropicbird is a rather scarce breeding species at Ashmore Reef. Milton (2005) estimated that up to two pairs nested within the reserve each year (between 1983 and 1988) and recent data suggests this population size remains largely unchanged (Table 2). Foraging ecology appears to be similar to that of the Red-tailed Tropicbird, with the species being a surface forager that occasionally undertakes shallow dives (Marchant & Higgins 1990b). Pennycuick *et al.* (1990) demonstrated that the White-tailed Tropicbird forages up to 89 km from the nest site when breeding and moves considerably larger distances when not breeding. Thus, like the Red-tailed Tropicbird, the foraging distribution of the White-tailed Tropicbird is likely to have extended to sea surface areas affected by oil in 2009. Neither species of tropicbird was observed at sea by Watson *et al.* (2009), however given the small size of both breeding populations on Ashmore Reef, chance encounters at sea are likely to be infrequent. White-tailed Tropicbird is a listed migratory species under both JAMBA and CAMBA and is a listed marine species under the *EPBC Act 1999*. Significantly, the species breeds at only three other locations in Australian territory.

Figure 15 White-tailed Tropicbird adult in flight over West Island, Ashmore Reef, October 2009.

A complete count of White-tailed Tropicbird nests and a count of adults present on the islands are feasible during any visit, though nests are often very well concealed and careful search effort is required. As with the Red-tailed Tropicbird, the position of all nests should also be recorded. As the species occurs in very low numbers monitoring is unlikely to reveal statistically significant changes in population size unless those changes are very large (i.e. an order of magnitude).

Masked Booby

Small but increasing numbers of Masked Booby breed on Middle and East Islands, Ashmore Reef. In October 1949 Serventy (1952) reported a single adult on East Island and two adults on Middle Island. Between 1983 and 1988 Milton (2005) estimated up to two pairs nested there in any one year. More recent data demonstrates the population has been increasing, with 28 birds counted across Middle and East Island in January 2003 (Swann 2005b) (Tables 3 and 4). The highest count to date was obtained in April 2010 when a total of 48 adults were counted ashore and 33 active nests were located on the two breeding islands. When combined with historic data, it would appear that after a period of absence (there are no records between 1979 and 1986 despite 44 survey visits to Middle island and 36 survey visits to East Island during this period; DSEWPaC unpubl. data), the species has now successfully recolonised Ashmore Reef. This change in status likely reflects the level of protection afforded to seabirds at Ashmore Reef following the increased presence of staff from DSEWPaC (and its predecessors) and border protection agencies (For further insight see the species account for Brown Booby p. 27).

The Masked Booby pursues its prey (fish) by shallow plunge diving and surface seizing (Marchant & Higgins 1990b). In the eastern tropical Pacific Ocean, where foraging ecology has been well studied, Weimerskirch *et al.* (2009) demonstrated that individuals spent between 15 and 30% of their time on the sea surface when at sea. In the same study, core foraging areas were situated approximately 85 km from the breeding site (males 83.1 ± 61.1 km; females 85.6 ± 38.3) and birds commuted to these on a daily basis. That the species can travel considerable distances is further demonstrated by observations in the Ashmore Reef region (Study team unpubl. data), where adults have been detected in excess of 240 km from the nearest breeding site[1]. Although Watson *et al.* (2009) did not detect this species within oil affected transects in September and October 2009, detection rates elsewhere during their surveys were very low (1% off all transects) and use of the oil affected areas remains possible. Masked Booby is a listed migratory species under both JAMBA and ROKAMA and is a listed marine species under the *EPBC Act 1999*. The taxon present at Ashmore Reef is *Sula dactylatra bedouti.* This East Indian Ocean form breeds at only four locations (Ashmore Reef, Adele Island, Lacepede Islands and Cocos Keeling Islands. As such the taxon is recognised as nationally Vulnerable (Garnet and Crowley 2000, S. Garnett in prep. 2010).

[1] During October 2009 two adults were detected 240-245 km from the nearest known breeding sites at a time when breeders where attending large chicks.

Masked Boobies nest in exposed areas (typically bare substrate) on Middle and East Island. Owing to their large size, it is possible to count all adults and active nests with a high degree of accuracy during each survey visit. Given apparent peaks in abundance and nest stage, the optimal period for monitoring appears to be during April and May.

Red-footed Booby

The Red-footed Booby is either a recent colonist at Ashmore Reef or it has recently re-established after a long period of absence. Serventy (1952) reported 'some substantial old nests in a clump of tall bushes' on West Island and suggested they may have belonged to the Red-footed Booby, though he was unable to confirm this and did not report any Red-footed Boobies at Ashmore Reef. Milton (2005) did not report any Red-footed Boobies nesting within the reserve to 1988 and the first reports of birds ashore were in May 1995 when two individuals were noted on Middle Island (DSEWPaC unpubl. data). Since 2000, birds have been present during every documented visit to Middle Island. Subsequently, the species appears to have also colonised East Island during 2002 (Tables 3 and 4). The highest count was obtained on the most recent visit (April 2010) when a total of 101 active nests were recorded across Middle (91 nests) and East Islands (10 nests). As Red-footed Boobies construct their nest in elevated positions[1] (Marchant & Higgins 1990b), the breeding population may ultimately be limited by available nest sites. That nest site availability may already be limiting is demonstrated by recent observations of birds nesting (atypically) ~0.2 - 0.5 m above ground on compacted herbaceous material (Figure 16).

Figure 16 Pale morph Red-footed Booby adult on a nest built atop a dense stand of the herbaceous *Amaranthus interruptus*, East Island, Ashmore Reef, April 2010.

[1] On Middle Island Red-footed Booby nests are typically located in the woody remnants of large shrubs that have died in the last decade. In the absence of further recruitment of shrubs to East and Middle Island, when the present material breaks down, there will be few suitable nest sites available to this species.

The Red-footed Booby obtains its prey by aerial pursuits (of flying fish), shallow plunge diving and surface seizing. The species readily settles on the sea surface and typically forages within the first 2 m of the water column (Weimerskirch *et al.* 2006). In a study of foraging behaviour in the western Indian Ocean, Weimerskirch *et al.* (2006) demonstrated that females range farther during incubation periods than males (85 km vs. 50 km), and feed mostly at the extremity of their foraging trip, whereas males actively seek food throughout foraging trips. Weimerskirch *et al.* (2006) also provides data on time spent at the sea surface with males and females devoting approximately 30% and 34% of their time respectively to this activity. In the Ashmore region adults have been detected up to 125 km from the nearest breeding islands during October (Study team unpubl. data). A single individual was detected at sea during a rapid assessment of the impact of the Montara Well release (in a non-oil affected transect) (Watson *et al.* 2009), but this sample is inadequate to draw conclusions regarding the potential threat posed by the event. As females travel further than males when foraging it is possible that any impact is biased towards females. The Red-footed Booby is a listed migratory species under both JAMBA and CAMBA and is a listed marine species under the *EPBC Act 1999*.

That Red-footed Booby typically nests on elevated structures ensures counts are highly repeatable. However, given the potential for this species to nest amongst lower herbaceous material (as was observed in April 2010), such habitats should also be carefully searched during future counts. As the population now exceeds 100 pairs, long term monitoring of the species for the purposes of impact assessment is appropriate. Apparent peaks in abundance and optimal nest stages (primarily eggs) dictate that the April or May is an appropriate time to undertake monitoring.

Brown Booby

The Brown Booby is the most abundant of the three species of *Sulidae* breeding at Ashmore Reef. The present abundance of the species reflects a remarkable recovery. In October 1949 Serventy (1952) reported approximately 40 birds over West Island but no nesting, 200 birds at Middle Island including many free flying immature birds, and a few adults but no young on East Island. Significantly, Serventy (1952) reported the remains of birds killed by visiting Indonesian fishermen on all three islands. The ‘take’ was implied to be high with ‘a small heap of remains of immature boobies’ on West Island, a ‘few remains of killed birds’ on Middle Island and ‘quantities of remains of birds killed by visiting fishermen’ on East Island (Serventy 1952). Between 1983 and 1988 Milton (2005) estimated the between zero and 20 pairs nested there in any year. More recent data demonstrates a pronounced increase suggesting the population has been released from the oppressive effects of harvesting. In the late 1990s; a high count of 1050 on Middle Island in May 1998 and 293 on East Island in the same month was documented (DSEWPaC unpubl. data). This upward trend continued through the last decade such that by April 2010 a record 4379 nests (extrapolated to 8758 breeding adults) were counted across Middle and East Islands (Tables 3 and 4). Like other large seabirds at Ashmore Reef this change in status likely reflects an increased level of protection afforded following the more permanent presence of staff from border protection agencies and DSEWPaC (and its predecessors).

The Brown Booby pursues its prey by shallow plunge diving and surface seizing (Marchant & Higgins 1990b). There is limited information regarding the daily foraging range of the Brown Booby, however available evidence is that birds return to land each night to roost (Study team unpubl. data). At sea it is the most frequently encountered of the four species of *Sulidae* recorded in the region (Study team unpubl. data). Although the species can travel considerable distances when foraging it is less frequently detected in distant waters (e.g. >80 km from land) than either the Masked or Red-footed Boobies. Consistent with these observations Abbott (1979) reported that the species was most abundant 18 to 36 km from land off north west Australia. The Brown Booby was the second most abundant seabird recorded by Watson *et al.* (2009) during their rapid assessment of the impacts of the Montara Well release in September and October 2009. In total 183 individuals were recorded, with 19% of oil affected transects containing this species. In a similar survey conducted in late September 2009, AES (2009) also reported two Brown Boobies in the vicinity of light oil sheen on the sea surface. The Brown Booby is a listed migratory species under both JAMBA and CAMBA and is a listed marine species under the *EPBC Act 1999*.

Figure 17 Adult male Brown Booby attending medium/large chick amongst dense herb field of *Amaranthus interruptus*, with *Eragrostis cumingii* East Island, Ashmore Reef, April 2010.

The Brown Booby nests in exposed areas (typically bare substrate) on Middle and East Island. Owing to their large size and the rather even distribution of nests it is possible to count all adults and active nests with a high degree of accuracy during each survey visit. Given the current population size at Ashmore Reef, the strength of existing data and the fact that this species was frequently recorded in waters affected by the Montara Well release (Watson *et al.* 2009) the Brown Booby is a high priority for ongoing monitoring at Ashmore Reef. Given apparent peaks in abundance and nest stage, the optimal period for monitoring appears to be in the months of April and May.

Great Frigatebird

Small but increasing numbers of Great Frigatebirds breed on Middle Island, Ashmore Reef. There are also regularly reports of adults from East Island but at present (likely due to an absence of suitable nesting sites) the species does not breed there. Historic records of both frigatebird species are confounded by difficulties with identification. Until 1990 field identification of the two species was poorly covered in ornithological literature (including Australian bird field guides) and as a consequence it is likely that the two species were at times misidentified. Milton (2005) did not report the Great Frigatebird to be breeding at Ashmore Reef between 1983 and 1988, yet on the first occasion that this species was explicitly recognised 24 birds were counted (Middle Island, May 1995; DSEWPaC unpubl. data) Since that time numbers have remained relatively stable with regular counts of ~20 in the last five years (Table 3). More recently on Middle Island a high count of 65 adults and 40 active nests was obtained in April 2010. An irregular but upward trend in population size may reflect the fact that Great Frigatebirds share parental duties and only raise one offspring every two years (Marchant & Higgins 1990b). Thus the total breeding population at any site is best measured by counting all breeding attempts over a two year period.

The Great Frigatebird is kleptoparasitic in that it obtains a potion of its food requirements by pursuing individuals of a variety of other seabird species, forcing them to drop or regurgitate food items. Once the food is released by the hapless target, the frigatebird then catches it in mid-air or picks it from the sea surface. Frigatebirds also catch their own prey during aerial pursuit (e.g. flying fish) and by picking from the sea surface (Marchant & Higgins 1990b). Despite being a bird of the open ocean, frigatebirds are unable to dive and rarely alight on the sea surface as their plumage wets easily, preventing them from subsequently taking off. The at-sea distribution of the Great Frigatebird is poorly understood. Nevertheless, the species can travel considerable distances from land, as adults have been detected in excess of 190 km from the nearest breeding site (Study team unpubl. data). Although Watson *et al.* (2009) did not detect this species within oil affected transects in September and October 2009, given the relatively small population at Ashmore Reef the species' use of oil affected areas remains possible. The Great Frigatebird is a listed migratory species under both JAMBA and CAMBA and is a listed marine species under the *EPBC Act 1999*.

Figure 18 Nest attendance duties by female Great Frigatebird (adult despite darker grey throat) on a nest atop a dead *Scaevola taccada* shrub on Middle Island, Ashmore Reef, April 2010.

All Great Frigatebird nests are currently restricted to a collection of dead woody shrubs on Middle Island. Following the vegetation map of Pike and Leach (1997), these were once *Scaevola taccada* shrubs (Figure 6). Given that Great Frigatebirds are large, it is possible to accurately count all adults and active nests with a high degree of certainty during each survey visit. Given apparent peaks in abundance and nest stage, the optimal period for monitoring appears to be in the months of April and May. Although the species population size and ecology suggests the Great Frigatebird is suitable for monitoring purposes, consideration must be given to the fact that this species breeds biannually.

Lesser Frigatebird

Relatively large numbers of Lesser Frigatebirds breed on Middle and East Islands, Ashmore Reef. As with the Great Frigatebird, historic records for this species may confounded by difficulties with identification (see that account). Milton (2005) reported between zero and 750 Lesser Frigatebird pairs bred at Ashmore Reef between 1983 and 1988. Since that time numbers have gradually increased (Tables 3 and 4). By January 2003, 2300 birds were reported to be nesting across both breeding islands (Swann 2005b). More recently in April 2010, 4277 adults were counted across Middle and East Islands. Whilst the current population trend is upward, year to year population size fluctuates more than for some other seabird species. This may reflect the fact that Lesser Frigatebirds share parental duties and only raise one offspring every two years (Marchant & Higgins 1990b). Thus the total, as with the Great Frigatebird breeding population, may be best measured by counting all breeding attempts over a two year period.

