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

FINAL IMPACT ASSESSMENT FOR THE MONTARA OIL SPILL

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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

DPAW - Western Australian Department of Parks and Wildlife

DotE - Australian Federal Department of the Environment

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All of these surveys relied on vessels to travel to and from the field sites safely and to move about the islands on a daily basis. One voyage each was undertaken on the *MV King Tide*, *MV Kimberley Escape* and *MV Great Escape*. The remaining seven voyages were undertaken on *MV Diversity II*. The skipper and crew of all vessels are thanked for their professional conduct and assistance during those voyages.

Cover photo: Mixed colony of seabirds, predominantly Brown Boobies and Common Noddies, East Island, Ashmore Reef Commonwealth Marine Reserve, April 2011, by Rohan Clarke.

EXECUTIVE SUMMARY

- Ashmore Reef, Cartier Reef and Browse Islands are situated on or near the Sahul Shelf, off north-west Australia. These reserves support internationally significant numbers of breeding seabirds and migratory shorebirds with species variously listed under the *EPBC Act 1999*.
- An uncontrolled well release occurred from August to early November 2009. 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 Department of the Environment, Water, Heritage and the Arts, a monitoring program for seabirds and shorebirds, terrestrial habitats and vegetation condition was implemented for Ashmore Reef, Cartier Reef and Browse Island in 2010. This included twice annual (April and November) surveys for a period of five years to 2014.
- Fifteen species of seabird were confirmed breeding at Ashmore Reef, and numbers of breeding seabirds were shown to exceed 100,000 individuals during a single year. Up to 33 migratory shorebird species of over 10,000 individuals also used Ashmore Reef. Small numbers of seabirds and shorebirds frequented Cartier Reef and Browse Island; from an avian perspective neither of these sites met the criteria for international significance.
- There were no appropriate control sites against which population trajectories of Ashmore Reef seabirds could be compared, and a before/after comparison was made. The *total number of seabirds* breeding at Ashmore Reef increased after the spill event when compared to pre-impact data. This trend also applied to *breeding populations of individual seabird species*. Declines in non-breeding seabirds during November surveys were detected and some of these declines met the *a priori* definition of significant impact. As breeding populations increased over the same time period, these declines likely reflect variability in seasonal response rather than evidence for significant impact arising from the Montara Oil Spill. Change-point analyses support these conclusions as there were no well supported negative change points centred on or in the 12 months following the 2009 spill event.
- Population trajectories of migratory shorebirds that occur at Ashmore Reef were compared with those from Eighty-mile Beach, WA using a Before-After-Control-Impact design. Numbers of shorebirds at Ashmore Reef declined significantly when populations before and after the Montara Oil Spill were compared. This response however was anticipated given ongoing declines of migratory shorebirds throughout the flyway. Although the Ashmore Reef population decline was greater than that documented for the control site the difference was not significant and no significant impact as a result of the Montara Oil Spill was detected. There were however some species-specific responses demonstrating significantly greater decline at Ashmore Reef than the control site.
- Whilst the Montara Oil Spill was known to extend to marine waters in proximity to Ashmore Reef, Cartier Reef and Browse Island and small numbers of dead seabirds were detected during the spill event, this study did not detect evidence that the avifauna at these sites suffered significant impact as a result of the oil spill.
- The results of the five-year avian monitoring program make a substantial contribution to the available baseline against which the efficacy of future management actions and potential impacts may be assessed.

INTRODUCTION

The Montara Oil Spill

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 (Figure 1) occurred on 21st August 2009. 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 Cartier Reef Commonwealth Marine Reserve (CMR) and Ashmore Reef CMR to the west of the Montara Well, and in proximity to Browse Island Nature Reserve (NR) 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 CMR (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 kilometers surrounding the Montara Well. The closest terrestrial habitats to the Montara Well head are Cartier Island CMR situated 105 km to the west, and Ashmore Reef CMR situated 157 km to the west-north-west. Browse Island is located 195 km to the south west of the Montara Well head.

Land areas and reef systems of relevance to seabirds and shorebirds

Ashmore Reef CMR and Cartier Island CMR lie within Australian Commonwealth waters. Ashmore Reef CMR 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 CMR is situated ~52 km to the south-east of Ashmore Reef CMR at 12°32'S, 123°33'E (Commonwealth of Australia 2002) (Figure 1). The Federal Department of the Environment, (DotE) is the managing authority for these reserves. Browse Island Nature Reserve is situated at 14°06'S 123°32'E and is 172 km south of Cartier Island CMR and approximately 450 km north- north-east of Broome. The reserve is managed by the Western Australian Department of Parks and Wildlife (DPAW).

Ashmore Reef CMR and Cartier Island CMR serve to protect marine ecosystems with high biological diversity (Commonwealth of Australia 2002). Ashmore Reef CMR contains four lightly vegetated islands (total land area ~55 ha). Within its fringing reef, Cartier Island Commonwealth Marine Reserve contains a single sand cay (~2 ha) devoid of vegetation (Pike & Leach 1997). Browse Island is also situated within a relatively small fringing reef. The northern and eastern shores of Browse Island consist of low lying sparsely vegetated eroded coral rubble, while the remainder of the island is slightly more elevated and vegetated with herbs and low shrubs (R. Clarke pers. obs.).

Ashmore Reef CMR supports a large population of seabirds, including some of the most important seabird rookeries on the North West Shelf (Milton 2005, Clarke *et al.* 2011). Many of these seabirds are breeding visitors and are thus present in large numbers on a seasonal basis. Large colonies of Sooty Terns[1], Greater Crested Terns, Common Noddy, Lesser Frigatebirds and Brown Boobies breed on East and Middle Islands. Smaller breeding colonies of Wedge-tailed Shearwaters, Masked Boobies, Red-footed Boobies, Great Frigatebirds, Little Egrets, Eastern Reef Egrets, Black Noddy, Lesser Noddy and Roseate Terns also occur (Australian National Parks and Wildlife Service 1989, Milton 2005, Clarke *et al.* 2011). 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 CMR is also recognised as a Ramsar wetland of international significance with an area of 58,300 ha being designated in 2002 (Ramsar Convention Bureau 2009). Ashmore Reef CMR 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). At the time of the Montara Oil Spill there was limited information available concerning seabird populations present at Cartier Island CMR and Browse Island. Just a handful of species had been reported from Cartier Island and its surrounding reef (Serventy 1952, Guinea 1993). Greater Crested Terns had previously been reported to nest at Browse Island (Smith *et al.* 1978), and prior to guano extraction in the 19th century Browse Island supported significant numbers of seabirds (Serventy 1952).

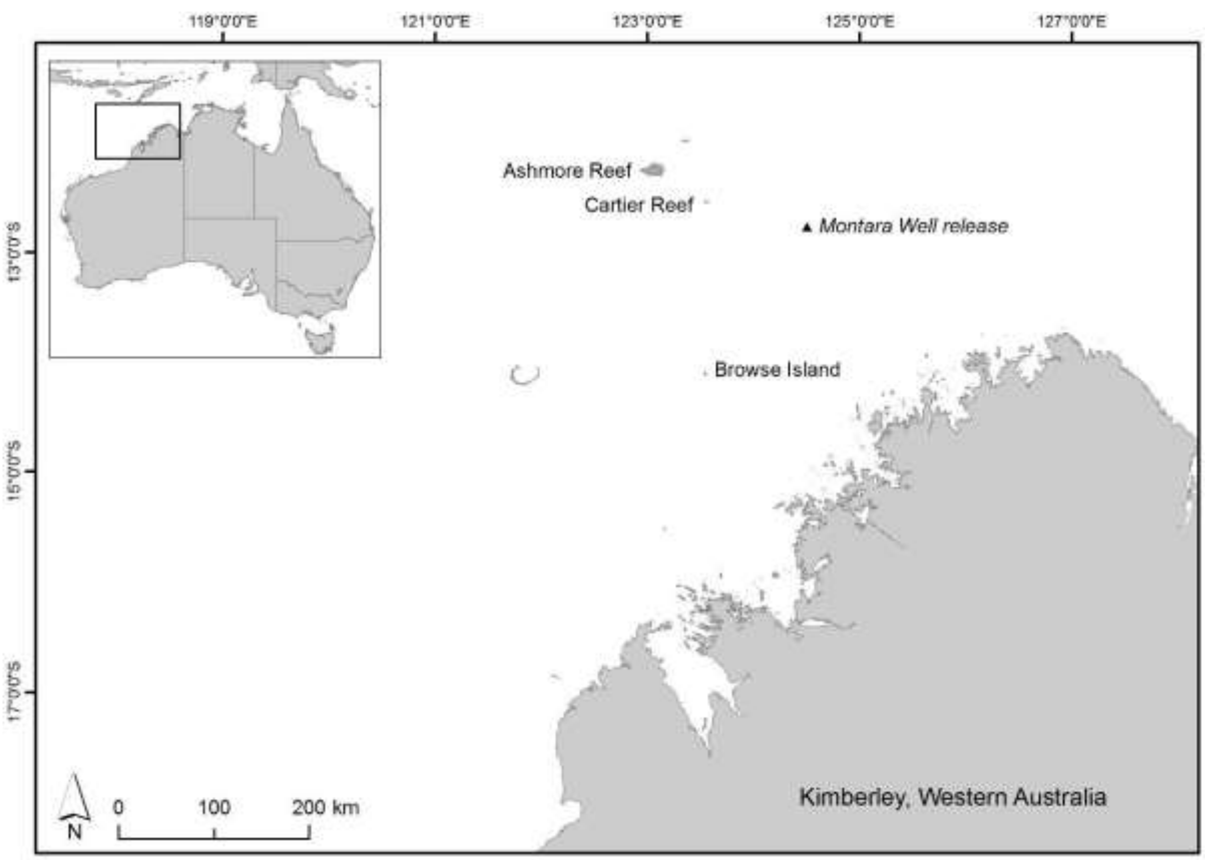


Figure 1 Location of Ashmore Reef CMR, Cartier Reef CMR and Browse Island NR relative to the site of the Montara Oil Spill and the Kimberley coastline Australia.

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

Ashmore Reef CMR also provides important foraging areas for migratory shorebirds that visit the region. Numbers of shorebirds are highest between October and April when non-breeding adults visit from the northern hemisphere. Large numbers of shorebirds are often still present during the remainder of the year as juveniles (first year birds) and immatures (second to third year birds) of many species remain on the non-breeding grounds for the first few years of life (Higgins & Davis 1996). The extensive sand flats exposed at low tide are known to provide foraging opportunities for internationally significant numbers of some species including Grey Plover and Sanderling (Swann 2005a; 2005b). Small numbers of shorebirds have previously been reported from Cartier Reef and Browse Island but the importance of these sites to shorebirds has not previously been quantified (e.g. Smith *et al.* 1978, Guinea 1993).

The Montara Oil Spill may have directly exposed breeding seabirds at the Reserves to oils via a number of potential pathways. Birds foraging at sea had the potential to directly interact with oil on the sea surface some considerable distance from marine reserves 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 were considered most at risk. As seabirds are top-order predators any impact on other marine life (e.g. fish kills) may have also impacted seabirds through secondary ingestion or disruption to the food supply both for the maintenance of free flying individuals (adults and immatures), and the provisioning of young. Any direct impact of oil on terrestrial habitats within the Reserves, including the shorelines of islands, also had 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 was considered a minimum requirement to determine if seabirds that breed within the Reserves suffered significant impacts from the Montara Oil Spill.

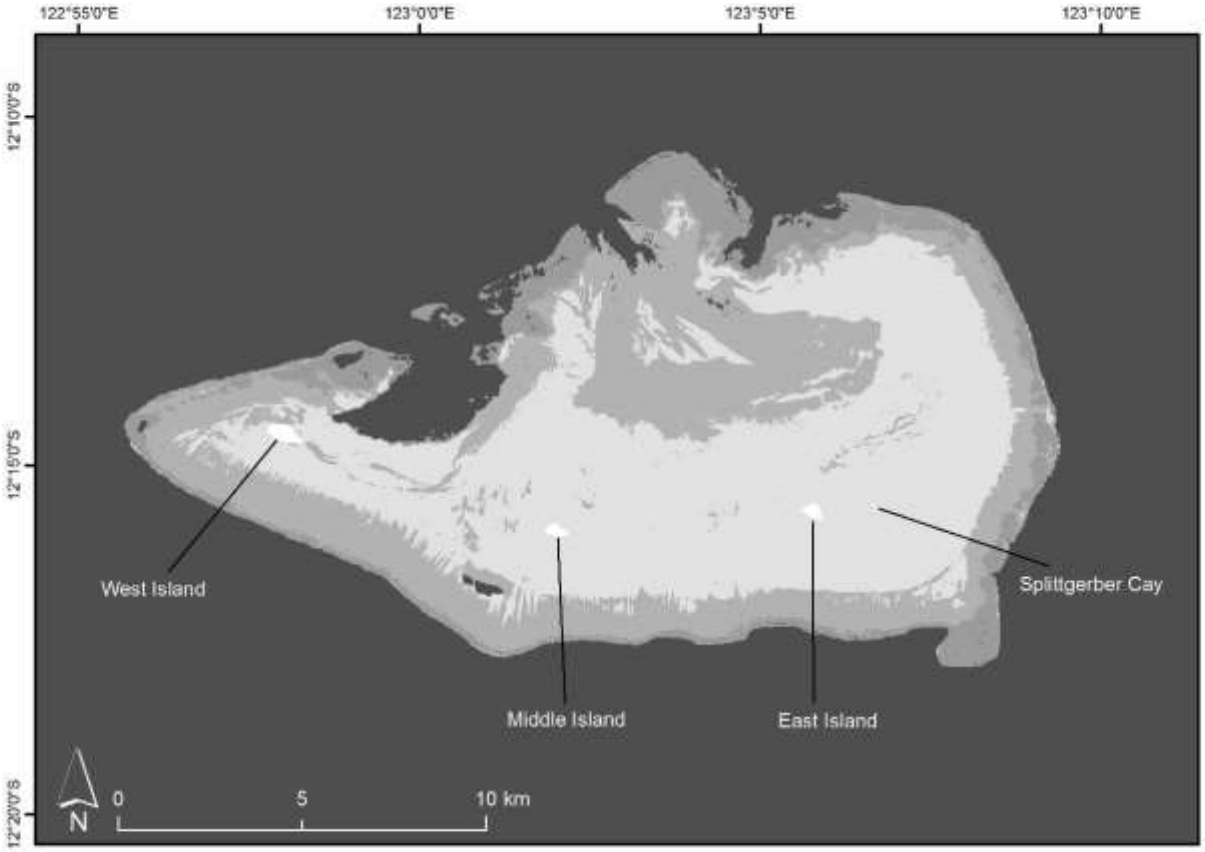


Figure 2 Overview of Ashmore Reef CMR showing the locations and relative sizes of West Island, Middle Island, East Island and Splittgerber Cay discussed in the text. Darker shades indicate deeper water.

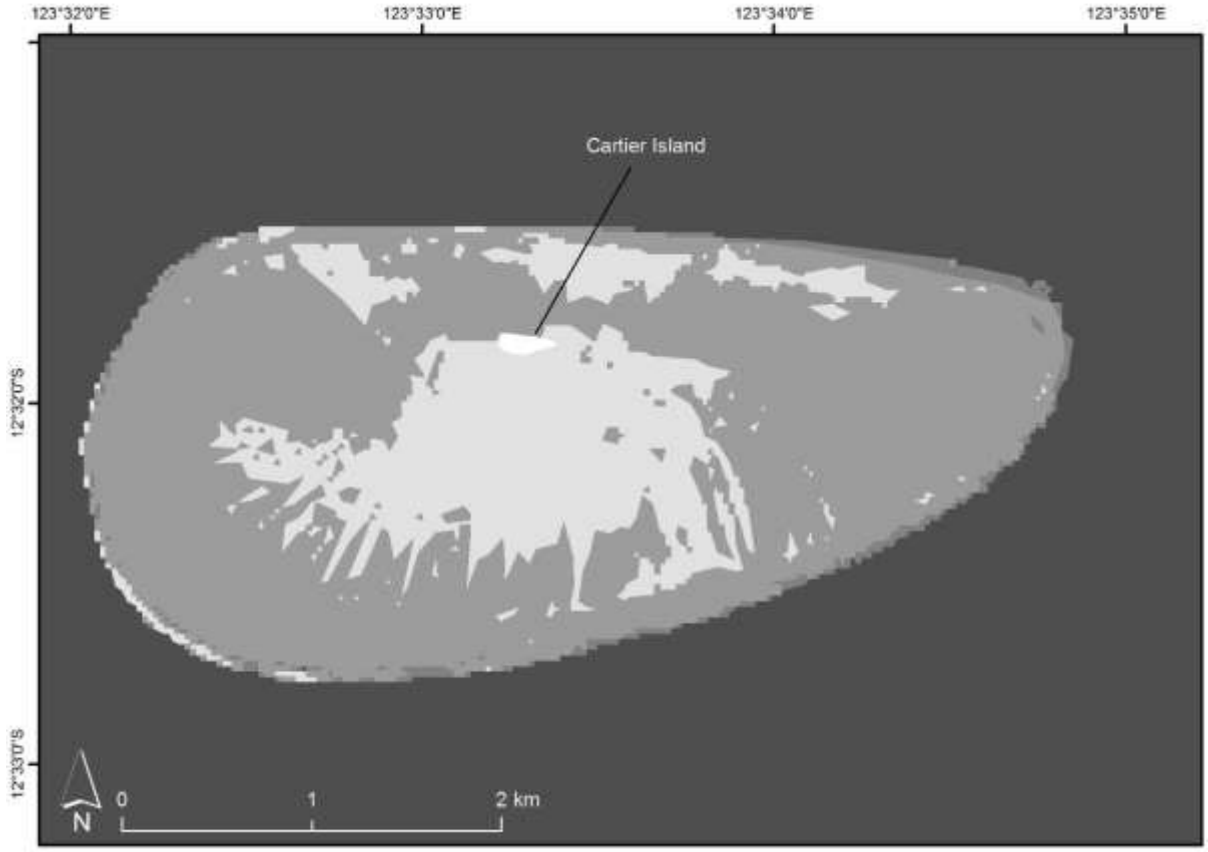


Figure 3 Overview of Cartier Reef CMR showing the location of Cartier Island towards the centre of the reef. Darker shades of blue indicate deeper water.

In contrast to seabirds, shorebirds were only likely to be exposed to oil if it directly impacted areas of exposed 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 etc.) 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 bare parts) 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 was considered a minimum requirement to determine if shorebird species that regularly occur within the Reserves suffered significant impacts from the Montara Oil Spill.

In an agreement between PTTEP Australasia and DEWHA (now DotE) a monitoring plan for the Montara Oil Spill in the Timor Sea was developed (9th October 2009). The plan identified triggers for monitoring of seabirds and shorebirds as follows:

"If shoreline impact is anticipated (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."

During the period of uncontrolled release, triggers were determined to have been met for both pre-impact and post-impact monitoring of seabirds and shorebirds.

- The source of the Montara Oil Spill was located approximately 105 km from Cartier Island Marine Reserve, 157 km from Ashmore Reef CMR 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 Oil Spill were detected at or in the vicinity of Ashmore Reef CMR (DEWHA (now DotE) website accessed 25 Nov. 2009, R. Clarke pers. obs.), Cartier Island (Watson *et al.* 2009) and Browse Island (DEWHA communication).

- Oiled seabirds (notably Common Noddies) were detected both at sea and on islands within the Reserves, indicating direct impact (DEWHA (now DotE) website accessed 25 Nov. 2009, Watson *et al.* 2009).

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

Ashmore Reef CMR supports internationally significant numbers of breeding seabirds (Bellio *et al.* 1997, this study) and migratory shorebirds (Bamford *et al.* 2008, this study). Clarke (2010) demonstrated that in excess of 100,000 seabirds utilize the islands for breeding purposes on an annual basis. At least 18,000 migratory shorebirds had been present during a single wet season in the preceding decade (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.

Under the *EPBC Act 1999* both Ashmore Reef CMR and the seabirds and shorebirds that utilize the available terrestrial habitats are specified ‘matters of national environmental significance’. Ashmore Reef CMR qualifies on the grounds that it is a Commonwealth Marine Reserve 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 CMR (Clarke 2010). Nevertheless, Cartier Island is recognised as a matter of national environmental significance on the grounds that it too is a Commonwealth Marine Reserve. The breeding seabirds (namely Greater 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.'*

A pre-impact assessment (Clarke 2010) reviewed the status of seabirds and shorebirds prior to any potential impact from the Montara Oil Spill and developed a post-impact monitoring program for seabirds and shorebirds that occur within the Reserves. Within this review significant impact criteria (Commonwealth of Australia 2009) of relevance were identified as follows:

- For *migratory species* where the Montara Oil Spill had led to 1) a substantial modification (including by alteration to nutrient cycles or alteration to hydrological cycles), destruction or isolation of 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 Oil Spill had led to the habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetland being seriously affected;

- For the *Commonwealth Marine environment* where the Montara Oil Spill had 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, was 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 were identified (Table 1). These criteria were based on expert opinion and took into account a number of factors. First, the statistical power present within existing datasets was recognized. Second, it was 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 would need to 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. The five-year period over which this assessment took place was necessary for a number of reasons. Firstly, both shorebirds and seabird numbers at Ashmore Reef CMR fluctuate on an annual cycle (as they do at most sites) and thus inter-annual comparisons must be made using data collected at the same time each year. Secondly, seabirds undergo substantial natural fluctuations on an inter-annual basis and thus the period over which sampling took place needed to be sufficiently long so as to have some smoothing effect on these natural fluctuations.

Table 1 Established criteria applied for the purposes of identifying a significant impact on seabird and shorebird populations within Reserves on the Sahul Shelf. Cohort sizes in column 1 refer to pre-impact population sizes (Clarke 2010, Clarke *et al.* 2011, Rogers *et al.* 2011).

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 1,000 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 1,000 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 > 1,000 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 1,000 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

Study Objectives

This post-impact assessment seeks to utilize targeted investigations to quantify population trajectories for seabirds and shorebirds at Ashmore Reef CMR, Cartier Island CMR and Browse Island NR in the periods before (prior to August 2009) and after (April 2010 to November 2014) the Montara Well release.

More specifically this post-impact assessment seeks to:

- Concatenate the results of a targeted five year post-impact monitoring program for breeding seabirds and migratory shorebirds within the Reserves
- Interrogate the results of this post-impact monitoring against existing data on seabird and shorebird numbers established by Clarke (2010) as they relate to terrestrial environments at Ashmore Reef CMR, Cartier Island CMR and Browse Island NR
- Determine if population trajectories for targeted seabird and shorebird species that occur within the Reserves exceeded thresholds that would identify significant impact
- Make recommendations with regards to population trajectories should significant impact be identified
- Make recommendations regarding appropriate baseline data requirements with respect to potential incidents in the future.

This approach is consistent with the objectives agreed upon by PTTEP Australasia and DEWHA (now DotE) (PTTEP Australasia 2009). As Ashmore Reef CMR and Cartier Island CMR 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).

Given available baseline for each reserve differed considerably, the objectives for seabird and shorebird monitoring at each reserve also differed. As a consequence, this report is structured such that methods, results and findings are presented in full as separate sections for each of Ashmore Reef CMR, Cartier Reef CMR and Browse Island NR.

ASHMORE REEF CMR

Pre-impact Assessment

Collation and analysis & review of data prior to 2010

Ashmore Reef CMR 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 DotE) staff. These visits occurred in all months, with at least two visits taking place in any calendar year (Milton 2005, DotE unpubl. data). A summary of these data have been presented by Milton (2005). Between 1996 and 2010 members of the Study team collectively visited Ashmore

Reef CMR 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 DotE did 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) did 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 being either 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 of the pre-impact data are that they 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 CMR were visited on every expedition.

Post-Impact Assessment 2010-2014

<u>Detailed census methods</u>

Breeding seabirds

Post-impact assessment surveys commenced in April 2010, seven to eight months after the uncontrolled well release commenced, and five to six months after the well release was successfully killed. Complete island wide counts of breeding seabirds were undertaken on all islands visited at Ashmore Reef CMR (West, Middle and East Islands, Splittgerber Cay) in April and November 2010 to 2014 inclusive. Counts were systematic with observers recording the number of adults and the number of active nests for each species encountered.

For species that are breeding during surveys, 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 or when breeding is not taking place. For most species two separate counts were made – all active nests and all adults present (Great Frigatebird; Brown, Red-footed and Masked Boobies and Crested

Tern). As anticipated, Sooty and Bridled Tern, Common, Black and Lesser Noddy were nesting amongst herbaceous vegetation and in aggregations that precluded counts of individual nests as these 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.

Middle and East Island, Ashmore Reef CMR, were each visited on at least three separate dates during the course of each complete survey at the reef. For the three booby species, Great Frigatebirds and the less abundant tern species (e.g. Bridled Terns) one to three complete counts of nests and adults was made. For abundant species, or species that occur at very high local densities (e.g. Greater Crested Terns within breeding colonies) three or more counts by at least two observers were undertaken to ensure a degree of consistency was achieved.

West Island, Ashmore Reef CMR, was visited on a number of occasions during each survey 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.

Shorebirds

Complete counts of shorebirds at Ashmore Reef CMR were conducted by visiting all high tide roosts. Shorebirds rest (roost) in dense flocks during higher tides on remaining exposed sandbanks, and (to a lesser degree) on the vegetated islands. All birds were identified to species and counted with the aid of spotting scopes. 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 with a degree of confidence.

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). Re-sightings of leg flagged shorebirds provides valuable information on migration routes, delineation of sub-populations and the identification of important ‘stop-over’ areas for shorebirds during active migration. During shorebird counts at Ashmore Reef CMR, Cartier Island CMR and Browse Island NR, 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.

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

Vegetation condition

As most plant species present at Ashmore Reef CMR 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 vegetation monitoring purposes. Two exceptions are Coconut Palm *Cocos nucifera* and Octopus Bush *Heliotropium foertherianum* on West Island.

Established photo monitoring points served 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 Octopus Bushes on West Island, Ashmore Reef CMR. Photo monitoring points were established using standard procedures on all islands and significant sandbanks at Ashmore Reef CMR (15 photo points during the initial ground assessment (April 2010) (see Clarke 2009). Images were taken using a 17 mm lens and Canon 1D digital SLR 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 was 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.

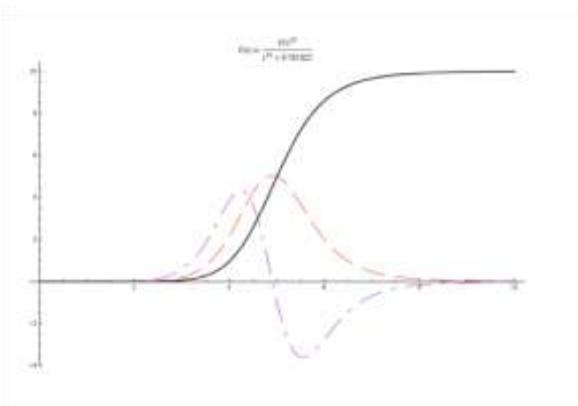
Leaf fitness measures were developed for Octopus Bush on West Island in accordance with PTTEP Australasia (2009). The protocol involved selecting the nearest Octopus Bush shrub to each photo monitoring point, then randomly selecting two clumps of leaves at a height of 1.5 m. The first 10 leaves in each clump were 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).

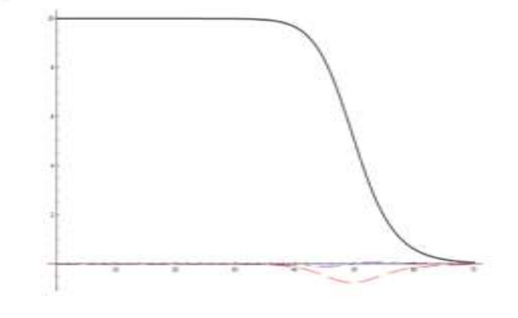
Statistical Analyses

Statistical analyses are focussed on identifying and quantifying changes in the temporal patterns of species counts on Ashmore Reef CMR following the Montara Oil Spill. The simplest approach is to compare the means of pre- and post- impact 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).

To model these trends, first a Hill function was used to assess changes in abundance over time. The Hill function is generally represented by four key parameters (Vmin = the lowest stable state, Vmax = the higher stable state, h = the x-axis value around where the change is centred, and n = the rate at which the states change). These parameters allow the curve to shift from one stable state to another (positive or negative), to not change at all, or to increase in a linear manner over time (positively or negatively). This provides flexibility in fitting the model and allows exploration of the data changes in stable states. Changes in stable states associated with the 2009 Montara Oil Spill would then warrant further attention (Appendix 3).

