Vertebrate Fauna: a Survey of Australia's Oldest National Park and Adjoining Reserves

Martin Schulz[1] and Elizabeth Magarey[2]

[1]34 Wilford Street, Corrimal NSW 2518; [2]Office of Environment and Heritage, PO Box 1967, Hurstville NSW 1482 (Elizabeth.Magarey@environment.nsw.gov.au)

Published on 3 September 2012 at http://escholarship.library.usyd.edu.au/journals/index.php/LIN

Schulz, M. and Magarey, E. (2012). Vertebrate fauna: a survey of Australia's oldest national park and adjoining reserves. *Proceedings of the Linnean Society of New South Wales* **134**, B215-B247.

This study compiles an inventory of amphibians, reptiles, birds and mammals in Royal National Park, Garawarra State Conservation Area and Heathcote National Park. It investigates patterns of species occurrence and puts the results into a regional context. Systematic and targeted field surveys were undertaken and previously existing data were reviewed. The surveys detected 283 species. This high species richness can be attributed to the diversity of habitats present. The Rainforests and Heathlands vegetation formations each support a distinct suite of fauna, while many species only occur on the ocean and/or estuarine shoreline. Rainforests and Heathlands have a restricted distribution in the Sydney basin, and in that context the reserves support large numbers of heath-dependant fauna species. The reserves also have relatively high numbers of at least five threatened species. The field surveys detected seven species not previously documented, including Australasian bittern (*Botaurus poiciloptilus*) and eastern grass owl (*Tyto longimembris*). Also notable is the discovery of roosts of eastern horseshoe-bat (*Rhinolophus megaphyllus*) and little bent-wing-bat (*Miniopterus australis*). However, many species previously known from the reserves could not be found, such as ground parrot (*Pezoporus wallicus*), green and golden bell frog (*Litoria aurea*), parma wallaby (*Macropus parma*) and platypus (*Ornithorhynchus anatinus*).

Manuscript received 26 July 2012, accepted for publication 14 August 2012.

KEYWORDS: Garawarra State Conservation Area, Heathcote National Park, management, Royal National Park, species loss, systematic survey, targeted survey, threatened species, vegetation formation.

INTRODUCTION

Information that describes the type, distribution and status of biodiversity in NSW is required for regulation, conservation assessment and land management. In the Sydney Basin Bioregion over 60 per cent of extant native vegetation occurs in Office of Environment and Heritage (OEH) reserves. OEH is working towards generating comprehensive information on flora and vertebrate fauna across all reserves in this region, irrespective of size and location, and ensuring that biodiversity data is collected in a strategic and systematic way. The current study in Royal National Park (NP) and the adjoining Garawarra State Conservation Area (SCA) and Heathcote NP is part of this biodiversity data acquisition program.

Royal NP, proclaimed in 1879, was the first national park gazetted in Australia (NPWS 2000a). Garawarra SCA was dedicated in 1934 as a primitive wilderness and Heathcote NP was gazetted in 1943 as a primitive area; the primary objective of both reserves was the retention of natural conditions (NPWS 2000a). From the early days of Royal NP the Trustees determined to "effectively preserve the flora and fauna committed to their care" thus making it an offence to "discharge firearms or interfere in any way with the birds and animals in the Park" (Trustees 1915). Yet despite the perceived importance of the fauna the vertebrate species present at or prior to the gazettal of the reserves has been little documented, with the exception of isolated accounts of single visits (Cayley 1923) or as part of past regional assessments (Robinson 1987, 1988).

More recent accounts of bird, mammal, reptile and amphibian species exist in several forms. Current avifauna within the three reserves has been summarised by Anyon-Smith (2006). Fauna records are reported in various reports as components of larger studies (such as the nationwide Atlas of Australian

Birds (Blakers et al. 1984; Barrett et al. 2003)) and regional fauna surveys (NPWS 2000b, 2002; DECC 2008), in reports on local fauna surveys undertaken by consultants (Kevin Mills and Associates 1995; LesryK Environmental Consultants 1996, 2005, 2007, 2008, 2010), and as records gathered by various government agencies and private individuals which have been entered into statewide databases (OEH 2012) or posted on internet sites (e.g. Birding-aus and NSW Birdline). A number of single species studies have been undertaken in the reserves, such as on the sooty owl (Chafer and Anderson 1994; Kavanagh and Jackson 1997; Bilney et al. 2007), brown antechinus (Whelan et al. 1996), eastern pygmy-possum (Tulloch 2001), swamp wallaby (Evans 2000; Ramp and Ben-Ami 2006), and the rusa deer (Tuck 1971; Giles and McKenzie 1973; Hamilton 1981; Mahood 1981; Moriarty 2004; Keith and Pellow 2005). A post-fire fauna survey was undertaken following the 1994 wildfire which burnt over 90 per cent of Royal NP (Andrew 2001). This transect-based survey included cage trapping, hair tube sampling, transect spotlighting, predator scat collection, transect bird censuses, pitfall trapping, Elliott trapping, active searches for diurnal and nocturnal herpetofauna, nocturnal call playback for owls, bat trapping and bat ultrasound censuses. A subset of sites was resampled in January 2006 concentrating on heathland communities in Royal NP, and then following the 2001 wildfire that burnt over 90 per cent of Heathcote NP, a repeat survey of all Heathcote NP sites was undertaken (Nolan 2006). The aims of these post-fire surveys were to investigate the impact on vertebrate fauna of the 1994 and 2001 wildfires. The surveys concentrated on widespread vegetation types in particular parts of the reserves, with little or no survey effort in restricted habitats such as freshwater wetlands, mangroves, saltmarsh and grasslands.

This study sought to compile a current accurate and comprehensive inventory of terrestrial vertebrate fauna species on the reserves, assess species relative distributions and broad habitat associations, and put the occurrence of fauna species in a regional context. The field survey design was based upon systematic survey techniques that are currently used by OEH across the Sydney Basin Bioregion, thus contributing to a large region-wide data set that enables comparison across areas and is repeatable in the future. The study also undertook targeted survey techniques and a review of previously existing data, to enable comparison with historical records and an assessment of species that may have been lost from the reserves. The information is intended to assist land managers with conservation and management of vertebrate fauna on the reserves.

MATERIALS AND METHODS

Study area

The study area comprised Royal NP (15,315 ha), Heathcote NP (2,727 ha) and Garawarra SCA (973 ha). These reserves are situated on the southern fringe of metropolitan Sydney and the northern margins of the Wollongong Local Government Area. The area is bounded to the east by the Pacific Ocean and to the west primarily by Holsworthy Military Area and the water catchments that include Woronora Special Area. The coastline of the study area includes intertidal zones such as rock platforms, beaches and rocky cliff bases of the ocean shoreline, however subtidal and adjacent inshore waters were excluded from the study.

The study area consists of a Triassic Hawkesbury sandstone plateau rising to over 200 m above sea level. It is deeply dissected by the Hacking River system which drains northward to the Port Hacking estuary and the Woronora River system which drains into the Georges River. The landscape is characterised by steep valleys and ridges, rocky outcrops and streams, many of which are punctuated by waterfalls and pools (NPWS 2000a). In the east, the plateau is characterised by broad, gently sloping ridges and small eastward-flowing drainage lines. The coastline is dominated by variable height cliffs cut in the Hawkesbury sandstone north of Curracurrong Creek, while extending to the south the cliffs are formed from the softer Narrabeen group of rocks with small beaches at creek mouths (Young and Young 2006). There are a number of geomorphological features that vary from the typical Hawkesbury sandstone plateau environment. Such features include: the cliff-top dunes of unconsolidated sand in the Jibbon Head and Marley Beach areas of Royal NP; a system of low beach ridges on the eastern side of Cabbage Tree Basin in Royal NP; patches of laterite on the higher parts of ridges across the area; and upland swamp areas on low-relief terrain primarily in parts of Royal NP (NPWS 2000a; Young and Young 2006).

A wide range of vegetation communities are present owing to the reserves' coastal location, geological and geomorphological characteristics and variation in climate (Keith and Tozer unpublished; DECCW 2009). The reserves are dominated by Hawkesbury sandstone forests, woodlands and heaths, although smaller patches of a variety of other vegetation types occur. For example, maximum rainfall occurs in the south due to the increased elevation and coastal escarpment resulting in the formation of rainforest communities (NPWS 2000a). For the purposes of the current study vegetation was identified into formations following the statewide

Table 1. Vegetation formations (after Keith 2004) present in the three reserves in order of area covered.

Statewide vegetation formation	Area (ha)	Distribution within the reserves
Dry Sclerophyll Forests (DSF)	11,372	The most widely distributed vegetation formation occurring on Hawkesbury sandstone ridges, slopes and gullies. For this study riparian scrub, which occurs along larger watercourses, has been included in this formation.
Heathlands (HL)	4,780	Occurs widely on skeletal rock sandstone, including coastal headlands, and on coastal sand dunes at Jibbon and Marley beaches.
Wet Sclerophyll Forests (WSF)	1,690	The shrubby subformation of Wet Sclerophyll Forest (after Keith 2004) is found in the southern end of Royal NP in protected Narrabeen sandstone gullies. Small stands of the grassy subformation of Wet Sclerophyll Forests (after Keith 2004) are distributed on residual shale and ironstone caps at Garawarra, Heathcote and Otford.
Rainforests (RF)	384	Situated in the southern end of Royal NP and parts of Garrawarra SCA in protected Narrabeen sandstone gullies, headlands and escarpment slopes.
Freshwater Wetlands (FrW)	217	Includes isolated patches of sedgelands and heaths on poorly drained sandstone ridgetops and gentle slopes, as well as depressions within the sand dunes behind Jibbon and Marley beaches.
Grasslands (GL)	58	Includes small patches of maritime grasslands on exposed coastal headlands and along frontal beach sand dunes.
Forested Wetlands (FoW)	39	Occurs as small patches primarily in the Bundeena-Bonnievale area.
Saline Wetlands (SW)	32	Mangrove swamps and estuarine saltmarshes restricted to the estuarine mudflats exposed to tidal inundation on the lower Hacking River to Bundeena in Port Hacking.

vegetation classification of Keith (2004). The allocation of vegetation community to statewide formation largely follows the system used in the draft mapping of vegetation across the Sydney metropolitan area (DECCW 2009). Under this classification eight vegetation formations occur within the reserves (Table 1; Fig. 1). Additional environments that are not covered by the Keith (2004) classification also occur as follows: shoreline including intertidal reef platforms and sandy beaches; open waterbodies such as larger river reaches; parkland and other modified habitats including picnic areas and mown landscapes.

Review of previous records

Previous fauna records were compiled by a review of scientific publications and published books, published regional fauna survey reports which included parts of the study area, unpublished OEH and consultancy reports, records entered into wildlife databases and on birding internet sites, relevant files held in the OEH office at Royal NP and interviews with local bird watchers, naturalists and OEH staff. All compiled information on fauna species recorded in the reserves was reviewed. To ensure the compiled species inventory was accurate, species were excluded if they met any of the following criteria: a) all of the records have poor location accuracy where the locality description does not actually occur within the reserves, or where the methods used to identify the location of the sighting had very low spatial accuracy; b) all of the records are probable misidentifications as no suitable habitat is present, the species is outside it's known range, and/or the species has been target surveyed within the reserves by experts on the species and never confirmed to occur; c) they are non-local species that have not established wild populations in the study area or neighbouring lands, including aviary escapees; or d) they are pelagic species that do not use the reserves for resting, foraging or nesting purposes such as various cetacean, seabird and marine reptile species.

Field survey

The field survey included systematic and targeted survey techniques, supported by incidental observations. The majority of surveys were undertaken between July 2009 and June 2010 across all three reserves. An earlier survey was undertaken between February and September 2007 in the Kelly Falls area of Garawarra SCA and the Bulgo-Bald Hill area in the far south of Royal NP.

All data collected during the field survey, together with the systematic survey effort, is stored in the Atlas of NSW Wildlife (OEH 2012) which is available to the public.