The foraging ecology of the Lesser Frigatebird is similar to that of the Great Frigatebird in that it forages at or above the surface and rarely alights on the sea (see the Great

Frigatebird account for more details). Like the Great Frigatebird, the at-sea distribution of the Lesser Frigatebird is also poorly understood. Nevertheless, it is known that the species can travel considerable distances from land, as adults have been detected in excess of 250 km from the nearest breeding site in the Ashmore region (Study team unpubl. data). Watson *et al.* (2009) detected eight individuals at sea during their rapid assessment of the affects of the Montara Well release. Half of these individuals were noted over oil affected transects, suggesting that oil has the potential to affect the species directly, impact upon prey species or impact upon other seabirds that the Lesser Frigatebird parasitizes. The Lesser Frigatebird is a listed migratory species under both JAMBA and CAMBA and is a listed marine species under the *EPBC Act 1999*.

Lesser Frigatebirds nest in dense colonies on both Middle and East Island. In April 2010 a total count of all free flying individuals (here termed 'adults') was made. Some of these individuals may be non-breeding birds, but at this stage of the breeding cycle they are impossible to separate. Late in the dry season when Lesser Frigatebirds have finished nesting it is possible to accurately count the number of Lesser Frigatebird nests from the most recent season past, as the distinctive mound-like structures persist until the onset of wet season rains (Study team unpubl. data). Monitoring of Lesser Frigatebirds should therefore consist of two components; a complete count of all 'adults' within colonies in April or May when birds are on eggs, and a second complete count of all used nest mounds in the late dry season. While the species population size suggests the Lesser Frigatebird is suitable for monitoring purposes, observers must be mindful that this species breeds biannually.

Figure 19 Breeding colony of Lesser Frigatebirds nesting within a herb field dominated by *Amaranthus interruptus* on Middle Island, Ashmore Reef, April 2010.

Crested Tern

The Crested Tern is a common breeding species at Ashmore Reef. As early as November 1979, 800 individuals were reported to be breeding on East Island (DSEWPaC unpubl. data), and since that time the species has been reported breeding on all three vegetated islands (infrequently so on West Island). Between 1983 and 1988 Milton (2005) estimated between 1000 and 4500 pairs nested there in any one year. More recent data suggests that the breeding population is at the lower end of this range in most years (~1000 pairs); though on occasions larger breeding colonies have been reported. For example in April 2010, breeding colonies were present on both Middle and East Islands. A total of 5937 adults and 2760 nests, all containing eggs, were documented. Given the breeding population appears to fluctuate on an annual basis, Crested Tern populations at Ashmore Reef may fluctuate in response to year to year movement of adults between other breeding sites (e.g. Cartier, Browse, Adele and the Lacepede Islands).

The Crested Tern pursues its prey (mainly small fish) by shallow plunge diving (typically < 0.5 m) and surface seizing (Higgins & Davies1996). The species will alight and rest on the sea surface in calm conditions (Brandis *et al.* 1992), however this behaviour appears rare (a single record in 10 years of at sea observation in the Ashmore region; Study team unpubl. data) and it assumed that most individuals return to land for roosting purposes. In the Ashmore region most Crested Terns are observed within 40 km of islands (Study team unpubl. data). Consistent with this, Abbott (1979) reported that the species was most abundant out to 18 km from land, with a slightly lower encounter rate between 18 and 36 km and very few birds more than 36 km from land. Watson *et al.* (2009) detected small numbers of this species within oil affected transects in September and October 2009. Although detection rates were generally low (2% off all transects), the species clearly has the potential to utilize marine areas impacted upon by the Montara Well release. The Crested Tern is a listed marine species under the *EPBC Act 1999*.

Crested Terns nest in dense colonies (up to 6.3 nests/m^2 have been reported; Higgins & Davies 1996). At Ashmore the species is reported breeding in most years on Middle and/or East Island (Tables 3 and 4). Typically, colonies select more open areas in which to nest, such that wet season colonies are mostly located immediately above the high tide line on exposed shell beds. In the dry season, once herbaceous vegetation has reduced in extent, colonies may be located in the centre of the islands (Study team unpubl. data). Owing to the compact nature of colonies, it is possible to count all adults and active nests with a degree of accuracy during each survey visit. However, to improve confidence in counts it is necessary for multiple observers to repeat-count at least two to three times (R. Clarke pers. obs.). The species displays a variable breeding season with nesting colonies with eggs reported in January, April and October (Figure 12) at Ashmore Reef. As such, surveys at any time of the year have the potential to coincide with a breeding event. Nevertheless, on current knowledge, two annual surveys, one in the late wet season and the other in the late dry season should provide adequate opportunity to assess Crested Tern numbers during periods for which there are existing pre-impact data.

Figure 20 A portion of a Crested Tern colony that contained 2368 adults, East Island, Ashmore Reef, April 2010.

Lesser Crested Tern

The Lesser Crested Tern is reported to be a scarce and irregular breeding species at Ashmore Reef, with Milton (2005) estimating that between zero and 500 pairs nested on the island each year (between1983 and 1988). However, the Study team has never recorded the species within the reserve in over a decade and there are just two records prior to 1998 (a singleton in Oct 1984 and 100 individuals in August 1986; DSEWPaC unpubl. data). More recently, Watson *et al.* (2009) reported 10-100 Lesser Crested Terns on Middle Island and included an observation of courtship displays during a rapid assessment in late September/early October 2009. Less than 30 days later the Study team (30 October 2009) recorded a breeding colony of (Greater) Crested Terns and no Lesser Crested Terns at this same site. As Watson *et al.* (2009) did not record any (Greater) Crested Terns, the identification of these birds should be treated with caution. Observations of Lesser Crested Terns at sea in the north-west region demonstrate most individuals are restricted to shallow waters closer to the Australian mainland (Study team unpubl. data), where the species is known to breed annually (e.g. Lacepede Islands; Study Team unpubl. data). The Lesser Crested Tern is a listed migratory species under CAMBA and is a listed marine species under the *EPBC Act 1999*.

Given the questionable nature of Lesser Crested Tern records at Ashmore Reef, counts of this species are unlikely to underpin any long-term monitoring program for seabirds within the reserve. Nevertheless, in the event that the species is detected breeding, counts of colony size (total adults and total active nests) should be undertaken.

Roseate Tern

The Roseate Tern is reported to breed on an irregular breeding basis at Ashmore Reef, with Milton (2005) estimating that between zero and 60 pairs nested on the island each year (between1983 and 1988). Data spanning the period 1979 to 1998 reveals Roseate Tern records are restricted to the dry season months of May to August with aggregations and breeding records in just four years (1986, 1987, 1995, 1996; DSEWPaC unpubl. data). The highest count during this period was 280 on East Island in May 1995, though most other records refer to aggregations of <70. Although the Study team has not recorded the species breeding within the reserve in over a decade of observations, during April 2010, 75 adults (in breeding plumage) were counted within the reserve. During this period, individuals were observed participating in paired flight displays on a number of occasions at both West and Middle Island. This may indicate nesting was about to commence. If this is the case then it would seem likely that breeding by the species is under-reported given the lack of recent data from the dry season. Large non-breeding concentrations of Roseate Terns occur at the Lacepede Islands in October of most years (up to 30,000; Study team unpubl. data), demonstrating that at least regionally the species remains abundant. Roseate Terns are known to breed on the Kimberley coast (e.g. Sterna Island, Admiralty Gulf (G. Swann pers. comm.) and historically bred at the Lacepede Islands (Serventy 1952)). Using transect data, Roseate Terns are the most frequently detected smaller tern in waters >40 km from land (Study team unpubl. data). As the species readily alights and rafts in large flocks on the sea surface it seems likely that this species does not have to return to land on a daily basis, nevertheless most apparently chose to do so (M. Carter pers. obs.). Despite this, Watson *et al.* (2009) did not record any Roseate Terns (either at sea or at Ashmore Reef) during their rapid assessment of the impacts of the Montara Well release in September and October 2009. The Roseate Tern is a listed migratory species under JAMBA and is a listed marine species under the *EPBC Act 1999*.

As Roseate Terns appear to breed irregularly at Ashmore Reef, with no confirmed breeding events in the past decade, counts of this species are unlikely to underpin any long-term monitoring program within the reserve. Nevertheless, in the event that the species is detected breeding, counts of colony size (total adults and total active nests) should be undertaken. If this species were to be targeted for monitoring purposes (not recommended), then the period spanning late May to early August would appear to provide the best opportunity to encounter breeding colonies.

Bridled Tern

The Bridled Tern is a common breeding species at Ashmore Reef. The highest count since 1979 is of 2400 birds on East Island in June 1984. Other high counts include 1405 in October 1984 and 1440 in August 1985 (DSEWPaC unpubl. data). Available data suggests the species is most abundant during the period April to September, with most birds apparently departing the reserve after breeding is complete. For example, fewer than 10 individuals have been reported in each of six October visits since 2004 (Tables 3 and 4). Although data is incomplete, it would appear that larger numbers of Bridled Terns breed on East Island when compared with Middle Island (DSEWPaC unpubl. data)

The Bridled Tern forages mostly by shallow plunge diving, dipping and surface seizing, especially in association with predatory fish (Higgins & Davies 1996, R. Clarke pers. obs.). Whilst distant Sooty and Bridled Terns pose identification challenges at sea, Bridled Terns are typically more abundant over shallow waters and thus usually occur closer to land than Sooty Terns (Study team unpubl. data). Higgins & Davies (1996) further state that the species mostly forages in offshore waters (as opposed to pelagic waters). Watson *et al.* (2009) conservatively pooled most observations of Sooty and Bridled Terns at sea. This species pair was the third-most abundant seabird recorded during their rapid assessment of the impacts of the Montara Well release in September and October 2009. In total 92 individuals of the two species were recorded, with a reported occurrence in at least 19% of oil affected transects. The Bridled Tern is a listed migratory species under both JAMBA and CAMBA and is a listed marine species under the *EPBC Act 1999*.

Bridled Terns typically nest in loose aggregations of birds on Middle and East Island. Individuals within colonies are sparsely distributed because, unlike many other surface nesting seabirds, Bridled Terns conceal their nests under cover of vegetation. On East and Middle Island nests are therefore concealed amongst herbaceous vegetation, often at the ends of short tunnels formed by the birds themselves (G. Swann pers. obs.). As a consequence, accurate counts of Bridled Tern nests are not possible without causing undue disturbance to colonies and the vegetation in which they nest. Repeated counts of visible adults, to obtain a reasonable estimate of the total number of Bridled Terns present on each island, is the most appropriate measure under the circumstances. As the species appears to be an obligate dry season breeder at Ashmore Reef, with nesting commencing in April, annual monitoring of this species would ideally be conducted during the period April to May.

Figure 21 Adult Bridled Tern perched atop the herb *Amaranthus interruptus* on Middle Island, Ashmore Reef, April 2010.

Sooty Tern

The Sooty Tern is one of the most abundant breeding seabirds at Ashmore Reef and this appears to have been the case for a considerable period of time. For example 18,000 birds were present in November 1979 and 45,000 were estimated to be present in April 1983 (DSEWPaC unpubl. data). Between 1983 and 1988 Milton (2005) estimated 10,000 to 50,000 pairs nested there in any one year. More recent data supports these conclusions with 10,000 or more individuals counted during most visits over the last decade and a maximum count of 40,000 in January 2002. In April 2010, 7500 adults were present across Middle and East Islands (Tables 3 and 4) with egg laying having just commenced. Generally, larger numbers of Sooty Terns breed on East Island when compared with Middle Island (DSEWPaC unpubl. data, Study team unpubl. data, Tables 3 and 4).

The Sooty Tern forages mostly by shallow plunge diving and surface seizing, especially in deeper water locations where predatory fish force smaller fish to the sea surface (Au *et al.* 1986, Higgins & Davies 1996, R. Clarke pers. obs.). Although Sooty and Bridled Terns pose some identification challenges at sea, especially when birds are distant, Sooty Terns typically occur over deeper water and at greater distances from land than Bridled Terns (Study team unpubl. data) and as a consequence Higgins & Davies (1996) define the species as strongly pelagic. As Watson *et al.* (2009) pooled observations of Bridled and Sooty Terns their findings are presented under the former species account. Most notably the species pair was reported in 19% of oil affected transects. In a survey conducted in late September 2009 within the vicinity of the Montara Well release, AES (2009) reported 87 encounters (176 individuals) with Sooty Terns of which 84% were in areas with some visible oil on the sea surface. The Sooty Tern is a listed marine species under the *EPBC Act 1999*.

Figure 22 Large breeding colony of Sooty Terns, containing ~7000 adults on East Island, Ashmore Reef, October 2009. Note the lack of vegetation and the arid appearance of the island in this late dry season scene (c.f. Figure 1).

The Sooty Tern nests in densely packed aggregations of birds on Middle and East Island. Breeding across an entire colony is highly synchronised with egg laying by most colony members occurring over several weeks (G. Swann pers. obs.). Whilst they appear to prefer open areas for nesting purposes, colonies do establish within areas of low herbaceous growth during the wet season. Over time, with the comings and goings of the colony this vegetation is then flattened (R. Clarke pers. obs.). Although Sooty Terns tend to nest in discrete aggregations the extremely high densities mean that accurate counts are challenging. It is essential that multiple observers repeat counts at least two to three times to provide some confidence in the collected data. Inter-annual variation in colony sizes in recent years (10,000 – 40,000), may reflect the variable timing of breeding in this species; to date eggs have been reported in the months of January, April and October to November (Figure 12). As such, surveys at any time of the year have the potential to coincide with a breeding event, though two annual surveys, one in the late wet season and the other in the late dry season should provide adequate opportunity to assess Sooty Tern numbers during periods for which there are existing pre-impact data. As this species was frequently recorded in waters affected by the Montara Well release (AES 2009, Watson *et al.* 2009) the Sooty Tern is a high priority for ongoing monitoring at Ashmore Reef.