Vmax * x n / (hn + xn) + Vmin





As there are substantial within-year fluctuations in seabirds that are correlated with breeding season, changes across years were assessed separately for surveys conducted in April and November. Where surveys were undertaken in the months March and May or September and October a calibration model was used to estimate what the count in the focal month would have been. Given the origins of these estimates a large uncertainty was placed around these derived estimates. This approach facilitated the retention of data from survey years where only non-ideal data had been collected (i.e. not April and not November).

A second set of more conservative assessments of change over time are also modelled (Appendix 3). In this instance data collection was limited to the period after the year 2000 to determine if there was evidence for a change point arising from the effects from the Montara Oil Spill (in 2009). By using this more restrictive dataset we are able to consider the possibility that the large effects from the long term data set (e.g. very high or very low counts in the 1980s) could swamp any smaller or later effects that arose from the Montara Oil Spill. By their very nature these models are based on a smaller number of data points and thus should be interpreted alongside patterns from the other analyses.

Bayesian change-point models, using free-knot piecewise linear splines (Thomson *et al.* 2010), provide a flexible tool for characterizing temporal trends and objectively identifying 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:

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

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

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.

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).

Ashmore Reef CMR Results

Terrestrial environments

The vegetation at Ashmore Reef CMR has been well documented by Pike & Leach (1997). As one would expect for islands that are relatively isolated, vegetation communities are simplified. On West Island there is a single dominant shrub species, Octopus Bush, two Coconut Palms, several other shrubs represented by small numbers of individuals and a range of creepers, annual herbs and grasses (Pike & Leach 1997). Fish Plate Shrub *Guettarda speciose* was represented by a handful of specimens on the eastern and northern shore of West Island in April 2010. By November 2014, following a seeding event, 20-30 tall shrubs of this species had established towards the north-eastern end of the island. 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). Middle Island supported two living Octopus Bushes less than 50 cm in height in April 2010. These had grown to ~2.5 m in height by November 2015. During the 2010-2014 survey period there were no established woody shrubs on East Island (R. Clarke pers. obs.). All other vegetation on Middle and East Islands was characterised by ground creepers, annual herbs and grasses. Thus the vegetation on East and Middle Island reflected a considerable change since the publication of Pike & Leach (1997). All three Coconut Palms on Middle Island had died, with a single palm stem remaining near the well until April 2012 when it fell during a tropical squall. Similarly, shrubs reported by Pike & Leach (1997) on Middle and East Island had all died by the commencement of surveys. This was presumably due to damage caused by nesting seabirds (especially Red-footed Boobies and Great Frigatebirds) and roosting Common Noddy. The dead remnants of *Scaevola taccada* shrubs served as the principal nesting sites for both Red-footed Boobies and Great Frigatebirds on Middle Island until April 2014 when both Octopus Bushes attained a size that was conducive to nesting by these two seabird species. Splittgerber Cay is a sandbank to the east of East Island that was first vegetated in October 2009 (Study team unpubl. data). Three grass species were present 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. Whilst Splittgerber Cay has shifted slightly during the five year monitoring period the vegetation has remained largely unchanged during this time. Changes in vegetation on all islands at Ashmore Reef CMR between seasons (Apr and Nov) and across time (2010-2014) can be seen in the series of photos taken at the photo points established on the islands at the beginning of the project. These photos have been made available to The Department of the Environment.

The total land area of vegetated islands at Ashmore Reef CMR has been previously 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.

Incidental observations on West Island noted that there has been some die-off of Octopus Bush on the south eastern corner of the island in April 2010 but this loss of shrubs had largely been replaced by November 2014 following seedling recruitment in 2011 and 2012. Wind damage was also noted to many Octopus Bushes in April 2014. 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 and remained in this state for several years before recovering towards the end of the survey period. Mean leaf scores of Octopus Bush on West Island were collected in April and November 2010 to 2014 and are presented in Table 1a. These data show a clear seasonal trend with leaf condition being poor in November at the end of the dry season and good in April towards the end of the wet season.

Table 1a Leaf scores of Octopus Bush on West Island, Ashmore Reef: mean leaf damage and mean leaf colour for April and November, 2010-2014

	2010	2011	2012	2013	2014
			April		
Mean leaf damage	2.03	1.5	1.5	1.72	1.62
Mean leaf colour	1.08	1.03	1.02	1.1	1
			November		
Mean leaf damage	1.65	1.76	1.86	2.83	2.07
Mean leaf colour	1.57	2.07	2.3	2.68	3.17

Seabirds

Sixteen species of seabird and four species of heron had been reported to breed at Ashmore Reef CMR prior to the Montara Oil Spill (Commonwealth of Australia 2002, Milton 2005, Study team unpubl. data) (Table 2). Surveys between April 2010 and November 2014 documented 15 species of breeding seabird. Previous reports of Lesser Crested Tern breeding events (the 16th species, e.g. Milton 2005) are now believed to have been in error. The highest diversity and greatest densities of breeding seabirds at Ashmore Reef CMR are found on Middle and East Islands (both with 14 breeding seabirds), with West Island hosting relatively small numbers of Wedge-tailed Shearwater and tropicbirds on an annual basis (Table 3). 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 CMR 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).

Table 2 Breeding distribution of seabirds and herons on the four vegetated islands of Ashmore Reef CMR, Australia. Dashes indicate *breeding activity* was not observed in the period 1990 to Nov 2014.

	East Island	West Island	Middle Island	Splittgerber Cay
Wedge-tailed Shearwater	-	Regular	-	-
Red-tailed Tropicbird	Infrequent	Regular	Infrequent	-
White-tailed Tropicbird	Infrequent	Regular	Infrequent	-
Masked Booby	Regular	-	Regular	-
Red-footed Booby	Regular	-	Regular	-
Brown Booby	Regular	-	Regular	Occasional
Great Frigatebird	Occasional	-	Regular	-
Lesser Frigatebird	Regular	-	Regular	-
Crested Tern	Regular	Infrequent	Regular	-
Lesser Crested Tern	-	-	-	-
Roseate Tern	Regular	-	Regular	Occasional
Bridled Tern	Regular	-	Regular	-
Sooty Tern	Regular	-	Regular	-
Common Noddy	Regular	-	Regular	-
Black Noddy	Regular	-	Regular	-
Lesser Noddy	Regular	-	Regular	-
Great Egret	-	-	Infrequent?	-
Little Egret	Infrequent	Occasional	Infrequent	-
Intermediate Egret	Infrequent	-	-	-
Eastern Reef Egret	Regular	Regular	Regular	Occasional
Nankeen Night-Heron	-	Infrequent	-	-

Table 3 Count of tropicbirds on West Island, Ashmore Reef CMR during 25 visits between October 1998 and November 2014. 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 4 and 5.

	Red-tailed Tropicbird		White-tailed Tropicbird	
Survey	adults	nests	adults	nests
Oct-00	4	2	-	-
Oct-01	2	1	-	-
Nov-01	10	5	4	2
Jan-02	8	2	2	1
Feb-03	10	4	4	-
Sep-03	20	7	3	-
Oct-04	4	2	3	2
Nov-04	4	3	-	-
Jan-05	17	14	8	2
Oct-05	12	3	-	-
Oct-06	4	3	3	-
Oct-07	4	3	3	-
Oct-08	10	8	4	-
Oct-09	3	1	1	-
Apr-10	24	17	3	1
Nov-10	16	8	9	2
Apr-11	15	10	4	1
Nov-11	15	8	7	2
Apr-12	21	24	7	4
Nov-12	12	7	8	
Apr-13	26	20	13	1
Nov-13	25	8	7	1
Apr-14	34	22	12	3
Nov-14	13	7	4	-

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

The seabirds present at Ashmore Reef CMR display a variety of reproductive strategies. Most species breed annually, however several species have been reported to breed at Ashmore Reef CMR only occasionally. For example, Milton (2005) reported that Roseate Terns are breeding species within the reserve, yet the Study Team had not observed breeding Roseate Terns in over 10 years of visits up to April 2010. Clarke (2010) speculated that this may reflect a seasonal bias in sampling and this suggestion has since gained support as small nesting colonies of Roseate Terns have now been noted on several late April surveys. Most seabirds at Ashmore Reef CMR are dry season breeders, with the majority of species commencing egg laying and incubation in early to mid-April. 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. Several other species display a more variable response to season. For example, Crested and Sooty Terns have been noted with eggs 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 survey data also indicates both species of tropicbirds are most abundant between the months of January and April (Table 3). Eastern Reef Egrets, which are the only abundant breeding heron present within the reserve system, breed mostly in the late dry season although available evidence suggests this species may not breed every year at Ashmore Reef CMR (Appendix B).

The islands of Ashmore Reef CMR support internationally significant numbers of seabirds. Up to 54,000 Common Noddies, 40,000 Sooty Terns, 5,000 Brown Boobies and in excess of 2,000 Lesser Frigatebirds had been reported breeding on Middle and East Island prior to the commencement of this study (Milton 2005, DotE unpubl. data; Tables 4 and 6). During the post-impact monitoring period significant maximum daily counts across Middle and East Island included 62,227 Common Noddies, 25,160 Sooty Terns, 10,466 Brown Boobies, 5,937 Crested Terns and 4,960 Lesser Frigatebirds (Tables 5 and 7). Some of these colonies are amongst the largest breeding colonies of that species in the Australasian region (Bellio *et al.* 2007). Whilst numbers are not as spectacular, the largest ever reported colony sizes at Ashmore Reef CMR for Great Frigatebird (65 adults), Red-footed Booby (188 adults), Masked Booby (83 adults) and Red-tailed Tropicbird (24 nests) were also obtained during post-impact surveys (Tables 5 and 7). Significantly, Lesser Noddy was also confirmed as a breeding species at Ashmore Reef CMR with 117 adults being the maximum number detected on a single day (Tables 5 and 7). Although previous authors have concluded that Ashmore Reef CMR may support up to 50,000 breeding seabirds (Milton 2005, Bellio *et al.* 2007), based on post-impact surveys reported here, the total number of breeding seabirds exceeds 100,000 breeding individuals on occasion (Study Team unpubl. data; Tables 5 and 7).

Table 4 The maximum count of seabirds obtained during 48 visits between 1979 and 1998 and counts of seabirds during 10 visits between January 2002 and October 2009 at Middle Island, Ashmore Reef CMR. Numbers in bold indicate breeding of that species was explicitly reported for that count.

Date	Max. count 1979-1998	Jan-02	Jan-03	Sep-03	Oct-04	Jan-05	Oct-05	Oct-06	Oct-07	Oct-08	Oct-09
Red-tailed Tropicbird	1	0	1	1	1	0	0	2	0	0	0
White-tailed Tropicbird	6	0	3	0	0	2	0	1	1	1	0
Masked Booby	3	4	3	**2**	3	**14**	10	**20**	**10**	**20**	**30**
Red-footed Booby	15	**46**	**42**	**40**	60	220	30	**50**	**80**	**80**	**100**
Brown Booby	1050	**1530**	**1250**	**1000**	**1000**	**2300**	**1000**	**2000**	**5000**	**1000**	**3000**
Great Frigatebird	24	**8**	**4**	2	3	**20**	20	**30**	**20**	**20**	**20**
Lesser Frigatebird	1991	**1000**	**300**	**100**	300	300	200	**2000**	**800**	**300**	**1000**
Crested Tern	400	**150**	**105**	300	60	325	70	**500**	300	10	**250**
Bridled Tern	239	0	0	0	10	0	0	5	8	1	2
Sooty Tern	40000	**15000**	**5000**	50	**5000**	50	**3000**	**10000**	**15000**	**100**	500
Common Noddy	10000	1500	260	**5000**	**15000**	60	200	**3000**	**700**	**2000**	**1800**
Black Noddy	120	100	3	2	6	0	10	5	5	0	30
Lesser Noddy	120	0	0	0	0	0	0	0	0	0	1

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

Table 5 The maximum count of seabirds obtained during 10 visits between April 2010 and November 2014 at Middle Island, Ashmore Reef CMR. 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	Apr-10	Nov-10	Apr-11	Nov-11	Apr-12	Nov-12	Apr-13	Nov-13	Apr-14	Nov-14
Red-tailed Tropicbird	0	3	2	2	2	0	2	0	2	0
White-tailed Tropicbird	0	3	1	1	1	2	5	0	1	1
Masked Booby	28	9	16	8	18	16	55	63	32	16
Red-footed Booby	101	100	128	99	140	37	42	64	60	16
Brown Booby	2841n	1204	3523	673	5233	869	3950	2977	5478	531
Great Frigatebird	65	6	49	11	42	14	20	27	31	15
Lesser Frigatebird	2504	1200	2232	1737	3240	1355	2746	898	1873	537
Crested Tern	2814	523	250	265	1261	359	381	117	100	342
Bridled Tern	50	0	10	0	88	1	55	4	18	0
Sooty Tern	2500	4930	2170	1500	2425	750	7300	380	10028	700
Common Noddy	13875	4070	15650	1664	22087	729	18906	1721	11632	316
Black Noddy	180	60	276	36	759	30	89	35	17	1
Lesser Noddy	7	6	25	4	97	0	3	6	1	1

Table 6 The maximum count of seabirds obtained during 51 visits between 1979 and 1998 and counts of seabirds during seven visits between January 2002 and October 2009 at East Island, Ashmore Reef CMR. 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.

	Max. count 1979-1998	Jan-02	Jan-03	Jan-05	Oct-05	Oct-06	Oct-07	Oct-09
Red-tailed Tropicbird	6	1	1	0	0	0	0	0
White-tailed Tropicbird	1	0	0	0	2	2	5	0
Masked Booby	9	5	25	**4**	**10**	**5**	**15**	**8**
Red-footed Booby	0	0	**12**	**8**	**10**	**12**	**40**	**30**
Brown Booby	500	**1800**	**2000**	**2200**	**1000**	**3000**	**3000**	**1900**
Great Frigatebird	2	0	**4**	0	**5**	2	**10**	0
Lesser Frigatebird	140	**800**	**2000**	**600**	**300**	**1000**	**500**	**300**
Crested Tern	2700	**310**	**310**	150	10	10	400	85
Bridled Tern	2400	0	0	0	**3**	**5**	**6**	5
Sooty Tern	20000	**25000**	**10000**	350	**10000**	**10000**	**10000**	**7000**
Common Noddy	54000	3000	**1800**	530	**3000**	**5000**	400	**1070**
Black Noddy	375	1500	5	3	20	10	20	70
Lesser Noddy	20	0	0	0	0	0	0	0

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

Table 7 The maximum count of seabirds obtained during ten visits between April 2010 and November 2014 at East Island, Ashmore Reef CMR. 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	Apr-10	Nov-10	Apr-11	Nov-11	Apr-12	Nov-12	Apr-13	Nov-13	Apr-14	Nov-14
Red-tailed Tropicbird	0	1	0	0	0	0	0	0	0	2
White-tailed Tropicbird	0	0	0	3	0	1	4	0	2	2
Masked Booby	10	8	16	9	10	3	28	14	19	3
Red-footed Booby	20	11	30	17	30	14	122	124	51	10
Brown Booby	1538n	625	1908	839	5233	924	3230	2291	3938	971
Great Frigatebird	0	0	2	0	0	2	4	9	3	5
Lesser Frigatebird	1773	382	1654	481	1720	415	1200	666	1183	1094
Crested Tern	2568	20	477	12	2165	6	1932	132	150	1
Bridled Tern	300	3	42	1	89	1	39	0	200	2
Sooty Tern	5000	4850	8940	4100	8190	1200	17860	4330	10469	1180
Common Noddy	30930	4360	39600	1458	40140	1558	40992	6270	35689	2686
Black Noddy	450	92	97	10	663	57	1382	41	2480	43
Lesser Noddy	6	6	24	1	20	4	95	9	72	9

Figure 4 Breeding seasons of seabirds and herons, and 'peak abundance' for migratory shorebirds, at Ashmore Reef CMR.

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		LC						B	B	E	E	
Red-tailed Tropicbird	All			All				MC, LC	MC	All	All	
White-tailed Tropicbird	E			E							E	
Masked Booby				All					E, MC, LC	LC	All	
Red-footed Booby	B	E, SC		E, SC				LC	E, SC, B	LC	E, LC	
Brown Booby	E	E		E, SC				LC	LC	LC	LC	
Great Frigatebird	B	E		E				MC	SC, MC LC	LC		
Lesser Frigatebird				E, SC				SC-LC	MC, LC		**LC**	
Crested Tern	E, SC			E, SC, LC					E	E, LC	E	
Roseate Tern												
Bridled Tern				E				LC	LC	LC		
Sooty Tern	E			E				LC		E, LC	E	
Common Noddy				E				E	E, MC	E		
Black Noddy				E						Empty nests		
Lesser Noddy				E						Empty nests		
Great Egret										E		
Little Egret										E, LC		
Intermediate Egret												
Eastern Reef Egret	E, SC, MC							SC	B	E, SC - LC	B	
Nankeen Night-Heron										E, LC		
Migratory shorebirds												

Shorebirds

Shorebirds have been counted at Ashmore Reef CMR on numerous occasions since 1979 (Milton 2005, DotE unpubl. data) (Table 9). However, complete counts, where shorebirds on all islands and important sandbanks are systematically counted, 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). Whilst some attempt to undertake complete counts may have occurred at other times, we can find no documentation that demonstrates this is the case. As part of the post-impact monitoring program complete counts of shorebirds were made in November of 2010-2014. November is recognised as an ideal time to count shorebirds in Australia as almost all adults and juveniles have arrived from the breeding grounds in the northern hemisphere and movements associated with migration have largely ceased.

The highest count of shorebirds reported at Ashmore Reef CMR 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 9), 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 CMR in numbers that exceed 1% of their total estimated East Asian – Australasian Flyway population (Table 8). Such measures are significant as they identify Ashmore Reef CMR 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). Following 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.

In addition to complete counts of all shorebird sites at Ashmore Reef CMR, there is some evidence that counts of shorebirds on West Island remain relatively stable on a year-to-year basis (see Swann 2005b). Given this, all complete counts of shorebirds undertaken at West Island have been collated to assess trends in population change with a larger time-series dataset. Thirteen such counts by the Study team and others have been identified, followed by five post-impact counts (Table 10).

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 DotE unpubl. data). Both of these counts are exceptional when compared with data collected by the Study Team since 2000 and may reflect misidentifications. No more than 3 Eastern Curlew have been detected on any one visit by the

Study Team since 2000. 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]

It has previously been reported that Ashmore Reef CMR 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 CMR 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 CMR are very rarely encountered (see Table 11; 0-0.09% of birds flagged), indicating there is very little interchange between populations of shorebirds visiting Ashmore Reef CMR and those that visit key shorebird sites on the north-west Australian mainland (e.g. Swann 2005a, 2005b, this study). As a consequence, for impact assessment purposes and management purposes, shorebird populations at Ashmore Reef CMR are best considered independent of those in north-west Australia.

During the post-impact monitoring period, five complete counts (November 2010 – November 2014) documented between 8,821 and 12,151 shorebirds per visit (Table 9). These counts detected a total of 30 species of shorebird using Ashmore Reef CMR of which 18 species were detected during each November count during the post-impact monitoring. At West Island a total of 32 shorebird species have been detected during whole-island surveys and nine species being recorded on almost all surveys (Table 10). Previously, the West Island dataset had been identified as a potential site where sufficient pre- and post-impact data may be available to assess shorebird population trends against significant impact criteria. Longer term monitoring in the post-impact period has proved this island is not suitable as a sub-site at which to assess impact as daily counts have been shown to fluctuate widely in response to prevailing weather conditions. For example strong easterly winds for a day or two often result in a near-doubling of the shorebird numbers at West Island. These birds are almost certainly individuals from the many thousands that roost in the eastern sector of Ashmore Reef CMR and in these conditions choose to roost on West Island rather than fly into a head wind to return to their more usual roost site.

[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.

Table 8 Maximum counts of shorebirds recorded at Ashmore Reef CMR between 1979 and 2014. 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 CMR

Species	Max reported count (1979-Nov 2014)	% of flyway population	% of Aust. population
Beach Stone-curlew	1[c]		
Black-winged Stilt	21[a]		
Masked Lapwing	1[c]		
Pacific Golden Plover	746[f]	0.7	7.5j
Grey Plover	1511[f]	1.2	15.1j
Lesser Sand Plover	32[c,i]		
Greater Sand Plover	2559[f]	2.3	3.5
Oriental Plover	2[a]		
Swinhoe's Snipe	2[a]		
Asian Dowitcher	10[a]		
Black-tailed Godwit	13[e]		
Bar-tailed Godwit	4560[f]	1.4	2.5
Little Curlew	50[b]		
Whimbrel	536[f]	0.5	5.4j
Far Eastern Curlew	4[a,g]		
Common Redshank	1[a]		
Marsh Sandpiper	1[a]		
Common Greenshank	590[f]	1	3.1
Wood Sandpiper	1[a]		
Grey-tailed Tattler	1791[f]	3.6	4
Terek Sandpiper	216[f]	0.4	0.9
Common Sandpiper	11[a]		
Ruddy Turnstone	1708[e]	4.9	8.5
Great Knot	1592[d]	0.4	0.4
Red Knot	55[f]		
Sanderling	1181	5.4	11.8
Red-necked Stint	1530[f]	0.5	0.6
Little Stint	1[a]		
Long-toed Stint	2[a]		
Sharp-tailed Sandpiper	19[a]		
Curlew Sandpiper	850[e]	0.5	0.7
Broad-billed Sandpiper	5[a]		
[Red-necked Phalarope	2[a,h]]		
Australian Pratincole	13[a]		
Oriental Pratincole	1043[a]		
Total			

[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 CMR, [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.

Table 9 The maximum count of shorebirds obtained during 69 visits to Ashmore Reef CMR between 1979 and 1998, and data from eight complete counts of shorebirds at Ashmore Reef CMR between January 2002 and November 2014.

	Max. count 1979-1998	Jan-02	Feb-03	Jan-05	Nov-10	Nov-11	Nov-12	Nov-13	Nov-14
	Milton (2005)	Swann (2005a)	Swann (2005b)	Swann (2005c)	This study	This study	This study	This study	This study
Black-winged Stilt	0	0	14	0	0	0	8	0	0
Pacific Golden Plover	200	373	563	746	285	356	436	472	370
Grey Plover	0	616	1,475	1,511	736	653	975	917	769
Lesser Sand Plover	550[a]	11	16	32	17	24	26	21	23
Greater Sand Plover	180[a]	1,196	1,295	2,559	1,115	955	1,158	1,208	768
Oriental Plover	0	0	0	0	1	**3**	0	0	0
Swinhoe's Snipe	0	0	0	0	1	0	0	0	0
Gallinago species	0	0	1	1	0	0	0	0	0
Asian Dowitcher	0	6	3	8	8	9	10	10	6
Black-tailed Godwit	0	6	8	6	9	**13**	9	9	7
Bar-tailed Godwit	0	2,536	2,785	4,560	3,568	1,093	1,717	2,163	1,725
Little Curlew	0	0	0	0	3	0	0	0	0
Whimbrel	250[a]	344	402	536	285	307	254	199	244
Far Eastern Curlew	300[a]	1	0	0	0	0	2	0	2
Common Greenshank	0	185	252	590	285	241	293	252	213
Wood Sandpiper	0	0	0	0	0	0	0	1	0
Grey-tailed Tattler	1,631	1,301	1,593	1,791	1,181	1,269	1,211	1,017	983
Terek Sandpiper	0	60	83	216	98	72	79	49	40
Common Sandpiper	0	9	6	4	8	8	11	3	7
Ruddy Turnstone	1,101	1,644	1,708	1,660	1,378	1,009	1,066	1,142	1,283
Great Knot	82	1,592	838	1,090	923	903	1,096	760	957
Red Knot	0	15	13	55	46	28	20	42	18
Sanderling	0	313	1,132	1,101	767	920	782	730	1,181
Red-necked Stint	120	975	1,128	1,530	873	584	905	854	1,061
Little Stint	0	0	0	0	0	0	1	0	0
Long-toed Stint	0	0	0	0	0	0	0	2	1
Sharp-tailed Sandpiper	0	1	0	0	19	8	2	0	4
Curlew Sandpiper	252	150	850	260	183	243	330	107	418
Broad-billed Sandpiper	0	0	0	0	**5**	5	0	1	0
Australian Pratincole	0	0	0	0	**13**	0	0	0	0
Oriental Pratincole	0	1	0	1	**238**	118	44	1,043	1
Total	-	11,334	14,164	18,255	12,151	8,821	10,435	9,959	10,081

Table 10 Counts of shorebirds roosting on West Island, Ashmore Reef CMR during 18 visits between Oct 1998 and November 2014. In instances where several counts were made over consecutive days the highest count from that period is presented.

Species	Oct-98[a]	Feb-00[b]	Oct-00[c]	Oct-01[c]	Nov-01[c]	Jan-02[d]	Feb-03[b]	Oct-04[c]	Jan-05[e]	Oct-06[c]	Oct-07[c]	Oct-08[c]	Oct-09[c]	Nov-10	Nov-11	Nov-12	Nov-13	Nov-14
Black-winged Stilt							13									8		
Pacific Golden Plover	32	39	12	60	27	20	56	10	80	30	8	20	30	40	20	49	49	7
Grey Plover							1					4	6					
Lesser Sand Plover			1	1	1	1	3		3	2		1				4		
Greater Sand Plover	83	79	20	80	66	70	96	40	90	100	40	100	50	94	56	87	58	4
Oriental Plover								2		1	5	1		1	1			
Swinhoe's Snipe													[1]					
Snipe spp.														1				
Asian Dowitcher																		
Black-tailed Godwit									1									
Bar-tailed Godwit			1	2			2	1	2				6	1		1		
Little Curlew	50		2											3				
Whimbrel	10	103	70	120	97	40	76	50	36	70	60	80	60	44	44	45	33	1
Far Eastern Curlew		2	1	2	1	1		2		1	1	1				2		
Marsh Sandpiper													1					
Common Greenshank	9	14	1	2	3	3	8		3	12	1	1	4		1	6	1	
Wood Sandpiper																	1	
Grey-tailed Tattler	131	100	20	90	56	40	136	40	96	50	50	20	50	8	27	13	9	13
Terek Sandpiper														1				
Common Sandpiper		2	4	4	3	6	6	4	4	3	12	10	8	4	4	6	3	6
Ruddy Turnstone	65	81	100	150	142	150	101	70	125	100	120	100	150	139	84	95	28	6
Great Knot							1				2	1	2	9		3	1	
Red Knot																		
Sanderling	4	1	2	10	9	15	15	6	16	35	30	20	15	29	9	20	8	
Red-necked Stint		42	6	10	16	20	50	15	65	100	40	25	10	37	11	12	7	
Little Stint																		
Long-toed Stint																	1	
Sharp-tailed Sandpiper			1	1	2	1					3	13	3	13	6			1
Curlew Sandpiper				2			5					2						
Broad-billed Sandpiper																		
Australian Pratincole	2		5	1	1						6	1		13				
Oriental Pratincole														230	113*	39*	775	
Total	386	463	246	535	424	367	569	240	521	504	378	400	395	678	376	390	974	38

[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.

Table 11 Migratory shorebird leg flag sightings, Ashmore Reef CMR, April 2010-November 2014.