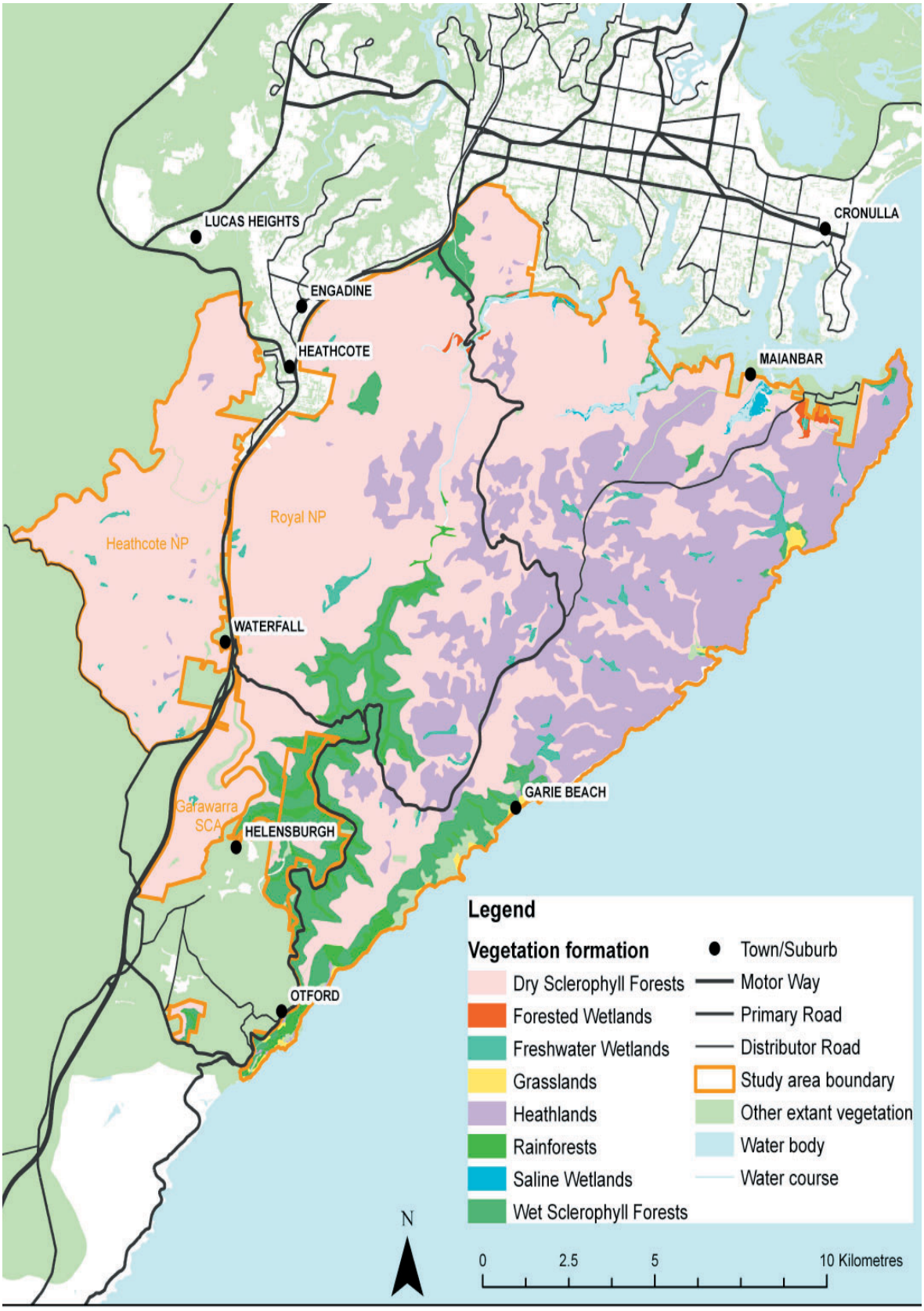

Figure 1. Vegetation formations within Garawarra SCA, Royal and Heathcote NP (adapted from Keith and Tozer unpublished; DECCW 2009).

Table 2. Systematic fauna survey techniques.

Name of technique	Fauna group	Census/equipment type	Effort	Area of search	Climatic conditions and timing
Diurnal bird census	Active diurnal birds	Visual and aural search	20 minutes	100 x 200 m	During periods of relatively high bird activity (early morning and less frequently late afternoon) and reasonable detectability (e.g. low wind and cicada activity).
Diurnal herpetofauna search	Active and sheltering reptiles and frogs	Active search of microhabitats by hand	60 minutes	100 x 50 m	Between mid-morning and late afternoon. Not during overcast, rainy or windy conditions.
Site spotlighting census	Active nocturnal mammals and birds	Active search with 50 watt hand-held spotlight	30 minutes	200 m transect. Predominantly confined to areas with trees taller than 5 m.	Not during windy conditions.
Nocturnal streamside search	Active nocturnal frogs	Active search with 50 watt hand-held spotlight	30 minutes	200 m transect along a watercourse or the edge of a still waterbody.	Primarily on warm, dark, humid and wet nights within two days of rain.
Harp trapping	Active microbats	Single harp trap	1 night	-	Traps set on tracks, over watercourses or in gaps between trees.
Bat ultrasound recording	Active microbats	SD1 Anabat detector (Titley Electronics, Ballina, NSW). Recorded signals indentified by one of the authors (MS).	30 minutes	-	Not during rainy or windy conditions.

Systematic survey techniques

This study deployed the point-based systematic fauna survey techniques that are currently widely used by OEH across the Sydney region and elsewhere in NSW (Table 2). An important component of the OEH systematic survey design is stratification, that is sampling fauna habitats in approximate proportion to the area they cover. Statewide vegetation formation (Keith 2004) was used as the a priori surrogate for fauna habitat.

A gap analysis was undertaken of OEH systematic survey techniques in the study area which had previously been entered into the Atlas of NSW Wildlife (OEH 2012). This analysis identified that limited OEH systematic surveys had been conducted for the following fauna groups: amphibians (n=4), diurnal birds (n=17), reptiles (n=19) and microchiropteran bats (n=5 using ultrasonic detectors and n=31 using harp traps). Nocturnal birds were considered adequately sampled by OEH systematic survey (n=58), as were small mammals (n=63 using Elliott and cage trapping, n=45 using pitfall trapping and n=58 using hair tubes).

This study aimed to fill identified gaps in OEH systematic survey effort. As an a priori surrogate for habitat type, the study sought to sample each vegetation formation by each systematic survey technique in approximate proportion to the area the formation covered. However, additional OEH systematic survey techniques were undertaken at additional sites where time allowed, particularly in vegetation formations that occupied a small total area. A systematic site is defined as any locality where one or more OEH systematic survey techniques were undertaken; not every technique was undertaken at each site. Multiple sites were selected and surveyed in each vegetation formation to account for variation within formations (Table 3). Systematic sites were selected using a Geographic Information System (ArcGIS 9.3) coupled with information from DECCW (2009), topographic maps and knowledge held by OEH staff and other park users. Wherever possible, sites with the same systematic survey techniques were separated by a straight-line distance of 1 km (Fig. 2). However due to the limited distribution of some vegetation formations this was not always possible. Vegetation

Table 3. Number of each systematic survey technique undertaken in each vegetation formation.

Statewide vegetation formation	Diurnal bird census	Diurnal herpetofauna search	Site spotlighting census	Nocturnal streamside search	Harp trapping	Bat ultrasound recording
Dry Sclerophyll Forests	44	33	31	7	33	17
Forested Wetlands	7	7	6	2	3	2
Freshwater Wetlands	16	8	1	5	1	6
Grasslands	5	5	0	2	0	0
Heathlands	22	22	0	0	2	1
Rainforests	20	15	12	3	16	7
Saline Wetlands	3	3	0	0	1	0
Wet Sclerophyll Forests	17	16	13	1	7	9
Total	134	109	63	20	63	42

formations occupying less than 0.5% of the reserves were sampled by a minimum of two systematic survey sites, separated by a straight-line distance of 0.5 km. Vegetation formations occupying greater than 0.5% of the reserves had a minimum of six systematic survey site replicates which were separated by a straight-line distance of more than 1 km. Sites were positioned primarily adjacent or close to access trails and walking tracks to maximise the number of sites that could be accessed. The exceptions to this were sites selected in restricted vegetation formations. The placement of harp traps to capture microbats was limited by the availability of suitable fly-ways, such as vegetation constrictions along roads and creek lines.

Targeted survey techniques

Targeted survey techniques (Table 4, Fig. 3) were applied to sample species that had uncertain status in the study area (based on review of previous records), are not adequately sampled by the OEH systematic survey techniques and had not previously been adequately surveyed. These species included cryptic and rare taxa. A list of target species was derived, with particular emphasis on regionally restricted species (following Chafer et al. 1999; DECC 2007a; DECC 2008) and threatened species listed under the NSW Threatened Species Conservation Act 1995 (TSC Act). Techniques were designed to target each species or group of species and centred on the known ecology and habitat preferences for the species (e.g. for birds: Higgins 1999; Higgins and Davies 1996; Higgins and Peter 2002; Higgins et al. 2001). Established survey techniques for particular species were used where possible. Targeted survey techniques were separated by a minimum straight-line distance of 300 m.

Incidental observations

Incidental records were collected of species that were opportunistically encountered and were not well sampled by the systematic or targeted techniques of this study, such as large ground mammals, raptors, non-vocalising birds and secretive or cryptic fauna species. Additionally, incidental records were collected of fauna species that were not recorded during systematic or targeted surveys at a given location. A number of incidental records were collected during traverses across sections of the reserves where no systematic or targeted survey sites were located, and during driving of roads at night (particularly during warm humid conditions in search of active and road killed individuals). Predator scats were collected whenever encountered during the survey and analysed for the identification of mammalian prey remains.

Data analysis

Results of the OEH systematic survey techniques were compiled to examine patterns in fauna species distribution across vegetation formations. Sites that did not conform to a single vegetation formation were considered to be heterogeneous habitats and were excluded from the analysis (n=7).

Relative occurrence of species across vegetation formations

For all species detected twice or more by any of the systematic survey techniques, the number of systematic survey techniques in which the species was detected was tallied for each vegetation formation. This total was then converted to a percentage for each vegetation formation. All systematic techniques were included in this analysis.

Differences in fauna species composition between vegetation formations

The aim of these analyses was to typify the fauna species that use different vegetation formations in the reserves and identify distinct habitats. The software

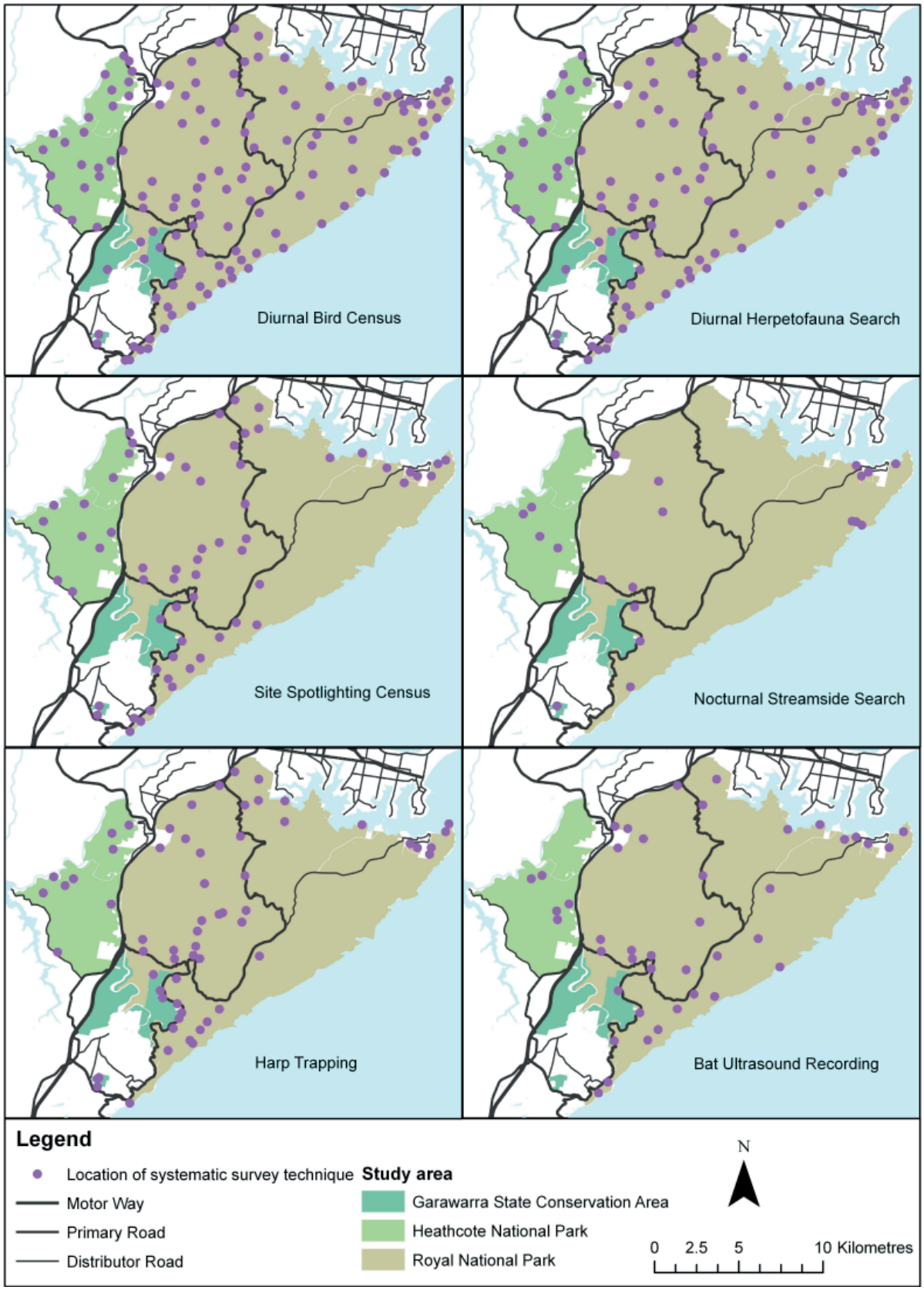

Figure 2. Location of OEH systematic survey techniques undertaken during the current study.

Table 4. Targeted fauna survey techniques.