Common Noddy

The Common Noddy is one of the most abundant breeding seabirds at Ashmore Reef. A total of 15,000 were counted across Middle and East Islands in April 1983 whilst 54,000 were present at the same locations in June 1984. These counts are the basis on which Milton (2005) estimated some 13,500 to 35,000 pairs of Common Noddy nested at Ashmore Reef between 1983 and 1988. More recent data from the late dry season (mostly October) demonstrates that even as the breeding season draws to an end between 5000 and 10,000 birds are typically present on the islands (Tables 3 and 4). Recent counts when birds are actively nesting are more scarce. However, in April 2010 when large numbers of birds were commencing incubation a total count of 44,805 adult Common Noddy was obtained across Middle and East Islands (Tables 3 and 4).

Like so many species of seabird breeding at Ashmore Reef the Common Noddy pursues its prey by shallow plunge diving, dipping and surface seizing (Higgins & Davies 1996). There is limited information regarding the daily foraging range of the Common Noddy, however available evidence is that birds tend to forage over shelf waters and return to land each night to roost (Study team unpubl. data). At sea it is one of the most frequently encountered tern or noddy species recorded in the region (Study team unpubl. data). Although the species can travel considerable distances when foraging, it is less frequently detected in distant waters (e.g. >60 km from land) than, for example, the Sooty Tern (Study team unpubl. data). The Common Noddy was the most abundant seabird (by an order of magnitude) recorded by Watson *et al.* (2009) during their rapid assessment of the impacts of the Montara Well release in September and October 2009. In total, 2178 individuals were recorded, with 52%

of oil affected transects containing this species. In a similar survey conducted in late September 2009, AES (2009) also reported Common Noddy in the vicinity of oil on the sea surface. This was also the species most frequently reported to be directly contaminated by oil during the uncontrolled well release (Watson *et al.* 2009, images supplied by DSEWPaC, R. Clarke pers. obs.). Common Noddy is a listed migratory species under both JAMBA and CAMBA and is a listed marine species under the *EPBC Act 1999*.

The Common Noddy nests both on and amongst herbaceous vegetation on Middle and East Island. Colonies can be dense on occasions, but owing to vegetation condition nests can also be somewhat dispersed. After trialling counts in April 2010, the Study team concluded that it is not possible to accurately count nests during a ground assessment and rather a total count of adults during each visit is the most appropriate measure for monitoring purposes. It is essential that multiple observers repeat counts at least two to three times to provide some confidence in the collected data. Given the current population size at Ashmore Reef, the strength of existing data and the fact that this species was frequently recorded in waters affected by the Montara Well release (Watson *et al.* 2009) the Common Noddy is a high priority for ongoing monitoring at Ashmore Reef. Given apparent peaks in abundance and nest stage, the optimal period for monitoring appears to be in the months of April and May.

Black Noddy

The Black Noddy is a common breeding species at Ashmore Reef. The highest count since 1979 is of 1500 birds on East Island and a further 100 birds on Middle Island in January 2002 (Swann 2005a). Other high counts include 420 in July 1985, 175 in July 1986 (both East Island), 120 in July 1987 (Middle Island) and 630 across both islands in April 2010 (DSEWPaC unpubl. data, this study). Milton (2005) estimated that between 50 and 100 pairs of the Black Noddy bred at Ashmore Reef between 1983 and 1988. Given apparent misidentification as Lesser Noddy (see that species account) it is likely that this was an underestimate. Available data suggests the species breeds during the period April to September. Outside the breeding season, when not foraging at sea, birds appear to roost on the island beaches (e.g. 1600 in January 2002).

The Black Noddy forages mostly by shallow plunge diving, dipping and surface seizing, especially in association with predatory fish (Higgins & Davies 1996). The majority of at sea records of the Black Noddy obtained by the Study team are in close proximity to Ashmore Reef (Study team unpubl. data). These observations may indicate that the Black Noddy forages in marine areas not typically traversed by the Study team (when travelling to or from Ashmore Reef). Nevertheless, there is evidence that this species is capable of foraging considerable distances from breeding colonies. Higgins & Davies (1996) report the species forages well out to sea and typically 15 to 30 km from land. Although Watson *et al.* (2009) did not record this species during their assessment of the impacts of the Montara Well release, it remains probable that the Black Noddy forages in areas affected by oil. This is especially so given the very high numbers of the congener Common Noddy recorded the same survey. Black Noddy is a listed marine species under the *EPBC Act 1999*.

Figure 23 Adult Black Noddy carrying seagrass *Thalassia* sp. for nesting purposes on Middle Island, Ashmore Reef, April 2010.

The Black Noddy constructs an elevated nest in herbaceous vegetation on both Middle and East Islands. Colonies are generally on the periphery of Common Noddy colonies and appear to be preferentially established in areas of taller *Sesbania cannibina*[1] and *Amaranthus interruptus* (Swann 2005c, R. Clarke pers. obs.). Most colonies contain several to tens of pairs and on occasion include one or two pairs of Lesser Noddy. Accurate counts of Black Noddy nests are difficult to achieve when birds are breeding as it is not possible to enter colonies without causing some level of disturbance to breeding birds and the vegetation in which they nest. Repeat counts of visible adults to obtain a reasonable estimate of the total number of Black Noddies, is therefore, the most appropriate measure when birds are attending nests. However, as this species constructs a distinctive nest, once breeding is completed, it is possible to count vacant nests with a high degree of accuracy (and no disturbance)[2]. As the species appears to be an obligate dry season breeder, with nesting commencing in April, annual monitoring of adults would ideally be conducted during the period April to May and annual monitoring of vacant nests should be undertaken in the late dry season before nests are damaged by wet season rains.

Lesser Noddy

The Lesser Noddy is a scarce breeding species at Ashmore Reef. McKean (1980) first reported the species from within the reserve in November 1979 based on an observation of a bird at sea near West Island. Milton (2005) estimated between 100 and 150 pairs bred within the reserve each year between 1983 and 1988. However, scrutiny of the original data reveals some potential anomalies and suggests this conclusion should be treated with caution. For example in each of the three instances where Lesser Noddy was documented prior to 1995, one of the two common species of noddy (Common Noddy or Black Noddy) was inexplicably absent (DSEWPaC unpubl. data); further, reported counts of 20 to 120 are inconsistent with more recent data. Stokes and Hinchey (1990) present observations of breeding by all three noddy species on Middle Island in June 1986. Although they were conservative in their approach regarding the identity of these birds, their published photographs provide conclusive evidence that both Black and Lesser Noddy were breeding in mixed colonies at that time. Although the original data includes a record of 120 Lesser Noddy that coincides with Stokes and Hinchey's (1990) observations, there are no records of Black Noddy for this month in the database (DSEWPaC unpubl. data). In that instance it would appear that counts for Black and Lesser Noddies were pooled, with the identity later being resolved from photographs. More plausible database records of the Lesser Noddy are single birds in May 1995 and May 1998 on Middle Island and a singleton in May 1995 and a count of 14 in September 1995 on East Island (DSEWPaC unpubl. data).

Despite being alert to the possibility, during 12 visits to the reserve, the Study team recorded singletons on only two occasions (at sea on the edge of the reef, Oct. 2000 and on Middle Island, Oct. 2009; Study team unpubl. data). In April 2010 breeding of Lesser Noddy was

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[1] The Sesbania Pea *Sesbania cannibina* is an erect annual herb to 3 m (Pike & Leach 1997)

[2] Current information suggests Lesser Noddy build a nest that is indistinguishable from that of the Black Noddy. Estimates of the total number of breeding pairs of the Lesser Noddy (based on April-May monitoring) should be taken into account when counting putative Black Noddy nests in the late dry season.

confirmed on East Island with two pairs present and at least one nest containing a single egg. On Middle Island several more pairs were present. These birds appeared to be at the nest construction and pre-laying stage of breeding as they repeatedly returned to freshly constructed nests (that were empty) within Black Noddy colonies. Nests were similar to those of the Black Noddy and were built in *Sesbania cannibina* and *Amaranthus interruptus* (this study).

Like other noddies the Lesser Noddy presumably obtains its prey by shallow plunge diving and surface seizing. There is no quantitative data regarding distances over which the species forages, however birds at the Abrolhos (where the bulk of the Australian population occurs), appear mostly to forage close to the breeding islands (Higgins & Davies 1996). The Australian Lesser Noddy *Anous tenuirostris melanops* is considered Vulnerable and is a listed marine species under the *EPBC Act 1999*. Applying the precautionary principal, in the absence of information to the contrary, it is assumed that the Lesser Noddies that breed at Ashmore Reef belong to this threatened subspecies.

Figure 24 Adult Lesser Noddy flying over nesting grounds on East Island, Ashmore Reef, April 2010.

Current evidence suggests a small number of Lesser Noddy breed within Black Noddy colonies at Ashmore Reef. It would appear the species is easily overlooked given they are superficially similar to Black Noddy. Counts of adults and active nests should be made at every opportunity so that the status of this species within the reserve continues to be clarified. Nevertheless, given the nesting event in April 2010 was the first breeding documented in over a decade, data relating to the Lesser Noddy is unlikely to provide any substantial contribution to a seabird monitoring program focussed on impact assessment at this site. As the species was recorded nest building and incubating in April 2010 the months of April and May would appear to be an appropriate time to census the population.

Egrets and Herons

Counts and of all egrets and herons present at Ashmore Reef have been undertaken on an annual basis since 2000 (Table 5; Study team unpubl. data). Four species of egret and heron have been reported breeding at Ashmore Reef. The Eastern Reef Egret occurs in relatively large numbers (typically between 400 and 700 birds) and breeds on an annual basis. Milton (2005) estimated that between 300 and 500 pairs nested at Ashmore Reef between 1983 and 1988. In contrast the Eastern Great Egret (< 10), Little Egret (<100) and Nankeen Night-Heron (<30) only appear to breed on an occasional basis. Eastern Reef Egrets have been reported to breed on all three vegetated islands. For the remaining species, nests have been reported on West Island (Little Egret and Nankeen-Night Heron), Middle Island (Eastern Great Egret) and breeding has been suspected but is not confirmed on East Island (Little Egret) (DSEWPaC unpubl. data, Study team unpubl. data).

Figure 25 Dark morph adult Eastern Reef Egret perched atop *Argusia argentea* shrub on West Island, Ashmore Reef, October 2010.

Egrets and herons roost on the vegetated islands and sandbanks at high tides and forage on the reef flats during low tides. Any impact on these populations stemming from the Montara Well release would occur via similar avenues to that which may impact shorebirds, namely direct contamination of birds through contact with oil or impacts on prey species within Ashmore Reef. All four breeding herons and egrets are listed marine species under the *EPBC Act 1999*. The Eastern Great Egret is also a listed migratory species under both JAMBA and CAMBA, while the Eastern Reef Egret is a listed migratory species under CAMBA.

Egrets and herons nest within *Argusia argentea* and *Guettarda speciosa* shrubs on West Island. On Middle and East Islands they breed on or close to the ground amongst herbaceous vegetation. Active nests have been recorded in most months and years (the

survey in April 2010 is the only the exception over the past decade). Nest timing appears variable, with numerous instances when eggs, small chicks and large chicks are all present at the same time (Bellio *et al.* 2007; Study team unpubl. data). Surveys should therefore seek to quantify the number of adults of each species that are present. The number of active nests and the breeding stage of each species should also be documented. It is essential that multiple observers repeat counts so as to provide some confidence in the collected data. As Ashmore Reef supports a large population of Eastern Reef Egrets, and there exists a large data set for this species, the species should be a high priority for ongoing monitoring. As the Eastern Reef Egret is restricted to terrestrial areas and tidal flats of Ashmore Reef this would also provide an opportunity to monitor another species (in addition to shorebirds) that are unlikely to interact with contaminated marine environments that may be remote from Ashmore Reef (c.f. breeding seabirds). Surveys at any time of the year have the potential to coincide with a breeding event, though two annual surveys, one in the late wet season and the other in the late dry season will provide adequate opportunity to assess egret and heron numbers during periods for which there are existing pre-impact data.

Shorebirds

Shorebirds have been counted at Ashmore Reef on numerous occasions since 1979 (Milton 2005, DSEWPaC unpubl. data) (Table 6). However, complete counts, where shorebirds on all islands and important sandbanks are systematically counted, appear to have occurred on just three occasions prior to this study. These complete counts were conducted in January 2002, February 2003 and January 2005 (Swann 2005a, 2005b, 2005c). As a component of the current study, a fourth series of counts was undertaken in April 2010 (Table 7). Whilst some attempt to undertake complete counts may have occurred at other times, the author can find no documentation that demonstrates this is the case. In April 2010, on high tide events that covered all but two sandbanks, the largest numbers of shorebirds roosted on the sandbank between Middle and East Island and on the recently vegetated sandbank to the east of East Island. A sandy spit on the south-east point of Middle Island was also an important roost site, especially when peak tides ‘pushed’ shorebirds off sandbanks (Figure 26). Smaller numbers of shorebirds generally roosted on beaches and within the vegetated centres of West, Middle and East Island, although one species, Ruddy Turnstone, appears to preferentially roost on these islands (c.f. with available sandbanks and sand spits) (also Swann 2005b).

The highest count of shorebirds reported at Ashmore Reef was in January 2005 when a total of 18,255 migratory shorebirds were present within the reserve (Swann 2005c). Utilizing data gathered during complete counts (Table 7), and historic counts where maximum reported numbers exceed those of complete counts (since 1979), seven species of migratory shorebird have been reported to occur at Ashmore Reef in numbers that exceed 1% of their total estimated East Asian – Australasian Flyway population (Table 6). Such measures are significant as they identify Ashmore Reef as a wetland of international importance for these species. Counts for Sanderling and Grey Plover are particularly notable as numbers exceed 10% of the estimated total Australian population (following Bamford *et al.* 2008).