Survey	Species	Leg flags	Where sighted?	Where flagged?	Approx. distance
Apr-10	Grey-tailed Tattler		Btwn Middle Is and Splittgerber Cay	Taiwan	
Nov-10	Bar-tailed Godwit	black on white	Btwn Middle Is and Splittgerber Cay	Shanghai, China	4,862
Nov-10	Curlew Sandpiper	black on white	Btwn Middle Is and Splittgerber Cay	Shanghai, China	4,862
Nov-10	Great Knot	black on white	Btwn Middle Is and Splittgerber Cay	Shanghai, China	4,862
Nov-10	Great Knot	black on white	Btwn Middle Is and Splittgerber Cay	Shanghai, China	4,862
Nov-10	Great Knot	black on white	Btwn Middle Is and Splittgerber Cay	Shanghai, China	4,862
Nov-10	Great Knot	black on white	Btwn Middle Is and Splittgerber Cay	Shanghai, China	4,862
Nov-10	Great Knot	black on white	Btwn Middle Is and Splittgerber Cay	Shanghai, China	4,862
Nov-10	Grey-tailed Tattler	white on blue	Btwn Middle Is and Splittgerber Cay	Taipei-Kaohsiung (Taiwan)	4,051
Nov-10	Ruddy Turnstone	orange on yellow	Btwn Middle Is and Splittgerber Cay	SE South Australia	3,319
Nov-10	Ruddy Turnstone	black on white	Btwn Middle Is and Splittgerber Cay	Shanghai, China	4,862
Nov-10	Terek Sandpiper	black on white	Btwn Middle Is and Splittgerber Cay	Shanghai, China	4,862
Nov-11	Great Knot	yellow 'PUS'	Splittgerber Cay	NW Australia	759
Nov-11	Great Knot	black on white	Splittgerber Cay	Chongming Dao, Shanghai, China	4,862
Nov-11	Great Knot	black on white	Splittgerber Cay	Chongming Dao, Shanghai, China	4,862
Nov-11	Great Knot	yellow	Splittgerber Cay	NW Australia	759
Nov-11	Grey Tattler	white on blue	Splittgerber Cay	Taipei-Kaohsiung, Taiwan	4,051
Nov-11	Ruddy Turnstone	black on white	Middle Island	Chongming Dao, Shanghai, China	4,862
Nov-11	Ruddy Turnstone	orange 'ZCB on yellow	Middle Island	South east of South Australia	3,319
Apr-12	Red-necked Stint	yellow on white	Btwn Middle Is and Splittgerber Cay	Sakhalin Island, Russia	7,410
Nov-12	Great Knot	black on white	Splittgerber Cay	Chongming, Dao, Shanghai, China	4,860
Nov-12	Greater Sand Plover	white on blue '10'	Splittgerber Cay	Taipei-Kaohsiung, Taiwan	4,051
Nov-12	Grey-tailed Tattler	white on blue '41'	Splittgerber Cay	Taipei-Kaohsiung, Taiwan	4,051
Nov-12	Red-necked Stint	yellow on white	Splittgerber Cay	Sakhalin Island, Russia	7,410
Nov-12	Ruddy Turnstone	orange on metal	Sandbar btwn Middle and East Islands	Victoria, Australia	3,600
Nov-12	Ruddy Turnstone	orange 'ZCB' on yellow	Splittgerber Cay	South Australia, Australia	3,319
Apr-13	Red-necked Stint	yellow on white	Splittgerber Cay	Sakhalin Island, Russia	7,410
Nov-13	Bar-tailed Godwit	black on white	Sandbar btwn Middle and East Islands	Chongming, Dao, Shanghai, China	4,860
Nov-13	Bar-tailed Godwit	black on white	Sandbar btwn Middle and East Islands	Chongming, Dao, Shanghai, China	4,860
Nov-13	Great Knot	black on white	Splittgerber Cay	Chongming, Dao, Shanghai, China	4,860
Nov-13	Ruddy Turnstone	black on white	Sandbar btwn Middle and East Islands	Chongming, Dao, Shanghai, China	4,860
Nov-13	Ruddy Turnstone	black on white	Splittgerber Cay	Chongming, Dao, Shanghai, China	4,860
Nov-13	Sanderling	black on white	Splittgerber Cay	Chongming, Dao, Shanghai, China	4,860
Nov-14	Great Knot	black on white	Splittgerber Cay	Chongming, Dao, Shanghai, China	4,860
Nov-14	Greater Sand Plover	white on blue 'JJ'	Splittgerber Cay	Taiwan, China	4,035
Nov-14	Red-necked Stint	black on yellow	Splittgerber Cay	Malaysia	2,950
Nov-14	Sanderling	black on white	Splittgerber Cay	Chongming, Dao, Shanghai, China	4,860

IMPACT ASSESSMENT AT ASHMORE REEF CMR

Seabird population trajectories

An assessment of the impact of the Montara Oil Spill on the breeding seabird populations at Ashmore Reef CMR must be prefaced by recognition that no targeted survey of seabirds for the purposes of impact assessment was undertaken at Ashmore Reef CMR prior to the Montara Oil Spill. Rather, prior to the Montara Oil Spill there existed counts of breeding seabirds undertaken with variable intensity in the periods 1983 to 1990 and 2000 to 2009. Counts in the period 1983 to 1990 were undertaken by Parks Australia staff and were largely confined to the dry season (especially May to October). Counts in the period 2000 to 2010 involved annual visits to Ashmore Reef CMR in late September to early November. There is almost no data on the breeding seabirds at Ashmore Reef CMR for the period 1991 to 1999 and most data collected in the decade immediately prior to the Montara Oil Spill were obtained at the end of the dry season (e.g. Oct) after most seabird species have concluded breeding at the site.

Whilst recognising these limitations it remains appropriate to assess the population trajectories of breeding seabirds at Ashmore Reef CMR against the *a priori* criteria (Commonwealth of Australia 2009, Clarke 2010). These criteria identified a *significant impact* as one with a decline below a specified threshold over a three-year period (2010-12) following the Montara Oil Spill *and* a failure to recover to pre-impact levels in the subsequent two years (2013-14).

Population trajectories for key seabird species with populations consisting of >10 breeding pairs show that most species displayed larger population sizes in the post-impact monitoring period when compared with the available data collected prior to the Montara Oil Spill (Figures 5 & 6). Gaps in the dataset, especially for most of the 1990s and for the peak seabird breeding season (March-May) from 2000-2009 are clearly evident. Assessment of these trajectories against significant impact criteria support the conclusion that most breeding seabird populations at Ashmore Reef CMR have been increasing at Ashmore Reef CMR in recent decades and continued to do so after the Montara Oil Spill (Figures 5 & 6). For survey periods at an optimal time relative to most seabird breeding activity at Ashmore Reef CMR (March to May) the overwhelm trend was for a substantial increase in seabird numbers between pre-impact monitoring and post-impact monitoring periods though it is important to note that these comparisons are being made between 1983-1990 data and data collected in the five years following the oil spill. When this comparison is made, eight of 10 breeding seabird species (80%) showed increasing populations at both Middle and East Island and most of these displayed a doubling or more of the known populations at each breeding island. Two exceptions to this pattern involving the Sooty Tern and Lesser Noddy occurred on a single island. For the Sooty Tern, numbers were substantially lower (45% of the pre-impact population) at Middle Island in the three-years immediately after the spill. This was followed by a rebound in the number of Sooty Terns such that the population exceeded pre-impact size in the final two years of the five year monitoring period. Lesser Noddies also displayed a lower population size on Middle Island but this was not in the three year period immediately following the spill, but rather in the last two years of the post-impact monitoring period. In this context, the five year post-impact monitoring period detected no *significant* impact of the Montara Oil Spill on breeding seabird populations at Ashmore Reef CMR. Given a lack of data during the breeding season in the decade prior to the oil spill it remains plausible that the numbers of breeding seabirds at Ashmore

Reef CMR had grown to levels higher than those documented here and in that scenario some impact would have been measurable had data been available.

Results differ for the non-breeding period (September to November) when a second round of surveys were undertaken to coincide with the more extensive time series dataset collected in the period 2000-2009. Whilst the trajectories for six of 10 seabird species did not reveal significant impact, Sooty Tern populations on both islands demonstrated a substantial decline and an absence of apparent recovery during the five year monitoring period. Similarly, Common Noddy on Middle Island, and Crested Tern and Brown Booby on East Island also declined from pre-impact levels and did not rebound during the five year monitoring period. It is plausible that some of this observed decline may be attributable to the Montara Oil Spill. This is especially so for Brown Booby populations which display both a seasonal breeding pattern and site fidelity between breeding seasons at Ashmore Reef CMR (R. Clarke unpubl. data). With these life history strategies substantial natural inter-annual fluctuations are likely to be small and thus impact from the oil spill is an increasingly plausible explanation. The decline in the number of Sooty Tern, Crested Tern and Common Noddy between the pre- and post-impact monitoring periods is more difficult to disentangle from natural inter-annual fluctuations; indeed each of these declines is driven largely by a single large count for each species in the pre-impact data (e.g. 10,000 Sooty Terns in 2006 and 2007 and 76,275 Common Noddy in 1984). Additional counts made in November 2015 (after the post-impact monitoring period concluded) documented 13,200 Sooty Terns and 16,000 Common Noddies on East Island. Although outside the post impact monitoring period they do demonstrate that populations in 2015 were again similar to those documented in the pre-impact period.

Change point analyses

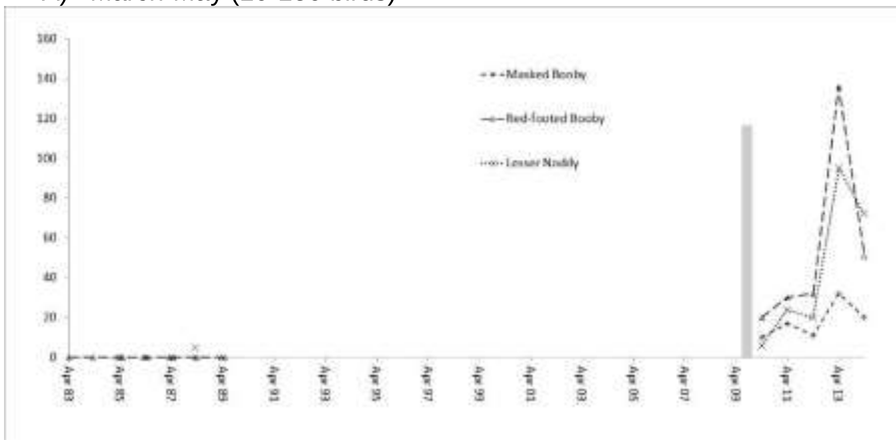
Change point analyses and assessment of population trajectories using Hill's function did not identify any decline in key breeding seabird species at Ashmore Reef CMR that would be consistent with impact from the Montara Oil Spill (i.e. a negative population trajectory and associated change point inflection in the years 2009 or 2010 was not detected). This was true for both the complete time-series data (e.g. post 1950) and the dataset that was truncated to the period 2001-2015. Truncation of this latter dataset was undertaken to remove the influence of large historic population changes that may have been swamping more moderate signal(s) from the Montara Oil Spill event. That this precautionary approach also failed to detect negative population inflections and associated change point inflections around the time of the Montara Oil Spill adds weight to the conclusion that the Montara Oil Spill did not have a significant impact on the breeding seabird populations at Ashmore Reef CMR. Four species of breeding seabird displayed population increases with associated positive change point inflections in the years prior to the Montara Oil Spill (e.g. Masked Booby, Red-footed Booby, Brown Booby, Lesser Frigatebird). For these four species these change points were evident in time series data for both April surveys and November surveys, though the actual year(s) around which the inflection was centred varied depending of the availability of data. No change point was detected for the Crested Tern in the April time series data but a positive change point in the mid-1980s was evident. No change points were evident for the Sooty Tern or Common Noddy in either time series. Outputs showing models of population trajectories for key breeding seabird species (as identified by Clarke 2010) are presented in Appendix 3.

Table 12 Trajectory of the Ashmore Reef CMR seabird population and individual seabird species at Ashmore Reef CMR. Values show the percentage change in mean population size taken in the period prior to the Montara Oil Spill and in years 1 to 3 (2010-2012) and years 4-5 (2013-2014) immediately after the spill. Data collected in October 2010 is excluded as it was gathered *during* the spill event and any potential impact on seabird populations may not have been realised by that time. Green cells indicate a net increase in the seabird population when comparing post-impact date with pre-impact data. Orange cells indicate a net decline in seabird populations but recognition that these declines did not meet the pre-defined criteria for significant impact. Red cells indicate a net decline and meet the pre-defined criteria for significant impact: interpretation of these declines is discussed in the text.

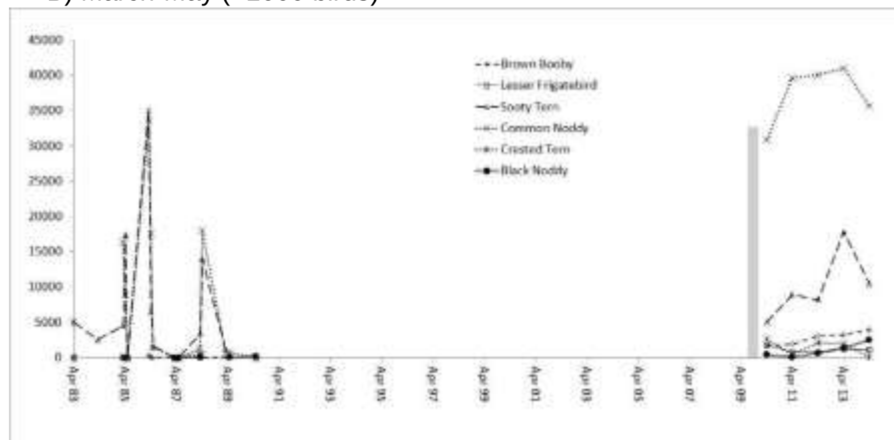
		Middle Island Mar-May		**East Island Mar-May**		**Middle Island Sep-Nov**		**East Island Sep-Nov**	
		Yr 1-3	Yr 4-5	Yr 1-3	Yr 4-5	Yr 1-3	Yr 4-5	Yr 1-3	Yr 4-5
Seabird population		>200%	>200%	>200%	>200%	53%	32%	45%	62%
Species	**Colony size**								
Masked Booby	10-100	>200%	>200%	>200%	>200%	111%	>200%	87%	115%
Red-footed Booby	10-100	>200%	>200%	>200%	>200%	149%	74%	84%	>200%
Brown Booby	1000-10,000	>200%	>200%	>200%	>200%	46%	88%	34%	70%
Great Frigatebird	10-100	>200%	>200%	<10 pairs		125%	113%	<10 pairs	
Lesser Frigatebird	1000-10,000	>200%	>200%	>200%	>200%	>200%	130%	71%	152%
Crested Tern	1000-10,000	>200%	>200%	>200%	>200%	>200%	122%	9%	48%
Sooty Tern	10,000+	45%	164%	105%	>200%	36%	8%	34%	28%
Common Noddy	10,000+	>200%	>200%	>200%	>200%	52%	24%	88%	160%
Black Noddy	100-1000	>200%	>200%	>200%	>200%	>200%	>200%	>200%	>200%
Lesser Noddy	10-100	172%	8%	>200%	>200%	>200%	>200%	>200%	>200%
		West Island Mar-May				**West Island Sep-Nov**			
Red-tailed Tropicbird	10-100	Insufficient pre-impact data				>200%	>200%		
Wedge-tailed Shearwater	10-100	Not present				111%	143%		

Figure 5 Seabird population trajectories at East Island Ashmore Reef CMR from counts obtained in the periods March to May (A & B) and September to November (C & D). Small breeding populations (10 to 150 birds) and large breeding populations (>1000 birds) are displayed on separate plots. The grey bar represents the timing of the Montara Oil Spill.

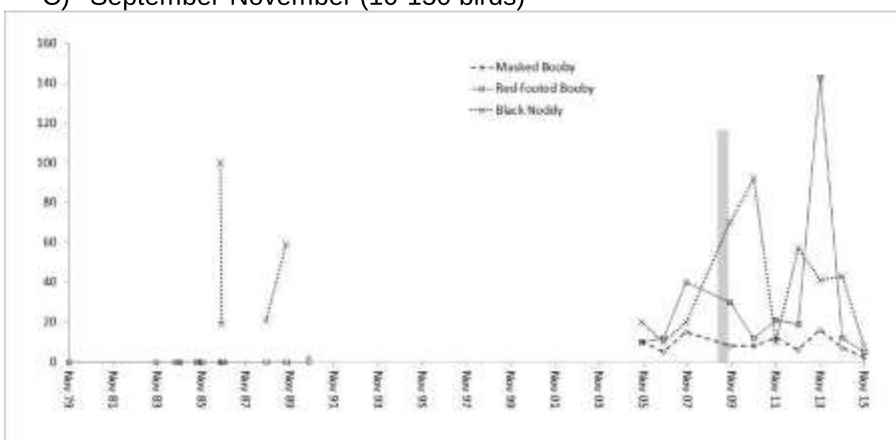
A) March-May (10-150 birds)



B) March-May (>1000 birds)



C) September-November (10-150 birds)



D) September-November (>1000 birds)

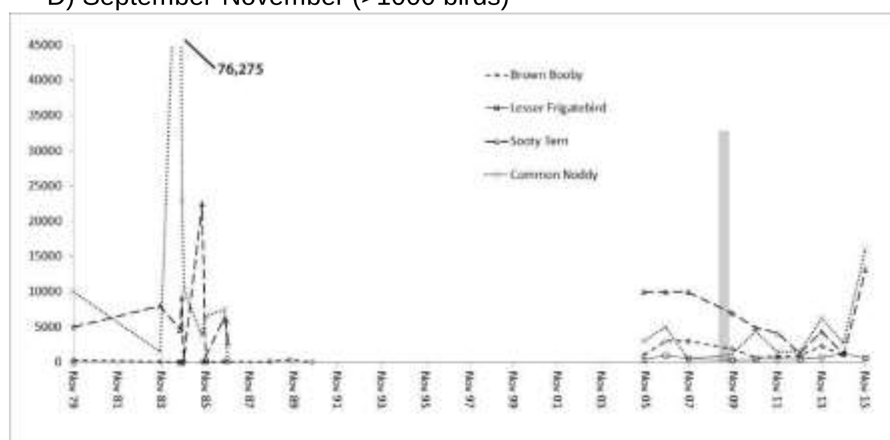
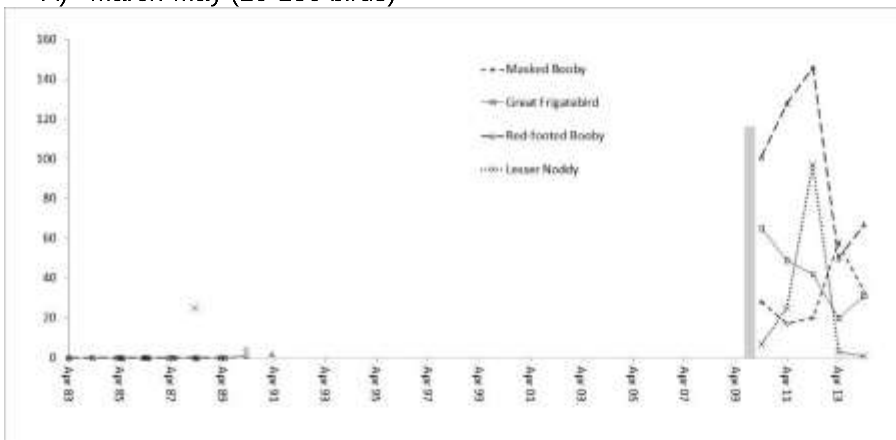
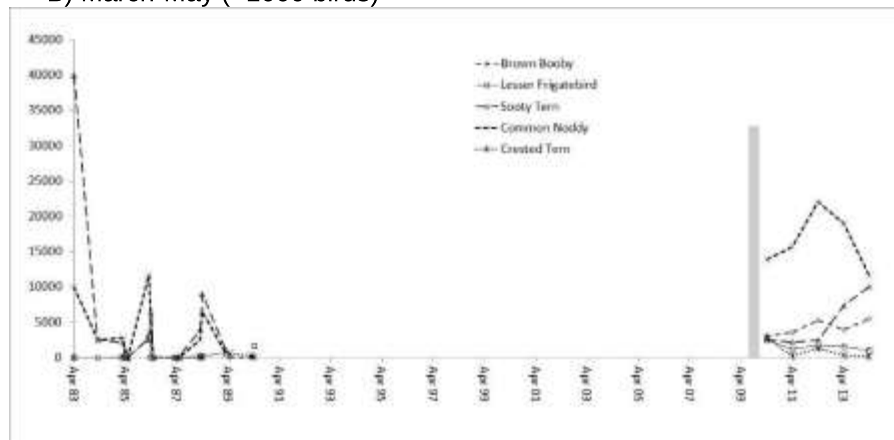


Figure 6 Seabird population trajectories at Middle Island Ashmore Reef CMR from counts obtained in the periods March to May (A & B) and September to November (C & D). Small breeding populations (10 to 150 birds) and large breeding populations (>1000 birds) are displayed on separate plots. The grey bar represents the timing of the Montara Oil Spill.

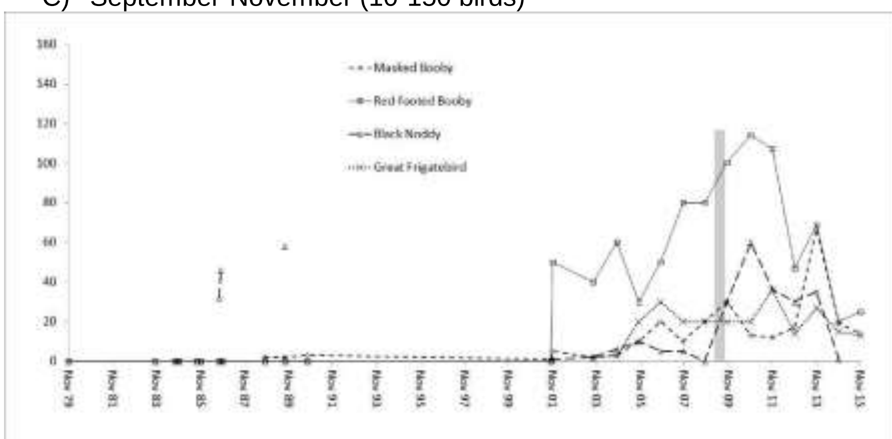
A) March-May (10-150 birds)



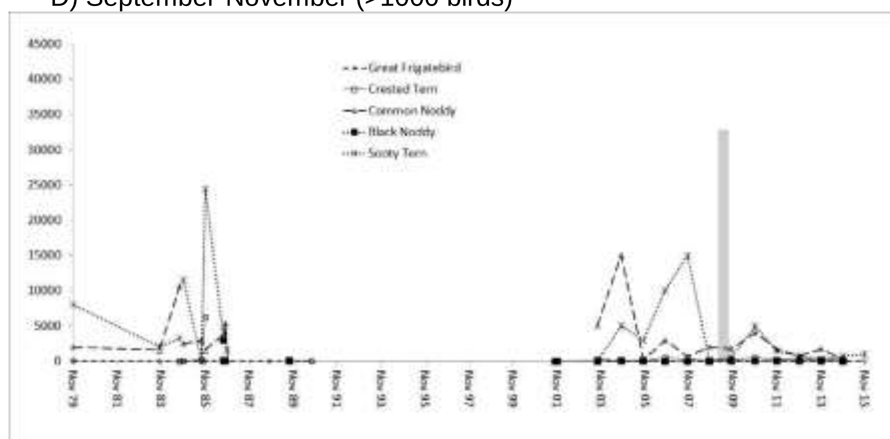
B) March-May (>1000 birds)



C) September-November (10-150 birds)



D) September-November (>1000 birds)



Overview of shorebird population trajectories

As with the seabird population trajectories, assessment of the impact of the Montara Oil Spill on shorebird populations at Ashmore Reef CMR is prefaced by recognition that no targeted survey of shorebirds *for the purposes of impact assessment* was undertaken at Ashmore Reef CMR prior to the Montara Oil Spill. Rather, there existed three reserve-wide surveys of shorebirds for the years 2002, 2003 and 2005. These counts followed standard techniques for shorebird monitoring and involved one or more experienced ornithologists. The key limitation is therefore not the quality of pre-impact surveys but rather the quantity (small number). Nevertheless, it remains appropriate to assess the population trajectories of shorebird at Ashmore Reef CMR against the *a priori* criteria (Commonwealth of Australia 2009, Clarke 2010). These criteria specified a *significant impact* as one with a decline below a specified threshold over a three-year period (2010-12) following the Montara Oil Spill *and* a failure to recover to pre-impact levels in the subsequent two years (2013-14). In contrast to seabirds that occur at Ashmore Reef CMR, migratory shorebird numbers are known to be undergoing a significant decline throughout the flyway and this is thought to be largely driven by habitat loss in eastern Asia, especially coastal mudflat reclamation projects in Korea and China (e.g. Murray et al. 2014, Clemens et al. 2016). For a significant impact from the Montara Oil Spill to be detected any decline must therefore take into account the background population trajectory. For this reason a Before-After-Control-Impact design was established. The internationally significant shorebird site at Eighty-mile Beach in northern Western Australia was selected as the control site for reasons outlined in Clarke (2010).

A) Small migratory populations

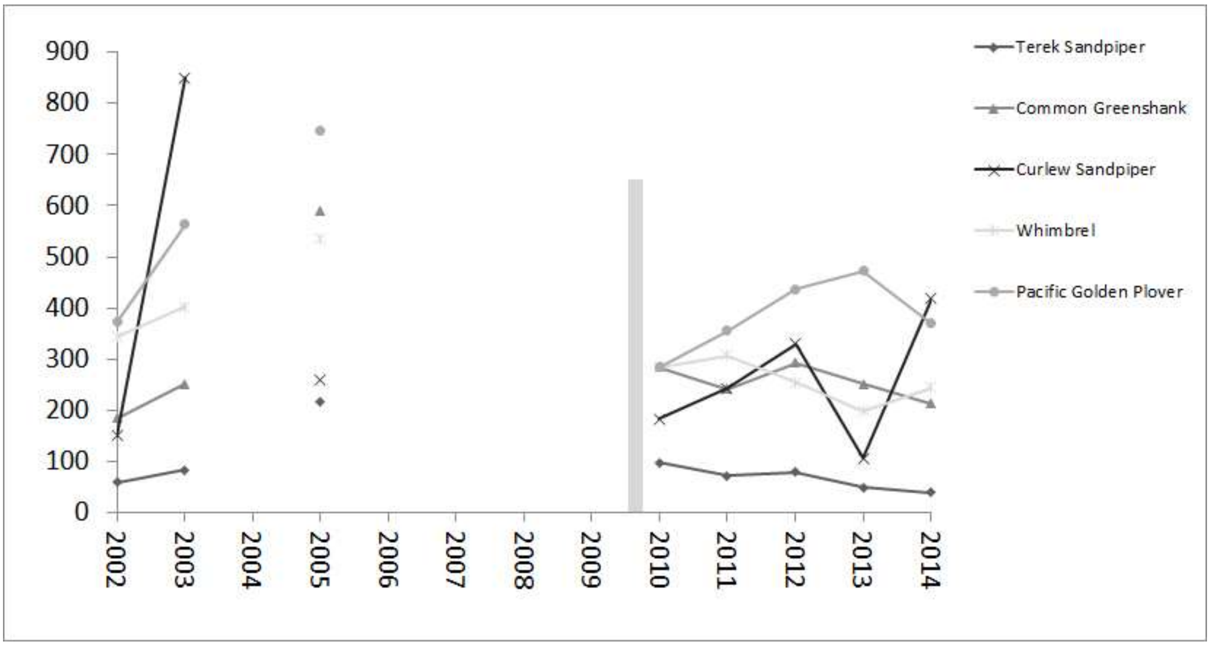


Figure 7 Shorebird population trajectories at Ashmore Reef CMR from counts obtained in the period November to February. Small migratory populations (mean population size <500 birds) and large migratory populations (mean population size >800 birds) are displayed on separate plots (A and B respectively). The vertical grey bar represents the timing of the Montara Oil Spill.

B) Large migratory populations

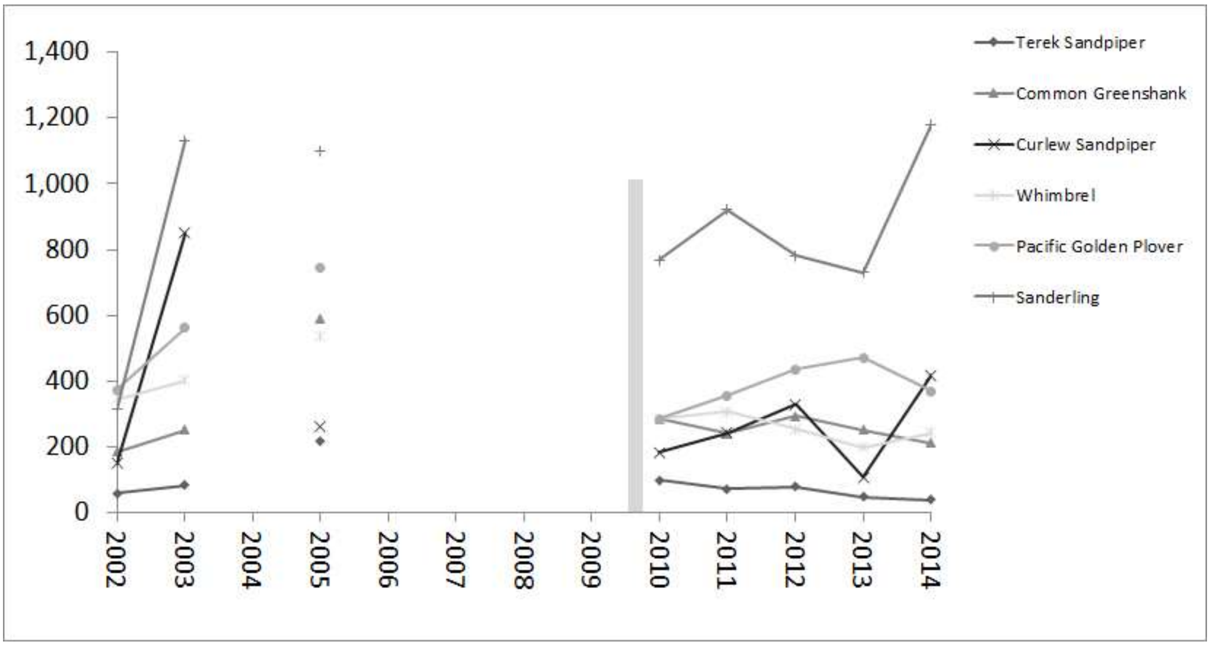


Figure 7 (cont.) Shorebird population trajectories at Ashmore Reef CMR from counts obtained in the period November to February. Small migratory populations (mean population size <500 birds) and large migratory populations (mean population size >800 birds) are displayed on separate plots (A and B respectively). The vertical grey bar represents the timing of the Montara Oil Spill.