Name of technique	Target species	Location/habitat type	Census/equipment type
Early evening call playback and passive listening in wet heaths and wetlands	Eastern grass owl, ground parrot, king quail, Australasian bittern	Areas of potential habitat identified by aerial photography (primarily wetlands and wet heaths dominated by sedgelands with little tree or shrub cover, including extensive sedgeland areas fringing mangroves).	Listening survey commenced approximately one hour prior to dusk and continued until dark. Included five minutes call playback of ground parrot and king quail before dusk, and five minutes call playback of eastern grass owl and Australasian bittern after dusk. Only undertaken during calm conditions.
Active daytime searching in wet heaths and wetlands	Above species	Areas of potential habitat identified by aerial photography (primarily wetlands and wet heaths dominated by sedgelands with little tree or shrub cover, including extensive sedgeland areas fringing mangroves).	Active searching comprising an observer undertaking criss-cross traverse of sites during the day looking for roosting or sheltering target species.
Riparian dusk watch and listening	Platypus, water rat, black bittern	Straight reaches of watercourses where there was good visibility of the water.	Survey commenced approximately one hour prior to dusk and continued until dark. An observer sat at the water's edge listening and watching for active target species (following techniques of Rohweder and Baverstock (1999) and Curtis (2001)).
Infra-red camera trapping	Dusky antechinus, spotted-tailed quoll, parma wallaby, red-necked pademelon, ground parrot, eastern bristlebird (depending on location)	Areas of potential habitat for one or more target species.	A single Moultrie Model 160 Digital Game Camera at each location, attached to a sapling or small tree, and aimed at a bait station approximately two metres from the camera and baited with peanut butter, rolled oats, honey and walnuts. Left in place for 7-12 nights. Species in the photos were identified by one of the authors (MS).
Targeted nocturnal call playback	Barking owl	Loftus Heights-Heathcote areas where there are previous records (Anyon-Smith 2006; OEH 2012; R. Jackson pers. comm.).	After dusk an observer listened for five minutes and searched the area with a 50 watt hand-held spotlight. Five minutes of call playback was then undertaken, followed by a final listening period.
Listening survey for amphibians	Brown toadlet, wallum froglet, Littlejohn's tree frog	Brown toadlet: Goarra Ridge area where there are previous records. Wallum froglet: wetlands on sand or alluvium in the Bundeena-Jibbon and Marley Lagoon areas. Littlejohn's tree frog: wet sedgelands and adjoining watercourses in Heathcote NP.	Listening surveys were undertaken during peak calling periods for each species (after Lemckert and Mahony 2008).
Tadpole survey	Stuttering frog, green and golden bell frog	Areas of potential habitat for one or more target species.	Searches for tadpoles, as well as for active adults, were undertaken between spring and autumn (after Anstis 2002).
Active searching of caves, tunnels, overhangs and culverts	Roosting microbats	All caves, overhangs and abandoned railway tunnels that were either identified during interviews with OEH staff, naturalists and park users, or were incidentally encountered during the field survey.	Active searches were undertaken with a head torch or hand-held spotlight.
Active searching of yellow-throated scrubwren nests	Roosting golden-tipped bat	All accessible yellow-throated scrub-wren nests encountered in rainforest and wet sclerophyll forest (n=44).	The golden-tipped bat primarily roosts in the suspended nests of the yellow-throated scrub-wren (Schulz 2000a, b, c), modifying the nest to provide access through a basal hole (Schulz 2000a). Surveys involved checking these nests for roosting bats or the presence of basal holes.
Active searching in mangroves	Mangrove gerygone	All larger mangrove patches.	Aural surveys were undertaken on at least two occasions at each location, by a single observer on a kayak at high tide.
Active searching in flowering swamp mahogany	Swift parrot, regent honeyeater	Flowering stands of swamp mahogany (*Eucalyptus robusta*) in the Bundeena area.	Visual and aural searches for the target species were undertaken on 20 occasions during autumn.
Shoreline observations	Australian pied oystercatcher, sooty oystercatcher, little tern, eastern osprey, water rat and other species using the shoreline.	Oceanic shoreline and Port Hacking shoreline.	Routine scanning of shoreline areas was undertaken during all seasons. The presence of water rat was assessed by searching for signs (tracks and the chewed remains of molluscs, yabbies and other food items that may have been deposited on flat rocks, stumps or logs (Triggs 2001)).

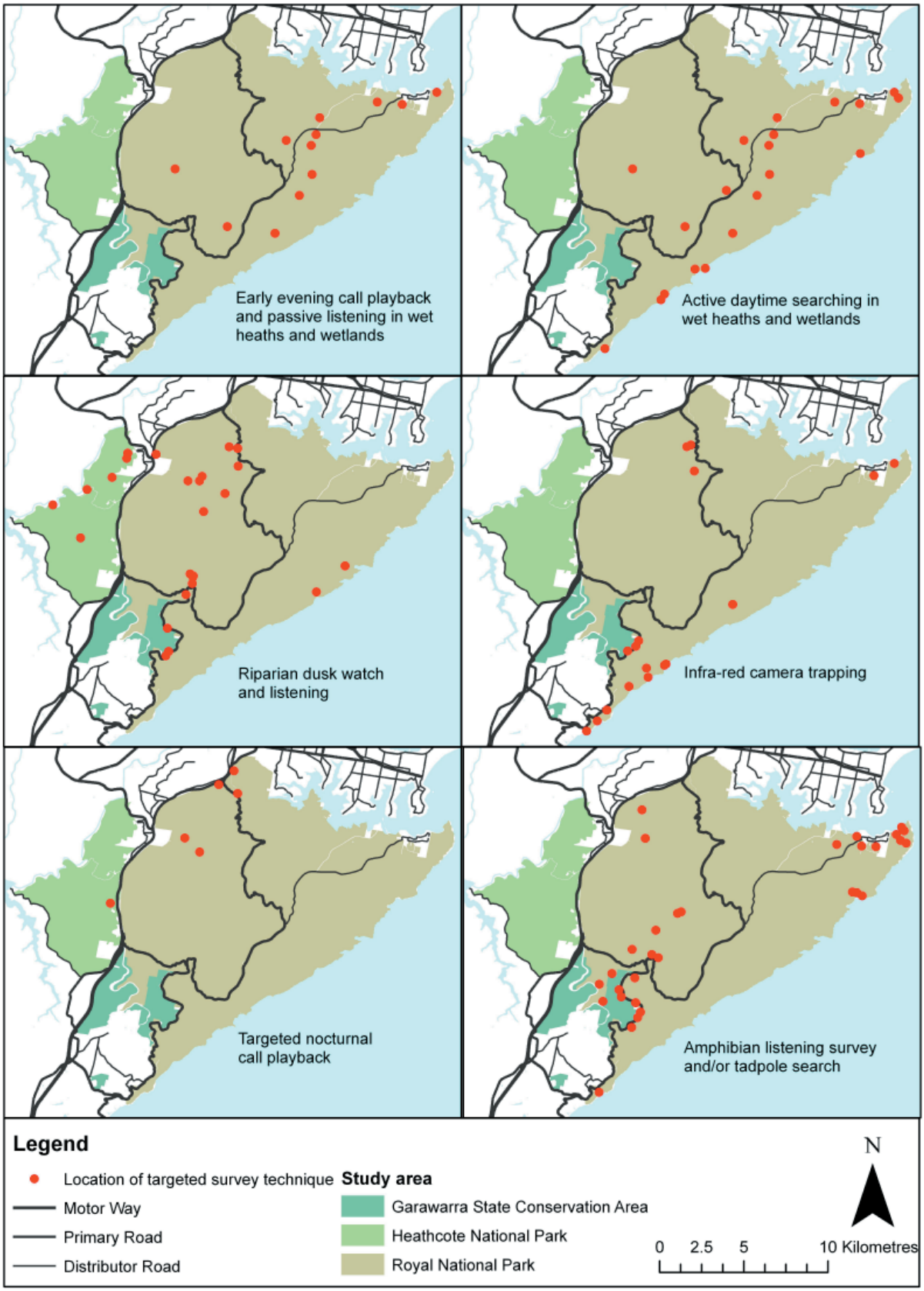

Figure 3. Location of selected targeted survey techniques undertaken during the current study.

package Primer 6 (Version 6.1.10) was used for statistical analyses. Only results from the diurnal bird and diurnal herpetofauna systematic techniques were used in these analyses as these techniques and fauna groups had the greatest number of replicates and species, giving sufficient power to statistical analyses. Bird and reptile data were analysed together, and hence only sites that had both diurnal bird and diurnal herpetofauna censuses undertaken at them were used. A site by species table was constructed, populated by presence-absence data for each species at each site. Species that were only recorded from a single site were excluded, so that single occurrences of rare species did not overly influence the data. A Bray-Curtis resemblance (similarity) matrix was then derived. An Analysis of Similarities (ANOSIM) was conducted to test for differences in the fauna species composition between the eight statewide vegetation formations. Non-parametric multi-dimensional scaling (MDS) was used to graphically present the pattern of similarity between sites, categorised by statewide vegetation formation. Several factors were considered in determining whether pairs of vegetation formations were different, following the method of Clarke and Warwick (2001), including the R statistic and significance level % for each pair-wise comparison (as generated by the ANOSIM), the number of randomly-generated R values that were above the pair-wise R value (also generated from ANOSIM) and the relative separation between pairs in the three-dimensional MDS. Finally, similarity percentages (SIMPER) was used to identify which fauna species primarily account for the observed differences between vegetation formations, and hence species that typify the formations.

RESULTS

Systematic survey results and analyses

A total of 228 species were detected by the systematic survey techniques (Appendix 1). One hundred and forty-seven bird species were recorded on site during diurnal bird censuses, the three most frequent species being the white-browed scrub-wren (66% of censuses), brown thornbill (72%) and eastern spinebill (72%). The diurnal herpetofauna searches detected 34 reptile and 8 frog species, the most frequent being the dark-flecked garden sunskink (81% of searches) and eastern water-skink (33%). The dark-flecked garden sunskink was even encountered basking on logs on the edge of saltmarsh and mangrove areas in Port Hacking. The site spotlighting censuses detected 15 nocturnal mammal, 9 nocturnal bird, 11 frog and 5 nocturnally active reptile species, the most frequent being the sugar glider (49% of censuses) and Australian owlet-nightjar (43%). The nocturnal streamside searches detected 12 frog and 2 reptile species, with the common eastern froglet (75% of searches) and leaf-green tree frog (60%) the most frequently detected. The harp trapping resulted in capture of 12 microbat species, with the little forest bat captured in 60% of traps. Gould's wattled bat was the most frequently identified microbat from the bat ultrasound recording sites (identified from 60% of sites), followed by the little forest bat at 55% of sites; this technique detected a total of 7 microbat species.

An examination of the distribution of fauna species across vegetation formations (Appendix 1) found that many species are widespread across vegetation types, while others are restricted. The dark-flecked garden sunskink, Australian raven, brown thornbill, silvereye, superb fairy-wren and the welcome swallow were each detected in all formations, while the common eastern froglet, crimson rosella, eastern spinebill, variegated fairy-wren, white-browed scrub-wren and the little forest bat were recorded in all but one formation. In contrast, 21 species which were recorded more than once using systematic survey techniques were only detected in a single vegetation formation. Eleven of these species were restricted to Dry Sclerophyll Forests: Lesueur's frog, wood gecko, thick-tailed gecko, pale-flecked garden sunskink, eastern blue-tongue, brush cuckoo, buff-rumped thornbill, scarlet honeyeater, striated pardalote, varied sittella and greater broad-nosed bat. Four species were only located in Heathlands, comprising the Cunningham's skink, eastern brown snake, peregrine falcon and Horsfield's bronze-cuckoo. Four species were only located in Rainforests, comprising the wonga pigeon, green catbird, sooty owl and the long-nosed bandicoot. Three additional species, the large-billed scrubwren, logrunner and the eastern shrike-tit, were confined to Rainforests and adjoining Wet Sclerophyll Forests with a well developed mesic understorey. Based on records from systematic techniques only, no species were only detected in Saline Wetlands, Forested Wetlands, Grasslands or Wet Sclerophyll Forests.

The results of the ANOSIM indicated that there is a significant difference in bird and reptile species composition between statewide vegetation formations (global $R=0.559$, significant at the $p<0.1\%$ level). Differences were not clear between all formations, however, with some proving distinctive and others not. Table 5 displays pair-wise comparisons between each vegetation formation and whether each are considered significant. The three-dimensional MDS plot had a stress of 0.17 and the two-dimensional plot a stress of

Table 5. Degree of separation in bird and reptile species composition between statewide vegetation formations. Assessment of significance is derived from outputs of the ANOSIM analysis and visual examination of the three-dimensional MDS.

	Rainforests	Wet Sclerophyll Forests	Grasslands	Dry Sclerophyll Forests	Heathlands	Freshwater Wetlands	Forested Wetlands
Wet Sclerophyll Forests	Yes (moderate) R = 0.409						
Grasslands	Yes (strong) R = 0.969	Yes (strong) R = 0.898					
Dry Sclerophyll Forests	Yes (moderate) R = 0.481	No (weak) R = 0.177	Yes (strong) R = 0.849				
Heathlands	Yes (strong) R = 0.919	Yes (strong) R = 0.869	Yes (strong) R = 0.89	Yes (moderate) R = 0.449			
Freshwater Wetlands	Yes (strong) R = 0.812	Yes (moderate) R = 0.621	Yes (moderate) R = 0.636	No (weak) 0.336	No (moderate) R = 0.402		
Forested Wetlands	Yes (moderate) R = 0.619	No (weak) R = 0.309	No (moderate) R = 0.644	Yes (moderate) 0.409	Yes (moderate) R = 0.798	No (weak) R = 0.347	
Saline Wetlands	Yes (strong) R = 0.972	Yes (strong) R = 0.929	No (weak) R = 0.446	Yes (strong) 0.805	Yes (strong) R = 0.929	No (moderate) R = 0.573	Yes (moderate) R = 0.575

0.23. For ease of viewing, the two-dimensional plot is shown in Fig. 4, coded by vegetation formation, though the three-dimensional plot was used to examine separation of vegetation formations. The formations that were most distinct from the other groups were Rainforests (different from all other formations) and Heathlands (different from all formations except Freshwater Wetlands). The species that contributed most to the distinction of Rainforests are the brown gerygone, rufous fantail, golden whistler, black-faced monarch, yellow-throated scrubwren and green catbird. The species recorded more consistently in Heathlands than in the other formations are welcome swallow, White's skink, beautiful firetail, southern emu-wren, tawny-crowned honeyeater and pheasant coucal. Table 6 shows the bird and reptile species that are typical of Heathlands and Rainforests.