A 1% threshold of the total East Asian – Australasian Flyway population is also significant as Criterion 6 of the Ramsar Convention states "a wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of a species or subspecies of waterbirds" (Ramsar Conservation Bureau 2000). According to Ramsar Convention guidelines, for a site to be considered to regularly support 1% of the population, the 1% threshold must be achieved in at least two out of three seasons, or must be met by the mean of at least five maximum annual counts. As Ashmore Reef has not been counted in three consecutive seasons or during five separate years, following Bamford *et al.* (2008), the site has been assessed against the 1% criterion on the basis of individual counts.

In addition to complete counts of all shorebird sites at Ashmore Reef, there is some evidence that counts of shorebirds on West Island remain relatively stable on a year-to-year basis (see Swann 2003b). Given this, all complete counts of shorebirds undertaken at West Island have been collated with the intention that they may provide further opportunity to assess trends in population change with a larger time-series dataset. Fourteen such counts by the Study team and others have been identified, with an additional count conducted in April 2010 (Table 8).

Figure 26 A dense flock of migratory shorebirds on Middle Island, Ashmore Reef, April 2010. There are 14 species of shorebird and a single Crested Tern visible in this image.

April 2010 counts

Initial counts of shorebirds that form part of this study were conducted over four days; 14-17 April 2010. Although fieldworkers were mobilised within 24 hours of the contract being signed, by these dates a large proportion of shorebird populations that visit Australia had already departed on northward migration. As such, the low total count of 4213 shorebirds when compared with summer counts in 2002, 2003 and 2005 (11334, 14164 and 18255 respectively) (Table 7), is likely a reflection of count timing. To best estimate the total

population of shorebirds making use of Ashmore Reef during the summer period it is recommended that at least one count per year take place during the period November to February. Based on a minimum threshold of 100 individuals Table 6 presents a list of species that have been identified as most suitable for ongoing monitoring purposes at Ashmore Reef.

Previous records

A number of observers with varying expertise have been involved in shorebird counts since 1979 (see Milton 2005). Based on current data it would seem likely that two species of shorebird previously reported in large numbers were misidentified. Data in Milton (2005) includes a report of 300 Eastern Curlew in the month of March and 550 Lesser Sand Plover in the month of October (also DSEWPaC unpubl. data). Both of these counts are exceptional when compared with data collected by the Study team since 2000 and may reflect misidentifications. Eastern Curlew has been detected on 8 of 13 visits by the Study team since 2000 with a maximum count of just two individuals. Similarly, whilst Lesser Sand Plover are detected on most visits, the maximum count was just 32 during the same period. Whimbrel (max count of 536 by the Study team) and Greater Sand Plover (max count 2559 by the Study team) are the species most likely to have been misidentified in each instance.[1]

Stop-over or non-breeding site?

It has previously been reported that Ashmore Reef is an important stop-over for large numbers of shorebirds moving to and from the Australian mainland during annual migration (Australian National Parks Service 1989, Commonwealth of Australia 2002, Milton 2005). Upon review, this premise is not supported by available data. Rather, Ashmore Reef is an important 'wintering' site for Palaearctic breeding shorebirds in its own right. A high proportion of Palaearctic breeding shorebirds that travel through the East Asian – Australasian Flyway and that visit key shorebird sites in north west Australia (e.g. Roebuck Bay, 80 Mile Beach) are marked with permanent coloured plastic leg flags as part of long-term monitoring programs (Commonwealth of Australia 2001). Despite this, colour marked birds at Ashmore Reef are very rarely encountered, indicating there is very little interchange between populations of shorebirds visiting Ashmore Reef and those that visit key shorebird sites on the north west Australian mainland (e.g. Swann 2005a, 2005b, this study)[2]. As a consequence, for impact assessment purposes and management purposes, shorebird populations at Ashmore Reef are best considered independent of those in north west Australia.

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[1]Whimbrel are superficially similar to Eastern Curlew and may be confused by inexperienced observers (Higgins & Davies 1996). Lesser and Greater Sand Plover are notoriously difficult for inexperienced observers to identify. Any potential for confusion is further compounded by the fact that in eastern Australia Lesser Sand Plover are the more abundant of the two (Higgins & Davies 1996, Bamford *et al.* 2008). Observers with experience in eastern Australia may therefore anticipate Lesser Sand Plover to be the more abundant species at Ashmore Reef.

[2] Despite specifically scanning for colour flags during counts of 4213 shorebirds in April 2010 just one flagged shorebird, a Great-tailed Tattler, was detected. The flag combination indicated it had been captured in Taiwan. Similarly, searches in 2002 (11,334 shorebirds counted) and January 2003 (14,164 shorebirds) did not detect any flagged shorebirds (Swann 2005a; 2005b), whilst searches in January 2005 (18,255 shorebirds) located two flagged shorebirds; one of which had been marked in NW Australia (Swann 2005c).

Table 6 Maximum counts of shorebirds recorded at Ashmore Reef between 1979 and 2010. Maximum counts are presented as a percentage of the total estimated East Asian – Australasian Flyway population and the total estimated Australian population following population estimates of Bamford *et al.* (2008). Species in bold font have been identified as most suitable for ongoing population monitoring purposes at Ashmore Reef

	Max reported count (1979 - 2010)	% of flyway population	% of Aust. population
Swinhoe's Snipe	1[a]		
Black-tailed Godwit	8[e]		
Bar-tailed Godwit	4560[f]	1.4	2.5
Little Curlew	50[b]		
Whimbrel	536[f]	0.5	5.4[j]
Eastern Curlew	4[a,g]		
Common Redshank	1[a]		
Marsh Sandpiper	1[a]		
Common Greenshank	590[f]	1.0	3.1
Terek Sandpiper	216[f]	0.4	0.9
Common Sandpiper	9[d]		
Grey-tailed Tattler	1791[f]	3.6	4.0
Ruddy Turnstone	1708[e]	4.9	8.5
Asian Dowitcher	8[f]		
Great Knot	1592[d]	0.4	0.4
Red Knot	55[f]		
Sanderling	1132[e]	5.1	11.3
Little Stint	1[a]		
Red-necked Stint	1530[f]	0.5	0.6
Sharp-tailed Sandpiper	3[a]		
Curlew Sandpiper	850[e]	0.5	0.7
[Red-necked Phalarope	2[a,h]]		
Broad-billed Sandpiper	1[a]		
Beach Stone-curlew	1[c]		
Black-winged Stilt	14[e]		
Pacific Golden Plover	746[f]	0.7	7.5[j]
Grey Plover	1511[f]	1.2	15.1[j]
Lesser Sand Plover	32[c,i]		
Greater Sand Plover	2559[f]	2.3	3.5
Oriental Plover	2[a]		
Masked Lapwing	1[c]		
Oriental Pratincole	1[d]		
Australian Pratincole	2[a]		

[a]Study team unpublished data, [b]Milton (1999), [c]Milton (2005), [d]Swann (2005a), [e]Swann (2005b), [f]Swann (2005c), [g]count of 300 published in Milton (2005) is considered erroneous, [h]recorded at sea within 10 Nm of Ashmore Reef, [i]count of 550 published in Milton (2005) is considered erroneous, [j]total Australian population set at 10,000 in the absence of more conclusive data (R. Clarke).

Table 7 The maximum count of shorebirds obtained during 69 visits to Ashmore Reef between 1979 and 1998 and data from four complete counts of shorebirds at Ashmore Reef between January 2002 and April 2010

	Max. count 1979-1998	28 Jan 2002	02 Feb 2003	28 Jan 2005	16 Apr 2010
Source	Milton (2005)	Swann (2005a)	Swann (2005b)	Swann (2005c)	this study
Gallinago Snipe species			1	1	
Black-tailed Godwit		6	8	6	3
Bar-tailed Godwit		2536	2785	4560	105
Little Curlew					1
Whimbrel	250[a]	344	402	536	240
Eastern Curlew	300[a]	1			
Common Greenshank		185	252	590	162
Terek Sandpiper		60	83	216	39
Common Sandpiper		9	6	4	5
Grey-tailed Tattler	1631	1301	1593	1791	1339
Ruddy Turnstone	1101	1644	1708	1660	662
Asian Dowitcher		6	3	8	
Great Knot	82	1592	838	1090	180
Red Knot		15	13	55	40
Sanderling		313	1132	1101	441
Red-necked Stint	120	975	1128	1530	229
Sharp-tailed Sandpiper		1			
Curlew Sandpiper	252	150	850	260	170
Black-winged Stilt			14		2
Pacific Golden Plover	200	373	563	746	78
Grey Plover		616	1475	1511	120
Lesser Sand Plover	550[a]	11	16	32	12
Greater Sand Plover	180[a]	1196	1295	2559	385
Oriental Pratincole		1		1	
Total	-	11334	14164	18255	4213

[a]this count is likely to be erroneous (see p. 43).

Table 8 Counts of shorebirds roosting on West Island, Ashmore Reef during 14 visits between Oct 1998 and October 2009. In instances where several counts were made over consecutive days the highest count from that period is presented.

	Oct-1998[a]	Feb-2000[b]	Oct-2000[c]	Oct-2001[c]	Nov-2001[c]	Jan-2002[d]	Feb-2003[b]	Sep-2003[c]	Oct-2004[c]	Jan-2005[e]	Oct-2006[c]	Oct-2007[c]	Oct-2008[c]	Oct-2009[c]
Swinhoe's Snipe														[1]
Black-tailed Godwit										1				
Bar-tailed Godwit			1	2			2		1	2				6
Little Curlew	50		2											
Whimbrel	10	103	70	120	97	40	76	80	50	36	70	60	80	60
Eastern Curlew		2	1	2	1	1		1	2		1	1	1	
Marsh Sandpiper														1
Common Greenshank	9	14	1	2	3	3	8	3		3	12	1	1	4
Common Sandpiper		2	4	4	3	6	6	3	4	4	3	12	10	8
Grey-tailed Tattler	131	100	20	90	56	40	136	30	40	96	50	50	20	50
Ruddy Turnstone	65	81	100	150	142	150	101	70	70	125	100	120	100	150
Great Knot							1	2				2	1	2
Sanderling	4	1	2	10	9	15	15	10	6	16	35	30	20	15
Red-necked Stint		42	6	10	16	20	50	20	15	65	100	40	25	10
Sharp-tailed Sandpiper			1	1	2	1						3	13	3
Curlew Sandpiper				2			5	1					2	
Black-winged Stilt							13							
Pacific Golden Plover	32	39	12	60	27	20	56	40	10	80	30	8	20	30
Grey Plover							1						4	6
Lesser Sand Plover			1	1	1	1	3			3	2		1	
Greater Sand Plover	83	79	20	80	66	70	96	50	40	90	100	40	100	50
Oriental Plover								3	2		1	5	1	
Australian Pratincole	2		5	1	1							6	1	

[a]Milton (1999), [b]Swann (2005b), [c]Study team unpublished data, [d]Swann (2005a), [e]Swann (2005c). Numbers in square brackets indicated identification not certain.

Cartier Island

Terrestrial environments

Cartier Island lies approximately 52 km to the south-east of Ashmore Reef at 12°32'S, 123°33'E. The island is a small coral cay surrounded by a small fringing reef. It consists of course grit and coral rubble rising some 1-2 m above the high tide line. In gales and cyclonic events it is probable that the entire island becomes wave washed. Although propagules of various plants are no doubt caste ashore with some regularity, there is no vegetation on the island now and this appears to have long been the case (Russell *et al.* 1993, Pike & Leach 1997, this study). A low dune ridge circles the rim of the island and here large numbers of marine Green Turtles nest (Guinea 1993). In its centre, the island consists of a relatively flat basin of compacted sand. This area appears to be used infrequently by nesting turtles (R. Clarke pers. obs.). Nevertheless, owing to the small size of Cartier Island and the large numbers of breeding turtles, almost all surface substrate is regularly disturbed by both the nesting activities and movement of turtles. The island is dynamic and the shifting sands have seen regular, though small, changes to both size and shape (Russell *et al.* 1993). In October 1949 Serventy (1952) estimated the island to be some 110 acres in size (44.5 ha) though this estimate may include sand flats exposed at low tide as Russell *et al.* (1993) presented a case with aerial images taken between 1943 and 1993 that demonstrate the cay had changed little during that time. Aerial images taken in the early 1990s (Russell *et al.* 1993) indicate the island has also remained largely unchanged through to 2010. In April 2010 Cartier Island had a total land area of 2.1 ha measured at the high tide mark.

During high tides the island provides a convenient roosting and resting place for both seabirds and shorebirds. At lower tides, reef flats provide foraging opportunities for egrets and shorebirds. Cartier Reef is roughly elliptical and about 4.6 km long and 2.3 km wide. Although not all of the reef is exposed during spring low tides, there is typically a large area of reef available for use by foraging shorebirds and egrets.

Two photo monitoring points were established at Cartier Island in April 2010 (Appendix C).

Avifauna

Cartier Island appears to have been infrequently visited by observers skilled in bird identification. Serventy (1952) reported Brown Boobies, Eastern Reef Egrets, Lesser Frigatebirds, Crested Terns and probable Sooty Terns from Cartier Reef, but did not land on the island.

More recently, in March 1990, six species of seabird and shorebird were observed there with reports of Ruddy Turnstone, Black-winged Stilt and Lesser Sand-Plover being new records for the island. In May 1992, Wedge-tailed Shearwater was added to the list (Guinea 1993) although it seems likely that this was seen in the vicinity of the reef rather than ashore on Cartier Island. The Study team has surveyed Cartier Island on two occasions prior this study; in October 1996 and again in January 2002. As part of the initial assessment in April 2010 the island was again surveyed. All available counts of seabirds and shorebirds are presented in Table 9.

In April 2010, five eggs of the Crested Tern were located on course grit and coral rubble at Cartier Island. The eggs were spread over an area of approximately 10 x 20 m. A bleached upper surface and dehydrated contents indicated the eggs had been abandoned for some time. This is the first evidence that Crested Terns breed on occasions at Cartier Island.

Table 9 All counts of seabirds and shorebirds from Cartier Island, north west Australia.