Comparison of shorebird population trajectories between Ashmore Reef CMR and the control site

The total median count of shorebirds (all species' counts pooled) declined from pre-impact to post-impact status at Ashmore Reef CMR, while it increased slightly at the Eighty Mile Beach control site (Figure 8). However, the difference between the pre and post-impact counts at Ashmore Reef CMR and the control site did not differ significantly. More explicitly, the interaction effect of impact status (pre-impact, post-impact) and location (Ashmore Reef CMR, control site) on standardised counts was not statistically significant in a pooled analysis when year was either included or not included in the model ($F_{2,14}$ = 3.08, P = 0.078; $F_{2,13}$ = 2.86, P = 0.093, respectively) (Figure 8).

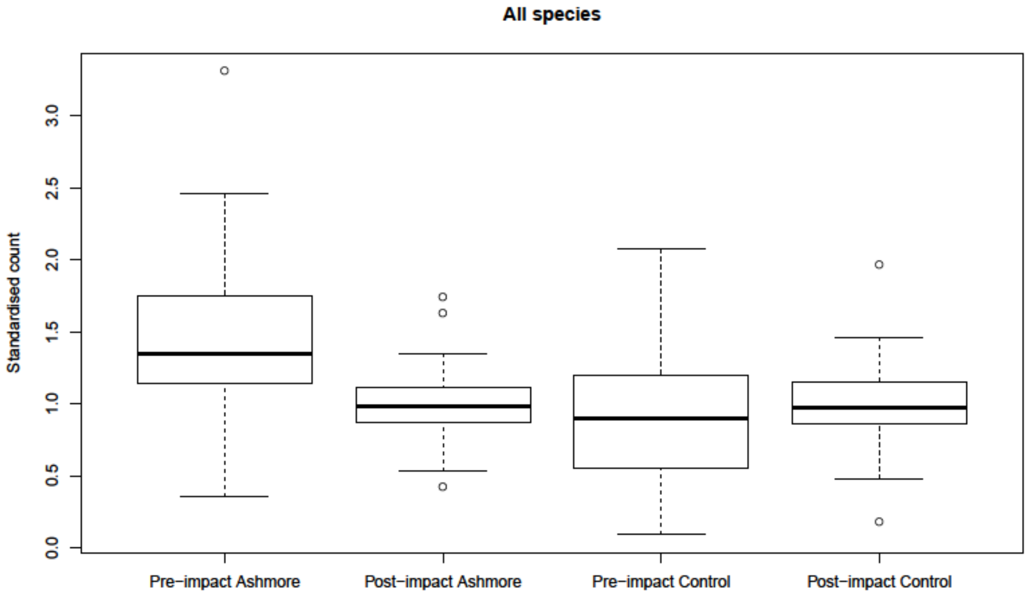


Figure 8. Pre-impact and post-impact counts (species pooled) at Ashmore Reef CMR (Ashmore) and the control site (Control). Data are standardised to mean within-site post-impact counts to show within-site proportional differences.

Comparison of shorebird species trajectories between Ashmore Reef CMR and the control site
Some individual species showed location-specific population trends, and some of these contrasts were statistically significant. Of the 12 species that occurred in sufficient numbers for analysis, median counts of 11 species (92 %) were lower at Ashmore Reef CMR post-impact compared to pre-impact, while one species remained the same (Common Greenshank) between the two time periods (Table 13, Figure 9).

At the control site however, median counts of six species were lower during the post-impact monitoring period compared to pre-impact period and counts of six species were higher post-impact compared to pre-impact (Table 13). This decrease in counts of 50% of species and increase in counts of 50% of species, resulted in the observed similar total median count between pre and post-impact status at the control site (Figure 8).

Five species showed a statistically significant interaction effect between location and impact status. Greater Sand Plover population counts decreased during the post-impact monitoring period at Ashmore Reef CMR while decreasing over the same time frame at the control site. Grey-tailed Tattler, Ruddy Turnstone, Sanderling and Whimbrel population counts decreased during the post-impact monitoring period at Ashmore Reef CMR while increasing during the same time frame at the control site (Table 13).

The reasons for these apparent declines are unclear. Whilst it is possible that the Montara Well release contributed to these declines we do not have the capacity to conclude this from the available data. Firstly, pre-impact shorebird data were last gathered at Ashmore Reef CMR in 2005, some five years prior to the first post-impact monitoring period. As such, we do not know what the shorebird population size was immediately prior to the Montara Oil Spill. Secondly, no visible shoreline impact by oil was documented at Ashmore Reef CMR during the spill event (submissions to Montara Commission of Inquiry) and thus a direct mechanism to drive shorebird declines has not been demonstrated. Thirdly, there is some recent evidence that shorebird populations that occupy island systems are declining at a greater rate than core or mainland wintering sites. This last observation may reflect regional population contractions to the highest quality shorebird sites available as global populations contract (A. Boyle pers. comm.).

Table 13. Summary of population trends for individual shorebird species. Summaries are from fitted models for each species. ‘x’ refer to medians within each location for each species: if the median count for a species was lower in the post-impact counts than pre-impact counts at Ashmore, and also lower in post-impact counts than pre-impact counts at the control site, that species is recorded as 'Ashmore down, control down'. Interaction significance indicates statistical significance of location: p = 0 – 0.001: '***'; p = 0.001 – 0.01: '**'; p = 0.01 – 0.05: '*'; p >0.5 'ns '. Interaction direction: negative = indicates that Ashmore Reef CMR lost proportionally more birds than the control site, positive = vice-versa.

Species	Interaction significance	Interaction direction	Ashmore down, Control down	Ashmore down, Control up	Ashmore up, Control up	Ashmore up, Control down
Bar-tailed Godwit	ns		x			
Common Greenshank	ns		Only control down			
Curlew Sandpiper	ns		x			
Great Knot	ns			x		
Greater Sand Plover	*	negative	x			
Grey Plover	ns		x			
Grey-tailed Tattler	**	negative		x		
Pacific Golden Plover	ns			x		
Red-necked Stint	ns		x			
Ruddy Turnstone	***	negative		x		
Sanderling	*	negative		x		
Whimbrel	***	negative		x		

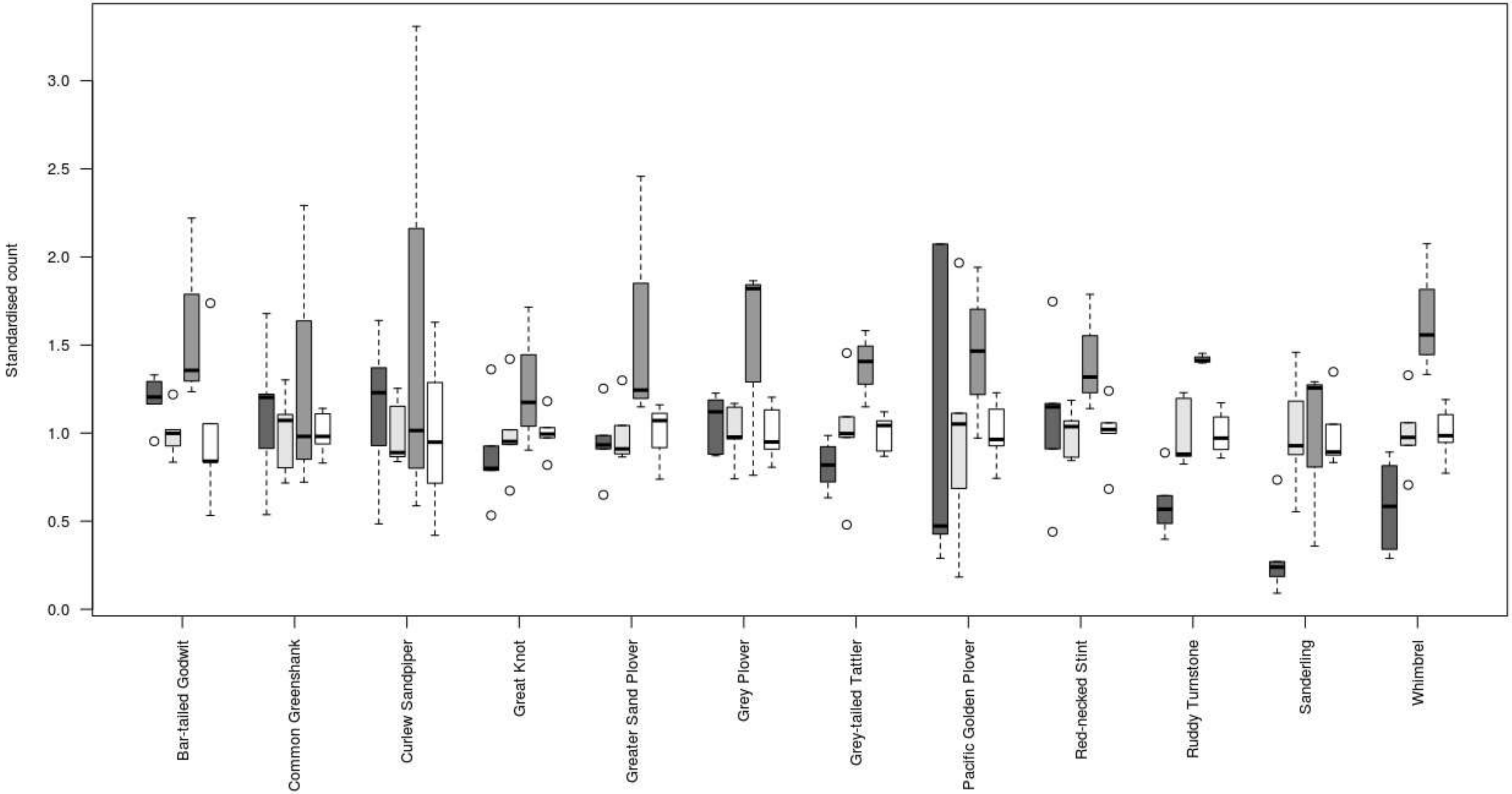


Figure 9. Mean pre-impact and post-impact counts at Ashmore Reef CMR and control site for each of the 12 species analysed. For each species, boxes are ordered as follows: 1) control site, pre-impact (dark grey box); 2) control site, post-impact (light grey box); 3) Ashmore Reef CMR, pre-impact (medium grey box); 4) Ashmore Reef CMR, post-impact (white box). Boxes are counts for each species, standardised to the mean post-impact count within that location: numbers represent proportional changes in population size within each site.

Cartier Island Commonwealth Marine Reserve

Location and context

Cartier Reef CMR is situated at 12°32’S, 123°33’E in the Timor Sea at the eastern edge of the Indian Ocean ~190 km south-east of the Indonesian island of Roti and ~290 km north-west of the Kimberley coastline in Australia. The nearest neighbouring islands are at Ashmore Reef CMR some 52 km to the north-west. Cartier Reef CMR has an elliptical boundary and is approximately 4.6 km long and 2.3 km wide. Cartier Island is a small uninhabited island within the reef that consists of course grit and coral rubble that rises 1-2 m above the high tide line. In April 2010 Cartier Island had a total land area of 2.1 ha measured at the high tide line using a handheld GPS (R. Clarke unpubl. data). Following gales and cyclonic events there is evidence that the entire island can be wave washed. Whilst shifting sands result in regular, small changes to both the size and shape of the island (Russell *et al.* 1993), the position of the island within the reef is stable as it is ‘anchored’ by a small platform of permanent beach rock at its south-western end. The island, reef and adjacent waters are protected under Commonwealth Marine Reserve classification, which has a circular boundary that extends in a 4 nM radius from Cartier Island.

Propagules of various plants are cast ashore with some regularity, yet there is no extant vegetation on the island and this appears to have long been the case (Russell *et al.* 1993, Pike & Leach 1997). A low dune ridge (<1 m) encircles the rim of the island and here large numbers of Green Turtles *Chelonia mydas* 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 the island and the large numbers of breeding turtles, almost all surface substrate is regularly disturbed by the nesting activities of turtles.

During high tides the island provides the only available land within the reef for roosting birds. At lower tides, reef flats provide additional resting and foraging substrates for species such as egrets and shorebirds.

History of human visitation to Cartier Island CMR

A history of human visitation in the Ashmore region is presented in Russell (2005). What follows is a condensed history, of relevance to the avifauna in the region especially as it relates anthropogenic pressures on breeding seabirds at Ashmore Reef CMR (a likely source of visiting seabirds to Cartier Island CMR), and legislation that has played a role in the management of the region. Ashmore Reef CMR, and by inference Cartier Island CMR, were known to Indonesian fishers as early as the first half of the 18th century, with regular visits beginning sometime between 1725 and 1750 (Fox 1977, Russell 2005). The first recorded European discovery of Cartier Island CMR was in 1800 by Captain Nash aboard the ship *Cartier*, whilst nearby Ashmore Reef CMR was discovered by Captain Samuel Ashmore, commander of the Hibernia 11 years later (King 1827). American whalers began operating in the area in the 1850s, and with the discovery of guano deposits on the islands at Ashmore Reef CMR, phosphate mining began at Ashmore in the latter half of the nineteenth century. In the late nineteenth century Britain and the United States of America contested the ownership of Ashmore Reef CMR, with Britain annexing the reef in 1878. As Cartier Reef was of perceived lower value it was not annexed until 1909 (Langdon 1966). Guano deposits were exhausted at Ashmore by 1891 and with a decline in European activity in the region, Indonesian fishers are said to have resumed visits to the islands in the following years (Langdon 1966). In 1931 Britain placed Ashmore and Cartier Islands under the authority of the Commonwealth of Australia and this passed through the Australian parliament as the Ashmore and Cartier Island's Acceptance Bill in 1934 (Russell 2005). Both areas were under the control of the Administrator of the Northern Territory before responsibility for administration was transferred to the Commonwealth of Australia when self-government was instituted in the Northern Territory in 1978. During the Second World War the territory was visited regularly by the navy and Cartier Island was used as a bombing and air weapons range for Defence training. The use of Cartier Reef for this purpose ceased sometime prior to the 1980s and in 1986 a clearance operation was conducted to remove any obvious unexploded ordinance from the island and surrounding reef flats. In 2000 the Cartier Island Commonwealth Marine Reserve was established under the National Parks and Wildlife Conservation Act 1975. The reserve has a circular boundary and extends 4nM from Cartier Island (172 km^2). Subsequently, the reef remained a gazetted, but unused, Defence Practice Area until 2011. In recent times it is apparent that Indonesian fishers have maintained occasional visits to Cartier Reef and landings at Cartier Island: the grave of an Indonesian fisher who was buried there in the early 2000s remains a prominent feature on the otherwise barren island (R. Clarke pers. obs.).

Ornithological observations

Cartier Island CMR is infrequently visited by birdwatchers and ornithologists. The first report of an ornithological nature was by Serventy (1952) who noted Brown Booby[5], Pacific Reef Heron, Lesser Frigatebird, Greater Crested Tern and probable Sooty Tern at Cartier Reef, but did not land on the island when he visited aboard the FRV *Wareen* in October 1949. No doubt owing to the use of Cartier Island CMR as a bombing range, and the associated restricted access, there are just four further visits up to 2010 where ornithological observations have been reported. Two visits occurred in the early 1990s (March 1990 and May 1992) when six species of seabird and shorebird were observed on each landing (Guinea 1993). Two subsequent landings were made by GS and MJC in October 1996 and again in January 2002. These visits documented similar species richness and resulted in two further species being added to the reserve list (Table 13).

Following the Montara Oil Spill from August to October 2009, surveys of seabirds and shorebirds at Cartier Island CMR were included in the Montara post-impact monitoring program at the request of the Commonwealth Department of Environment. Although this area was expected to support relatively few birds, the anticipated benefits of these surveys were two-fold. First, it provided opportunity to rigorously document the avifauna at Cartier Island CMR during repeat visits and compare these results with previous opportunistic surveys. Secondly, it presented an opportunity to establish a baseline of bird occurrence gathered in a standardised fashion against which future change may be assessed. Note that because monitoring data for birds was known to be inadequate to assess impact at Cartier

[5] Scientific names for most species are presented in Appendix A.

Island CMR prior to the commencement of monitoring in 2010, impact assessment per se using before and after comparisons was not an objective of these surveys. Rather, here we summarise the results of those surveys and place these records in context with past ornithological observations at Cartier Island CMR. Further, we discuss the capacity for these data to serve as baseline for potential future impacts at Cartier Island CMR.

Methods

2010-2014 surveys

Cartier Reef and Cartier Island were visited over one to two days via a live-aboard vessel in April and November of each year from 2010 to 2014 (n = 10 surveys). Surveys were timed to coincide with known peaks in breeding activity of seabirds (mostly egg laying and incubation) at nearby Ashmore Reef CMR (April surveys; Clarke 2010) and at a time when migratory shorebird numbers are stable around an annual upper limit having largely completed southbound migration from the northern hemisphere (November surveys; Rogers *et al.* 2011). During each visit a single landing by the survey team consisting of 2-6 experienced ornithologists was made on Cartier Island. All birds present were identified to species and counted, a traverse of the perimeter of the island was made on foot at the high tide mark and the centre of the island was inspected for evidence of seabird breeding. The presence of any dead birds was also noted. The survey team was typically ashore on Cartier Island for 1-2 hours. On occasion the vessel remained at anchor overnight just beyond the fringing reef and any incidental observations made during this time are referred to in the annotated species list.

When travelling to and from Cartier Island CMR a constant watch was maintained from the bow of the vessel by one or more observers. All seabirds that were encountered were identified to species, counted, and the coordinates and time of each sighting were logged to marine Palm Pilots with purpose-built software.

Results

Cartier Island

Documented landings on Cartier Island and visits to Cartier Reef where ornithological observations have been made total just 15 visits over a ~65 year period. Standardised surveys between April 2010 and November 2014 recorded between five and 12 species per visit and saw the addition of 18 species to the Cartier Island CMR list (Tables 14 and 15).

When all surveys are combined it is apparent that several species including the Brown Booby, Pacific Reef Heron, Greater Crested Tern and Ruddy Turnstone are regular visitors to Cartier Island and Cartier Reef. Evidence of past breeding by Greater Crested Tern was detected on five visits. No other bird species have been detected breeding. The majority of species now recorded within the reserve are best categorized as occasional visitors or vagrants (Table 14).

Marine waters of Cartier Island Commonwealth Marine Reserve

A total of 88.98 km of shipboard transects were completed within the Cartier Island CMR (i.e. within a 4 nM radius of Cartier Island) during 10 surveys conducted between 2010 and 2014. Survey effort varied between visits (range: 1.65 to 16.42 km of transects per survey) given some night-time travel and weather conditions unsuitable for survey. A total of nine seabird species were recorded during these surveys, with the Brown Booby and Sooty Tern being the most frequently encountered species. A single flock of migratory Rainbow Bee-eaters were also noted overflying the sea (Table 14).

Discussion

A total of 34 species of bird have been recorded from Cartier Island CMR. Most species occur as occasional visitors or as overflying trans-Timor Sea migrants. Small numbers of seabirds including species that breed at nearby Ashmore Reef CMR (e.g. Wedge-tailed Shearwater, Brown Booby, Sooty Tern, Brown Noddy and Greater Crested Tern), as well as migrant species from the northern hemisphere (e.g. Bulwer's Petrel, Streaked Shearwater and White-winged Tern) have been detected in the offshore waters of the reserve. Surveys and review of previous avian records demonstrate that whilst the exposed reef flats and island provide an important feeding area and roost site for small numbers of shorebirds, herons and seabirds, these areas do not support internationally significant numbers of any species (e.g. Bamford *et al.* 2008). Surveys in marine areas are less conclusive given the limited coverage achieved to date (88 linear km of at-sea surveys).

Table 14 Counts of all birds recorded inside the fringing reef at Cartier Island CMR, 1949-2014.

	Oct 1949	Mar 1990	May 1992	Oct 1996	Jan 2002	Apr 2010	Nov 2010	Apr 2011	Nov 2011	Apr 2012	Nov 2012	Apr 2013	Nov 2013	Apr 2014	Nov 2014
Source:	*Serventy (1952)*	*Guinea (1993)*	*Guinea (1993)*	*(Clarke 2010)*	*(Clarke 2010)*	*This study*	*This study*	*This study*	*This study*	*This study*	*This study*	*This study*	*This study*	*This study*	*This study*
Wedge-tailed Shearwater	-	-	nc	-	-	-	-	-	-	(1D)	-	-	-	-	-
Bulwer's Petrel	-	-	-	-	-	-	-		-	-	-	-	-	-	-
Little Egret	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Pacific Reef Heron	3	6	15	-	-	14	-	17	3	9	-	23	2	15	1
Australian Pelican	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Lesser Frigatebird	1	-	6	2	3	1	1	-	-	-	-	-	-	1	-
Brown Booby	6	3	nc	-	-	-	-	17	-	1	5	3	1	-	6
Little Pied Cormorant	-	-	-	-	-	-	(1D)	-	-	-	-	-	-	-	-
Australasian Darter	-	-	-	-	-	-	-	-	-	-	(2D)	-	-	-	-
Black-winged Stilt	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-
Pacific Golden Plover	-	-	-	-	-	-	-	-	1	-	1	-	2	-	-
Lesser Sand Plover	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Greater Sand Plover	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Whimbrel	-	-	-	-	-	3	-	-	-	-	-	-	-	-	1
Common Greenshank	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-
Grey-tailed Tattler	-	-	-	-	-	-	1	-	-	-	1	-	-	-	3
Ruddy Turnstone	-	24	15	-	24	8	46	26	44	19	38	36	14	-	-
Sanderling	-	-	-	-	-	-	-	-	-	-	1	-	4	-	-
Red-necked Stint	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-
Oriental Pratincole	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Brown Noddy	-	-	-	-	-	1	-	-	(1D)	(2D)	-	-	2(3D)	3(1D)	-
Greater Crested Tern	2	200+	50	400	85	165[a]	(61D)	290	1(2D)	322	4(20D)[b]	109	13(4D)[c]	335	3
Bridled Tern	-	-	-	-	-	-	-	1	1	-	-	-	-	(4D)	-
Sooty Tern	2	-	-	3	2	-	1	20	3	5	-	-	-	-	5
Common Tern	-	-	-	-	-	-	2	-	1	-	-	1	-	-	-
White-winged Tern	-	-	-	-	-	-	1	-	3	-	-	-	-	-	-
Sacred Kingfisher	-	1	-	1	-	-	-	-	-	-	-	1	-	-	3
Pacific Swift	-	-	-	-	-	-	-	40	-	-	-	-	-	-	-
Rainbow Bee-eater	-	-	-	-	-	6	-	1	-	-	-	-	-	-	-
Fairy Martin	-	-	[1][d]	-	-	-	-	-	-	-	-	-	-	-	-

nc indicates the species was present on the reef but not specifically counted. D = dead. [a]5, [b]365 and [c]134 old nests also present, [d]specific identification is questioned (see text).

Table 15 Counts of all birds recorded during shipboard transects within Cartier Island CMR, between April 2010 and November 2014.

	Apr-10	Nov-10	Apr-11	Nov-11	Apr-12	Nov-12	Apr-13	Nov-13	Apr-14	Nov-14	Total
Length of shipboard transects (km)	10.36	13.91	12.24	16.42	4.78	10.82	6.25	6.47	6.08	1.65	88.98
Bulwer's Petrel	2	-	-	-	-	-	-	-	-	-	2
Streaked Shearwater	-	-	3	-	-	-	-	-	-	-	3
Brown Booby	1	1	2	-	-	2	4	-	-	1	11
Lesser Frigatebird	-	-	-	-	-	-	-	-	1	-	1
Frigatebird sp.	-	-	-	1	-	-	-	-	-	-	1
Brown Noddy	2	-	-	-	-	-	-	-	-	-	2
Greater Crested Tern	1	-	2	5	-	-	2	-	3	-	13
Sooty Tern	4	18	5	1	-	10	2	-	-	-	40
Bridled Tern	-	-	1	-	-	-	-	-	-	-	1
Bridled/Sooty Tern	2	-	-	-	-	12	-	-	66	-	80
White-winged Tern	-	1	-	1	-	-	-	-	-	-	2
Rainbow Bee-eater	-	-	24	-	-	-	-	-	-	-	24

Annotated list of bird species recorded on Cartier Island

Wedge-tailed Shearwater *Puffinus pacificus*: Visitor to waters of Cartier Island Commonwealth Marine Reserve (CICMR). Whilst ~40 pairs breed at nearby Ashmore Reef CMR (Clarke *et al.* 2011) there are only two records from within the reserve: an observation of an unspecified number in May 1992 (Guinea 1993) and the desiccated remains of a single bird on Cartier Island in April 2012.

Bulwer's Petrel *Bulweria bulwerii*: Visitor to waters of CICMR. Two individuals were detected within the boundary of the CICMR during shipboard surveys in April 2010. Another individual was observed in flight 1-2 km outside of the reef fringe whilst the vessel was at anchor in April 2011. This species mostly occurs over waters >200 m depth in the region (Lavers *et al.* 2014).

Streaked Shearwater *Calonectris leucomelas*: Visitor to waters of CICMR. A common non-breeding visitor to the Browse and Bonaparte Basins (Lavers *et al.* 2014), three individuals were detected within the reserve during shipboard surveys in April 2011.

Red-tailed Tropicbird *Phaethon rubricauda*: Visitor to waters of CICMR. One GPS-tracked individual that originated from Ashmore Reef CMR recorded overflying the reserve in April 2014 (R Clarke, A. Herrod unpubl. data).

Little Egret *Egretta garzetta*: Vagrant to land and intertidal areas of CICMR. A single bird was recorded on the reef flats in January 2002. This species is present year-round in small numbers at Ashmore Reef CMR (Clarke *et al.* 2011), so occasional visits to Cartier Reef are not surprising.

Pacific Reef Heron *Egretta sacra*: Visitor to land and intertidal areas of CICMR. Present during most surveys, with between one and 23 individuals being counted. The species is a common breeding resident at Ashmore Reef CMR (Clarke *et al.* 2011), but to date there is no evidence of breeding at Cartier Island.

Australian Pelican *Pelecanus conspicillatus*: Vagrant to land and intertidal areas of CICMR. A single adult present at the reef in November 2010.

Great Frigatebird *Fregata minor*: Visitor to waters of CICMR. One GPS-tracked individual that originated from Ashmore Reef CMR recorded overflying the reserve in April 2014 (R. Mott, R Clarke unpubl. data).

Lesser Frigatebird *Fregata ariel*: Visitor to waters of CICMR. Small numbers reported on most visits to the reserve. Individuals were mostly observed in flight, though a single adult female was observed perched on a large piece of driftwood that projected from the sand on Cartier Island in April 2014. At least three GPS-tracked individuals (all from April 2014) that originated from Ashmore Reef CMR were recorded overflying the reserve (R. Mott, R Clarke unpubl. data).

Brown Booby *Sula leucogaster*: Visitor to all areas of CICMR. Small numbers are present within the reserve on most visits. Generally observed flying over offshore waters or the fringing reef, with occasional birds perched on the exposed reef platform or the shoreline of Cartier Island.

Red-footed Booby *Sula sula*: Visitor to waters of CICMR. One GPS-tracked individual that originated from Ashmore Reef CMR was recorded overflying the reserve in September 2013 (R Clarke unpubl. data).

Little Pied Cormorant *Microcarbo melanoleucos*: Vagrant to land and intertidal areas of CICMR. The desiccated remains of a single individual were present on Cartier Island in November 2010.

Australasian Darter *Anhinga novaehollandiae*: Vagrant to land and intertidal areas of CICMR. The desiccated remains of two individuals were present on Cartier Island in November 2012.

Black-winged Stilt *Himantopus himantopus*: Visitor to land and intertidal areas of CICMR. Single individuals were reported in March 1990 and November 2010 from the shoreline of Cartier Island. Observations at Ashmore Reef CMR indicate small numbers of this species move through the Ashmore region regularly.

Pacific Golden Plover *Pluvialis fulva*: Visitor to land and intertidal areas of CICMR. One to two birds recorded on three separate occasions on the shoreline of Cartier Island. The species is common at nearby Ashmore Reef CMR (Rogers *et al.* 2011, Clarke 2010).