The weakest separation in vegetation formation pairs was between Dry Sclerophyll Forests and Wet Sclerophyll Forests (R=0.177). Since Dry and Wet Sclerophyll Forests were not found to be significantly different from each other, yet each had a large number of sites and together cover a large proportion of reserves, the typical species that occur in both of these formations are listed in Table 6 together. The degree of difference in species composition for the wetlands and grasslands formations, between themselves and in comparison to the above formations, is variable. These formations also tended to have a lower degree of similarity between sites within the formation, with the exception of Grasslands which have a mixed history of disturbance; for these reasons the typical species have not been presented in Table 6.

Targeted and incidental survey results

A total of 55 species were detected only by targeted survey techniques and/or incidental observations (Appendix 1).

The targeted surveys of wet heaths and wetlands (i.e. the early evening call playback and passive listening and the active daytime searching) resulted in the detection of the Australasian bittern and eastern grass owl in one location each. The Australasian bittern was detected on two occasions at Jibbon Lagoon (July and October 2009), while the eastern grass owl was flushed from a densely vegetated wetland in a drainage line south of Bundeena Drive in March 2010. The detection of the eastern grass

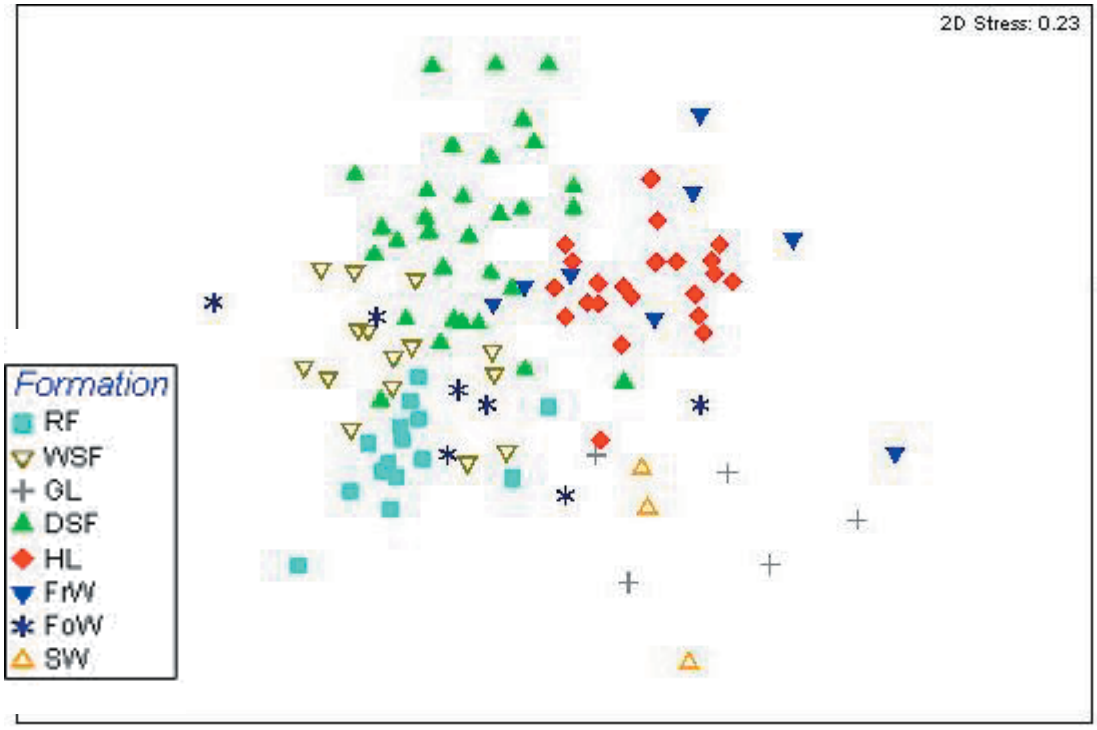

Figure 4. Two-dimensional MDS of sites coded by statewide vegetation formation.

owl is particularly noteworthy since this species is generally considered to be a rare visitor to the Sydney region, with one confirmed record from Homebush Bay in October 1982 and one from St Albans in the Hawkesbury Valley in September 1991 (Hobcroft and James 1997). However, prior to the sighting during the current study a single individual was flushed from a coastal sand swamp sedgeland inland of Cape Baily Lighthouse in Kamay Botany Bay NP some 14 km to the north east (Schulz and Magarey 2010).

The riparian dusk watch and listening surveys did not detect the target species. However, a single black bittern was flushed incidentally from the tidal limits of Cabbage Tree Creek.

The infra-red camera trapping did not detect the target species. However this technique detected 25 other species, comprising 9 mammal species and 16 bird species. Three species were only detected in the study area by the use of infra-red camera trapping, being the emerald dove, noisy pitta and buff-banded rail. The first two species were each located once in Rainforests, the emerald dove in Hell Hole north of Bulgo and the noisy pitta south of Bald Hill. Both of these species are considered rare in the Illawarra region (Chafer et al. 1999).

The active searches of caves, tunnels, overhangs and culverts resulted in the location of a number of microbat roosts. The most significant find was a maternity roost of the eastern horseshoe-bat in the Bola Creek area, with up to 100 individuals present. This location is one of the only documented maternity roosts within the Sydney Basin Bioregion (OEH 2012). The eastern horseshoe-bat was the most frequently encountered cave-dwelling bat species, also found roosting in aggregations of less than 10 individuals in culverts and under bridges in the Hacking River valley and Garie Beach areas. Up to 20 individuals were encountered in Dingo Tunnel, while less than five individuals were encountered in a deep rock fissure adjacent to the Woronora River in Heathcote NP and various locations in Royal NP including in caves west of Yenabilli Point and adjacent to Flat Rock Creek crossing.

Another significant find was the location of at least 20 roosting little bentwing-bat individuals in March 2007 in the abandoned Stanwell Park-Otford railway tunnel which passed under the extreme southern edge of the study area. This is the southern-most documented roost for this species, with the nearest known roost being in a concrete-lined underground section of Brookvale Creek on the Northern Beaches of Sydney (DECC 2008). The roost site in the Stanwell Park-Otford railway tunnel was resurveyed in March and May 2010, and trapping undertaken near the tunnel entrance, but this species was not subsequently located. Hence the status of this species within the study area remains uncertain. Small eastern bentwing-bat roosts of less than 20

Table 6. Typical bird and reptile species of statewide vegetation formations. In brackets is the percentage of sites in the vegetation formation that contained the species (derived from the SIMPER analysis).

Statewide vegetation formation	Typical species
Rainforests (RF)	Brown thornbill (93%), brown gerygone (87%), eastern yellow robin (87%), rufous fantail (80%), golden whistler (80%), silvereye (80%), dark-flecked garden sunskink (80%), black-faced monarch (73%), Lewin's honeyeater (67%), yellow-throated scrubwren (67%), white-browed scrubwren (60%), eastern spinebill (60%), large-billed scrubwren (53%), three-toed skink (53%), eastern whipbird (53%), crimson rosella (47%), eastern water-skink (40%), bassian thrush (40%), superb lyrebird (40%).
Heathlands (HL)	White-browed scrubwren (95%), New Holland honeyeater (95%), welcome swallow (82%), little wattlebird (68%), dark-flecked garden sunskink (68%), variegated fairy-wren (64%), copper-tailed skink (64%), chestnut-rumped heathwren (59%), white's skink (59%), eastern whipbird (55%), common eastern froglet (50%), beautiful firetail (50%), jacky lizard (41%), brown thornbill (41%), southern emu-wren (41%), tawny-crowned honeyeater (36%), pheasant coucal (32%).
Dry and Wet Sclerophyll Forests combined (DSF and WSF)	Dark-flecked garden sunskink (90% DSF, 100% WSF), brown thornbill (55% DSF, 80% DSF), white-browed scrubwren (71% DSF, 67% WSF), eastern spinebill (81% DSF, 53% WSF), striated thornbill (55% DSF, 47% WSF), variegated fairy-wren (45% DSF, 47% WSF), eastern water-skink (35% DSF, 53% WSF), yellow-faced honeyeater (39% DSF, 47% WSF), crimson rosella (32% DSF, 40% WSF), grey fantail (35% DSF, 60% WSF), eastern yellow robin (23% DSF, 47% WSF), spotted pardalote (35% DSF, 47% WSF), grey shrike-thrush (23% DSF, 27% WSF), little wattlebird (29% DSF, 27% WSF).

individuals were also located in the abandoned Stanwell Park-Otford railway tunnel, as well as in deep overhangs west of Yenabilli Point. The only roost location found for the southern myotis was in the disused Otford-Stanwell Park railway tunnel, where at least 20 individuals were present in March 2007. However, similar to the little bentwing-bat no individuals were located on the revisit to the tunnel in March and May 2010. It is likely that the southern myotis roosts in additional sites in the study area. The capture of lactating female large-eared pied bat along the Cliff Trail on the plateau above the coastal escarpment indicates that maternity roosts for this species are present within the study area. No roost locations were found, but there are many cracks and crevices present on the vertical cliff face below the Cliff Track that are difficult to access and were not surveyed.

The shoreline observations found the targeted bird species to be uncommon, with no nesting activity observed and records primarily represented by the sighting of single individuals. For example, the only record of the little tern was of a single individual fishing just off the Bundeena sea cliffs in January 2010. Single eastern osprey individuals were encountered along the Port Hacking shoreline west of Yenabilli Point in January 2010 and at Red Jacks Point in March 2010. During this period, single birds were also sighted during calm conditions along the ocean shoreline of Royal NP, such as along the Bundeena sea cliffs, Marley and Wattamolla beaches (M. Schulz unpublished records). In contrast sooty oystercatcher was regularly observed on intertidal rock platforms and adjacent ocean beaches along the Royal NP coastline, with occasional birds observed on the rocky shoreline in the Jibbon Beach area and on the intertidal flats at Bonnie Vale. This species was predominantly encountered in small numbers, with maximum numbers of 11 individuals observed on exposed rock platforms in the Little Marley Beach area in August 2009 and 12 individuals on a reef platform at Bulgo in May 2007.

A number of other shoreline species were recorded incidentally on single occasions, including the ruddy turnstone, kelp gull and the white-fronted tern. Two little penguins were encountered moulting under boulders in a small embayment on Jibbon Head. A number of reptile species were detected during the

shoreline observations. The broad-tailed gecko was regularly encountered in crevices along sea cliffs south of Wattamolla Beach, while the eastern water dragon was located in the tidal lower reaches of the Hacking River and on intertidal rock platforms in the Bulgo area of Royal NP. In the latter locality, large adults were observed feeding in pools in the upper intertidal zone.

A number of wetland and water-dependant species were not detected by systematic or targeted survey techniques, but only by incidental observations. For example, the eastern snake-necked turtle and Eurasian coot were each only recorded incidentally in the wide lower freshwater reaches of the Hacking River. Similarly the Australian reed warbler, spotless crake and white-necked heron were only recorded incidentally at Engadine Waterhole.

Summary of threatened species recorded during the survey

A total of 26 threatened species listed under the TSC Act and/or the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) were recorded during the current survey (Appendix 1). However, only seven of these species were detected at 10 or more locations. The most frequently recorded was the red-crowned toadlet, which uses drains and runoffs on the edge of roads and management trails, including the main sealed roads within Royal NP. The grey-headed flying-fox was recorded in a range of habitats across the reserves, with occurrence varying depending on the flowering or fruiting of key plant species. During autumn 2010, for example, the majority of sightings were made around flowering heath-leaved banksia (*Banksia ericifolia*). The giant burrowing frog, detected at 17 locations all within Royal NP, was probably under-recorded during the survey due to the generally dry conditions. The majority of eastern pygmy-possum observations were of active or killed individuals seen at night on the sealed roads of Royal NP. Similarly, the majority of observations of the Rosenberg's goanna were incidental encounters along walking tracks and roads within the study area. These last two species, although predominantly Dry Sclerophyll Forests and Heathlands inhabitants, were also recorded in Rainforests. Several eastern pygmy-possums were observed along Lady Wakehurst Drive in rainforest in the Hacking River valley and a single Rosenberg's goanna was encountered feeding on ripe fig fruits that had fallen on to the ground in littoral rainforest in Palm Jungle at least 200 m straight-line distance from more open habitats. The remaining threatened species recorded in 10 or more localities were the large-eared pied bat (which was located in 11 sites in a range of habitats including Rainforests, Wet Sclerophyll Forests and Dry Sclerophyll Forests) and southern myotis (which was recorded at 10 locations the majority of which were on large watercourses).