	Oct 1949	Mar 1990	May 1992	Oct 1996	Jan 2002	Apr 2010
Source	*Serventy (1952)*	*Guinea (1993)*	*Guinea (1993)*	*Study team unpubl. data*	*Study team unpubl. data*	*This study*
Wedge-tailed Shearwater	-	-	nc	-	-	-
Brown Booby	6	3	nc	-	-	-
Lesser Frigatebird	1	-	6	2	3	1
Little Egret	-	-	-	-	1	-
Eastern Reef Egret	3	6	15	-	-	14
Black-winged Stilt	-	1	-	-	-	-
Whimbrel	-	-	-	-	-	3
Common Greenshank	-	-	-	1	-	-
Ruddy Turnstone	-	24	15	-	24	8
Lesser Sand Plover	-	1	-	-	-	-
Crested Tern	2	200+	50	400	85	165
Sooty Tern	2	-	-	3	2	-
Common Noddy	-	-	-	-	-	1

nc indicates the species was present on the reef but not specifically counted.

Browse Island

Terrestrial environments

Browse Island Nature Reserve is situated at 14°06'S 123°32'E and lies some 172 km south of Cartier Island and approximately 450 km north-north-east of Broome. The reserve is managed by the Western Australian Department of Environment and Conservation (DEC). Browse Island is situated within a small fringing reef. In October 1949 Serventy (1952) estimated the island to be some 150 acres in size (60.7 ha) though this estimate may include sand flats exposed at low tide as in April 2010 Browse Island had a total area of 17.2 ha measured at the high tide mark. The island consists largely of grit and coral rubble on a base of course limestone. It displays variable topography, with several sand dunes and, elsewhere, piles of limestone, both rising some 3-4 m above the high tide line. Much of the centre of the island shows evidence of extensive guano mining during the 19th century, with exposed areas of course limestone overlaid with neat stacks of the same material, at times forming obvious corridors and walkways.

Approximately two thirds of the island is vegetated. There are several different habitats on the island including a handful of *Scaevola taccada* shrubs on the vegetated fringes and *Ipomea* dominated sandy flats on the south west margin adjacent to the shoreline. Areas that were extensively modified in the guano mining days are cloaked in a low tangle of *Ipomea* creepers, whilst vegetated areas on sandy substrates are dominated by Indian Lantern Flower *Abutilon indicum* (Burbidge *et al.* 1978, this study). The unvegetated portion

of the island consists of more friable sand and grit and it is here that large numbers of Green Turtles nest (R. Clarke pers. obs.).

As the nearest land is ~142 km distant, Browse Island provides the only locally available site for both seabirds and shorebirds to roost. At lower tides, reef flats provide foraging opportunities for egrets and shorebirds. The fringing reef is roughly circular with a diameter of about 2.2 km. The reef is particularly shallow and a large portion of its ~380 ha area is exposed on spring tides (G. Swann pers. obs).

Six photo monitoring points were established at Browse Island in April 2010 (Figure 27, Appendix C).

Avifauna

Browse Island appears to have been very infrequently visited by observers skilled in bird identification. In the latter part of the 19th century, Browse Island was regarded as the most famous of the northern Australian guano islands, demonstrating that is was once a significant site for breeding seabirds (Serventy 1952). However, breeding seabirds were presumably extirpated from the island during the guano extraction process as D.L. Serventy landed there in October 1949 and reported that “the inspection proved a great disappointment as there were no seabirds of any kind, nor any indication that the island had been used as a nesting or roosting place for years” (Serventy 1949). In June 1978, Abbott (1979) reported a colony of Crested Terns containing approximately 400 eggs with a total of 300 adults present.

DEC maintains a database of all seabird breeding islands within the state of Western Australia. Accessed in May 2010 the database contained no further records of breeding seabirds for Browse Island, supporting the contention that this island has rarely been assessed in the past. The Study team has surveyed Browse Island on one occasion prior this study; in February 2000. On that occasion six species of seabird and shorebird were recorded but no breeding activity was evident (Table 10). The island was again surveyed in April 2010. Of note was a large breeding colony of Crested Terns. Some individuals within the colony were incubating eggs at the time of the visit but others were displaying pre-breeding behaviour. The total count of adult Crested Terns on Browse Island was 4283, with 3683 of these counted within the colony area. Also present were 70 Eastern Reef Egrets. Although this species was not breeding during April 2010, seven old stick nests attributed to this species were located within *Scaevola taccada* shrubs. All available counts of seabirds and shorebirds from Browse Island are presented in Table 10.

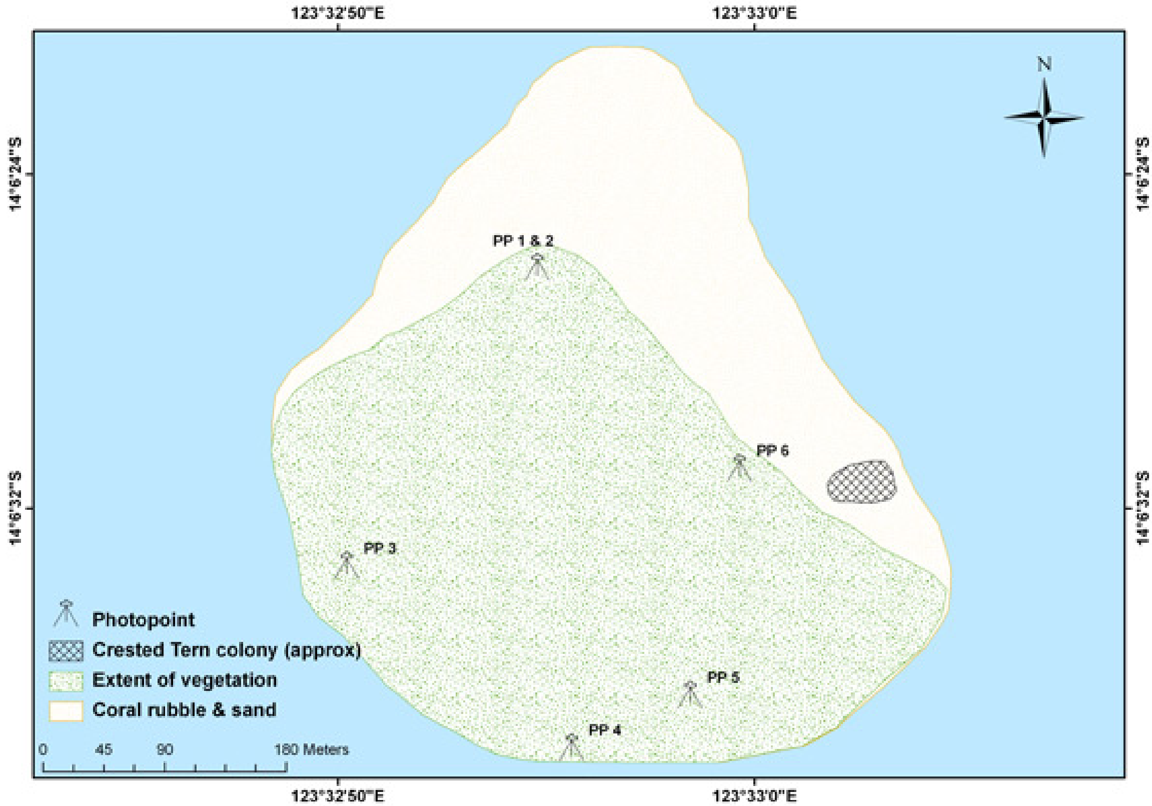

Figure 27 Map of Browse Island, north western Australia, showing the locations of photo monitoring points. The approximate boundaries of a Crested Tern colony, as recorded in April 2010, are also displayed.

Table 10 Counts of seabirds and shorebirds from Browse Island, Western Australia.

	Jun-72	Jun-78	Feb-00	Apr-10
Source	Smith *et al.* (1978)	Abbott (1979)	Study team	This study
Brown Booby			1	3
Lesser Frigatebird		2		2
Eastern Reef Egret	nc*		47	70
Pacific Golden Plover			9	
Ruddy Turnstone			21	8
Crested Tern		300*	34	4283*
Sooty Tern			3	4
Common Noddy				2

nc indicates the species was present on the reef but not specifically counted. * indicates breeding

Oil Contamination in April 2010

An objective of the initial survey conducted in April 2010 was to undertake an assessment of terrestrial habitats and biota for visible contaminants of a hydrocarbon origin. On each island the shoreline at or just above the high tide mark was inspected by circumnavigating the island. Particular attention was given to any tidal wrack. No visible oil contaminants were detected. A watching brief for any visible contaminates on live birds (i.e. soiled plumage) and nest contents (notably eggs) was also maintained throughout the counts conducted in April 2010. Similarly, all dead birds that were encountered were closely inspected. No visible evidence of oil was detected on live birds, nest contents or dead birds (<100) along the shoreline. That oil contaminates were not detected in April 2010 was consistent with the Study team's expectations as the Montara Well release was controlled 162 days (~5.4 months) prior to this first 'post-impact' assessment at Ashmore Reef. Further, inspection of a small number of apparently oiled birds in late October 2009 when the uncontrolled release remained active and the resultant oil slick was likely to be approaching the maximum area of extent (the well release was killed just four days after this inspection) demonstrated that the oil contaminants were generally difficult to detect during a visual assessment. This was especially so for species with dark plumage such as the Common Noddy (R. Clarke pers. obs.).

FUTURE DIRECTIONS

Ongoing Post-impact Assessment

Twice-annual ground assessments

Following the pre-impact assessment presented here, and initial field survey in which approaches to quantify population sizes of breeding seabirds and migratory shorebirds were trialled and tested (April 2010), it is proposed that post-impact assessment take the form of twice annual monitoring surveys to Ashmore Reef, Cartier and Browse Islands. It is recommended that twice-annual monitoring take place for a period of five years. Five years being considered the minimum timeframe over which seabird colony counts and shorebird counts at these locations will provide a defensible measure of population trends. This will provide for opportunities to detect trends and any points of significant change in total seabird and shorebird numbers within the Reserves. Efforts to quantify the breeding populations of all species of seabird and the populations of key migratory shorebird species (those species in bold in Table 6) should be made during each visit. It is proposed that survey methods repeat those of the initial field survey conducted in April 2010 (see Methods section of this report for more detail).

Twice-annual surveys are considered to represent the minimum number of visits necessary because:

- Seabird species that breed on Ashmore Reef islands do so at different times of year (e.g. Wedge-tailed Shearwater and Common Noddy, Figure 12).

- Some seabird nesting events may be aseasonal and their timing difficult to predict (e.g. Sooty Tern, Crested Tern this study, Figure 12). Twice annual visits increase the probability of detecting these events and adequately documenting them.

- Shorebird numbers are known to fluctuate in relation to seasons at Ashmore Reef (as is typical elsewhere), with peak abundances of shorebirds reported throughout the period October to March (this study, *contra* Commonwealth of Australia 2002). Twice annual visits will provide opportunities to document peak numbers of shorebirds during both the wet season (when adult shorebirds are present) and dry season (when adults have departed and birds that are mostly in the first and second years of life (species dependant) remain).

- Twice annual monitoring provides opportunity to gather more extensive time-series data on year-round resident breeding species such as the Eastern Reef Egret and Brown Booby.

Milton (2005) identified twice annual surveys in the periods April to June and October to December as an appropriate strategy to monitor population trends at Ashmore Reef National Nature Reserve. With the benefit of additional data, including annual counts for the past decade and a more robust understanding of shorebird movements and periods of residency, we are now able to further refine these optimal survey windows. Data presented in this assessment, identifies two periods that provide the most appropriate opportunities to survey seabirds and shorebirds within the Reserves. The first period, mid-April to mid-May, to coincide with the maximum possible number of breeding seabird species present on islands, particularly those at Ashmore Reef. Surveys at this time should provide data that underpin population trend and change point assessment for the majority of breeding seabirds. A second survey period conducted in November of each year will provide opportunity to survey migratory shorebirds at a peak time (this is not achievable in April as the majority of shorebirds have departed on northward migration; this study), assess several seabird populations that would be inadequately covered in April (e.g. Wedge-tailed Shearwater), count used nests of several further seabirds (Lesser Frigatebirds and Black Noddies) to provide a second assessment of the breeding population size for those species in any year and provide population-wide counts of all seabirds at a comparable time (October – November) to the bulk of existing data collected since 1996 (Study team unpubl. data, Milton 1999; 2005, Bellio *et al.* 2005). A list of data types to be collected for each species of seabird and all shorebirds during these proposed survey periods is presented in Table 11.

Table 11 Data types to be collected for each species of breeding seabird and all shorebirds during the periods April – May and November of each year.

Survey period	April - May	November
Wedge-tailed Shearwater	Assessment of colony boundaries	Count of active burrows (if disturbance is considered minimal)
Red-tailed Tropicbird	Count of all adults and active nests	Count of all adults and active nests
White-tailed Tropicbird	Count of all adults and active nests	Count of all adults and active nests
Masked Booby	Count of all adults and active nests	Count of all adults and active nests
Red-footed Booby	Count of all adults and active nests	Count of all adults and active nests
Brown Booby	Count of all adults and active nests	Count of all adults and active nests
Great Frigatebird	Count of all adults and active nests	Count of all adults and active nests
Lesser Frigatebird	Count of all adults	Count of used nests following the dry season breeding period
Crested Tern	Count of all adults and active nests	Count of all adults and active nests
Lesser Crested Tern	Unlikely to be present	Unlikely to be present
Roseate Tern	Count of all adults (and nests if present)	Count of all adults
Bridled Tern	Count of all adults	Unlikely to be present in any number
Sooty Tern	Count of all adults and active nests	Count of all adults and active nests
Common Noddy	Count of all adults	Count of all adults
Black Noddy	Count of all adults	Count of used nests following the dry season breeding period
Lesser Noddy	Count of all adults and active nests	Count of all adults
Eastern Great Egret	Count of all adults	Count of all adults and active nests
Little Egret	Count of all adults	Count of all adults and active nests
Eastern Reef Egret	Count of all adults	Count of all adults and active nests
Nankeen Night-Heron	Count of all adults	Count of all adults and active nests
Shorebirds	Count of all birds during an active migration period - this data provides insights into shorebird movement in a regional context and validates the use of control data from the north west mainland coastline.	Count of all birds during an over-wintering period appropriate for long term monitoring purposes

Statistical Analyses

Statistical analyses will focus on identifying and quantifying changes in the temporal patterns of species counts on Ashmore Reef, Cartier Island and Browse Island following the Montara Well release. The simplest approach is to compare the means of pre- and post- disturbance counts at potentially impacted sites, ideally with equivalent tests at control site(s). Such tests can be very powerful, but may give misleading results if (1) there are trends in abundance (counts) that are independent of the putative impact (e.g. counts already were declining prior to the oil spill), (2) effects on populations are delayed, or (3) effects on populations are short term and recovery occurs within the post-impact survey period. A more general approach is to model the trends in the response variable of interest and to identify any changes in trends that coincide with the putative impact, and/ or which would not have been expected to otherwise occur (based on pre-impact temporal patterns and concurrent patterns at control sites).