Lesser Sand Plover *Charadrius mongolus*: Visitor to land and intertidal areas of CICMR. A single individual recorded in March 1990 (Guinea 1993). Small numbers (10-50) occur annually at nearby Ashmore Reef CMR (Rogers *et al.* 2011, Clarke 2010).

Greater Sand Plover *Charadrius leschenaultii*: Visitor to land and intertidal areas of CICMR. Single individuals recorded in November 2012 and November 2014. Large numbers (up to 2559) occur annually at nearby Ashmore Reef CMR (Rogers *et al.* 2011, Clarke 2010).

Whimbrel *Numenius phaeopus*: Visitor to land and intertidal areas of CICMR. Three individuals in April 2010 and a single individual in November 2014. There are usually 200-300 present at Ashmore Reef CMR during summer shorebird counts.

Common Greenshank *Tringa nebularia*: Visitor to land and intertidal areas of CICMR. Singles in October 1996 and November 2011. There are usually 200-300 present at Ashmore Reef CMR during summer shorebird counts.

Grey-tailed Tattler *Tringa brevipes*: Visitor to land and intertidal areas of CICMR. One to three recorded on Cartier Island on three occasions. Numbers usually exceed 1000 at Ashmore Reef CMR during summer shorebird counts.

Ruddy Turnstone *Arenaria interpres*: Visitor to land and intertidal areas of CICMR. A regular visitor with small numbers apparently ‘over-summering’ in most years. The species was detected during 73% of visits with flock size varying between eight and 46 individuals. Since 2010, numbers have exceeded 1000 individuals at Ashmore Reef CMR during summer shorebird counts.

Sanderling *Calidris alba*: Visitor to land and intertidal areas of CICMR. A single individual in November 2012 and four individuals present in November 2013. In excess of 700 are regularly present at nearby Ashmore Reef CMR (Rogers *et al.* 2011, Clarke 2010).

Red-necked Stint *Calidris ruficollis*: Visitor to land and intertidal areas of CICMR. Single individuals present in November 2011 and November 2012. In excess of 800 are regularly present at nearby Ashmore Reef CMR (Rogers *et al.* 2011, Clarke 2010).

Oriental Pratincole *Glareola maldivarum*: Vagrant to land and intertidal areas of CICMR. Flocks of 100-300 are regularly observed in migration over nearby Ashmore Reef CMR in early November (author’s unpub. data) and similar numbers are likely to overfly CICMR during their annual migration. Nevertheless there is no suitable habitat for this grassland-frequenting species at Cartier Island and the single bird present in November 2011 is best regarded as a vagrant to the land area of the reserve.

Brown Noddy *Anous stolidus*: Visitor to all areas of the CICMR. One to three occasionally observed on the island or over adjacent waters within the reserve. Dead individuals are also regularly encountered on the shoreline of Cartier Island. Up to 70,000 birds breed at nearby Ashmore Reef CMR during the dry season so the small numbers of birds encountered at CICMR suggests the Ashmore breeding population does not range far.

Greater Crested Tern *Thalasseus bergii*: Breeding visitor to all areas of the CICMR. Numbers have exceeded 100 individuals on seven of these visits. Evidence of breeding by Greater Crested Terns on Cartier Island was first detected in April 2010 when five Greater Crested Tern eggs were located on course grit and coral rubble in the center of the island. All eggs were bleached on the upper surface and contained dehydrated contents indicating the eggs had been abandoned for some time. Further evidence of breeding was detected on four of the subsequent nine surveys: 1) the desiccated remains of 45 runners (a small flightless age-class) and a single desiccated egg in November 2010; 2) a small number of broken eggs in November 2011; 3) 365 old nests (visible scrapes made obvious by the build-up of guano), along with 20 dead runners in November 2012; and 4) 134 old nests in November 2013.

Bridled Tern *Onychoprion anaethetus*: Visitor to all areas of CICMR. Singletons observed at Cartier Island or at sea within the reserve on several occasions. The remains of four beach-cast individuals were present on the island in April 2014. Small numbers breed at nearby Ashmore Reef CMR with a maximum count of 377 since 2010.

Sooty Tern *Onychoprion fuscatus*: Visitor to all areas of CICMR. Commonly encountered at Cartier Island and in surrounding waters of the reserve with a maximum count of 20 on the island. Up to 25,000 have been reported breeding at Ashmore Reef CMR since 2010.

Common Tern *Sterna hirundo*: Visitor to all areas of CICMR. One to two recorded on three occasions on Cartier Island or overflying the fringing reef. A non-breeding migrant from the northern hemisphere, small numbers pass through the Ashmore region annually.

White-winged Tern *Chlidonias leucopterus*: Visitor to all areas of CICMR. Recorded in November 2010 and again in November 2011 both during shipboard surveys and surveys of Cartier Island and the fringing reed. A non-breeding migrant from the northern hemisphere, small numbers pass through the Ashmore region annually.

Sacred Kingfisher *Todiramphus sanctus*: Migrant and visitor to land and intertidal areas of CICMR. One to four individuals recorded on Cartier Island and exposed beach rock on four separate occasions. The species is a common migrant through the Ashmore Region (author's unpubl. data).

Pacific Swift *Apus pacificus*: An aerial migrant that overflies CICMR. A flock of approximately 40 birds passed over the reef fringe and the anchored vessel in April 2011. This observation coincided with the passage of a storm front over the reserve. The species is a common migrant through the Ashmore Region (author's unpubl. data).

Rainbow Bee-eater *Merops ornatus*: An aerial migrant that overflies CICMR. A flock of 24 were observed flying north past the vessel in offshore waters of the reserve in April 2011. A single bird was observed around the anchored vessel adjacent to the reef fringe later that same day. A flock of six was observed flying past the anchored vessel adjacent to the reef fringe in April 2012. Observations at Ashmore Reef CMR demonstrate that significant numbers pass through the Ashmore region annually (author's unpubl. data).

Fairy Martin *Petrochelidon ariel*: A possible aerial migrant that overflies CICMR. A single individual was reported in May 1992 (Guinea 1993). This species appears to be rare in the Ashmore region and the authors are yet to observe the species at Ashmore Reef CMR in ~25 visits though Milton (2005) lists a record for Ashmore Reef CMR in August 1985. By contrast the Tree Martin *P. nigricans* is a common annual migrant through the Ashmore Region in small numbers. Owing to similarities between the two species it is possible that the record refers to this latter species.

Browse Island

Location and context

Browse Island Nature Reserve is situated at 14°06'S 123°32'E ~172 km south of Cartier Island and ~175 km north-east of the Kimberley coast on the Australian mainland. The reserve is managed by the Western Australian Department of Parks and Wildlife (DPAW). Browse Island is located within a small circular fringing reef with a diameter of ~2.2 km. The reef is particularly shallow and a large portion of its ~380 ha area is exposed on spring tides. In April 2010 Browse Island had a total area of 17.2 ha measured at the high tide mark, but the position and shape of Browse Island is somewhat dynamic with evidence that the south-western shoreline receded by >20 m between 2010 and 2014. 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 rubble, 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 rubble overlaid with neat stacks of the same material, at times forming distinct corridors and walkways.

Approximately two thirds of the island is vegetated. This includes 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 during guano mining activities 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.

As the nearest land is ~142 km distant (inshore islands of the Kimberley coast), Browse Island NR 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 site also appears to be important for small numbers of landbirds that stop over here briefly whilst migrating across the Timor Sea between Australia, and Timor and Indonesia.

History of human visitation & ornithological observations at Browse Island NR

Browse Island NR and our knowledge of the birds that frequent this location have been linked since European discovery. In 1699 William Dampier noted a small low sandy island, "*but a little spot of sand scarcely a mile around that was inhabited only by boobies and man-of-war birds"* [frigatebirds]. Given Dampier's location off the coast of Western Australia at the time it is highly likely this statement, one of the earliest of European references to Australia, relates to Browse Island. The location then goes largely unreported in the literature until May 1872 when George Howlett aboard the *Wild Wave* followed converging seabirds to find the island. At a time when mining of guano to produce phosphate-enriched fertiliser was intensive in a global context, Howlett noted the immense flights of seabirds and took guano samples for analysis. These samples proved to be extremely rich in phosphates (Willing and Spencer 2012) and commercial-scale mining commenced at Browse Island in 1874. Later in that decade something of a local boom took place with reports that barques encircled the reef whilst they waited to load cargo. By 1887 mining activities ceased with the total volume of guano that was removed amounting to less than 40,000 tons. Although this marked the end to formal mining at the site, ongoing attempts to mine the island and an extensive history of transactions surrounding the holding of mining leases at Browse Island continued until 1936 (Willing and Spencer 2012). Activity at Browse Island was periodically intense, with in excess of 30 miners being resident at times, and the introduction of cats and mice as well as livestock including pigs all being documented. Some of these actions were clearly deliberate but others such as the introduction of mice may have coincided with one or more of the numerous shipwreck events on the surrounding reef. The pressures on any remaining seabird colonies from mining activity, subsistence living of workers on meagre rations and invasive mammals would have been immense. In this context it is not surprising that when noted seabird researcher Dom Serventy landed at Browse Island in October 1949 he reported that "*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 1952). Whilst seabirds were absent, it is noteworthy that the tracks of a feral cat were recorded at this time. Whilst Browse Island was regarded as the most famous of the northern Australian guano islands and breeding seabirds were once abundant, seabirds appear to have been all but extirpated from the island during the guano extraction process. Between Serventy's visit and the year 2000 there exists information on an additional five landings where there was some reference to birds. Most notable amongst these is the report of a colony of Crested Terns with approximately 400 eggs (Abbott 1979): the first evidence that any species of seabird had bred at Browse Island since the guano mining activities ceased. All historical (pre-2000) and anecdotal observations of birds at Browse Island are summarised in Table 16.

Table 16 A summary of anecdotal and historical observations of birds at Browse Island

Survey	Observer	Reference	Species	Account or record
Sep-1699	William Dampier		Boobies, frigatebirds	"small low sandy Island ….but a little spot of sand scarcely a mile around." Inhabited only by boobies and man-of-war birds.
May-1872	George Howlett		Birds	"Calms had detained him [Wild Wave]….the existence of an island….was well known aboard, and immense flights of birds were seen winging their way in one direction"
Jul-1874	Chief Mate Mr Farr		Birds	"It [Browse] is literally covered in birds; in fact, they are so thick, that there is no difficulty in catching them with the hand……"
May-1876	Steamer "Fairy"		Birds	"….but this small vantage ground [Browse] has been appropriated by millions of the feathered tribe, whose eggs lie scattered thickly over every available part of the islet"
Mar-1878	Unknown Artist		Birds	Painting 'Browse Island' held by the Yarmouth County Museum, Nova Scotia, Canada by unknown artist depicts the guano mining process on the island. Over Browse Island are considerable flocks of large-sized 'sea'birds.
Mar-1885	Steamship Victoria		Birds	"…birds eggs are plentiful…." with survivors from the wrecked schooner 'The Bittern' persisting on Browse for over 1 month before being rescued.
May-1885	Informant from Silver Stream		Birds, fowls	The Silver Stream arrived Port Darwin - called at Browse Island - "The flat, scrubby island was covered with one mass of birds, and on it were also seen a number of wild cats and some fowls and pigs." Page 5
Nov-1885	My informant W. Fielding, second mate		Boobies	"The birds seem to be almost entirely those known as boobies, and the island is literally alive with them."
Oct-1949	D.L. Serventy		No birds recorded	"On the sandy beach we were surprised to see the tracks of a domestic cat, possibly left here by one of the service parties which visited the island during the war."
Jun-1972	Smith, Dell, Burbidge		Eastern Reef Egret	Present (numbers not reported) Several nests were being constructed in a solitary mangrove tree
			Nankeen Kestrel	Single bird
			Turnix sp.	Unidentified quail seen
			Scared kingfisher	Present (numbers not reported)
Jun-1978	Ian Abbott		Lesser Frigatebird	Two over island at 1700 hr
			Greater Crested Tern	About 300 birds nesting NE edge of island. There were 400 eggs in an area 16 m * 5 m. About 30 eggs had been broken by a turtle.
			Eastern Reef Egret	Total of 34 birds of which 28 were white morph individuals. Old nests in *Scaevola taccada* bushes.
			Fairy Martin	1 + 1 mummified corpse
			Magpie-lark	2 seen, (G Young - reported 5 have been on the island at one time - note in Abbott)
Nov-1991	Bob Prince		Rainbow Bee-eater	3 vouchers collected (mummified)
			Fork-tailed Swift	1 voucher collected (mummified)
Aug-2003	Mike Lapwood		Eastern Reef Egret	5-6 breeding pairs (one nest with 2 eggs)
			Frigate birds	[no further detail]
			Tern species	[no further detail]
			Possible godwits on distant reefs	[no further detail]
Aug-2007	Alastair Smith		Dark Storm Petrels	[Sourced from eBird – no further detail]
			Brown Booby	[Sourced from eBird – no further detail]
			Greater Crested Tern	[Sourced from eBird – no further detail]

The Montara Oil Spill and recent ornithological surveys

Following the Montara Oil Spill from August to October 2009, surveys of seabirds and shorebirds at Browse Island NR were included in the Montara post-impact monitoring program at the request of the Commonwealth Department of Environment (Clarke 2010). Whilst it was recognised that Browse Island NR was historically a significant seabird site, and that contemporary evidence indicated this was no longer the case, few formal bird surveys have ever been conducted on Browse Island. In this context, surveys provided opportunity to rigorously document the avifauna of Browse Island NR during repeat visits and compare these results with previous opportunistic surveys. Secondly, it presented an opportunity to establish a baseline of bird occurrence gathered in a standardised fashion against which future change may be assessed. Given monitoring data for birds was known to be inadequate to assess any impact of the Montara Oil Spill at Browse Island NR prior to the commencement of monitoring in 2010, impact assessment *per se* using before and after comparisons was not an objective. Rather, here we summarise the results of those surveys and place these records in context with past ornithological observations at Browse Island NR. Further we discuss threatening processes identified during these surveys and make recommendations regarding the potential long-term restoration of what was once a significant seabird site.

Methods

Anecdotal and historic avian observations at Browse Island NR

Whilst the historic avian observations are outlined in the introduction to Browse Island NR (above) and Table 16, it is appropriate here to outline the methods applied to achieve this. We searched the literature for references to Browse Island and its avifauna. This included keyword searches of the online databases Web of Science and Google Scholar. Resources of the Western Australian Department of Parks and Wildlife were also searched, including their research library and an electronic database that seeks to document all seabird breeding events on islands within the state of Western Australia. Finally, where possible direct contact was made with observers that made recent (>1990) visits to Browse Island NR to further clarify and provide context to reported sightings.

Formal island-wide surveys

Browse Island NR was visited over one to two days via a live-aboard vessel in April and November of each year from 2010 to 2014 (n = 10 surveys). Surveys were timed to coincide with known peaks in breeding activity of seabirds (mostly egg laying and incubation) at Ashmore Reef CMR (April surveys; Clarke 2010) and at a time when migratory shorebird numbers are stable around an annual upper limit having largely completed southbound migration from the northern hemisphere (November surveys; Rogers *et al.* 2011). As it transpired, the November surveys also coincided with the commencement of breeding by a suite of seabirds at Adele Island – the nearest seabird breeding island to Browse Island NR (Lavers *et al.* 2014). Additional surveys were also made on an opportunistic basis during February 2000, June 2013 and November 2015. During each visit one to two landings by the survey team consisting of 2-5 experienced ornithologists were made on Browse Island. All birds present were identified to species and counted, a traverse of the perimeter of the island was made at the high tide mark and several passes across the centre of the island were made to document any birds here. The presence of any dead birds was also noted. The survey team was typically ashore on Browse Island for ~2 hours on each landing. The vessel usually remained at anchor overnight just beyond the fringing reef and any incidental observations made during this time are referred to in the annotated species list. One of the opportunistic visits, in June 2013, departed from the above methods in that it involved landings on five consecutive days by a single experienced ornithologist.

Results for Browse Island

A total of 62 bird species have now been recorded from Browse Island NR (Table 17). This includes 13 species of seabird, six herons and egrets, 18 species of shorebird and three birds of prey. Interestingly, 21 landbirds (e.g. kingfisher, cuckoos and passerines) have also been recorded here. The only seabird known to now breed at Browse Island NR is the Greater Crested Tern and breeding colonies were observed during four of the 13 surveys reported here. The Pacific Reef Heron and Buff-banded Rail (both non-seabirds) are the only other species that are known to have bred at Browse Island NR in recent decades and repeated detection across all 13 surveys documented here suggests that both species are resident on the island. Observations of non-breeding seabirds at Browse Island NR included a number of species that are known to breed elsewhere in the basin (e.g. Red-tailed Tropicbird, White-tailed Tropicbird, Great Frigatebird, Lesser Frigatebird, Brown Booby, Brown Noddy, Lesser Noddy, Bridled Tern and Sooty Tern). Of the non-breeding species most appear to be regular migrants (mostly shorebirds but also Sacred Kingfisher), or occasional visitors or vagrants.

Table 17 The results of all formal island-wide bird surveys conducted at Browse Island

Common Name	Feb-00 G. Swann	Apr-10 This study	Nov-10 This study	Apr-11 This study	Nov-11 This study	Apr-12 This study	Nov-12 This study	Apr-13 This study	Jun-13 R. Mott	Nov-13 This study	Apr-14 This study	Nov-14 This study	Nov-15 R. Clarke
Streaked Shearwater													1
Wedge-tailed Shearwater				(1D)									
Red-tailed Tropicbird											1		
White-tailed Tropicbird								1					
Black Bittern			1							1			
Nankeen Night Heron						1	(1D)	(1D)		1			
Striated Heron										1			1
Great Egret							1						
White-faced Heron												1	
Pacific Reef Heron	47	70	85	45	60	59	79	60	41	53*	93	105	60
Great Frigatebird									1				
Lesser Frigatebird		2		2		1		4	7				
Brown Booby	1	3	1(2D)	1(1D)	3(2D)	7	2	4					
Brown Goshawk									1(1D)				
Brahminy Kite												1	
Nankeen Kestrel						3		1					
Buff-banded Rail	1	3	3	2	3	1	1	5	1	5	8	5	3
Black-winged Stilt							9						
Pacific Golden Plover	9		4	1	4	2	11	3	3	11	3	5	6
Greater Sand Plover			1	1	1								1
Oriental Plover					1		2			2			
Bar-tailed Godwit			(1D)										
Whimbrel										1			
Common Greenshank									1	1			
Wood Sandpiper										1			
Grey-tailed Tattler			1		1							1	
Common Sandpiper			1	1	2		1						1
Ruddy Turnstone	21	8	41	9	55	8	43	8	7	27	12	58	56
Sanderling													1
Red-necked Stint					2							7	1
Long-toed Stint													(1D)

Sharp-tailed Sandpiper			(1D)									1	
Red-necked Phalarope													1
Australian Pratincole									2				
Oriental Pratincole			(1D)		2					(1D)		1	
Brown Noddy		2	1	2		1(5D)			5		2		
Lesser Noddy				2									
Greater Crested Tern	34	3983	(1D)	1800*	(1D)	535	(2D)	7,225*	2420*	(11D)	4062*		1(1D)
Bridled Tern								2					
Sooty Tern	3	4				1		2	2				
Sooty/Bridled Tern													25
Parasitic Jaeger		(1D)											
Horsfield's Bronze										1			
Shining Bronze Cuckoo											1		
Oriental Cuckoo			3		1					9		1	1
Pacific Swift												4	3
Oriental Dollarbird						1							
Collared Kingfisher													1
Sacred Kingfisher		4	8(1D)	3	10	3	7(1D)	4		5	4	8	12
Rainbow Bee-eater		4	25				(1D)					1	
Black-faced Cuckoo-				1		1		1	4				
Tiger Shrike		1										1	
Island Monarch					1		1						1
Magpie Lark													3
Barn Swallow										2		1	
Tree Martin		4		1				3					
Arctic Warbler												3	1[+2]
Tawny Grassbird												1	
Asian Brown Flycatcher						1							
Dark-sided Flycatcher										1			
Blue & white Flycatcher										1			
Eastern Yellow Wagtail					2		1						
Pechora Pipit					1								

*indicates breeding activity was observed.

Discussion for Browse Island

Formal surveys at Browse Island NR demonstrate there are considerable opportunities for birds at this site (62 species have now been recorded) but very few species currently breed there. These surveys also provide the first robust baseline against which future change may be assessed. As discussed later such change may stem from processes that impact on the avifauna of the island but also from management actions that seek to restore biodiversity values at the site, especially as they relate to breeding seabirds.

Substantial reserves of guano that were exploited from 1874-1887, and historic accounts of vast numbers of seabirds, collectively indicate that Browse Island NR was once a significant seabird breeding island. The extirpation of most breeding seabirds on Browse Island coincides with the timing of guano mining and there has been little recovery in the ensuing ~120 years. With respect to recovery, the Greater Crested Tern was first detected breeding in 1978 (Abbott 1978) and surveys since 2010 have documented four further colonial breeding events. Given infrequent visits of an ornithological nature it is highly probable that additional breeding events by Greater Crested Terns have gone undetected. This remains the only seabird species to have been detected breeding since guano mining ceased.

The absence of any real recovery in seabird numbers from historic impacts at Browse Island NR stands in stark contrast to other seabird breeding islands in the region. Nearby seabird breeding islands include Adele Island and the Lacepede island group (both inshore islands) and Ashmore Island (an offshore island). All three locations have been shown to support significant numbers of seabirds in recent years. Both the considerable abundance of seabirds and the high species diversity on each of these islands in part is a reflection of recent seabird colonisation events and population recovery. This includes the establishment of Great Frigatebird and Red-footed Booby as breeding species new to waters off north-western Australia in the 1980s and 90s (Ashmore Reef CMR and Adele Island), the ongoing growth in breeding colonies of, for example, Lesser Frigatebird and Brown Booby at Ashmore Reef CMR, and recovery of seabirds on previously rat-infested Middle Island in the Lacepede Island group. Recent recovery and/or colonisation events on each of these islands demonstrates the positive influence of rat removal (both Ashmore Reef CMR and the Lacepedes) and the cessation of unsustainable take and poaching of seabirds (Ashmore Reef CMR). That seabird populations at Browse Island NR have not recovered suggests threatening processes that have prevented re-establishment remain active.

Browse Island is exposed to a number of threats that may impact on seabirds and their capacity to breed there. Direct threats include the presence of the invasive House Mouse *Mus musculus* and anecdotal evidence of low level but persistent poaching. Other possible threats include the presence of noxious weeds and the potential presence of tramp ant species (as yet unquantified). Despite their small size, the House Mouse has been shown to be a voracious predator of large seabird chicks in sub-Antarctic environments. This includes graphic evidence of House Mouse killing albatross chicks by feeding on them over extended periods. Even when not preying directly on seabirds or their eggs House Mouse may still play a role in reducing reproductive output through nocturnal disturbance to incubating and brooding seabirds. A draft eradication plan for House Mouse at Browse Island NR has been formulated (Hodgson *et al.* 2015). Browse Island NR is within a traditional use zone designated as the MOU Box-74 whereby Indonesian fishers using traditional techniques may access the region for fishing purposes. For an extended period this led to excessive take of seabirds at Ashmore Reef CMR (evidence includes prosecution of Indonesian fishers arrested with 100s of tern eggs within the reserve boundary). Although not permitted, traditional Indonesian fishers routinely land at Browse Island NR. Most survey visits in this study observed traditional perahus within sight of Browse Island, with up to 15 anchored in the lee of the island on occasion, with these observations coinciding with evidence of nesting turtles being poached (dead adult female green turtles, ashore and on their backs, with clear cut marks around the edge of the plastron to access eggs or meat (n = 4 of 13 landings), large numbers of human footprints (bare feet) above the tideline at times when perahus were anchored offshore (n = x of 13 landings) and direct observations of Indonesian fishers free diving within the reserve boundary in contravention of the reserve rules. The presence of both rodents and frequent but low level poaching likely interact to prevent additional seabirds from colonising. Crested Terns may be less sensitive to these threats as they preferentially nest on exposed areas of sand which are likely to support only low densities of House Mouse. Further, colonies of more than 5,000 can form within a relatively short period, with egg lay being largely synchronised followed by rapid chick development and fledging meaning that the exposure window to potential poaching is relatively short. Further assessment and quantification of these threats (especially a weed assessment and thorough survey for tramp ants) and removal of known threats would provide further opportunity for additional species of seabird to recolonise Browse Island.

In the event that key threatening processes are clearly identified and can be mitigated, it seems likely that additional species of seabird will recolonise Browse Island without further management intervention. Other actions such as assisted colonisation of some key seabird species may further expedite this process.

REPORT CONCLUSIONS

Data summaries, population trajectories, statistical results, discussion and conclusions as they relate to seabirds and shorebirds are presented individually for Ashmore Reef CMR, Cartier Island CMR and Browse Island NR in the body of this report. Here we summarise the broader outcomes of the study as they relate to the study objectives.

1) *Concatenate the results of a targeted five year post-impact monitoring program for breeding seabirds and migratory shorebirds within the Reserves*

During the post-impact monitoring period, 15 species of seabird were confirmed breeding at Ashmore Reef CMR, and numbers of breeding seabirds were shown to exceed 100,000 individuals during a single year. Up to 33 migratory shorebirds species in excess of 10,000 individuals also used Ashmore Reef CMR during this same period. Previous assessments have concluded Ashmore Reef CMR supports internationally-significant numbers of seabirds and shorebirds (Birdlife International 2010). Monitoring in the period 2010-2014 demonstrates that Ashmore Reef CMR continues to support seabird and shorebird populations of international significance. Small numbers of seabirds and shorebirds frequented Cartier Island CMR and Browse Island NR; from an avian perspective neither of these sites meets the criteria for international significance.

The results of the five-year avian monitoring program make a substantial contribution to the available baseline data for Ashmore Reef CMR, Cartier Island CMR and Browse Island NR. These data provide opportunity to assess potential future impacts and the efficacy of future management actions.

2) *Interrogate the results of this post-impact monitoring against existing data on seabird and shorebird numbers established by Clarke (2010) as they relate to terrestrial environments at Ashmore Reef CMR, Cartier Island CMR and Browse Island NR*

The total number of seabirds breeding at Ashmore Reef CMR increased after the Montara Oil Spill event when compared to pre-impact data. This trend also applied to breeding populations of individual seabird species. Declines in non-breeding seabirds post-impact during the period Oct-Dec were detected and some of these declines met the *a priori* definition of significant impact. However, as breeding populations were shown to increase during the same five-year period, these declines within the non-breeding season likely reflect variability in seasonal response rather than evidence for impact arising from the Montara Oil Spill. As a Before-After-Control-Impact design was not possible for seabirds (owing to the absence of a suitable seabird control site) change-point analyses were conducted to assess seabird population trajectories for inflection points that may be associated with impact. These analyses revealed there were no well-supported negative change points associated with the 2009 Montara Oil Spill.

Population trajectories of migratory shorebirds that occur at Ashmore Reef CMR were compared with those from Eighty-mile Beach, WA using a Before-After-Control-Impact design. Numbers of shorebirds at Ashmore Reef CMR declined significantly, comparing populations before and after the Montara Oil Spill. This response was not unexpected given ongoing declines of migratory shorebirds throughout the flyway (Clemens et al. 2015). Although the Ashmore Reef CMR population decline was greater than that documented for the control site the difference was not significant and no significant impact as a result of the Montara Oil Spill was detected. There were however some species-specific responses where the decline was significantly greater at Ashmore Reef CMR than the control site. Whilst it is possible that the Montara Well release contributed to these declines there is not the capacity to conclude this from the available data.

3) *Determine if population trajectories for targeted seabird and shorebird species that occur within the Reserves exceeded thresholds that would identify significant impact*

Whilst the Montara Oil Spill was known to extend to marine waters in proximity to Ashmore Reef CMR, Cartier Island CMR and Browse Island NR, and small numbers of dead seabirds were detected during the spill event, this study did not detect evidence that seabird or shorebird populations at these sites suffered *significant impact* as a result of the oil spill event.

4) *Make recommendations regarding appropriate baseline data requirements with respect to potential incidents in the future.*

All data relating to seabirds and shorebirds at Ashmore Reef CMR, Cartier Island CMR and Browse Island NR have now been collated within a single database, analysed and summarised in this report. In addition to the standard monitoring protocol for seabirds and shorebirds that was established in 2010 and maintained as twice annual surveys to the end of 2014 (five years), there also exists substantial count data collected by the Study Team, Federal Parks Australia staff and other interested parties prior to 2010. It can be demonstrated that large population changes, notably population increases for many seabirds and declines of many shorebirds, have occurred in the period ~1980 to 2014. A five year monitoring program with twice annual surveys timed to coincide with peaks in breeding activity for seabirds and stability in non-breeding flocks of migratory shorebirds has provided adequate opportunity to assess impact following the Montara Oil Spill. In this context it should be recognised that the potential for existing data to serve as baseline data for the purposes of assessing efficacy of management actions or future impacts would be greatly enhanced if robust periodic additions were made to this baseline data, in order to ensure currency is maintained. In view of this it is recommended that efforts be made to survey the seabirds and shorebirds at Ashmore Reef CMR at intervals no greater than once every five years.