Species not detected during the survey

An important outcome of the current survey was the failure to locate a number of species that either were formerly known to occur (e.g. green and golden bell frog, stuttering frog, ground parrot, eastern bristlebird, spotted-tailed quoll, parma wallaby and red-necked pademelon); have an uncertain status within the reserves (e.g. brown toadlet, king quail, barking owl, mangrove gerygone, dusky antechinus, greater glider, platypus and water rat); are rare and declining visitors (swift parrot and regent honeyeater); or were considered to potentially be present since they are known from nearby localities or potential habitat is present (e.g. wallum froglet (*Crinia tinnula*), Littlejohn's tree frog (*Litoria littlejohni*) and golden-tipped bat *(Kerivoula papuensis*)). The species listed in this paragraph are now considered not likely to currently be present in the study area, with the exception of some of the bird species that occur as rare visitors (including barking owl, swift parrot and mangrove gerygone) (after Anyon-Smith 2006) and the greater glider which has recently been re-discovered in Royal NP (D. Andrew pers. comm.).

In total 107 species previously recorded from the study area were not located during the current survey (Appendix 2). This comprised seven amphibian, 15 mammal and 85 bird species. The review of previous records and relevant literature, together with results of the current survey, were used to assign a current status to each of these species; the list includes rare visitors or vagrants, sporadic visitors, regular winter-visiting birds, winter-vocalising frogs, species considered locally or regionally extinct, and species with uncertain status.

DISCUSSION

The current study demonstrates the value of dedicated fauna survey, even in reserves that are close to the Sydney metropolitan area, are long-established and have a high volume of visitation. The survey resulted in the location of seven species that had not previously been documented within the reserves, being common wallaroo, Wilcox's frog, white-plumed honeyeater, lesser long-eared bat, Australasian bittern, eastern grass owl and mainland she-oak skink. The first four species were only located

on the edge of the study area, while the latter three species were all found in wet heath or sedgelands in Royal NP. An examination of the species detected by the systematic and targeted survey techniques, as well as the incidental observations, indicates that many species were only recorded by a single technique type, or in restricted habitats. This demonstrates that a multi-faceted survey approach, including stratified systematic surveys and targeted surveys, is needed to compile a comprehensive species inventory for an area.

The Royal, Heathcote and Garawarra reserve complex has high vertebrate fauna species richness in comparison with other reserves in the Sydney basin (data from OEH 2012). This high species richness can be attributed to the diversity of environments present. It is fortuitous that the first national park in Australia protected such an important mix of habitats for vertebrate fauna. The systematic survey results showed that the Rainforests and Heathlands vegetation formations each support a distinct suite of fauna. In addition, many species only occur in shoreline or wetland habitats, elevating the number of species present in the reserves.

The vegetation communities that comprise the Heathlands vegetation formation have a restricted distribution in NSW (Keith 2004). Sydney coastal heaths occur on exposed coastal sandstone plateau between Gosford and Garie in Royal NP, with disjunct patches at Jervis Bay and the Budderoo Plateau (Keith 2004). In the central part of their distribution (around the Sydney metropolitan area) they have been almost obliterated by urban and coastal development (Keith 2004). The heaths in Royal NP are an important component of the remaining extent. Royal NP currently supports some of the largest numbers of heath-dependant fauna species in the Sydney metropolitan area, including southern emu-wren, beautiful firetail and tawny-crowned honeyeater (data from OEH 2012). The Heathlands also provide habitat for several species listed as threatened under the TSC Act and/or the EPBC Act, including red-crowned toadlet, broad-headed snake, Rosenberg's goanna, eastern pygmy-possum, New Holland mouse and giant burrowing frog.

The Rainforests of Royal NP and Garawarra SCA lie near the southern limit of the distribution of the northern warm temperate, subtropical and littoral rainforest groups (Keith 2004). Rainforests extend south from the study area along the Illawarra escarpment, but the continuity with the study area is subject to ongoing threats such as urban development. In a regional context the Rainforests in the study area, and the connection with the Illawarra escarpment, hold conservation significance to fauna species that are dependent on mesic forests, such as green catbird and logrunner. These two species have a restricted distribution in the Sydney basin and are likely to depend on the Rainforests of Royal NP, Garawarra SCA and the Illawarra escarpment for their ongoing survival in the Sydney region. The Rainforests also provide habitat for species listed as threatened under the TSC Act, such as the sooty owl, masked owl and the southern myotis.

The Dry Sclerophyll Forests vegetation formation contains vegetation communities from a wide range of environments within the study area, including relatively dry gully and creekline vegetation, open forest on sheltered to exposed dry sandstone slopes, low woodland on dry exposed ridgelines, and open forest on sand dunes. It is thus not surprising that systematic sites within this formation did not share a high degree of average similarity in bird and reptile species (Average Similarity=31.10 from SIMPER analysis) and that the sites were not found to significantly differ from the Wet Sclerophyll Forests. The Wet Sclerophyll Forests also contained a range of environments, though smaller than the Dry Sclerophyll Forests, ranging from mesic vegetation with rainforest species in the understorey to forests on shale-influenced soils adjacent to urban development. At the formation level, Dry Sclerophyll Forests and Wet Sclerophyll Forests are each widely distributed in the Sydney region (DECCW 2009) and the state (Keith 2004). Many of the species that occur in these habitats in Royal, Heathcote and Garawarra are also widespread through much of the Sydney water catchment lands and much of the greater Blue Mountains (data from OEH 2012). These forests thus do not account for the high species richness of the reserves compared to other areas in the Sydney basin. However, though many of these species are shared with other sandstone reserves, the abundance and density of a suite of threatened species is particularly high in the study area. The study area can be considered a regional 'hotspot' for broad-headed snake, giant burrowing frog, red-crowned toadlet and Rosenberg's goanna (data from OEH 2012). In a regional context, the study area also supports high numbers of eastern pygmy-possum (data from OEH 2012), which primarily occur in Heathlands and Dry Sclerophyll Forests.

Neither the Forested Wetlands nor the Freshwater Wetlands formations were found to support a highly distinctive suite of bird and reptile species based on systematic survey data. Forested Wetlands share many species with the Wet Sclerophyll Forests and Freshwater Wetlands, while the Freshwater Wetlands

also share many species with the Dry Sclerophyll Forests and Heathlands (Table 5). Again, however, the diversity of environments encompassed by these formations (and by the Dry Sclerophyll Forests) may have masked the importance of particular habitat features. The Freshwater Wetlands, for example, includes sedgelands, swamps and wet heaths on sandstone ridgetops and slopes, as well as deep open lagoons with reed beds in sand dunes. Systematic sites within this formation did not share a high degree of average similarity in bird and reptile species (Average Similarity=30.08). Fauna species are likely to respond to a finer degree of habitat differentiation than is represented by the statewide vegetation formation grouping. In addition, several species that are known to depend on sedgelands, swamps, wet heaths or lagoons were only recorded once or only by targeted or incidental surveys in the current study, and hence were not included in the analyses, such as eastern grass owl and Australasian bittern. Thus it could easily be argued that the variety of freshwater wetlands present in the study area do contribute to the high species richness of the reserves.

A suite of fauna species is only present in the study area due to the existence of oceanic and/or estuarine shorelines. Many species common along the oceanic shoreline of Royal NP occur up and down the coast, such as the great cormorant, silver gull, crested tern and white-bellied sea-eagle (data from OEH 2012). Other species are rarer along the Sydney coastline. The intertidal rock platforms in the south of Royal NP provide important habitat for species such as the sooty oystercatcher and eastern reef egret.

An important outcome of the current survey and review of previous data was the failure to detect many species previously known to occur. Some of these remain residents or visitors that were simply missed by the current field surveys (Appendix 2). However the lack of records of other species reflects true absences from the study area. Despite the current fauna species richness of the reserves, a range of species are known to have become locally extinct. Additional species that were common in the Sydney and/or Illawarra regions at the time of European settlement, but have since disappeared, are also likely to have once occurred within the reserves but no longer do. The species extinctions, losses and declines have occurred across a range of vegetation formations and other habitats, as follows.

Freshwater Wetlands: Species that have been lost include the green and golden bell frog and ground parrot. These species have both declined across the Sydney and Illawarra regions. The green and golden bell frog was formerly one of the most common frogs in Sydney but is now only known from a small number of localities (White and Pyke 1996; McEntee 2005). The ground parrot was described as "fast disappearing' by Cayley (1923) during his visit to Marley Beach in the early 1920s. It is likely that the black-necked stork (*Ephippiorhynchus asiaticus*) and magpie goose (*Anseranas semipalmata*) also occurred in the study area, but information regarding the distribution and status of these species at the time of European settlement is limited (DECC 2007b).

Watercourses: Both the platypus and water rat are suspected to have been lost from the reserves as neither has been seen since the 1970s, despite considerable search effort. The platypus was last recorded in the Hacking River and Kangaroo Creek catchments in the 1970s, with no recent records reported in a summary of the current occurrence of the species around Sydney (Grant 1998) or in subsequent years (Curtis 2001; T. Grant pers. comm.). Neither species has been encountered over a 25-year period on the lower Hacking River or on the lower reaches of Kangaroo Creek by the operators of the Audley Boatshed (J. Hughes, pers. comm.). Similarly, fish netting studies in the Hacking and Woronora rivers (e.g. Bishop 1993; Bruce et al. 2001) resulted in no captures or sightings of these species.

Heathlands: Species that appear to have become locally extinct include the ground parrot and eastern bristlebird. The former species also occurred in sedgelands within wetland habitats, while the latter species occurred in dense heathlands and was last reported from the region in the 1960s west of Mount Kembla (Chafer et al. 1999). It is also likely that the southern brown bandicoot (*Isoodon obesulus*) formerly occurred in heathland and heathy woodland, and that the long-nosed potoroo (*Potorous tridactylus*) utilised wet heath in addition to dense gully vegetation.

Rainforests: Species that have been lost from Rainforests and associated Wet Sclerophyll Forests with a rainforest subcanopy include the parma wallaby (now considered regionally extinct with the last sighting in the region in 1969 (Robinson 1988)), stuttering frog (last recorded in the Hacking River valley in 1994 (Rice 1995) and has declined throughout the southern part of its range (Gillespie 1996)) and the regent bowerbird (last reported from the study area in the 1920s (Anyon-Smith 2006)). The superb fruit-dove and the rose-crowned fruit-dove are considered to once have been more frequent seasonal visitors but are now only very rarely recorded. Although not documented (e.g. Anyon-Smith 2006), an additional species that was likely to have occurred is the wompoo fruit-dove (*Ptilinopus magnificus*) which was once resident in the Illawarra

region but has not been recorded since the 1920s (Chafer et al. 1999.). The fruit-doves have either become locally extinct or are now very rare visitors across the Illawarra region with all three species being vulnerable to fragmentation and disturbance (Recher et al. 1995; Moran et al. 2004). A number of species are suspected to have become locally extinct from the reserves; the red-necked pademelon was last reported in the 1980s and the dusky antechinus was last confirmed to be present in 1974. The greater glider was suspected to have been lost from the reserves since the 1994 wildfires, but has recently been sighted on Lady Carrington Drive (D. Andrew pers. comm.).

Wet Sclerophyll Forests with a grassy understorey*:* The Wet Sclerophyll Forests statewide vegetation formation includes two subformations: Wet Sclerophyll Forests with a shrubby understorey and Wet Sclerophyll Forests with a grassy understorey (Keith 2004). Vegetation communities that fall into the latter subformation are highly restricted in distribution within the study area, occurring only in small patches in residual shale and ironstone caps near Heathcote, Loftus, Otford and Garawarra. More extensive stands were once present on ridges and rises around the adjacent suburbs of Loftus, Engadine, Sutherland and Heathcote (DECCW 2009). These forests may have provided peripheral habitat for a suite of species that were once more extensively distributed within grassy woodlands across the drier Cumberland Plain to the west of the study area (DECC 2007a). The bush stone-curlew was formerly resident in the reserves but is now locally extinct (Anyon-Smith 2006). Other threatened species that are documented to have once utilised this habitat and have not been recorded in recent years (e.g. Anyon-Smith 2006) comprise a suite of grassy woodland bird species including the speckled warbler, painted honeyeater, black-chinned honeyeater and the diamond firetail, while barking owl now only occurs as a rare visitor. Additionally, a number of other species are known or suspected to have been lost from the reserves or today only occur as rare visitors including the peaceful dove, pallid cuckoo, white-throated gerygone, yellow-rumped thornbill, blue-faced honeyeater, little friarbird, white-winged triller, pied butcherbird, restless flycatcher, jacky winter and the rufous songlark. These species would have been largely confined to the Loftus-East Heathcote sections of the reserves. Within these areas some of the species were formerly common. For example, jacky winter was reported as “he should be the first bird recorded” around the National Park Station (Cayley 1923). Other species in this category from the same general area included the restless flycatcher, yellow-rumped thornbill, white-throated gerygone, white-browed woodswallow and the masked woodswallow (Cayley 1923). None of these birds occur in this part of the study area today.