Bayesian change-point models, using free-knot piecewise linear splines (Thomson *et al.* 2010), provide a flexible tool for characterizing temporal trends and identifying objectively abrupt changes in those trends. The basic model for response variable *y* (e.g. counts of species x) at time *t* may be expressed as:

$$y_t = \alpha_t + f(t) + \varepsilon_t, \qquad \text{equation (1)}$$

where, α_t is a time-dependent intercept, *f(t)* is a continuous function of time, and ε_t is an error term with appropriate distribution (e.g Normal) and correlation structure (e.g. first order autoregressive).

The time-dependent intercept allows for abrupt changes in *y* at some point in time, or step changes. Step changes are modelled as:

$$\alpha_t = \alpha_1 + \sum_{j=1}^{k_\alpha} \chi_j I(t \geq \delta_j), \qquad \text{equation (2)}$$

where α_1 is the species count at time zero (earliest count) , k_α is the number of step changes, δ_j is the timing of the j^{th} step change, and χ_j is the value of the change. $I(t \geq \delta_j)$ is an indicator function that equals 1 when $t \geq \delta_j$ and is 0 otherwise.

The temporal trend, $f_t(t)$, is modelled as a piecewise linear regression with an unknown number k_β of changes in slope, or trend changes, and a corresponding set of times θ_j of trend changes:

$$f_t(t) = \beta_1 t + \sum_{j=1}^{k_\beta} \beta_{[j+1]}(t - \theta_j)_{+} \cdot, \qquad \text{equation (3)}$$

where the term $(t-\theta_j)_+$ equals $I(t \geq \theta_j)(t-\theta_j)$.

Given a particular intercept, the term $f_t(t)$ is a piecewise linear and continuous function of time, but when the intercept α_t varies, the combination $\alpha_t + f_1(t)$ is a discontinuous piecewise linear model. Figures 28A and 28B illustrate the basic change-point model applied to data with step and/or trend changes.

In this model there are four key parameters that determine the number, k_α and k_β , and timing, δ_j and θ_j, of change-points. Using a Bayesian framework with reversible jump Markov chain Monte Carlo sampling (MCMC, Lunn *et al.* 2006; 2009) it is possible to evaluate, via likelihood functions, the relative evidence in the data for all possible models, or combinations of change-points. The relative support for each model is expressed as a posterior model probability. The range of models considered possible is specified in the prior distributions for these parameters. Given no prior information or expectations, very vague priors can be used that essentially let the data determine the most likely values of each parameter, although hyper-parameters must still be set which determine the penalty for complexity (and therefore the degree of smoothness in the fitted trend). The resulting posterior distributions allow for

probabilistic inferences about the occurrence of change-points in particular years, accounting for uncertainties in both data and other model parameters (including magnitudes and timing of other change-points). For example, the posterior probability that a change-point occurred at time *t* is the summed posterior probabilities of all models that include a change-point at time t_n (e.g. of all values of δ that include t_n as an element).

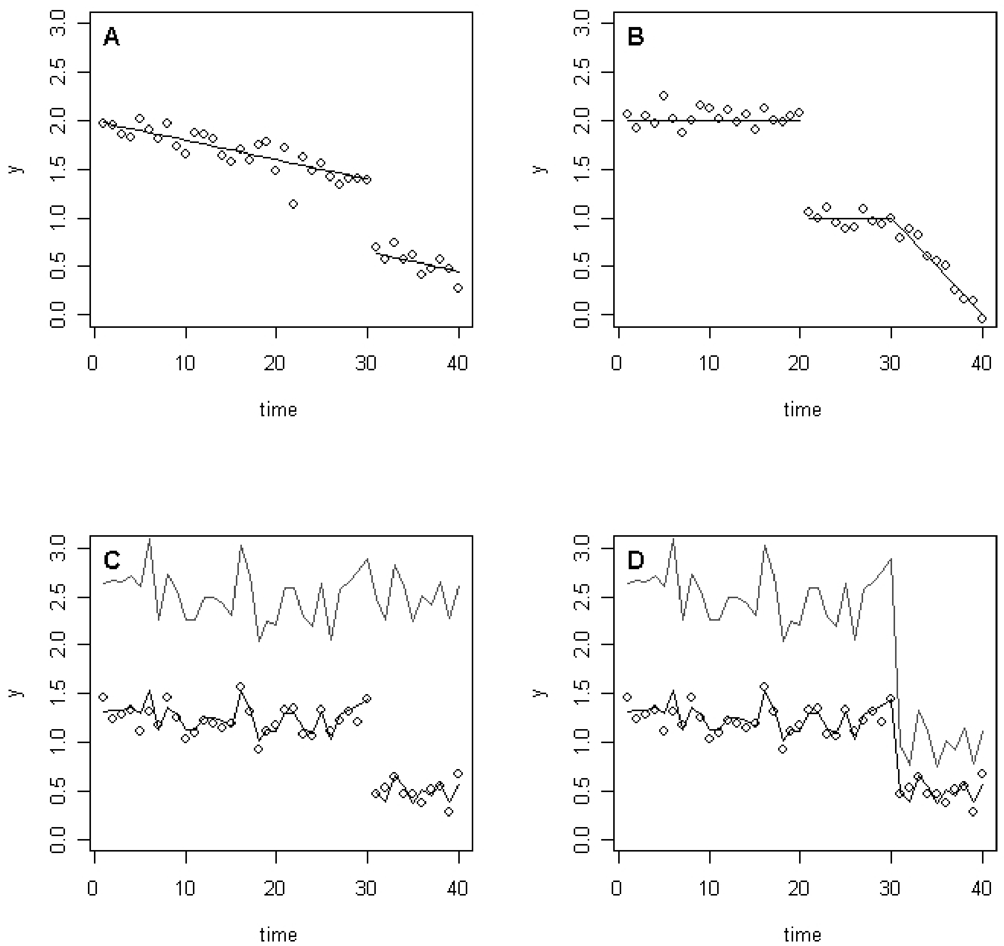

Figure 28 Examples of change-point models. All examples show a hypothetical time series ***y*** (dots) and corresponding piecewise linear models (dark lines). A: step change at time 31, modeled by $y_t = 2 - 0.75I(t \geq 31) - 0.02t + \varepsilon_t$. B: step change at time 21 and trend change at time 31, modeled by $y_t = 2 - 1I(t \geq 21) - 0.03(t-31)I(t \geq 31) + \varepsilon_t$. C: covariate model with step change at time 31, modeled by $y_t = 0 - 0.75I(t \geq 31) + 0.5x_t + \varepsilon_t$. D: covariate model with no change-points (change-point at time 31 in C is predicted by covariate), modeled by $y_t = 0 + 0.5x_t + \varepsilon_t$. In C and D, grey lines show the time series of the covariate x. Figure from Thomson *et al.* (2010).

Specific hypotheses can be tested or compared by restricting prior distributions for key parameters to values of interest. For example, the equivalent of a simple before vs after comparison of pre- and post-disturbance mean counts (allowing for any underlying trend) would be performed by comparing a model with exactly 1 step change ($k_\alpha = 1$, $k_\beta = 0$) at the time of the putative impact ($\delta_j = t_{impact}$) to a model with no change-points ($k_\alpha = 0$, $k_\beta = 0$).

More flexibly, all models with up to (say) 2 step changes [k_α = 0, 1 or 2, e.g. k_α~Binomial(2,0.5)] and 2 trend changes [k_α~Binomial(2,0.5)] any time after the putative impact [δ_j ~ Uniform($t_{disturbance}$, t_{max}); θ_j ~ Uniform($t_{disturbance}$, t_{max})] could be compared to each other and to a model with no post-disturbance change-points. A compound hypothesis (that there was some post-disturbance change abundance trends) would be tested by integrating the posterior probabilities of all models with post-disturbance change-points and comparing that integrated (= marginal) probability to the integrated probability of all models with no post-disturbance change-points.

Bayesian model comparison inherently penalizes model complexity, and the degree of penalty increases with the prior variance (or vagueness) of parameters. Therefore, models with change-points (i.e. additional parameters) are more likely to be supported if relatively narrow prior distributions are assigned to the timing and magnitude of any change-points. That is, testing specific hypothesis about the magnitude and timing of change-points is likely more powerful than searching exhaustively among all models for any change-points. The later approach may be useful however, for characterising general trends and identifying unexpected changes.

The Hierarchical Bayesian framework is very flexible and the change-point models can be extended in (at least) three ways that can increase power to detect changes and increase the precision of estimated effects. First, observation uncertainty (e.g. observer errors) can be included explicitly (and modelled as a function of covariates), which improves estimation of underlying process models (i.e. true underlying abundance trends). Second, covariates that are expected to affect abundances (e.g. climatic variations) can be included in models to reduce unexplained variability. With covariates included, the change-points identified are conditional on covariate effects – that is, they represent changes in temporal trends in *y* that would not be expected given observed trends in covariates (see Figure 28 for examples). Third, models for individual species can be fitted simultaneously and common change-points identified. This approach effectively combines evidence from multiple species (and / or locations) and identifies times when multiple species experienced similar abrupt changes in abundance (or trends). These extensions are discussed in detailed in Thomson *et al.* (2010). Figures 29-32 show results of basic change-point model applied to actual and hypothetical shorebird counts at West Islands.

Data presented in this report forms the basis of the pre-impact dataset for each island and reserve system to be assessed. Although every effort has been made to obtain all existing data it should be noted that the majority of available data for the planned analyses has been obtained from unpublished sources. As such, it remains possible, indeed likely, that more data of this nature will come to the attention of the Study team during the course of the study. It is the intention of the Study team that any additional data or new information that assists with further refinement of the existing dataset be incorporated into the final analyses.

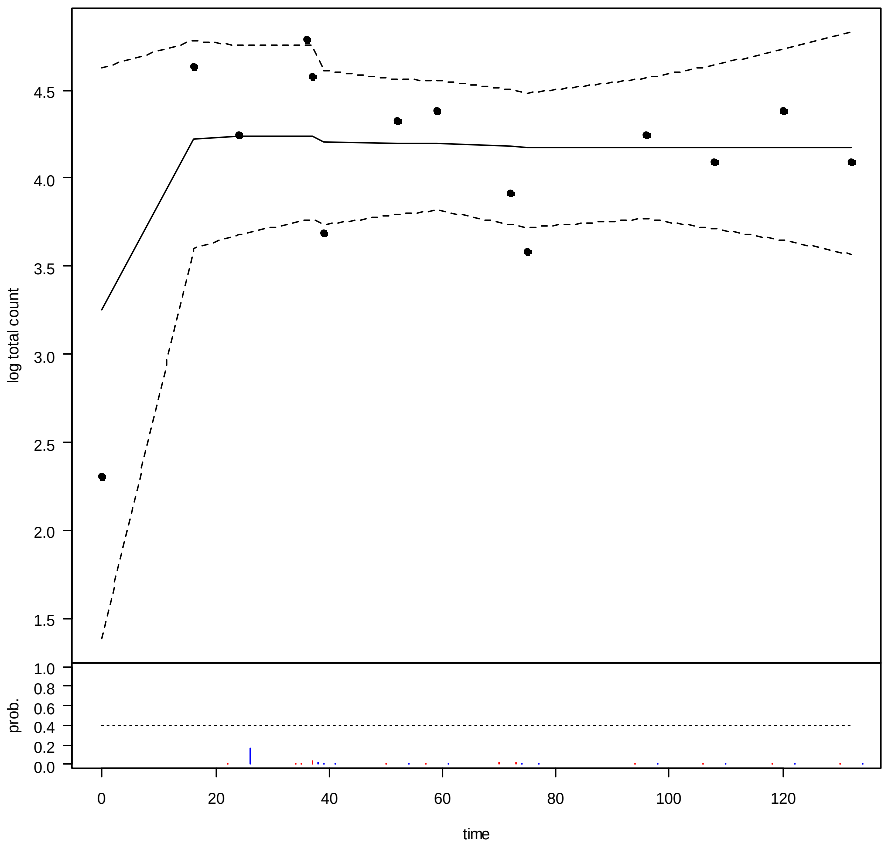

Figure 29 Results of change-point model applied to pre-impact (Oct 1998 through Oct 2009) counts Whimbrel at West Island. Main panel shows the log transformed total counts (points) and the fitted mean (solid line) and 95% credible intervals. Bottom panel shows the posterior probability of step (red bars) and trend (blue bars) changes at each survey time (x-axis is months since first survey). The dashed horizontal line corresponds to a threefold increase from the prior to posterior odds of a change- point: bars extending above this line would indicate substantial evidence of change-point in that year. For these data, there is no substantial evidence of any change-points (most probabilities are near-zero, and therefore do not appear).