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Appendix 1 – Vertebrate species mentioned in report

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 1 (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 2 – EASTERN REEF EGRET COUNTS, ASHMORE REEF CMR

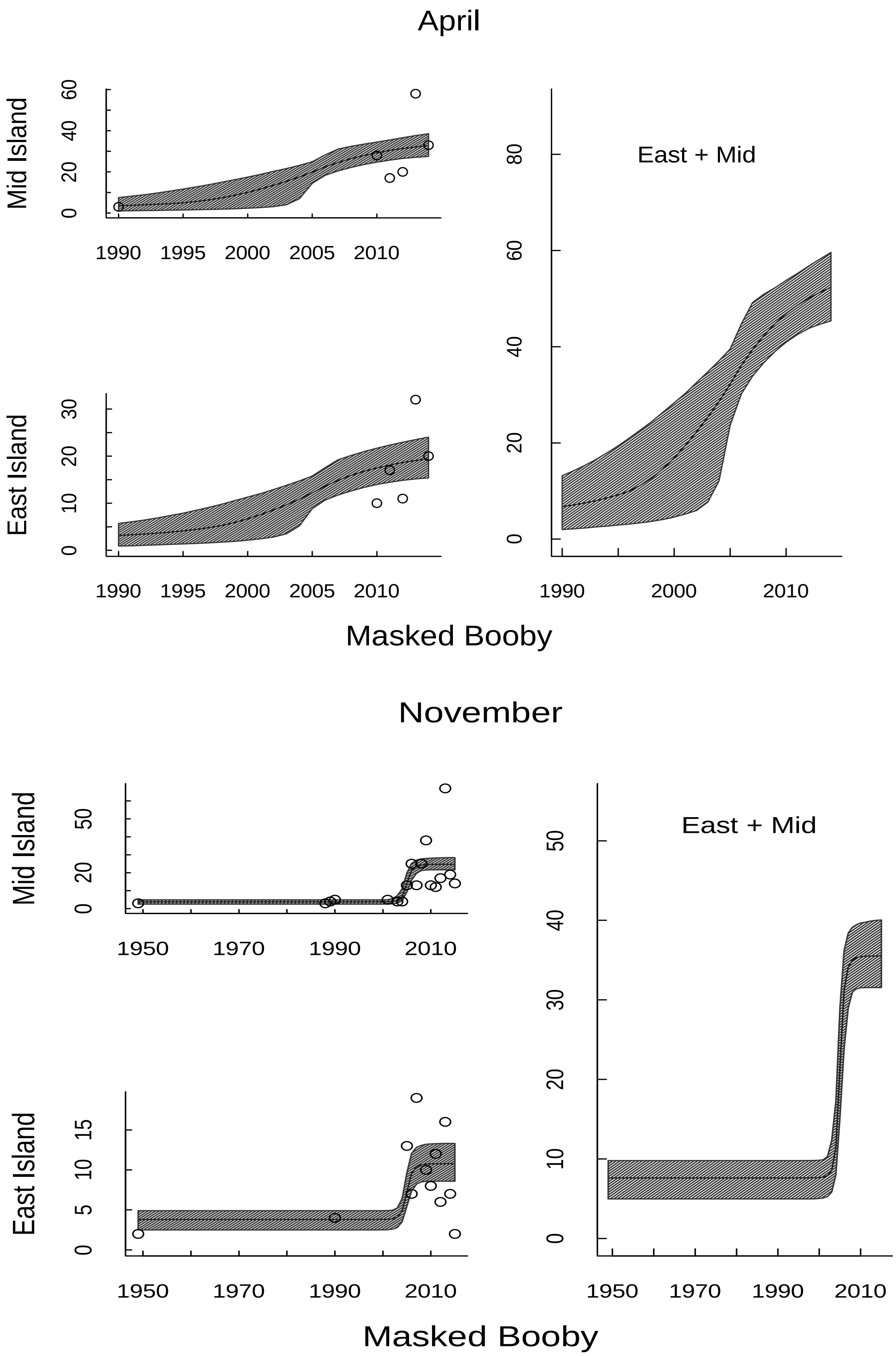
Count of Eastern Reef Egrets on West Island, Ashmore Reef during 25 visits between October 1998 and November 2014. In instances where several counts were made over consecutive days the highest count from that period is presented.

	Pacific Reef Heron	
survey	Count of adults	Active nests?
Oct-98	None reported	-
Oct-00	100	Yes
Oct-01	300	Yes
Nov-01	300	Yes
Jan-02	191	Yes
Feb-03	150	Yes
Sep-03	200	Yes
Oct-04	400	Yes
Nov-04	?	Yes
Jan-05	400	Yes
Oct-05	200	Yes
Oct-06	500	Yes
Oct-07	300	Yes
Oct-08	700	Yes
Oct-09	400	Yes
Apr-10	250	No
Nov-10	1,146	Yes
Apr-11	756	No
Nov-11	779	Yes
Apr-12	961	No
Nov-12	940	No
Apr-13	972	No
Nov-13	1,002	Yes
Apr-14	791	No
Nov-14	1,343	Yes

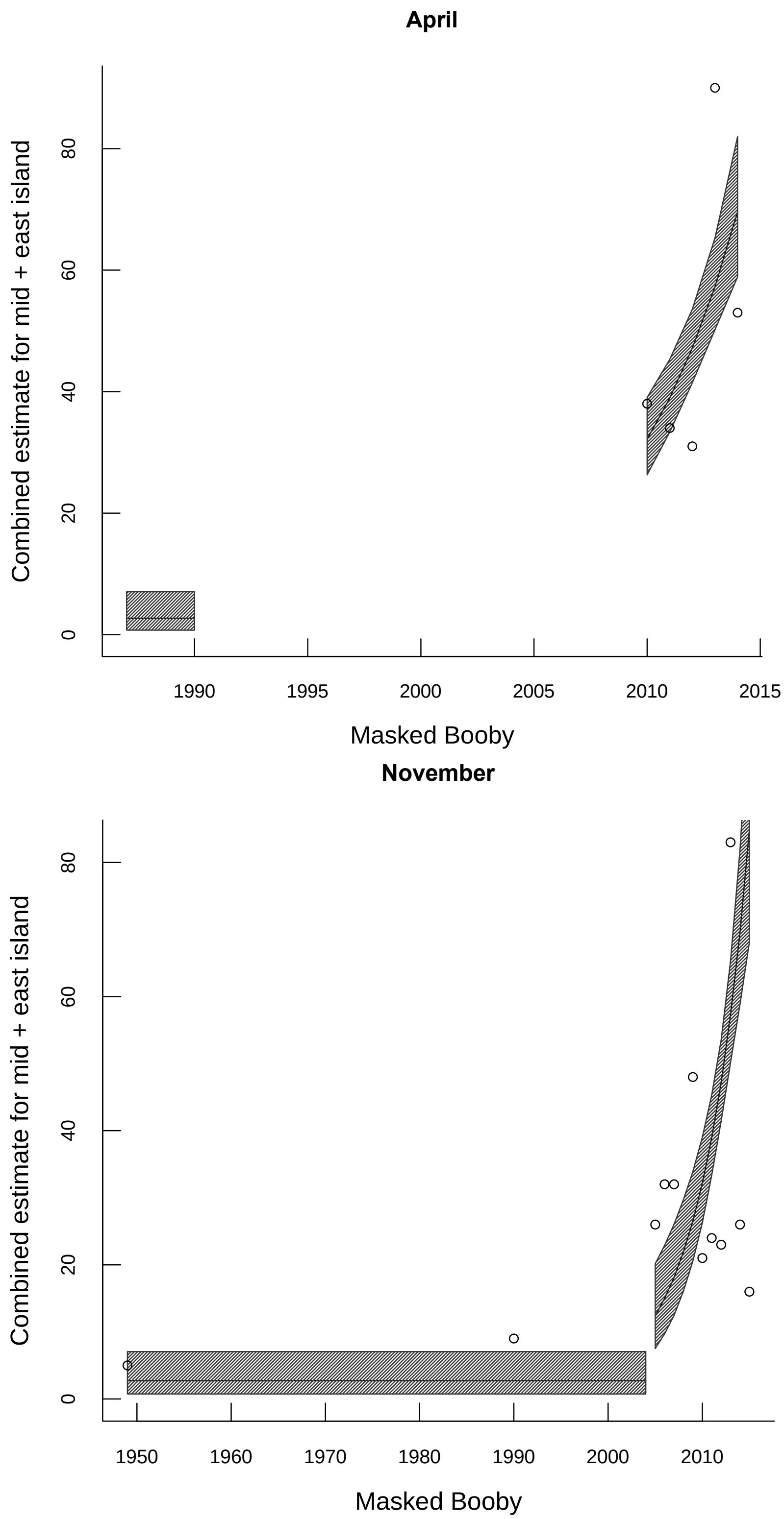
Sources: Study team unpublished data, Swann (2005a), Swann (2005b), Swann (2005c), Milton (2005), this study.

APPENDIX 3 – MODEL OUTPUTS FOR BAYESIAN CHANGE POINT ANALYSIS

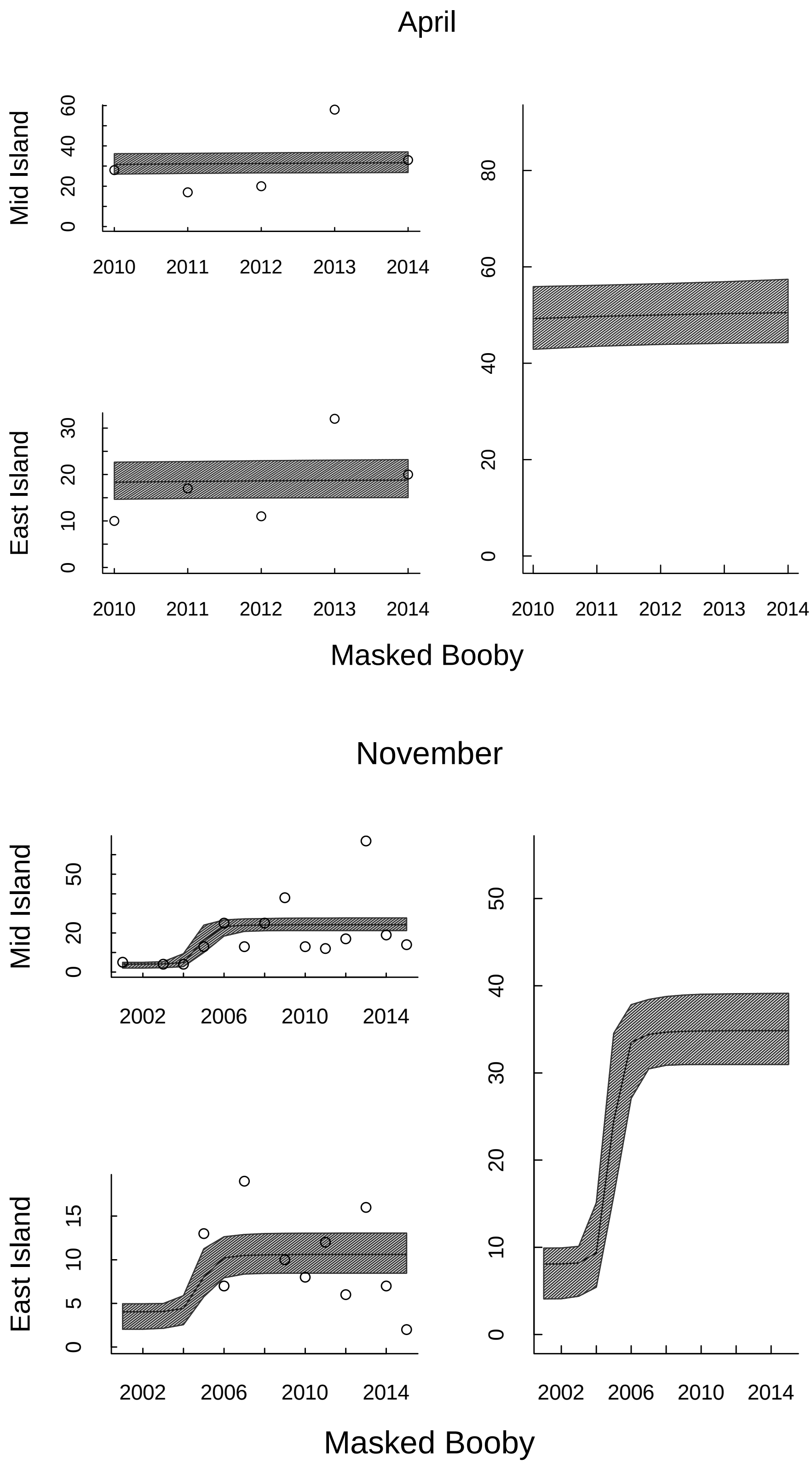
Masked Booby



A3-Figure 1 Hill function of Masked Booby counts across all years of available data at Middle Is., East Is., and the two islands combined for April surveys (top) and November surveys (bottom).

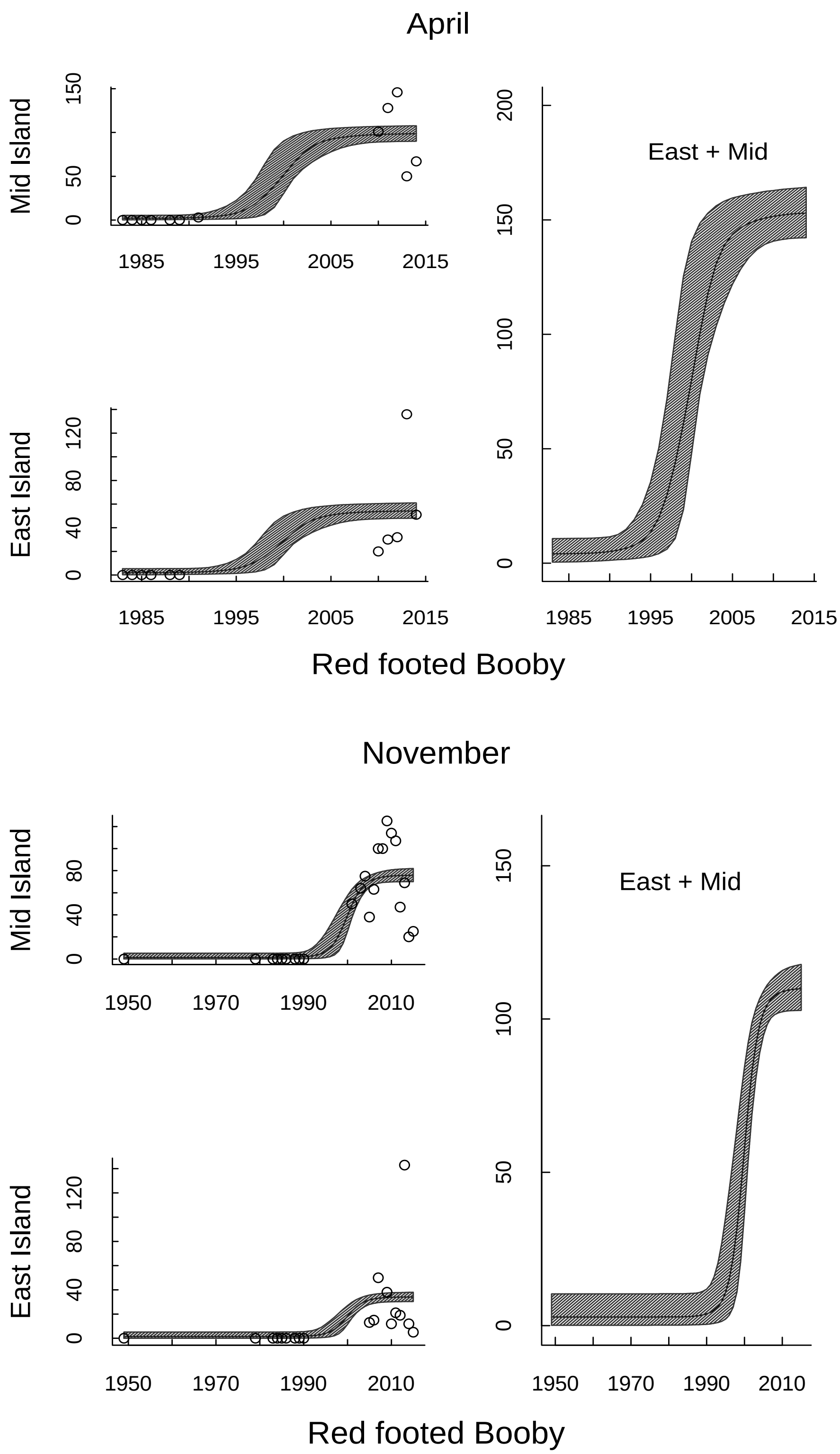


A3-Figure 2 Change point analysis of Masked Booby counts across all years using a combined estimate for Middle Is. and East Is. for April surveys (top) and November surveys (bottom).

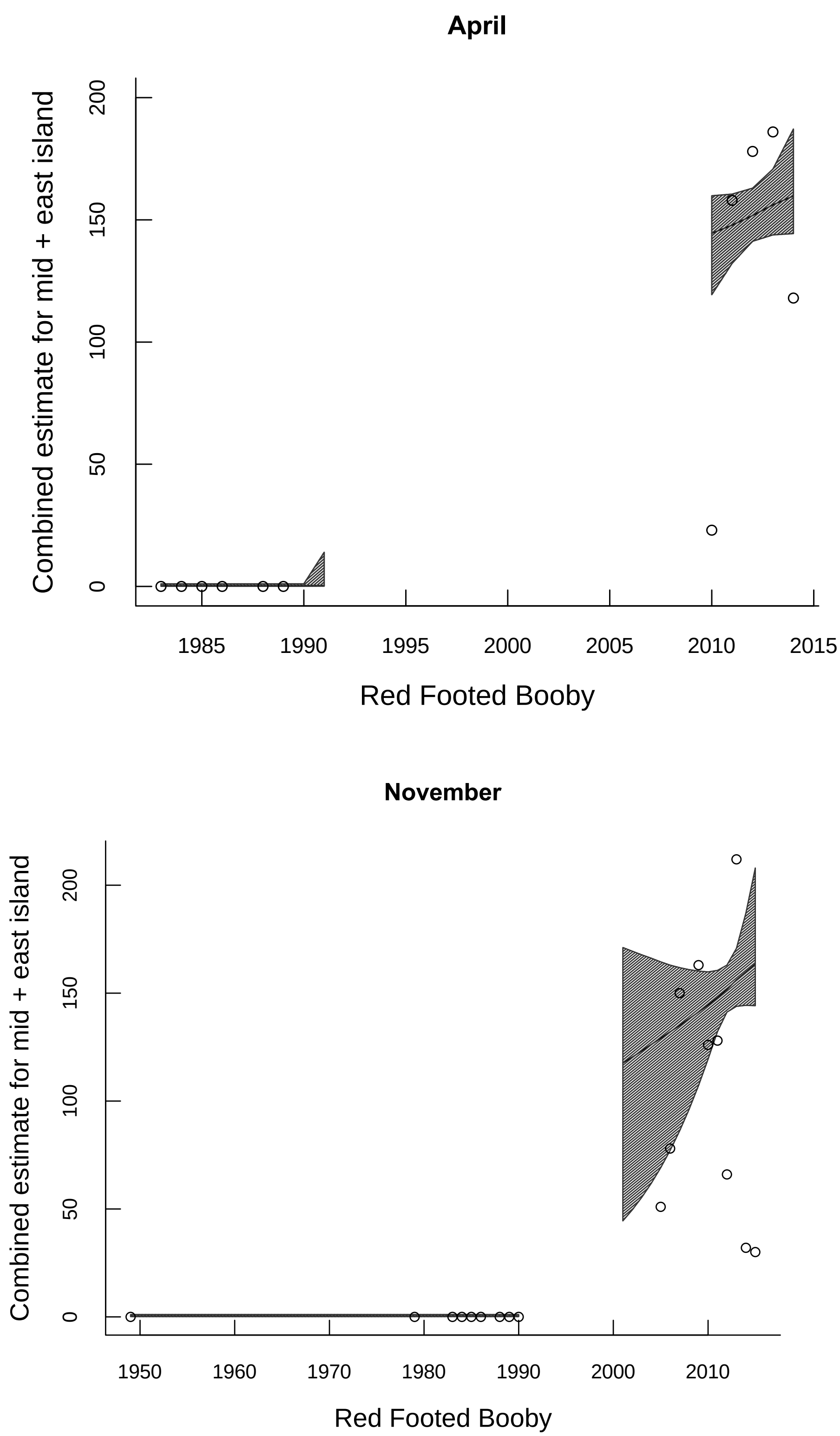


A3-Figure 3 Hill function of Masked Booby counts for all available data since 2002 at Middle Is., East Is., and the two islands combined for April surveys (2010-2015) (top) and November surveys (2002-2015) (bottom).

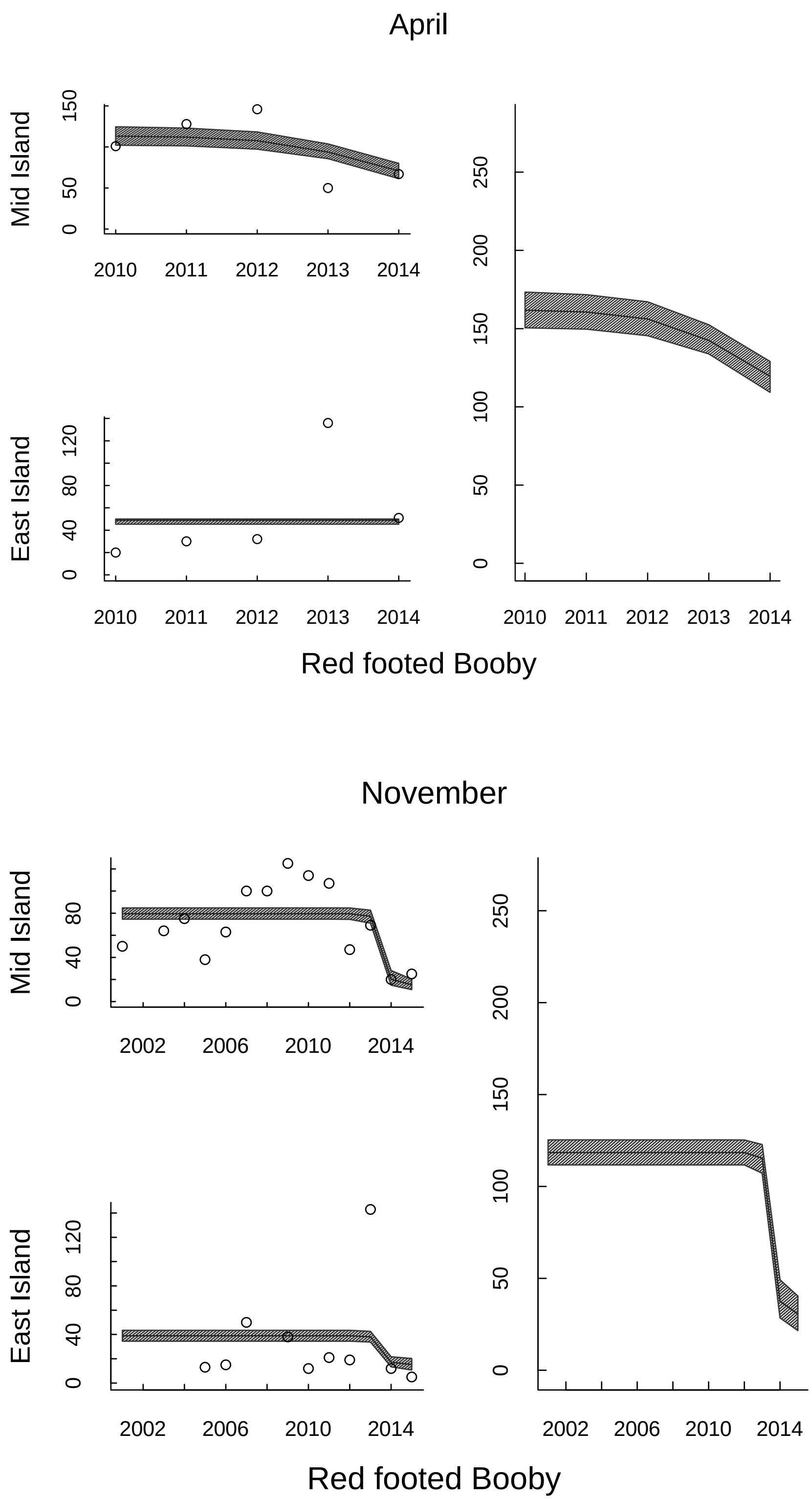
Red-footed Booby



A3-Figure 4 Hill function of Red-footed Booby counts across all years of available data at Middle Is., East Is., and the two islands combined for April surveys (top) and November surveys (bottom).

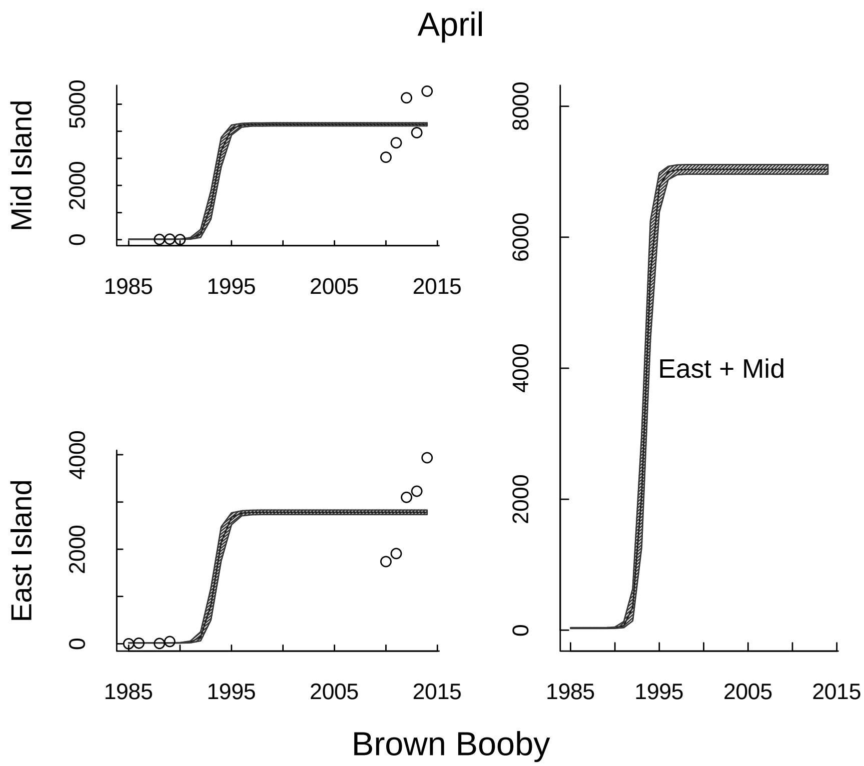


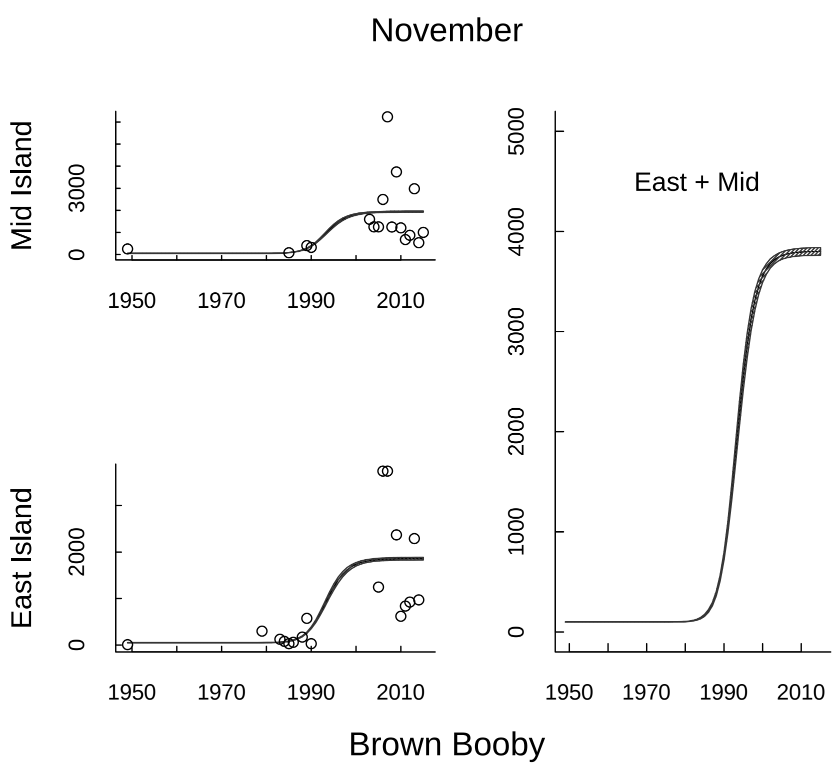
A3-Figure 5 Change point analysis of Red-footed Booby counts across all years using a combined estimate for Middle Is. and East Is. for April surveys (top) and November surveys (bottom).