Shoreline habitats: The shoreline species that were formerly present in the study area have not been documented. Species that probably once used shoreline habitats for breeding, but today only visit in very low numbers, are the eastern osprey, Australian pied oystercatcher and little tern. The eastern osprey was a resident species last century in the Port Hacking area (Hoskin et al. 1991), while the Australian pied oystercatcher and little tern are likely to have bred in areas such as Deeban Spit and other beaches on the southern shore of Port Hacking. There are a number of shorebird species that are likely to have once visited the intertidal mudflats and adjacent shorelines and wetlands of Port Hacking, but now would only occur as extremely rare visitors or no longer visit at all. These species include the pacific golden plover, lesser sand-plover (*Charadrius mongolus*), red-capped plover, hooded plover (*Thinornis rubricollis*), grey-tailed tattler, sanderling (*Calidris alba*), curlew sandpiper (*Calidris ferruginea*), sharp-tailed sandpiper, red-necked stint (*Calidris ruficollis*) and Pacific gull. This is a result of either a national decline in numbers (such as documented for curlew sandpiper and hooded plover), or a statewide decline in numbers (as demonstrated by a dramatic loss in numbers in the Hunter estuary for species such as lesser sand-plover or in the Sydney area for species such as such as sanderling (Hoskin et al. 1991; Straw 1996; Barrett et al. 2003; Watkins 2003; Herbert 2007). The range of the Pacific gull has contracted southwards, with it being common on Sydney beaches in the 1920s but now a rare visitor with most records attributed to mis-identifications of the similar-looking kelp gull (Higgins and Davies 1996).

Wide-ranging species: The eastern quoll was known from the reserves (Robinson 1988), but similar to the rest of the Australian mainland has now disappeared (Jones 2008). The status of spotted-tailed quoll in the reserves is less certain, but it is considered that the resident population that was known from Royal NP in the 1960s and 1970s has been lost (Robinson 1988). There have been no confirmed recent records within the reserves but given recent sightings on the Woronora Plateau (DECC 2007a), Holsworthy Military Area (DECC 2008) and in Coledale (M. Schulz, unpublished record) it is likely that individuals may occasionally wander into the reserves from other surviving populations. A population of koala occurred in the Helensburgh area in the 1940s and was reported to have become locally extinct in Royal NP in the 1970s (Robinson

1987). A number of recent records of this species exist for the study area, primarily in Heathcote NP and either represent rehabilitated released individuals (WIRES records) or wide-ranging individuals from the Campbelltown population (Ward and Close 2004) that is common along the Georges River, including in nearby areas of Holsworthy Military Area (DECC 2008).

The study area supports populations of a number of species which have declined in numbers across their national range in recent years (Barrett et al. 2003) or across the Sydney Basin Bioregion (e.g. DECC 2007b). These species include the swamp harrier, red-browed treecreeper, rockwarbler, southern emu-wren, tawny-crowned honeyeater, grey currawong, beautiful firetail and the Australian pipit. However, the population trends of birds and other fauna species occurring within the study area is unknown. A number of bird species, such as the topknot pigeon, pilotbird, rufous fantail and black-faced monarch are thought to have declined within the reserves in recent years (S. Anyon-Smith pers. comm.). Similarly, a variety of reptile species have declined in abundance, most notably the yellow-faced whip snake (K. Griffiths, unpublished records), while during the current survey the broad-headed snake could not be located at sites where it previously occurred such as along the coastal cliffs east of Bundeena (R. McLaggan, WIRES and Bundeena resident, pers. comm.). The eastern bearded dragon was common in the Jannali-Sutherland area in the 1960s and was seen in Engadine, North Engadine and also Heathcote NP more than ten years ago but not since (K. Griffiths, unpublished records). Given the lack of recent sightings, eastern bearded-dragon was suspected to have disappeared from the area (K. Griffiths pers. comm.), although during the current survey a single individual was encountered on the edge of the F6 freeway in wet sclerophyll forest with a grassy understorey. The status of extant amphibian species in the reserves is poorly known. Although red-crowned toadlet was recorded in a number of localities during the current survey, this species has declined in numbers and locations occupied most notably in Heathcote NP (R. Wells, unpublished records).

One approach to assessing species at risk of decline in the reserves is to investigate adjacent areas supporting similar habitat. Kamay Botany Bay NP, approximately 6 km north of the study area on the northern side of Port Hacking, supports a smaller area of Heathlands and Dry Sclerophyll Forests than the Royal, Heathcote and Garawarra reserves (298 ha compared to 16,152 ha in the study area) and is effectively isolated from other reserves with similar habitat due to urban and coastal development. There are no recent records of the following species in Kamay Botany Bay NP though they are likely to have once occurred (Morris 1989; DECCW 2011), and all still occur in the current study area: Freycinet's frog, Cunningham's skink, Rosenberg's goanna, broad-headed snake, painted button-quail, chestnut-rumped heathwren, beautiful firetail, brown antechinus, long-nosed bandicoot, eastern pygmy-possum, swamp wallaby, New Holland mouse and bush rat. The absence of these species from Kamay Botany NP, even given the marked difference in the size of available habitat, could potentially provide an indication of species at risk of decline in the current study area in the future.

This study did not include an investigation of the current threatening processes acting on fauna in the reserves. However, based on observations and interviews made during the surveys and a review of relevant literature, key current threats that require management include fire, feral animals, road fatalities, loss of connectivity, hydrological changes, public disturbance and wildlife poaching. Frequent fires in the Maddens Plains area on the Woronora Plateau have been implicated in the local extinction of the ground parrot and eastern bristlebird (DECC 2007a). A large proportion of Royal NP has been affected by at least three major wildfires over the last three decades since 1974, while during the same time period Heathcote NP was burnt by a single wildfire in summer 2001/2002 (NPWS 2001; Tulloch 2003). The study area potentially faces isolation for some species. Current Rainforests and Wet Sclerophyll Forests habitat connections with the Illawarra escarpment and other reserves to the south are under threat from housing development and habitat fragmentation. Less mobile fauna species in Royal NP are isolated from Heathcote NP and reserves to the west and south as a result of the Illawarra railway and F6 freeway corridors. The effects of isolation are generally gradual, resulting in a slow decline over several generations. It is likely that further fauna species loss will be experienced over time without abatement of these threatening processes. Without the establishment of a regular monitoring program across vegetation formations, particularly those supporting habitat specialists, the loss of species may go unnoticed. It is recommended that ongoing research, monitoring and management efforts focus on species that still occupy the reserves, especially species for which the reserves are significant in a regional conservation context.

ACKNOWLEDGEMENTS

This project was carried out by the Biodiversity Survey and Assessment Section in the Metropolitan Branch of the Office of Environment and Heritage (NSW). It was jointly funded by the Metropolitan Branch of the Parks and Wildlife Group. Special thanks to the following people for assistance with the field work: Debbie Andrew, Steven Anyon-Smith, Aaron Coutts-Smith, Mike Fleming, Tim Hager, Meagan Hinds, Wendy Kinsella, Manu Martinero, Kylie McClelland, Clare O'Brien, Patsy Ross, Megan Rowlatt, Joe Stammers and Jessica Zichar. We also thank Steve Anyon-Smith for providing information on birds; Anne Carrick for providing information on the birds of the Constables Point area; Richard Jackson for providing information on nocturnal birds; Gary Daly, Ken Griffiths, George Madani and Arthur White for providing information on frogs; Ken Griffiths, John Cann, Andrew Melrose and Henry Cook for providing information on reptiles; Ross Goldingay for providing information on broad-headed snakes; Tom Grant and Jason Hughes for providing information on the platypus and water rat; Harry Parnaby and Glen Hoye for providing details on the bat fauna; Ken Allen for providing location details of bat roosts within Royal National Park; Derek Engel and Rose McLaggan for providing general fauna information; Patsy Ross for providing valuable field logistical and communications support; Debbie Andrew, Bill Sullivan, Kylie Madden and Josh Madden for providing important background information; and Daniel Connolly, Kylie Madden and Debbie Andrew for commenting on an earlier draft of this paper.

REFERENCES

Andrew, D. (2001). 'Post fire vertebrate fauna survey – Royal and Heathcote National Parks and Garawarra State Recreation Area'. (NSW National Parks and Wildlife Service: Audley).

Anstis, M. (2002). 'Tadpoles of South-eastern Australia: a guide with keys'. (New Holland: Sydney).

Anyon-Smith, S. (2006). 'Birdwatching in Royal & Heathcote National Parks'. (NSW Department of Environment and Conservation: Audley).

Barrett, G., Silcocks, A., Barry S., Cunningham, R. and Poulter, R. (2003). 'The New Atlas of Australian Birds'. (Royal Australian Ornithologists Union: Victoria).

Bilney, R.J., Kavanagh, R.P. and Harris, J.M. (2007). Further observations on the diet of the Sooty Owl *Tyto tenebricosa* in the Royal National Park, Sydney. *Australian Field Ornithology* **24**, 64-69.

Bishop, K.A. (1993). 'Woronora River proposed water quality treatment plant freshwater fish study: Woronora River downstream' Unpublished report. (Sydney Water: Sydney).

Blakers, M., Davies, S.J.J.F. and Reilly, P.N. (1984). 'The Atlas of Australian Birds'. (Melbourne University Press: Victoria).

Bruce, A., Growns, I. and Gehrke, P. (2001). 'Woronora River Macquarie Perch survey'. NSW Fisheries Report Series 32. (NSW Fisheries: Sydney).

Cayley, N. W. (1923). The birds of National Park. In: 'Guide Book to the Excursions in the Sydney District'. (Ed. Anon.) pp. 27-29. (Pan Pacific Science Congress: Sydney).

Chafer, C.J. and Andersen, M. (1994). Sooty Owls in the Hacking River catchment. *Australian Birds* **27**, 77-84.

Chafer, C.J., Brandis, C.C.P. and Wright, D. (1999). 'Handbook of birds found in the Illawarra, Shoalhaven and adjacent tablelands'. (Illawarra Bird Observer's Club: Wollongong).

Clarke, K.R. and Warwick, R.M. (2001) Change in marine communities: An approach to statistical analysis and interpretation. 2nd Edition. PRIMER-E, Plymouth.

Curtis, D. (2001). 'Investigation to determine whether Platypus populations exist in waterways of the Royal and Heathcote National Parks'. Unpublished report. (NSW National Parks and Wildlife Service: Audley).

DECC (2007a). 'Terrestrial Vertebrate Fauna of the Greater Southern Sydney Region: Volume 2 – Fauna of Conservation Concern including priority pest species'. (NSW Department of Environment and Climate Change: Hurstville).

DECC (2007b). 'Terrestrial Vertebrate Fauna of the Greater Southern Sydney Region: Volume 1 – Background Report'. (NSW Department of Environment and Climate Change: Hurstville).

DECC (2008). 'Rapid Fauna Habitat Assessment of the Sydney Metropolitan Catchment Management Authority Area'. (NSW Department of Environment and Climate Change: Hurstville).

DECCW (2009). 'The Native Vegetation of the Sydney Metropolitan Catchment Management Authority Area. Volume 1: Technical Report and Volume 2: Vegetation Community Profiles'. (NSW Department of Environment, Climate Change and Water: Hurstville).

DECCW (2011). 'The Vertebrate Fauna of Kamay Botany Bay National Park'. (NSW Department of Environment, Climate Change and Water: Hurstville).

Evans, J. (2000). The fungi in the diet of the Swamp Wallaby (*Wallabia bicolor*) across different vegetation types in the Royal National Park. Hons thesis, University of Western Sydney, Penrith South.

Giles, J.R. and McKenzie, L.B. (1973). 'The ecology of the Javan Rusa in the Royal National Park'. Unpublished report. (NSW National Parks and Wildlife Service: Audley).

Gillespie, G.R. (1996). 'Survey design and management prescriptions for the Giant Burrowing Frog (*Heleioporus australiacus*) and the Stuttering Frog (*Mixophyes balbus*)'. (Arthur Rylah Institute, Dept of Natural Resources and Environment: Melbourne).

Grant, T.R. (1998). Current and historical occurrence of Platypuses, *Ornithorhynchus anatinus*, around Sydney. *Australian Mammalogy* **20**, 257-266.

Hamilton, C.A. (1981). Rusa Deer in the Royal National

Park: diet, dietary overlap with *Wallabia bicolor,* influence on the vegetation, distribution and movements. MSc thesis, University of Sydney, Sydney.

Herbert, C. (2007). 'Distribution, abundance and status of birds in the Hunter estuary'. Special Report No. 4 (Hunter Bird Observer's Club: Newcastle).

Higgins, P.J. (Ed.) (1999). 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 4. Parrots to Dollarbird'. (Oxford University Press: Victoria).

Higgins, P.J. and Davies, S.J.J.F. (Eds.) (1996). 'Handbook of Australian, New Zealand & Antarctic Birds. Volume 3: Snipe to Pigeons'. (Oxford University Press: Victoria).

Higgins, P.J. and Peter, J.M. (Eds.) (2002). 'Handbook of Australian, New Zealand & Antarctic Birds. Volume 6: Pardalotes to Shrike-thrushes'. (Oxford University Press: Victoria).

Higgins, P.J., Peter, J.M. and Steele, W.K. (Eds.) (2001). 'Handbook of Australian, New Zealand & Antarctic Birds. Volume 5: Tyrant-flycatchers to Chats'. (Oxford University Press: Victoria)

Hobcroft, D. and James, D.J. (1997). Records of the Grass Owl from southern New South Wales. *Australian Bird Watcher* **17**, 91-93.

Hoskin, E.S., Hindwood, K.A. and McGill, A.R. (1991). 'The birds of Sydney, County of Cumberland, New South Wales, 1770-1989'. *(*Surrey Beatty and Sons: Sydney).

Jones, M. (2008). Eastern Quoll *Dasyurus viverrinus*. In: 'The Mammals of Australia'. (Eds. S. van Dyck and R. Strahan). pp. 62-64. Third edition. (Reed New Holland: Sydney).