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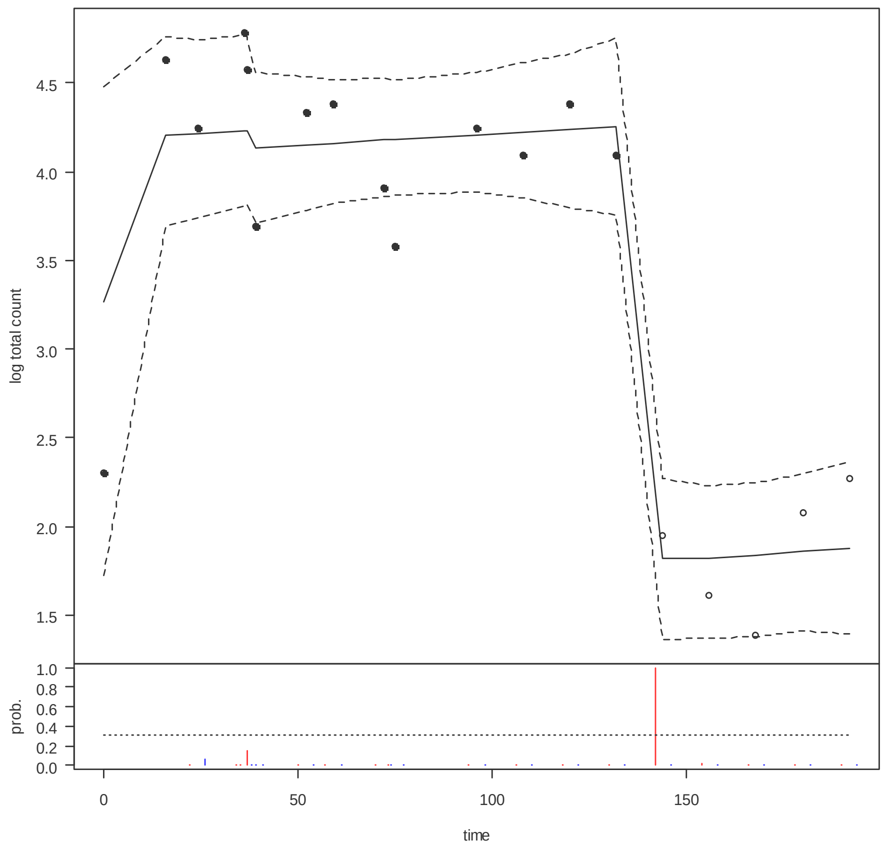

Figure 30 Results of change-point model applied to pre-impact (Oct 1998 through Oct 2009) counts Whimbrel at West Island and a hypothetical 80% (open points) reduction in post-disturbance counts. Main panel shows the log transformed total counts (closed circles = actual data, open circles = hypothetical counts) and the fitted mean (solid line) and 95% credible intervals. Bottom panel shows the posterior probability of step (red bars) and trend (blue bars) changes at each survey time (x-axis is months since first survey). The dashed horizontal line corresponds to a threefold increase from the prior to posterior odds of a change- point: bars extending above this line would indicate substantial evidence of change-point in that year. For these hypothetical data, there is overwhelming evidence of a step change at month 140 (~ mid 2010).

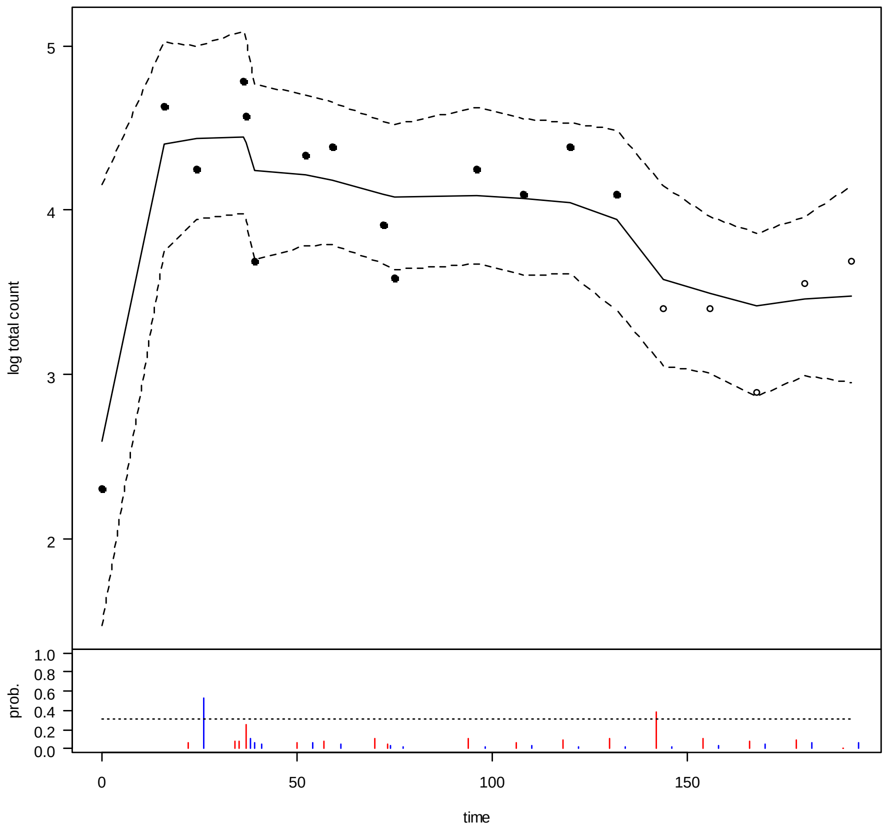

Figure 31 Results of change-point model applied to pre-impact (Oct 1998 through Oct 2009) counts Whimbrel at West Island and a hypothetical 50% (open points) reduction in post-disturbance counts. Main panel shows the log transformed total counts (closed circles = actual data, open circles = hypothetical counts) and the fitted mean (solid line) and 95% credible intervals. Bottom panel shows the posterior probability of step (red bars) and trend (blue bars) changes at each survey time (x-axis is months since first survey). The dashed horizontal line corresponds to a threefold increase from the prior to posterior odds of a change- point: bars extending above this line would indicate substantial evidence of change-point in that year. For these hypothetical data, there is substantial evidence of a step change at month 140 (~ mid 2010). There is also evidence of a trend change at month 25 (blue bar) – this is caused by the relatively good fit a model with a sharp initial increase (from the very low initial value) and a steady decline thereafter. The interpretation of these results would be that there may have already been a declining trend in counts, but there was probably an addition step decline following the disturbance.

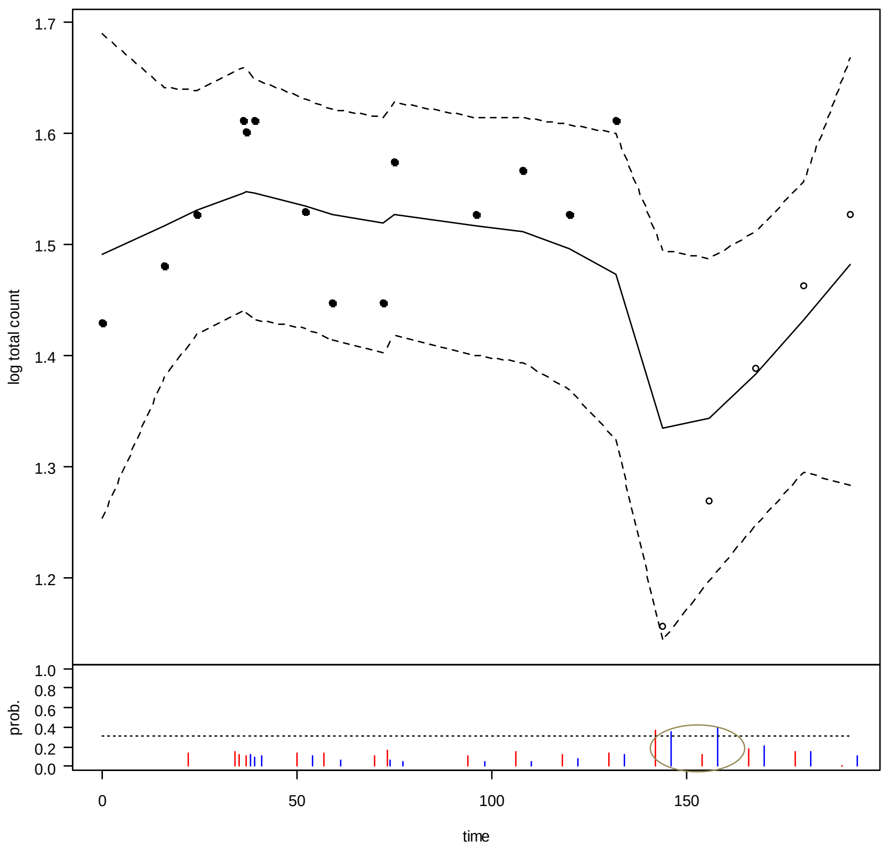

Figure 32 Results of change-point model applied to pre-impact (Oct 1998 through Oct 2009) counts of Ruddy Turnstone at West Island and a hypothetical (open points) 20% reduction in post-disturbance counts followed by a rapid recovery to pre-disturbance values. Main panel shows the log transformed total counts (closed circles = actual data, open circles = hypothetical counts) and the fitted mean (solid line) and 95% credible intervals. Bottom panel shows the posterior probability of step (red bars) and trend (blue bars) changes at each survey time (x-axis is months since first survey). The dashed horizontal line corresponds to a threefold increase from the prior to posterior odds of a change- point: bars extending above this line would indicate substantial evidence of change-point in that year. The initial decline and subsequent recovery is modelled as a combination of step and trend changes.

Control datasets

As outlined in the proposed statistically analyses, identified trends and change points would ideally be analysed against control data from relevant sites. For this approach to be valid appropriate control data is required. Such control data must be sourced from areas outside the area of predicted impact but not so distant that inter-regional variability of ecosystems confounds results. There are no additional seabird islands off north-western Australia for which appropriate baseline data exists, and further the Study team is unaware of any regularly monitored seabird islands elsewhere in nearby regions of the Timor Sea or Indian Ocean. As consequence, it is not possible to incorporate a control dataset for breeding populations of seabirds in the proposed analyses. The more extensive dataset for Ashmore Reef will however be employed as an ‘internal’ control for both Cartier and Browse Island were datasets are less extensive. That is trends and step point changes detected at Cartier and Browse Island will be examined and interpreted in relation to patterns of change observed at Ashmore Reef.

In contrast, a robust dataset of shorebird counts that would be suitable for control purposes does exist. The Australian Wader Study Group (AWSG) has been undertaking shorebird counts on the mainland in north west Australia since the early 1990s (see Watkins 1993). These counts have been further refined so that commencing in 2004, three counts per year (two summer and one winter count) have been conducted at a number of key shorebird sites (D. Rogers pers. comm.). These sites include Roebuck Bay (~170,000 shorebirds), Bush Point near Broome and a 60 km stretch of 80 Mile Beach (~470,000 shorebirds) (AWSG 1998, Bamford *et al.* 2008). Counts at these sites have been undertaken with the specific intention of monitoring shorebird population trends in north west Australia. Existing analysis by the AWSG demonstrates that the scale and frequency of these counts is sufficient to detect meaningful changes in shorebird population size (D. Rogers pers. comm.). These counts are ongoing, and with support under this current monitoring program for the Reserves the AWSG has undertaken to continue gathering data and provide access to this data for analysis purposes outlined here.

Given the proximity of this established monitoring program to the Reserves, the rigorous design (including refinement) of the monitoring program and the extended period over which counts have been conducted at these sites would serve as suitable control sites. As the count data spans an extended pre-impact period (since 2004) and is ongoing, the use of this data will ensure that shorebird data gathered at the Reserves can be placed in context with regional trends in shorebird numbers external to potential impact from the Montara Well release.

Reserve Systems on the Sahul Shelf: Significant Impact & Assessment Criteria

Ashmore Reef National Nature Reserve supports internationally significant numbers of breeding seabirds (Bellio *et al.* 1997, this study) and migratory shorebirds (Bamford *et al.* 2008, this study). Recent data demonstrates that some 100,000 seabirds utilize the islands for breeding purposes on an annual basis, whilst counts of shorebirds demonstrate at least 18,000 migratory shorebirds can be present during the wet season (Swann 2005c; this study). Most of these seabirds and all migratory shorebirds are listed under one or more of the bilateral migratory bird agreements that the Commonwealth of Australia is a signatory to (JAMBA, CAMBA and ROKAMBA). All of these species are listed under the *EPBC Act 1999* as marine species and/or migratory species.

Previous estimates of breeding seabird and migratory shorebird numbers at Ashmore Reef (lower than recognised in this study) led to the reserve being designated as a wetland of international importance under the Ramsar Convention (Ramsar Convention Bureau 2009). As a marine ecosystem with high biological diversity Ashmore Reef has also been designated as a National Nature Reserve administered by the Commonwealth under the *EPBC Act 1999*. On this basis, Ashmore Reef is defined as a Commonwealth marine area. Ashmore Reef has also been designated an Important Bird Area by BirdLife International on the grounds that it supports exceptionally large numbers of migratory or congregatory species (BirdLife International 2010).

Under the *EPBC Act 1999* both Ashmore Reef and the seabirds and shorebirds that utilize the available terrestrial habitats are specified 'matters of national environmental significance'. Ashmore Reef qualifies on the grounds that it is a National Nature Reserve, a Commonwealth marine area and a designated Ramsar site, while seabirds and shorebirds qualify independently on the grounds that they are listed marine and/or migratory species.

Both Cartier Island and Browse Island support fewer seabirds and shorebirds when compared with Ashmore Reef (this study). Nevertheless, Cartier Island is recognised as a matter of national environmental significance on the grounds that it too is a National Nature Reserve, and a Commonwealth marine area. The breeding seabirds (namely Crested Terns) and migratory shorebirds that utilize both Cartier Island and Browse Island qualify independently on the grounds that they are listed marine and/or migratory species.