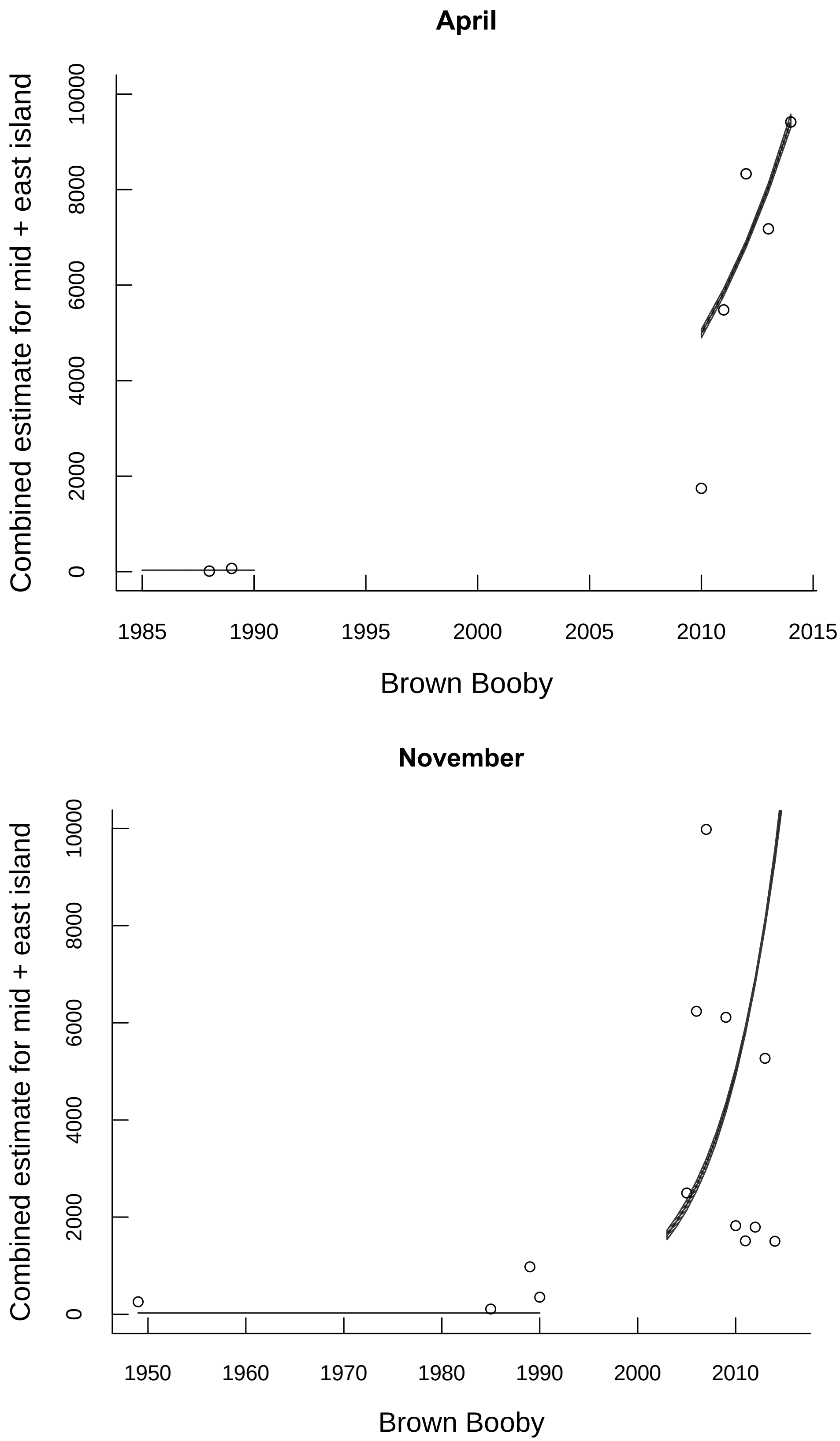
A3-Figure 6 Hill function of Red-footed Booby counts for all available data since 2002 at Middle Is., East Is., and the two islands combined for April surveys (2010-2015) (top) and November surveys (2002-2015) (bottom).

Brown Booby

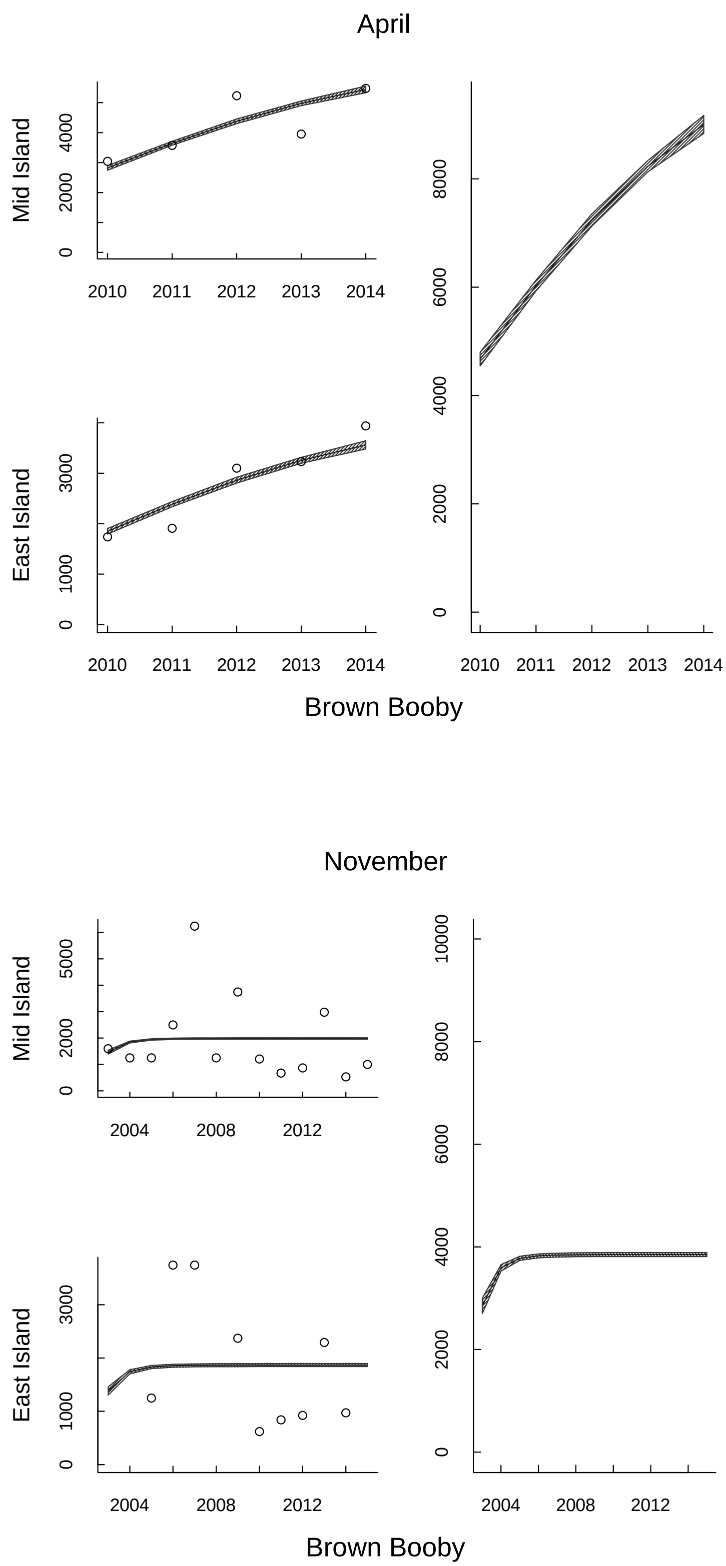




A3-Figure 7 Hill function of Brown Booby counts across all years of available data at Middle Is., East Is., and the two islands combined for April surveys (top) and November surveys (bottom).

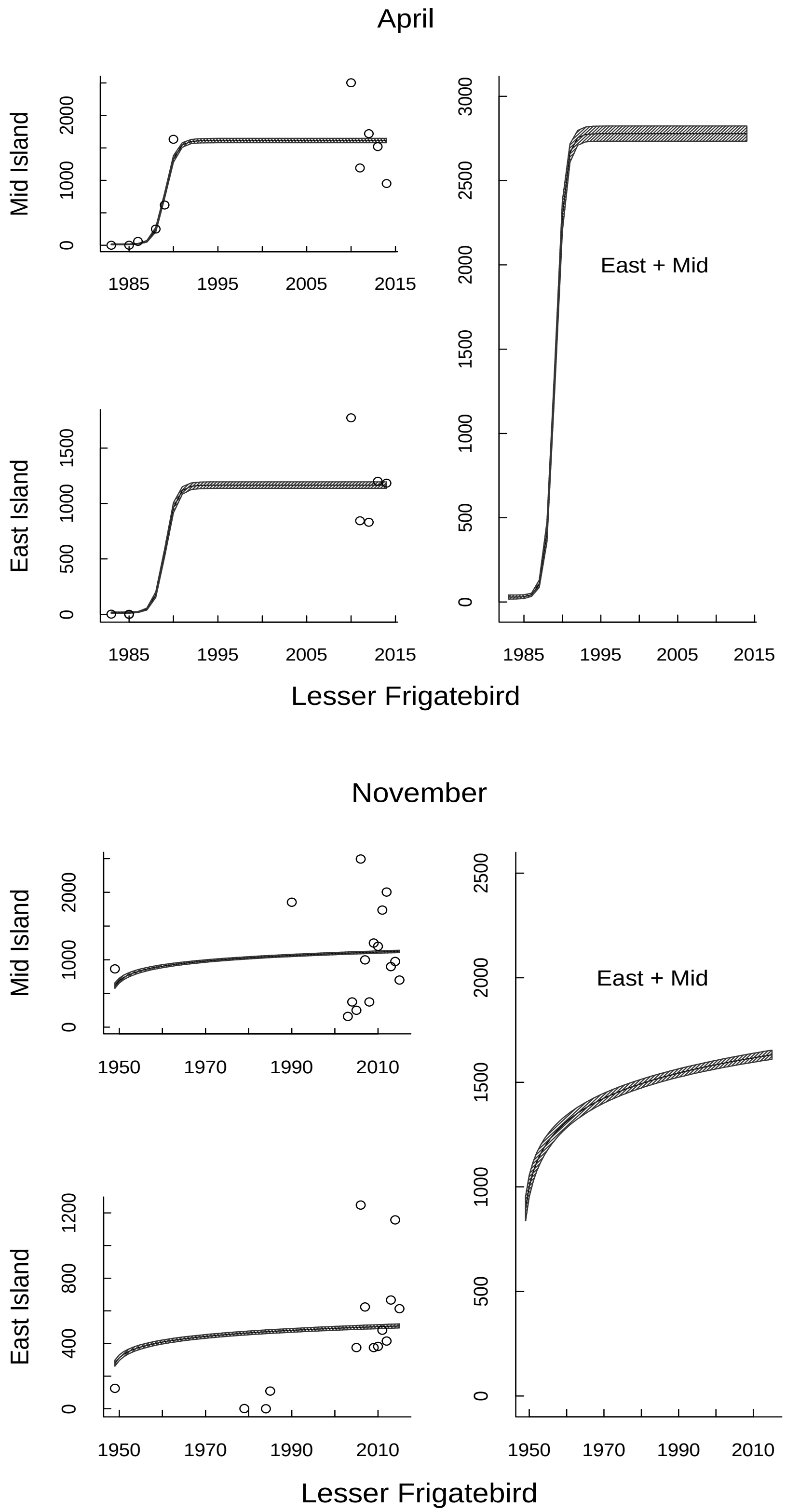


A3-Figure 8 Change point analysis of Brown Booby counts across all years using a combined estimate for Middle Is. and East Is. for April surveys (top) and November surveys (bottom).

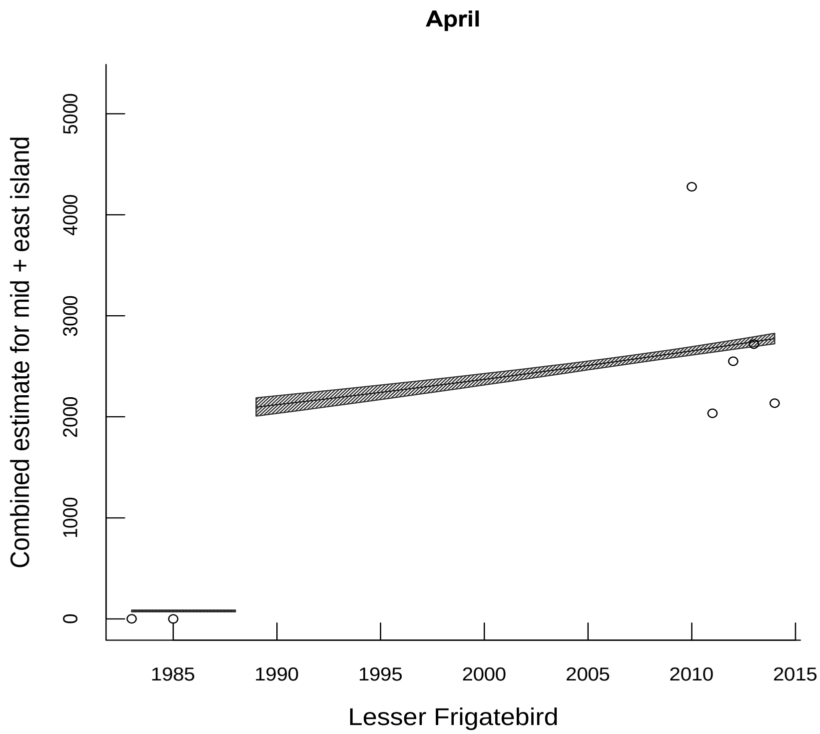


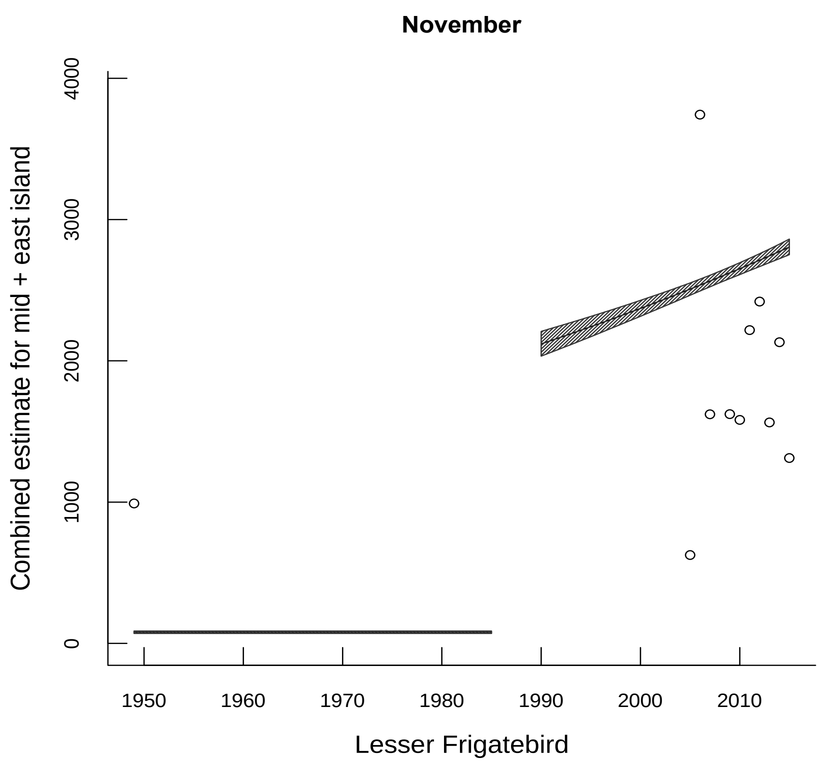
A3-Figure 9 Hill function of Brown Booby counts for all available data since 2002 at Middle Is., East Is., and the two islands combined for April surveys (2010-2015) (top) and November surveys (2002-2015) (bottom).

Lesser Frigatebird

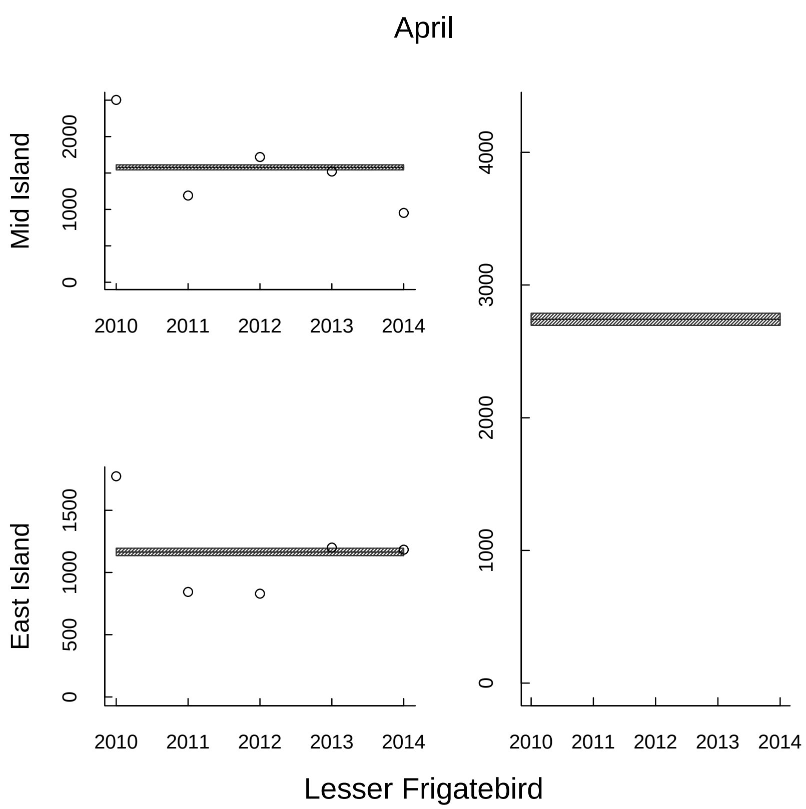


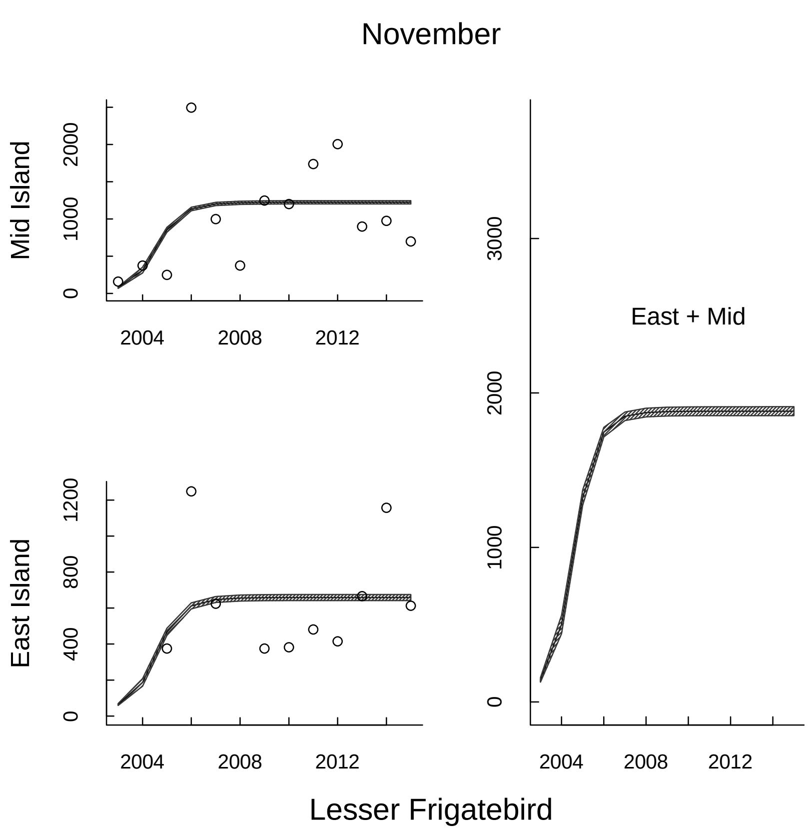
A3-Figure 10 Hill function of Lesser Frigatebird counts across all years of available data at Middle Is., East Is., and the two islands combined for April surveys (top) and November surveys (bottom).





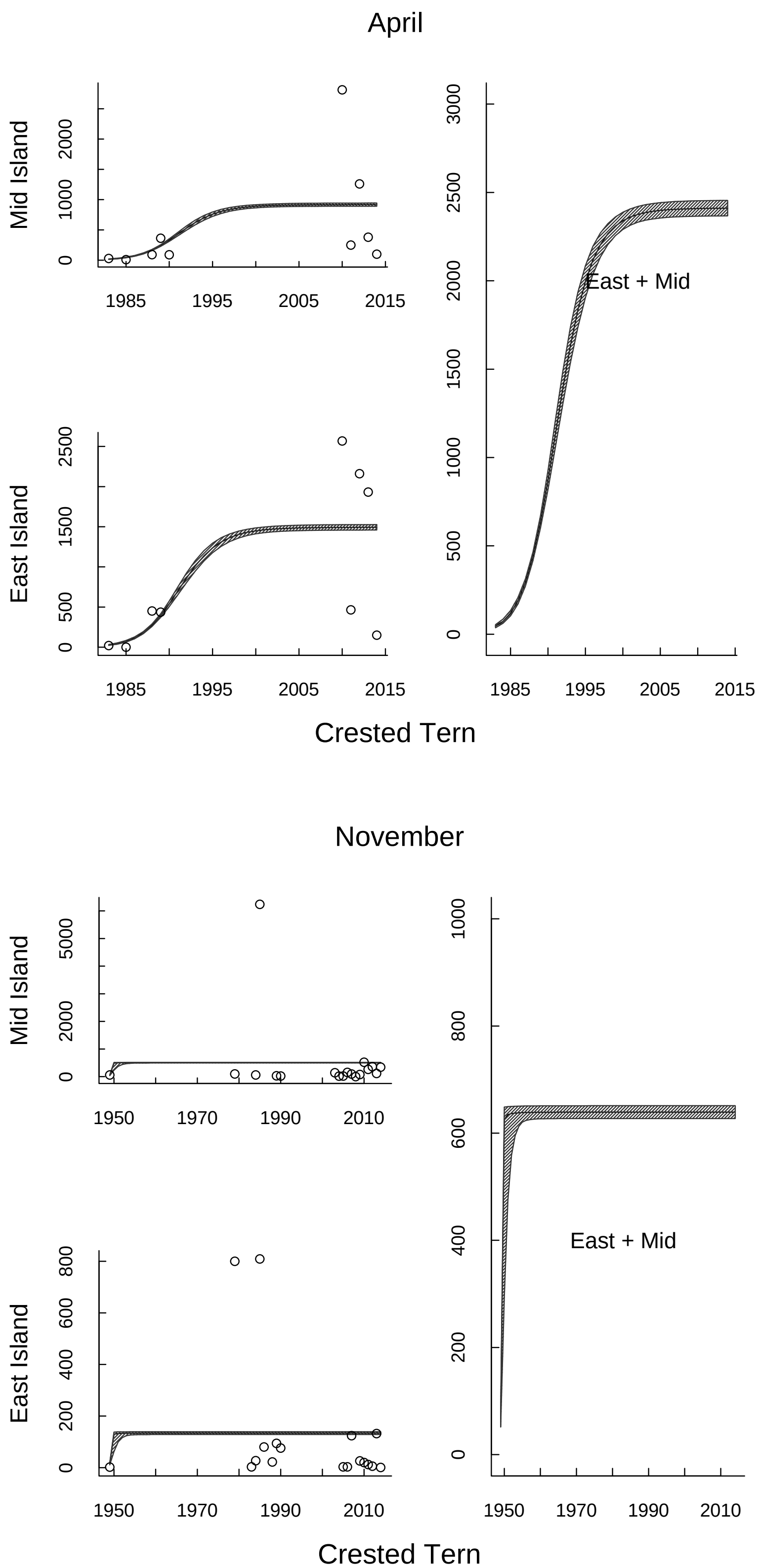
A3-Figure 11 Change point analysis of Lesser Frigatebird counts across all years using a combined estimate for Middle Is. and East Is. for April surveys (top) and November surveys (bottom).



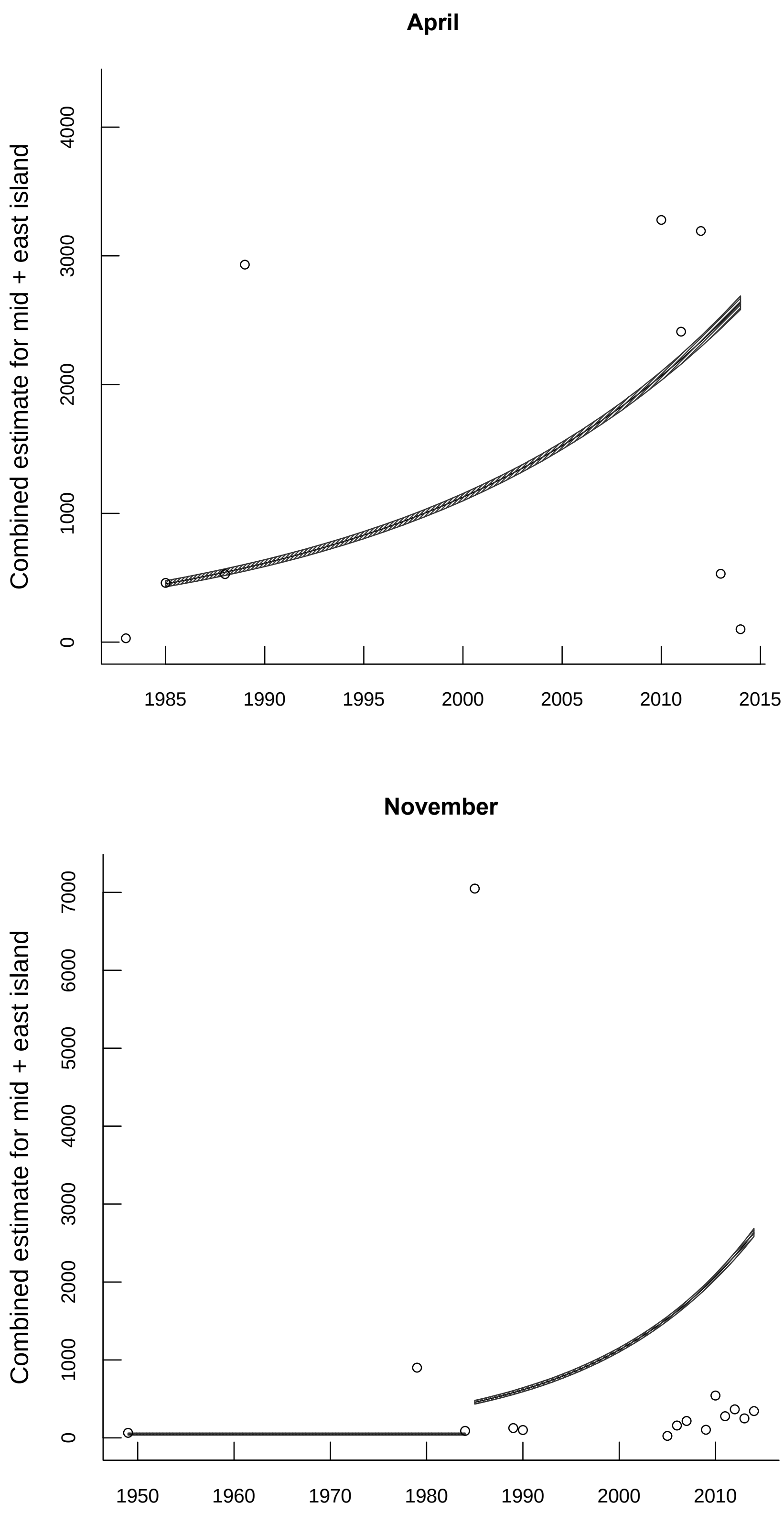


A3-Figure 12 Hill function of Lesser Frigatebird counts for all available data since 2002 at Middle Is., East Is., and the two islands combined for April surveys (2010-2015) (top) and November surveys (2002-2015) (bottom).