Kavanagh, R.P. and Jackson, R. (1997). Home-range, movements, habitat and diet of the Sooty Owl *Tyto tenebricosa* near Royal National Park. In: 'Australian Raptor Studies'. (Eds G.V. Czechura and S.J.S. Debus). Birds Australia Monographs No. 3, 2-13. (Royal Australasian Ornithologist's Union: Victoria).

Keith, D.A. (2004). 'Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT'. (NSW Dept of Environment and Conservation: Hurstville).

Keith, D. and Pellow, B. (2005). Effects of Javan Rusa Deer (*Cervus timorensis*) on native plant species in the Jibbon-Bundeena area, Royal National Park, New South Wales. *Proceedings of the Linnean Society of NSW* **126**, 99-110.

Keith, D.A. and Tozer, M. (unpubl.). 'Vegetation map of Royal National Park and surrounds'. (NSW National Parks and Wildlife Service: Hurstville).

Kevin Mills and Associates (1995). 'Fauna assessment of proposed wetland sites in Royal National Park, Engadine, Shire of Sutherland'. (Kevin Mills and Associates Pty Ltd: Jamberoo).

Lemckert, F. and Mahony, M. (2008). Core calling periods of the frogs of temperate New South Wales, Australia. *Herpetological Conservation and Biology* **3**, 71-76.

Lesryk Environmental Consultants (1996). 'Fauna assessment of proposed fencing programme adjacent to the Illawarra Railway Line between Heathcote and Waterfall Railway Stations'. Report prepared for State Rail. (Lesryk Environmental Consultants: Bundeena).

Lesryk Environmental Consultants (2005). 'Ecological assessment of proposed culvert works'. Report prepared for the Roads and Traffic Authority. (Lesryk Environmental Consultants: Bundeena).

Lesryk Environmental Consultants (2007). 'Flora and fauna assessment of proposed culvert works'. Report prepared for the Roads and Traffic Authority. (Lesryk Environmental Consultants: Bundeena).

Lesryk Environmental Consultants (2008). 'Roadside flora and fauna survey'. Report prepared for the Roads and Traffic Authority. (Lesryk Environmental Consultants: Bundeena).

Lesryk Environmental Consultants (2010). 'Flora and fauna assessment of proposed table drain clearing and culvert upgrading work'. Report prepared for the Roads and Traffic Authority. (Lesryk Environmental Consultants: Bundeena).

Mahood, I. (1981). Rusa of Royal National Park. *Australian Deer* **6**, 15-24.

McEntee, B.A. (2005). An investigation into the feasibility of reintroducing the Green and Golden Bell Frog (*Litoria aurea*) into Marley Lagoon, in the Royal National Park. Hons thesis, University of Wollongong, Wollongong.

Moran, C., Catterall, C.P., Green, R.J. and Olsen, M.F. (2004). Fate of feathered fruit-eaters in fragmented forests. In: 'Conservation of Australia's forest fauna'. (Ed. D. Lunney). pp. 699-712. (Royal Zoological Society of NSW: Sydney).

Moriarty, A. (2004). The environmental impacts of Rusa Deer in the Royal National Park. PhD thesis, University of Western Sydney, Penrith South.

Morris, A.K. (1989). The birds of Botany Bay National Park, New South Wales. *Australian Birds* **23**, 7-21.

Nolan, L. (2006). 'Biodiversity survey report 2006: Royal and Heathcote National Parks'. Unpublished report. (NSW National Parks and Wildlife Service: Audley).

NPWS (2000a). 'Royal National Park, Heathcote National Park and Garawarra State Recreation Area plan of management.' (NSW National Parks and Wildlife Service: Sydney).

NPWS (2000b). 'Biodiversity Study for the Georges River Catchment. Volume 2: Fauna Assessment'. (NSW National Parks and Wildlife Service: Hurstville).

NPWS (2001). 'Draft Fire Management Plan for Royal, Heathcote National Parks and Garawarra State Recreation Area'. (NSW National Parks and Wildlife Service: Sydney).

NPWS (2002). 'Wollongong LGA Bioregional Assessment (Part II): Fauna of the Illawarra Escarpment, Coastal Plain and Plateau'. (NSW National Parks and Wildlife Service: Sydney).

OEH (2012). The Atlas of NSW Wildlife. (NSW Office of Environment and Heritage: Hurstville).

Ramp, D. and Ben-Ami, D. (2006). The effect of road-based fatalities on the viability of a peri-urban Swamp Wallaby population. *Journal of Wildlife Management* **70**, 1615-1624.

Recher, H.F., Date, E.M. and Ford, H.A. (1995). 'The biology and management of rainforest pigeons in NSW'. Species Management Report No. 16. (NSW National Parks and Wildlife Service: Hurstville).

Rice, J.P. (1995). A survey of amphibian populations associated with permanent waterways in the Helensburgh region of the Upper Hacking River catchment. Hons thesis, University of Wollongong, Wollongong.

Robinson, N.H. (1987). 'Mammals of the national parks and nature reserves between Port Hacking and the Shoalhaven River'. (Illawarra Heritage Committee: Wollongong).

Robinson, N.H. (1988). The impact of European man on the status of mammals in the Illawarra Region. MSc thesis, University of Wollongong, Wollongong.

Rohweder, D.A. and Baverstock, P.R. (1999). Distribution of Platypus, *Ornithorhynchus anatinus*, in the Richmond River catchment, northern New South Wales. Australian Zoologist 31, 30-37.

Schulz, M. (2000a). Roosts used by the Golden-tipped Bat *Kerivoula papuensis* (Chiroptera: Vespertilionidae). *Journal of Zoology, London* **25**, 467-478.

Schulz, M. (2000b). Relative abundance and other aspects of the natural history of the rare Golden-tipped Bat, *Kerivoula papuensis* (Chiroptera: Vespertilionidae). *Acta Chiropterologica* **1**, 165-178.

Schulz, M. (2000c). Diet and foraging behaviour of the Golden-tipped Bat *Kerivoula papuensis*. *Journal of Mammalogy* **22**, 23-33.

Schulz, M. and Magarey, E. (2010). Diet of an Eastern Grass Owl at Kamay Botany Bay National Park, Sydney. *Australian Field Ornithology* **27**,177-178.

Straw, P. (1996). 'Wader population study of Botany Bay and Adjacent Wetlands'. (Royal Australian Ornithologists Union: Victoria).

Triggs. B. (2001). 'Tracks, scats and other traces: a field guide to Australian mammals'. (Oxford University Press: Victoria).

Trustees (1915). 'Official Guide to the National Park of New South Wales'. (Government Printer: Sydney).

Tuck, M. (1971). Javan Rusa Deer (*Cervus timorensis*) in the Royal National Park – habitat utilization and distribution. Hons thesis, University of Wollongong, Wollongong.

Tulloch, A. (2001). Distribution, abundance and habitat use of the Eastern Pygmy Possum, *Cercartetus nanus*, in Royal and Heathcote National Parks, New South Wales. Hons thesis, University of Sydney, Sydney.

Tulloch, A. (2003). 'Post-fire distribution, abundance and habitat use of small mammals in Royal National Park, Heathcote National Park and Garawarra State Recreation Area, New South Wales'. (NSW National Parks and Wildlife Service: Audley).

Ward, S. and Close, R. (2004). Southern Sydney's urban Koalas: community research and education at Campbelltown. In: '*Urban wildlife: more than meets the eye'*. (Eds. D. Lunney and S. Burgin). pp. 44-55. (Royal Zoological Society of NSW: Sydney).

Watkins, D. (2003). 'A national plan for shorebird conservation in Australia'. RAOU Report No. 90. (Royal Australasian Ornithologist's Union, Victoria).

Whelan, R.J., Ward, S., Hogbin, P. and Wasley, J. (1996). Responses of heathland *Antechinus stuartii* to the Royal National Park wildfire in 1994. *Proceedings of the Linnean Society of NSW* **116**, 97-108.

White, A.W. and Pyke, G.H. (1996). Distribution and conservation status of the Green and Golden Bell Frog (*Litoria aurea*) in New South Wales. *Australian Zoologist* **30**, 177-189.

Young, B. and Young, A. (2006). 'Understanding the Scenery: the Royal National Park and Heathcote National Park'. (Envirobook: Sydney).

APPENDIX 1. SPECIES RECORDED IN THE CURRENT SURVEY

Values are the percentage of systematic techniques in which the species was detected that were in the designated vegetation formation. Cells are shaded by the following percentage classes:

76 - 100% | 51 - 75% | 26 - 50% | 0.1 - 25%

Percentages are not presented for species recorded once only; these are denoted by #.
Introduced species are denoted by *.

Common name	Scientific name	Threatened species listed under the TSC Act and/or EPBC Act	Recorded during targeted or incidental techniques only	Recorded during systematic techniques							
				% RF	% WSF	% DSF	% HL	% FrW	% FoW	% SW	% GL
Amphibians											
Bleating tree frog	*Litoria dentata*				#						
Blue Mountains tree frog	*Litoria citropa*				#						
Brown-striped frog	*Limnodynastes peronii*					21.4		28.6	35.7		14.3
Common eastern froglet	*Crinia signifera*			4.2	4.2	35.4	22.9	14.6	12.5		6.3
Eastern banjo frog	*Limnodynastes dumerilii grayi*					#					
Eastern dwarf tree frog	*Litoria fallax*			15.4		30.8		23.1	30.8		
Freycinet's frog	*Litoria freycineti*					83.3		16.7			
Giant burrowing frog	*Heleioporus australiacus*	x				66.7	33.3				
Haswell's froglet	*Paracrinia haswelli*							#			
Leaf-green tree frog	*Litoria phyllochroa*			30	20	43.3			6.7		
Lesueur's frog	*Litoria lesueuri*					100					
Peron's tree frog	*Litoria peronii*					37.5		37.5	25		
Red-crowned toadlet	*Pseudophryne australis*	x				62.5	37.5				
Smooth toadlet	*Uperoleia laevigata*					50		50			
Wilcox's frog	*Litoria wilcoxii*					#					
Reptiles											
Bandy-bandy	*Vermicella annulata*		x								
Barred-sided skink	*Eulamprus tenuis*				66.7				33.3		
Bearded dragon	*Pogona barbata*		x								
Black-bellied swamp snake	*Hemiaspis signata*		x								
Blackish blind snake	*Ramphotyphlops nigrescens*					#					
Broad-headed snake	*Hoplocephalus bungaroides*	x				#					
Broad-tailed gecko	*Phyllurus platurus*			11.1	44.4	22.2	16.7		5.6		
Brown tree snake	*Boiga irregularis*					#					
Burton's snake-lizard	*Lialis burtonis*		x								
Common death adder	*Acanthophis antarcticus*				50	50					
Common scaly-foot	*Pygopus lepidopodus*					20	80				
Common tree snake	*Dendrelaphis punctulatus*				#						
Copper-tailed skink	*Ctenotus taeniolatus*					38.5	53.8	7.7			
Cream-striped shinning-skink	*Cryptoblepharus virgatus*				25	50	12.5		12.5		
Cunningham's skink	*Egernia cunninghami*						100				
Dark-flecked garden sunskink	*Lampropholis delicata*			13.6	18.2	34.1	17	4.5	8	2.3	2.3
Diamond python	*Morelia spilota spilota*			60					40		

Eastern blue-tongue	*Tiliqua scincoides*							100							
Eastern brown snake	*Pseudonaja textilis*								100						
Eastern small-eyed snake	*Cryptophis nigrescens*				14.3	71.4									14.3
Eastern snake-necked turtle	*Chelodina longicollis*		x												
Eastern water dragon	*Physignathus lesueurii lesueurii*				17.6	17.6	64.7								
Eastern water-skink	*Eulamprus quoyii*				19.4	22.2	36.1	13.9		8.3					
Emydura	*Emydura* sp.		x												
Golden-crowned snake	*Cacophis squamulosus*				66.7	16.7	16.7								
Jacky lizard	*Amphibolurus muricatus*				4.3	8.7	39.1	39.1							8.7
Lace monitor	*Varanus varius*					50	25			25					
Lesueur's velvet gecko	*Oedura lesueurii*						37.5	62.5							
Mainland she-oak skink	*Cyclodomorphus michaeli*								66.7		33.3				
Mountain dragon	*Rankinia diemensis*						50	50							
Pale-flecked garden sunskink	*Lampropholis guichenoti*						100								
Red-bellied black snake	*Pseudechis porphyriacus*				11.1		22.2	22.2	11.1	33.3					
Red-naped snake	*Furina diadema*		x												
Red-throated skink	*Acritoscincus platynota*						61.5	38.5							
Rosenberg's goanna	*Varanus rosenbergi*	x			20		40	40							
Thick-tailed gecko	*Underwoodisaurus milii*						100								
Three-toed skink	*Saiphos equalis*				30.8	34.6	11.5	3.8		15.4	3.8				
Tiger snake	*Notechis scutatus*					50		50							
Weasel skink	*Saproscincus mustelinus*				31.6	31.6	15.8	10.5		10.5					
White's skink	*Liopholis whitii*						12.5	81.3	6.3						
Wood gecko	*Diplodactylus vittatus*						100								
Yellow-faced whip snake	*Demansia psammophis*						50	50							
Birds															
Australasian bittern	*Botaurus poiciloptilus*	x	x												
Australasian darter	*Anhinga novaehollandiae*		x												
Australasian figbird	*Sphecotheres vieilloti*									#					
Australasian grebe	*Tachybaptus novaehollandiae*		x												
Australian hobby	*Falco longipennis*					#									
Australian king-parrot	*Alisterus scapularis*				42.9		42.9			14.3					
Australian magpie	*Cracticus tibicen*						28.6		14.3	14.3					42.9
Australian owlet-nightjar	*Aegotheles cristatus*				13.8	27.6	48.3			10.3					
Australian pelican	*Pelecanus conspicillatus*										#				
Australian pipit	*Anthus novaeseelandiae*							50							50
Australian raven	*Corvus coronoides*				4.8	4.8	23.8	23.8	9.5	14.3	4.8				14.3
Australian reed-warbler	*Acrocephalus australis*		x												