The *EPBC Act 1999* provides for the protection of matters of national environmental significance and seeks to prevent significant adverse impact to these matters. Commonwealth of Australia (2009) has defined a significant impact as '*an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts.'*

It is premature to provide comment on whether the Montara Well release has led to significant adverse impacts on the seabird and shorebird populations. Rather, this review seeks to concatenate knowledge concerning the status of seabirds and shorebirds prior to

any potential impact, refine a post-impact monitoring program for seabirds and shorebirds that occur within the Reserves and explore existing long-term data sets to identify statistical analyses most appropriate to detect potential changes due to the Montara Well release. Nevertheless, to ensure subsequent assessments of potential impact are defensible it is appropriate to consider what would constitute a significant impact on breeding seabird and shorebird populations within the Reserves.

In this context, significant impact criteria sourced from Commonwealth of Australia (2009) and of relevance to this study, are identified as follows:

- For *migratory species* where the Montara Well release has led to 1) a substantial modification (including by alteration to nutrient cycles or alteration to hydrological cycles), destruction or isolation an area of important habitat for a migratory species or; 2) a serious disruption to the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species;

- For a *declared Ramsar wetland* where the Montara Well release has led to the habitat or lifecycle of native species, including invertebrate fauna and fish species, dependant upon the wetland being seriously affected;

- For the *Commonwealth Marine environment* where the Montara Well release has led to 1) the modification, destruction, fragmentation, isolation or disturbance of an important or substantial area of habitat such that an adverse impact on marine ecosystem function or integrity in a Commonwealth marine area results or; 2) a substantial adverse effect on a population of a marine species including its life cycle or; 3) the persistence of organic chemicals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity or ecological integrity may be adversely affected.

The scope of the Monitoring Plan for the Montara Well release, as outlined here, is to assess trends in breeding populations of seabirds and visiting populations of migratory shorebirds. Therefore, criteria to be applied for the purposes of identifying a significant impact on these populations have been identified (Table 12). These criteria are based on expert opinion and take into account a number of factors. First, the statistical power present within existing datasets is recognized (e.g. Figures 30-32). Second, it is acknowledged that seabird and shorebird populations occur in variable environments that would be expected to naturally fluctuate to some degree on an inter-annual basis and that these fluctuations may occur over greater periods (e.g. decadal or longer) than the current datasets span. And third, under the *EPBC Act 1999*, for an adverse impact to be defined as significant, that impact should meet the criteria specified by Commonwealth of Australia (2009). Further, whilst monitoring programs must seek to achieve appropriate statistical power, any conclusions regarding statistically significant proof of impact must also be biologically meaningful in the context of the threatening process.

Table 12 Recommended criteria to be applied for the purposes of identifying a significant impact on seabird populations and shorebird populations within Reserves on the Sahul Shelf. Cohort sizes in column 1 refer to pre-impact population sizes (this study).

Seabird or shorebird cohort	Significant impact criteria
All breeding seabird populations (>10 pairs) combined	Decline of >20% within 3 years with no apparent recovery to pre-impact levels after 5 years
Seabird species with a population >10,000 pairs	Decline of >20% within 3 years with no apparent recovery to pre-impact levels after 5 years
Seabird species with a population of 1000 to 10,000 pairs	Decline of >40% within 3 years with no apparent recovery to pre-impact levels after 5 years
Seabird species with a population of 100 to 1000 pairs	Decline of >50% within 3 years with no apparent recovery to pre-impact levels after 5 years
All migratory shorebird populations (>10 individuals) combined	Decline of >20% (over and above any regional declines identified in control data from mainland north west Australia) within 3 years with no apparent recovery after 5 years
Shorebird species with a population > 1000 individuals	Decline of >20% (over and above any regional declines identified in control data from mainland north west Australia) within 3 years with no apparent recovery after 5 years
Shorebird species with a population of 100 to 1000 individuals	Decline of >40% (over and above any regional declines identified in control data from mainland north west Australia) within 3 years with no apparent recovery after 5 years

Conclusions

This report concatenates and summarizes existing data concerning seabird and shorebird populations at Ashmore Reef, Cartier Island and Browse Island. Some of these populations are internationally significant and all meet one or more criteria as matters of national environmental significance. The *potential* for the Montara Well release to have had (and continue to have) a significant impact on these populations has been demonstrated. A monitoring program that seeks to assess seabird and shorebird population trends and changes within the reserves has commenced (April 2010). It is recommended that monitoring using the established techniques continue on a twice annual basis for five years. It is further recommended that change point analysis be employed to analyse data collected and that any assessment of impact consider the threshold criteria as defined here.

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APPENDIX A

List of all vertebrate species mentioned in the text, including scientific names as presented in Christidis and Boles (2008).

English name	Latin name
Swinhoe's Snipe	*Gallinago megala*
Black-tailed Godwit	*Limosa limosa*
Bar-tailed Godwit	*Limosa lapponica*
Little Curlew	*Numenius minutus*
Whimbrel	*Numenius phaeopus*
Eastern Curlew	*Numenius madagascariensis*
Common Redshank	*Tringa totanus*
Marsh Sandpiper	*Tringa stagnatilis*
Common Greenshank	*Tringa nebularia*
Common Sandpiper	*Actitis hypoleucos*
Grey-tailed Tattler	*Tringa brevipes*
Ruddy Turnstone	*Arenaria interpres*
Asian Dowitcher	*Limnodromus semipalmatus*
Great Knot	*Calidris tenuirostris*
Red Knot	*Calidris canutus*
Sanderling	*Calidris alba*
Little Stint	*Calidris minuta*
Red-necked Stint	*Calidris ruficollis*
Sharp-tailed Sandpiper	*Calidris acuminata*
Curlew Sandpiper	*Calidris ferruginea*
Red-necked Phalarope	*Phalaropus lobatus*
Broad-billed Sandpiper	*Limicola falcinellus*
Beach Stone-curlew	*Esacus magnirostris*
Black-winged Stilt	*Himantopus himantopus*
Pacific Golden Plover	*Pluvialis fulva*
Grey Plover	*Pluvialis squatarola*
Lesser Sand Plover	*Charadrius mongolus*
Greater Sand Plover	*Charadrius leschenaultii*
Oriental Plover	*Charadrius veredus*
Masked Lapwing	*Vanellus miles*
Australian Pratincole	*Stiltia isabella*
Oriental Pratincole	*Glareola maldivarum*
Red-tailed Tropicbird	*Phaethon rubricauda*
White-tailed Tropicbird	*Phaethon lepturus*
Masked Booby	*Sula dactylatra*
Red-footed Booby	*Sula sula*
Brown Booby	*Sula leucogaster*
Great Frigatebird	*Fregata minor*
Lesser Frigatebird	*Fregata ariel*
Crested Tern	*Thalasseus bergii*
Lesser Crested Tern	*Thalasseus bengalensis*
Roseate Tern	*Sterna dougallii*
Bridled Tern	*Onychoprion anaethetus*
Sooty Tern	*Onychoprion fuscata*

APPENDIX A (CONT.)

List of all vertebrate species mentioned in the text, including scientific names as presented in Christidis and Boles (2008).

Common Noddy	*Anous stolidus*
Black Noddy	*Anous minutus*
Lesser Noddy	*Anous tenuirostris*
Wedge-tailed Shearwater	*Ardenna pacifica*
Little Egret	*Egretta garzetta*
Eastern Reef Egret	*Egretta sacra*
Eastern Great Egret	*Ardea modesta*
Nankeen Night-Heron	*Nycticorax caledonicus*
Green Turtle	*Chelonia mydas*

APPENDIX B

Coordinates for Tropicbird nests on West Island, Ashmore Reef, April 2010

Nest number	Nest status	Date located	Latitude	Longitude
Red-tailed Tropicbird				
1	I/B adult	15-April-2010	12.24265	122.96963
2	Medium chick	15-April-2010	12.24265	122.96963
3	Medium chick	15-April-2010	12.24280	122.96968
4	I/B adult	20-April-2010	12.24287	122.96405
5	I/B adult	16-April-2010	12.24340	122.97017
6	Large chick	15-April-2010	12.24343	122.96502
7	I/B adult	15-April-2010	12.24347	122.96720
8	I/B adult	15-April-2010	12.24350	122.96520
9	Medium chick	15-April-2010	12.24383	122.97028
10	I/B adult	15-April-2010	12.24385	122.96632
11	I/B adult	15-April-2010	12.24428	122.97020
12	Large chick	15-April-2010	12.24433	122.96745
13	I/B adult	15-April-2010	12.24438	122.97042
14	Large chick	15-April-2010	12.24440	122.96803
15	I/B adult	15-April-2010	12.24440	122.97035
16	I/B adult	15-April-2010	12.24443	122.97030
17	I/B adult	15-April-2010	12.24452	122.96953
White-tailed Tropicbird				
1	Inc. adult	17-April-2010	12.24043	122.96570

I/B adult = Adult incubating an egg or small nestling (nest contents not seen), Inc. adult = incubating adult (egg sighted).

APPENDIX C

Reference Images of Study Islands

Photo point name: West Island #1
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 14 April 2010
Location: South end of West Island, Ashmore Reef. Within sight of Coconut Palm
Coordinates of photo monitoring point: 51L 496769, 8646484
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Comments: Edge of nearest palm on left edge of frame.
Direction of photograph: North

Photo point name: West Island #2
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 16 April 2010
Location: Just south of water pump, West Island, Ashmore Reef. Within sight of Coconut Palm
Coordinates of photo monitoring point: 51L 0496593, 8646718
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Comments: Tallest met tower at left of frame
Direction of photograph: North

Photo point name: West Island #3
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 16 April 2010
Location: Southeast of *Spinifex longifolius* patch onWest Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 0496293, 8646856
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: West

Photo point name: West Island #4
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 16 April 2010
Location: NW end of West Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 495960, 8646798
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: South west

Photo point name: West Island #5
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 16 April 2010
Location: On western shore of West Island, Ashmore Reef facing Coconut Palm and graves.
Coordinates of photo monitoring point: 51L 496400, 8646516
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Comments: Coconut Palm to east is centre marker in frame
Direction of photograph: East south east

Photo point name: West Island #6
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 17 April 2010
Location: South end of West Island, Ashmore Reef in low dunes
Coordinates of photo monitoring point: 51L 496804, 8646434
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: East towards Middle Island

Photo point name: Middle Island #1
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 20 April 2010
Location: On NE corner of Middle Island, Ashmore Reef adjacent to sign.
Coordinates of photo monitoring point: 51L 503891, 8643996
Comments: Use sign as central marker
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: North north west

Photo point name: Middle Island #2
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 20 April 2010
Location: On southern shore of Middle Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 503475, 8643990
Comments: Use dead palm trunk as central marker
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: North east

Photo point name: Middle Island #3
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 20 April 2010
Location: On NE shore of Middle Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 503592, 8644246
Comments: Use dead palm trunk as central marker
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: South west

Photo point name: Middle Island #4
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 20 April 2010
Location: On NE shore of Middle Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 503592, 8644246
Comments: Same point as Middle Island #3 - Use distant sign as central marker
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: South

Photo point name: East Island #1
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 17 April 2010
Location: NW end of East Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 510193, 8644640
Comments: On rise with second peg as sighting marker 10 m distant
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: South east

Photo point name: East Island #2
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 17 April 2010
Location: Near NE corner of East Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 510582, 8644722
Comments: Inland by ~10 m with second peg as sighting marker 10 m distant
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: West south west

Photo point name: East Island #3
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 17 April 2010
Location: On eastern shore towards Southern corner of East Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 510674, 8644490
Comments: Inland by ~10 m with second peg as sighting marker 10 m distant
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: North west

Photo point name: Far East Island #1
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 17 April 2010
Location: NW end of Far East Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 0512042, 8644750
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: South east towards Photo monitoring point 2

Photo point name: Far East Island #2
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 17 April 2010
Location: SE end Far East Island, Ashmore Reef.
Coordinates of photo monitoring point: 51L 0512091, 8644704
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: North west towards Photo monitoring point 1

Photo point name: Cartier Island #1
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 21 April 2010
Location: East end of Cartier Island
Coordinates of photo monitoring point: 51L 560424, 8614700
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: West

Photo point name: Cartier Island #2
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 21 April 2010
Location: West end of Cartier Island
Coordinates of photo monitoring point: 51L 560146, 8614728
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: East

Photo point name: Browse Island #1
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 22 April 2010
Location: Northern extent of vegetation on Browse Island
Coordinates of photo monitoring point: 51L 559213, 8440340
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Direction of photograph: South towards tallest met tower (not lighthouse)

Photo point name: Browse Island #2
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 22 April 2010
Location: Northern extent of vegetation on Browse Island
Coordinates of photo monitoring point: 51L 559213, 8440340
How is site marked? Vertical steel spacer driven into ground – florescent orange.
Comments: Same photo monitoring point as Browse Island #1
Direction of photograph: South-East. Use rock pile as centre marker.

Photo point name: Browse Island #3
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 23 April 2010
Location: Western side of Browse Island
Coordinates of photo monitoring point: 51L 559075, 8440120
How is site marked? Met tower closest to beach on flat – florescent orange mark on pole
Comments: Light house to right edge of frame.
Direction of photograph: North east

Photo point name: Browse Island #4
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 23 April 2010
Location: Southern side of Browse Island
Coordinates of photo monitoring point: 51L 559237, 8439986
How is site marked? Vertical steel spacer driven into ground – florescent orange
Direction of photograph: North west

Photo point name: Browse Island #5
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 23 April 2010
Location: Marker on raised rocky wall near south side of Browse Island
Coordinates of photo monitoring point: 51L 559237, 8439986
How is site marked? Vertical steel spacer driven into ground – florescent orange
Comments: Light tower as central marker.
Direction of photograph: North north west

Photo point name: Browse Island #6
Project name: Monitoring program for the Montara Well release
Photo monitoring point Coordinator: Rohan Clarke
Organization responsible for establishing photo monitoring point: Monash University
Date of first photograph: 23 April 2010
Location: Marker on raised vegetated edge near east side of Browse Island
Coordinates of photo monitoring point: 51L 559357, 8440194
How is site marked? Vertical steel spacer driven into ground – florescent orange
Comments: Large shrub on left edge of frame
Direction of photograph: South east