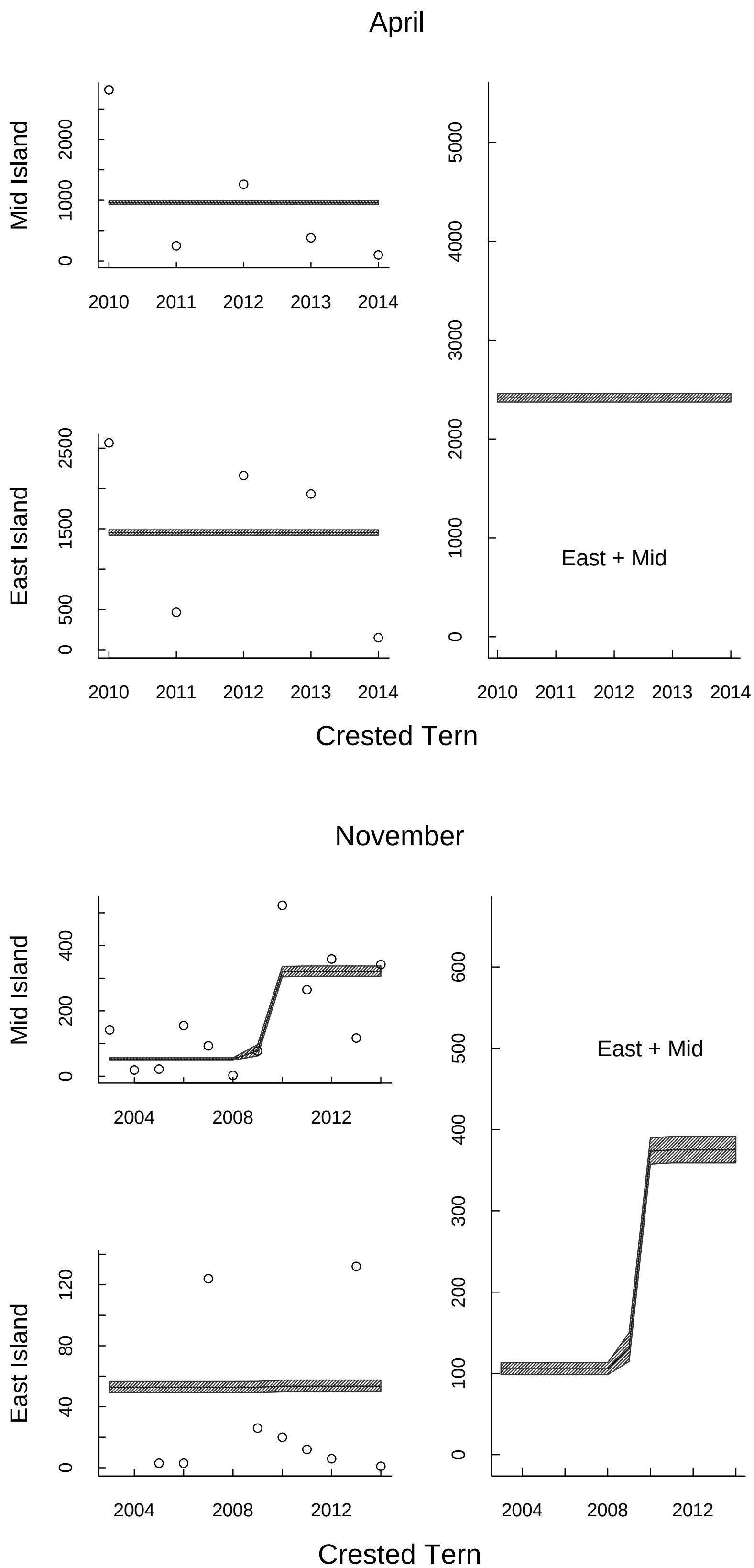
Crested Tern



A3-Figure 13 Hill function of Crested Tern counts across all years of available data at Middle Is., East Is., and the two islands combined for April surveys (top) and November surveys (bottom).

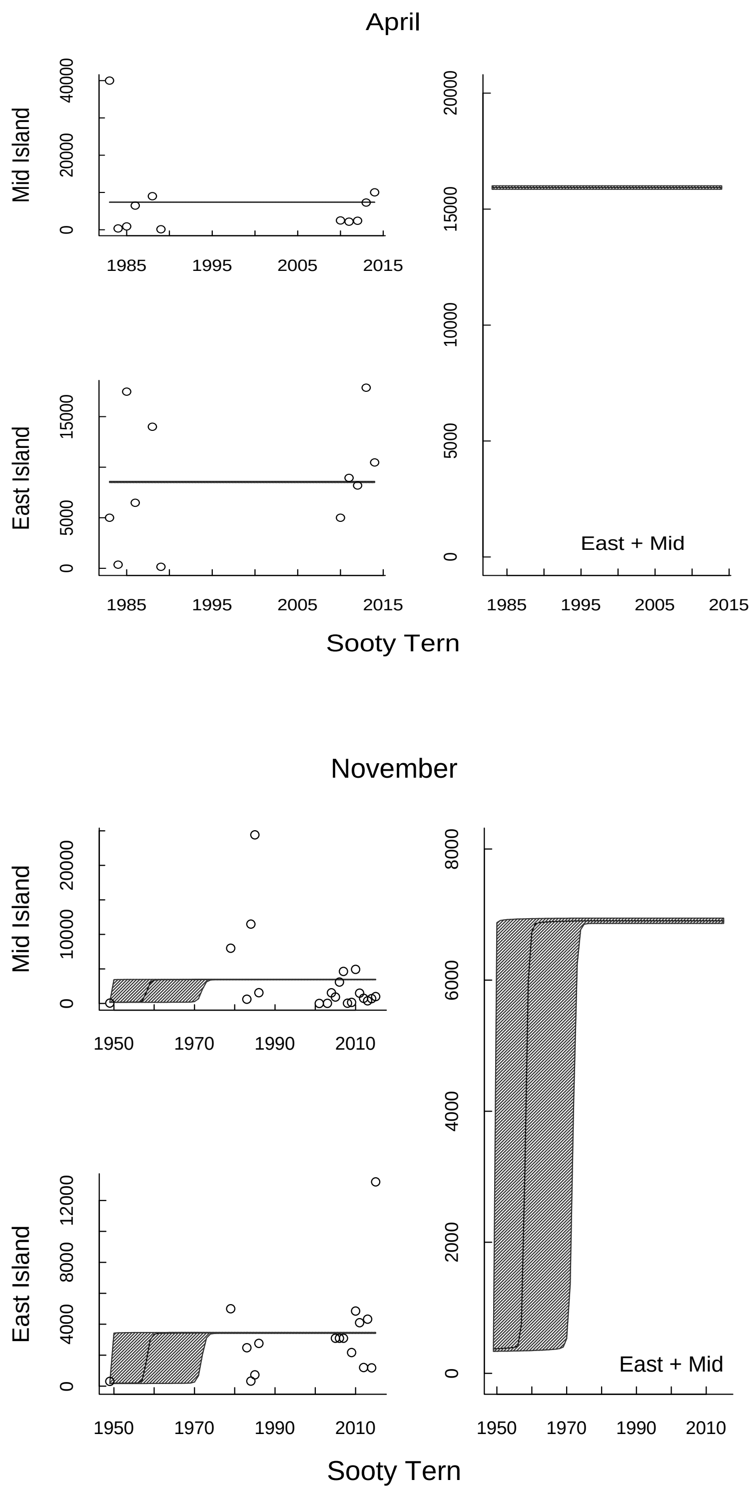


A3-Figure 13 Change point analysis of Crested Tern counts across all years using a combined estimate for Middle Is. and East Is. for April surveys (top) and November surveys (bottom).

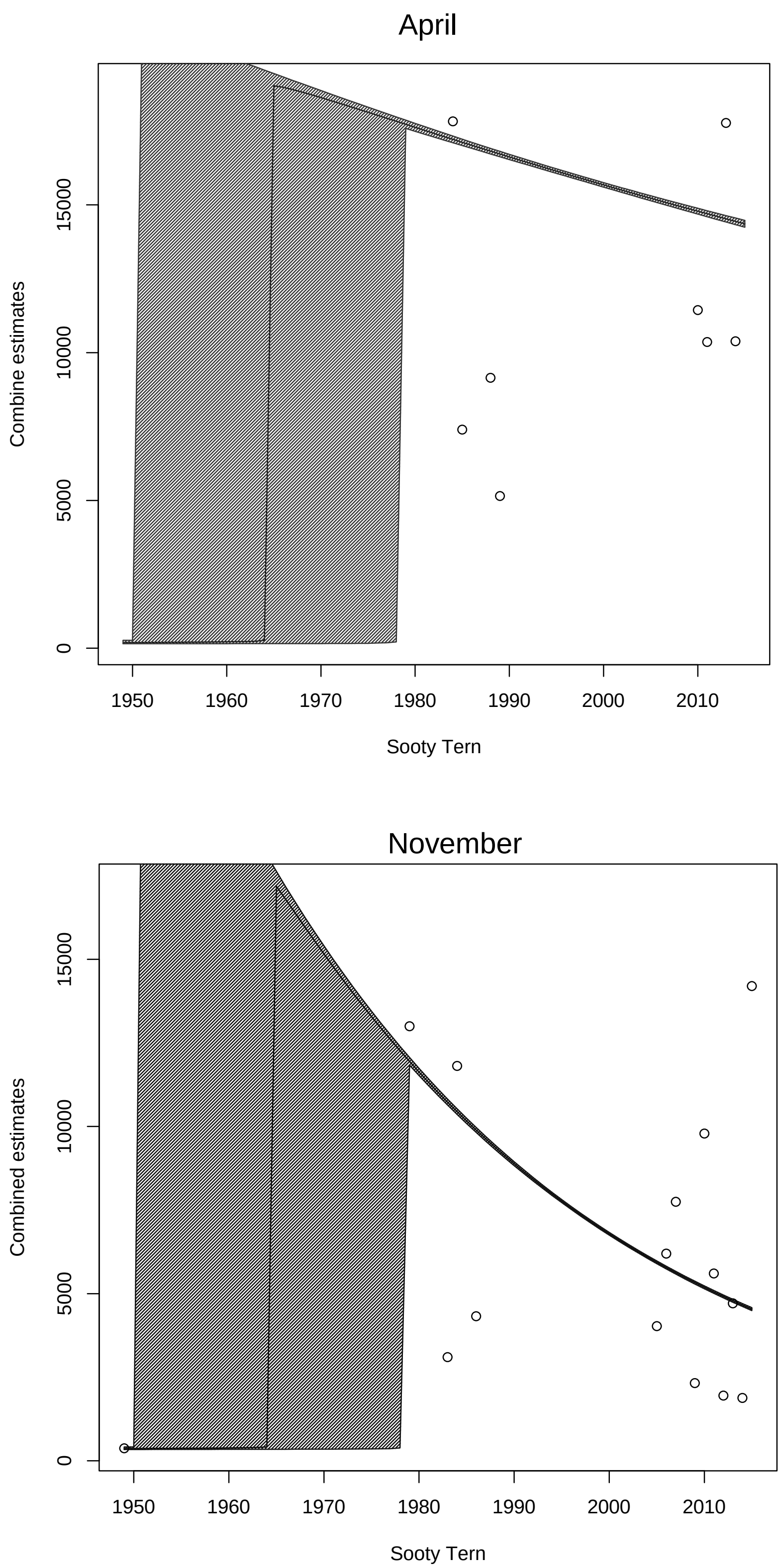


A3-Figure 14 Hill function of Crested Tern counts for all available data since 2002 at Middle Is., East Is., and the two islands combined for April surveys (2010-2015) (top) and November surveys (2002-2015) (bottom).

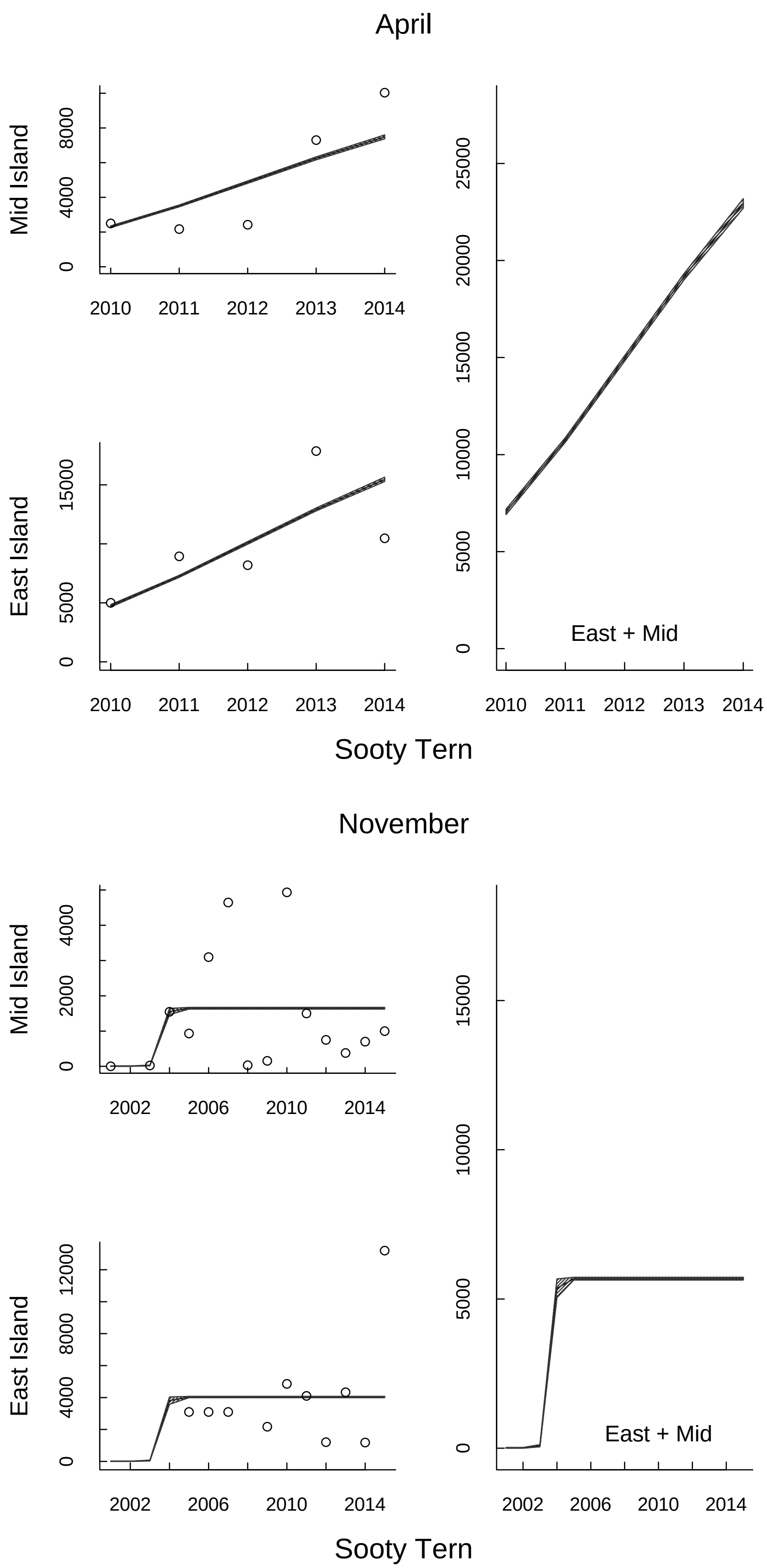
Sooty Tern



A3-Figure 15 Hill function of Sooty Tern counts across all years of available data at Middle Is., East Is., and the two islands combined for April surveys (top) and November surveys (bottom).

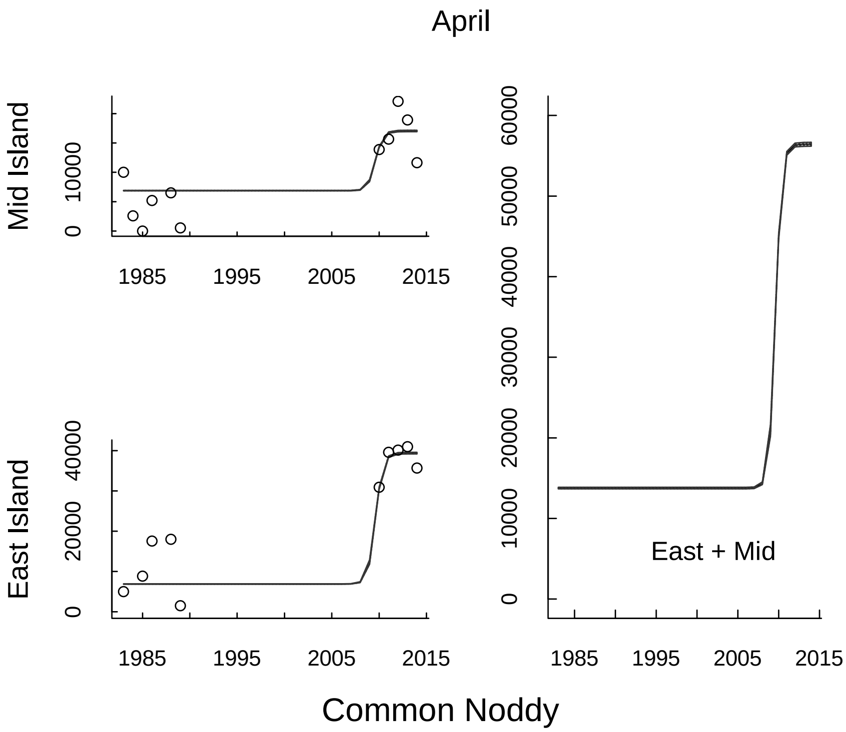


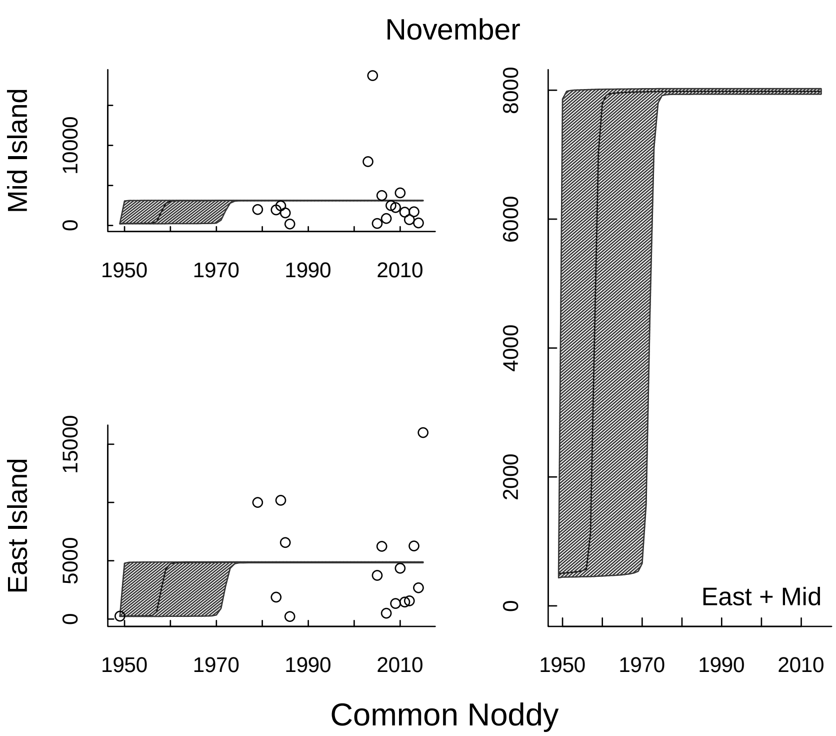
A3-Figure 16 Change point analysis of Sooty Tern counts across all years using a combined estimate for Middle Is. and East Is. for April surveys (top) and November surveys (bottom).



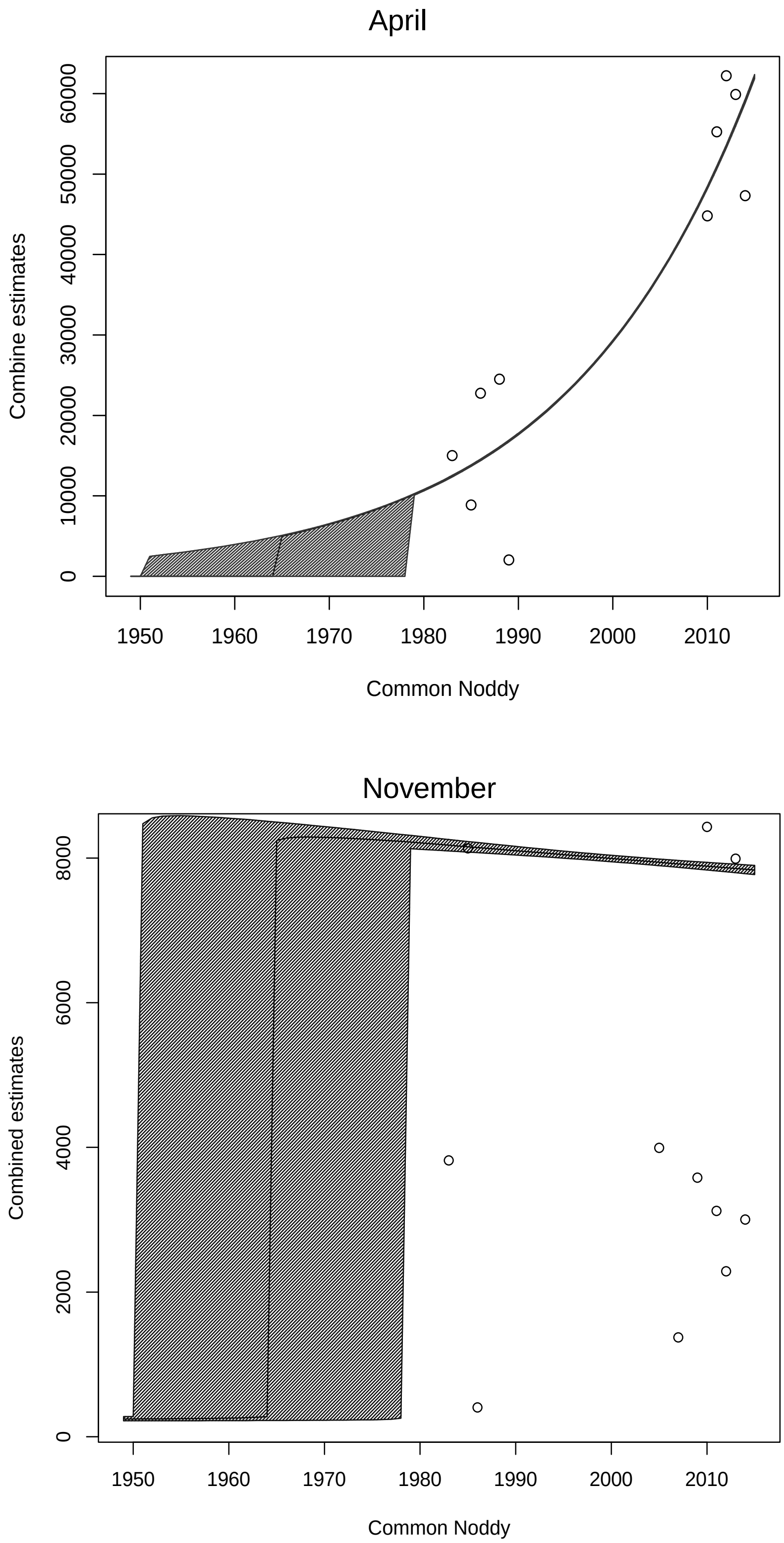
A3-Figure 17 Hill function of Sooty Tern counts for all available data since 2002 at Middle Is., East Is., and the two islands combined for April surveys (2010-2015) (top) and November surveys (2002-2015) (bottom).

Common Noddy

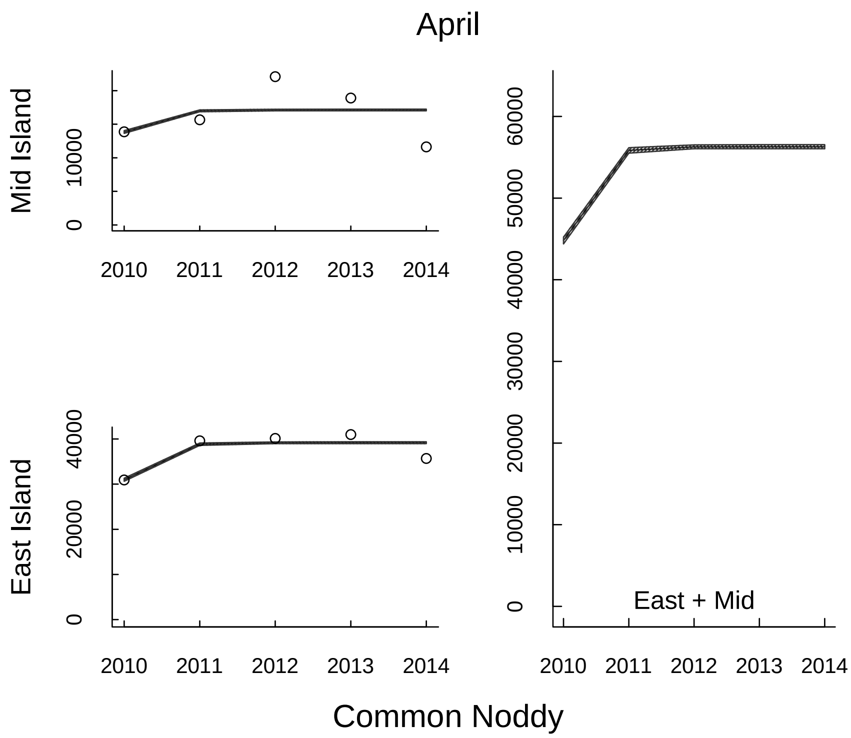


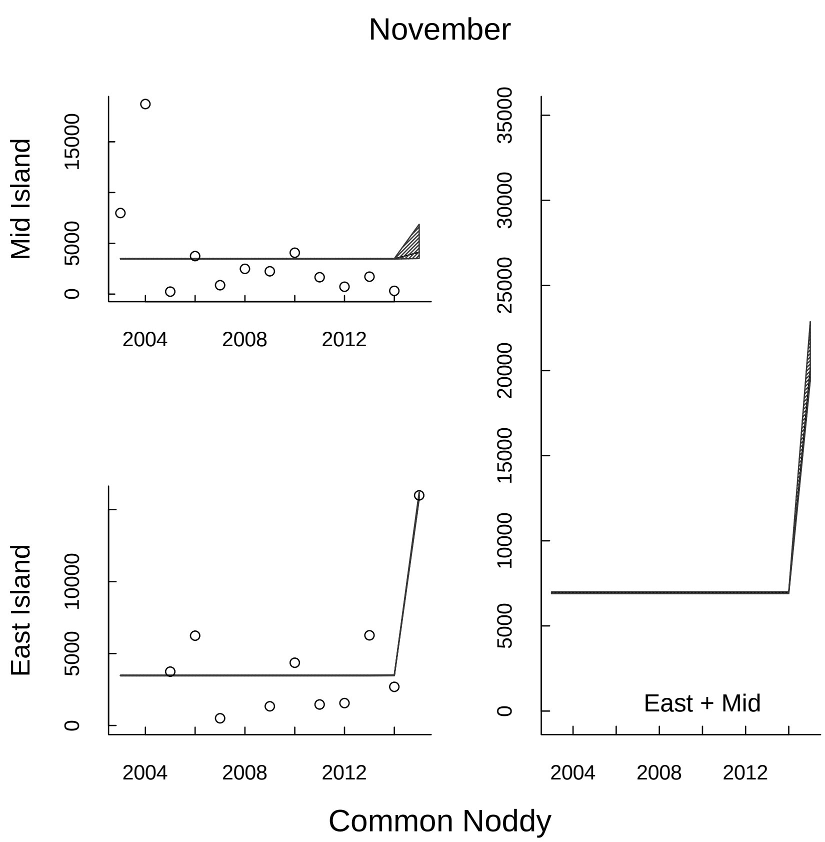


A3-Figure 18 Hill function of Common Noddy counts across all years of available data at Middle Is., East Is., and the two islands combined for April surveys (top) and November surveys (bottom).



A3-Figure 19 Change point analysis of Common Noddy counts across all years using a combined estimate for Middle Is. and East Is. for April surveys (top) and November surveys (bottom).





A3-Figure 20 Hill function of Common Noddy counts for all available data since 2002 at Middle Is., East Is., and the two islands combined for April surveys (2010-2015) (top) and November surveys (2002-2015) (bottom).