Australian white ibis	*Threskiornis molucca*							33.3		66.7	
Australian wood duck	*Chenonetta jubata*							50	50		
Azure kingfisher	*Ceyx azureus*			25	12.5	37.5			12.5	12.5	
Bar-shouldered dove	*Geopelia humeralis*			#							
Bar-tailed godwit	*Limosa lapponica*		x								
Bassian thrush	*Zoothera lunulata*			85.7			14.3				
Beautiful firetail	*Stagonopleura bella*				5.3	10.5	57.9	26.3			
Black bittern	*Ixobrychus flavicollis*	x	x								
Black swan	*Cygnus atratus*		x								
Black-faced cuckoo-shrike	*Coracina novaehollandiae*				46.6	33.3		6.7	13.3		
Black-faced monarch	*Monarcha melanopsis*			70	15	10			5		
Black-fronted dotterel	*Elseyornis melanops*							50			50
Black-shouldered kite	*Elanus axillaris*						75				25
Brown cuckoo-dove	*Macropygia amboinensis*			80		20					
Brown falcon	*Falco berigora*		x								
Brown gerygone	*Gerygone mouki*			66.7	20.8	4.2			8.3		
Brown goshawk	*Accipiter fasciatus*					50		50			
Brown quail	*Coturnix ypsilophora*			50				50			
Brown thornbill	*Acanthiza pusilla*			23.6	19.4	36.1	12.5	2.8	2.8	1.4	1.4
Brown-headed honeyeater	*Melithreptus brevirostris*					85.7			14.3		
Brush bronzewing	*Phaps elegans*						66.7	33.3			
Brush cuckoo	*Cacomantis variolosus*					100					
Buff-banded rail	*Gallirallus philippensis*		x								
Buff-rumped thornbill	*Acanthiza reguloides*					100					
Channel-billed cuckoo	*Scythrops novaehollandiae*				28.6	42.9		14.3	14.3		
Chestnut teal	*Anas castanea*								33.3	33.3	33.3
Chestnut-rumped heathwren	*Hylacola pyrrhopygia*					37.5	54.2	8.3			
Cicadabird	*Coracina tenuirostris*				50	40			10		
Collared sparrowhawk	*Accipiter cirrocephalus*						50	25	25		
Common bronzewing	*Phaps chalcoptera*					50	50				
Common myna*	*Sturnus tristis**				50				50		
Crescent honeyeater	*Phylidonyris pyrrhoptera*		x								
Crested pigeon	*Ocyphaps lophotes*					#					
Crested tern	*Thalasseus bergii*		x								
Crimson rosella	*Platycercus elegans*			28.6	19.1	42.9	2.4	2.4	2.4		2.4
Dollarbird	*Eurystomus orientalis*				37.5	12.5		12.5	37.5		
Dusky moorhen	*Gallinula tenebrosa*					25		25	50		
Dusky woodswallow	*Artamus cyanopterus*					14.3	85.7				
Eastern barn owl	*Tyto javanica*					#					

Eastern curlew	*Numenius madagascariensis*		x									
Eastern grass owl	*Tyto longimembris*	x								#		
Eastern great egret	*Ardea modesta*									50	50	
Eastern koel	*Eudynamys orientalis*					11.1	55.6			11.1	22.2	
Eastern osprey	*Pandion cristatus*	x				#						
Eastern reef egret	*Egretta sacra*		x									
Eastern rosella	*Platycercus eximius*									50	50	
Eastern shrike-tit	*Falcunculus frontatus frontatus*				50	50						
Eastern spinebill	*Acanthorhynchus tenuirostris*				15.3	12.5	50	8.3	8.3	4.2	1.4	
Eastern whipbird	*Psophodes olivaceus*				24.3	10.8	10.8	32.4	10.8	10.8		
Eastern yellow robin	*Eopsaltria australis*				36	18	30	2	6	8		
Emerald dove	*Chalcophaps indica*		x									
Eurasian coot	*Fulica atra*		x									
Fan-tailed cuckoo	*Cacomantis flabelliformis*						50	25	25			
Fork-tailed swift	*Apus pacificus*							#				
Fuscous honeyeater	*Lichenostomus fuscus*						#					
Galah	*Eolophus roseicapillus*								#			
Golden whistler	*Pachycephala pectoralis*				55.2	13.8	20.7	3.4		6.9		
Golden-headed cisticola	*Cisticola exilis*								#			
Great cormorant	*Phalacrocorax carbo*						50		50			
Green catbird	*Ailuroedus crassirostris*				100							
Grey butcherbird	*Cracticus torquatus*					60	30			20		
Grey currawong	*Strepera versicolor*		x									
Grey fantail	*Rhipidura albiscapa*				17.5	27.5	40	5	7.5	2.5		
Grey goshawk	*Accipiter novaehollandiae*				60	20	20					
Grey shrike-thrush	*Colluricincla harmonica*				12	16	36	20	4	12		
Grey teal	*Anas gracilis*		x									
Horsfield's bronze-cuckoo	*Chalcites basalis*							100				
House sparrow*	*Passer domesticus**		x									
Kelp gull	*Larus dominicanus*		x									
Large-billed scrubwren	*Sericornis magnirostra*				90.9	9.1						
Latham's snipe	*Gallinago hardwickii*											#
Laughing kookaburra	*Dacelo novaeguineae*				10	20	40		10	20		
Leaden flycatcher	*Myiagra rubecula*					22.2	66.7				11.1	
Lewin's honeyeater	*Meliphaga lewinii*				48.1	14.8	14.8		3.7	18.5		
Lewin's rail	*Lewinia pectoralis*								50	50		
Little black cormorant	*Phalacrocorax sulcirostris*								#			
Little corella	*Cacatua sanguinea*						50		50			

Little eagle	*Hieraaetus morphnoides*	x								#													
Little egret	*Egretta garzetta*		x																				
Little grassbird	*Megalurus gramineus*											#											
Little lorikeet	*Glossopsitta pusilla*	x						#															
Little penguin	*Eudyptula minor*		x																				
Little pied cormorant	*Microcarbo melanoleucos*					33.3			33.3				33.3										
Little tern	*Sterna albifrons*	x	x																				
Little wattlebird	*Anthochaera chrysoptera*			4.4	8.9	33.3	33.3	15.6	4.4														
Logrunner	*Orthonyx temminckii*			50	50																		
Long-billed corella	*Cacatua tenuirostris*											#											
Magpie-lark	*Grallina cyanoleuca*								100														
Mallard*	*Anas platyrhynchos**		x																				
Masked lapwing	*Vanellus miles*																				#		
Masked owl	*Tyto novaehollandiae*	x		#																			
Mistletoebird	*Dicaeum hirundinaceum*			7.7	15.4	69.2		7.7															
Musk lorikeet	*Glossopsitta concinna*												#										
Nankeen kestrel	*Falco cenchroides*							40													60		
Nankeen night heron	*Nycticorax caledonicus*											#											
New Holland honeyeater	*Phylidonyris novaehollandiae*			3.4	5.1	28.8	35.6	20.3	6.8														
Noisy friarbird	*Philemon corniculatus*				25	75																	
Noisy miner	*Manorina melanocephala*				33.3			16.7	50														
Noisy pitta	*Pitta versicolor*		x																				
Olive-backed oriole	*Oriolus sagittatus*				83.3				16.7														
Pacific baza	*Aviceda subcristata*								#														
Pacific black duck	*Anas superciliosa*					28.6		28.6	28.6												14.3		
Painted button-quail	*Turnix varius*					50	50																
Peregrine falcon	*Falco peregrinus*						100																
Pheasant coucal	*Centropus phasianinus*						87.5		12.5														
Pied cormorant	*Phalacrocorax varius*		x																				
Pied currawong	*Strepera graculina*			16	32	40		8	4														
Pilotbird	*Pycnoptilus floccosus*					75		25															
Powerful owl	*Ninox strenua*	x		#																			
Purple swamphen	*Porphyrio porphyrio*							25	75														
Rainbow lorikeet	*Trichoglossus haematodus*			4.3	17.4	52.2		13	13														
Red wattlebird	*Anthochaera carunculata*				18.2	72.7			9.1														
Red-browed finch	*Neochmia temporalis*			11.1	16.7	38.9	5.6	22.2	5.6														
Red-browed treecreeper	*Climacteris erythrops*				66.7	33.3																	
Red-whiskered bulbul*	*Pycnonotus jocosus**			14.3	14.3		14.3	14.3	28.6												14.3		
Rockwarbler	*Origma solitaria*				7.7	61.5	30.8																

Rose robin	*Petroica rosea*					#							
Royal spoonbill	*Platalea regia*								#				
Ruddy turnstone	*Arenaria interpres*		x										
Rufous fantail	*Rhipidura rufifrons*			61.5	19.2	15.4				3.8			
Rufous whistler	*Pachycephala rufiventris*				25	75							
Sacred kingfisher	*Todiramphus sanctus*			22.2	11.1	33.3			11.1	22.2			
Satin bowerbird	*Ptilonorhynchus violaceus*			33.3	33.3	33.3							
Scaly-breasted lorikeet	*Trichoglossus chlorolepidotus*		x										
Scarlet honeyeater	*Myzomela sanguinolenta*					100							
Scarlet robin	*Petroica boodang*	x	x										
Shining bronze-cuckoo	*Chalcites lucidus*			50		50							
Silver gull	*Chroicocephalus novaehollandiae*						50				50		
Silvereye	*Zosterops lateralis*			31.3	23	14.6	10.4	2.1	8.3	4.2	6.3		
Sooty owl	*Tyto tenebricosa*	x		100									
Sooty oystercatcher	*Haematopus fuliginosus*	x	x										
Southern boobook	*Ninox novaeseelandiae*			7.7	15.4	46.2				30.8			
Southern emu-wren	*Stipiturus malachurus*					4.3	39.1	39.1	4.3	4.3	8.7		
Spotless crake	*Porzana tabuensis*		x										
Spotted pardalote	*Pardalotus punctatus*			3.1	25	59.4		3.1	9.4				
Spotted turtle-dove*	*Streptopelia chinensis**			20	20	20		20	20				
Straw-necked ibis	*Threskiornis spinicollis*		x										
Striated heron	*Butorides striatus*										#		
Striated pardalote	*Pardalotus striatus*					100							
Striated thornbill	*Acanthiza lineata*			13.9	22.2	61.1			2.8				
Sulphur-crested cockatoo	*Cacatua galerita*			21.1	31.6	26.3		5.3	10.5	5.3			
Superb fairy-wren	*Malurus cyaneus*			5.3	10.5	10.5	10.5	15.8	15.8	5.3	26.3		
Superb lyrebird	*Menura novaehollandiae*			47.1	17.6	35.3							
Swamp harrier	*Circus approximans*						50		50				
Tawny frogmouth	*Podargus strigoides*				11.1	66.7			22.2				
Tawny-crowned honeyeater	*Gliciphila melanops*					7.1	57.1	35.7					
Topknot pigeon	*Lopholaimus antarcticus*			33.3	33.3	33.3							
Tree martin	*Petrochelidon nigricans*					12.5	37.5	50					
Varied sittella	*Daphoenositta chrysoptera*	x				100							
Variegated fairy-wren	*Malurus lamberti*			2.1	16.7	41.7	29.2	6.3	2.1	2.1			
Wedge-tailed eagle	*Aquila audax*		x										
Welcome swallow	*Hirundo neoxena*			5.7	2.9	8.6	51.4	14.3	2.9	8.6	5.7		
Whimbrel	*Numenius phaeopus*									#			
Whistling kite	*Haliastur sphenurus*								33.3	66.7			

White-bellied sea-eagle	*Haliaeetus leucogaster*				7.7		46.2	7.7		7.7	30.8		
White-browed scrubwren	*Sericornis frontalis*			13.6	13.6	33	23.9	8	5.7		2.3		
White-browed woodswallow	*Artamus superciliosus*		x										
White-cheeked honeyeater	*Phylidonyris niger*							100					
White-eared honeyeater	*Lichenostomus leucotis*					84.6	15.4						
White-faced heron	*Egretta novaehollandiae*									50	50		
White-fronted tern	*Sterna striata*		x										
White-naped honeyeater	*Melithreptus lunatus*					#							
White-necked heron	*Ardea pacifica*		x										
White-plumed honeyeater	*Lichenostomus penicillatus*		x										
White-throated needletail	*Hirundapus caudacutus*			8.3	8.3	25	41.7	8.3	8.3				
White-throated nightjar	*Eurostopodus mystacalis*				14.3	57.1			28.6				
White-throated treecreeper	*Cormobates leucophaea*			14.8	40.7	40.7			3.7				
Willie wagtail	*Rhipidura leucophrys*						20	20	40		20		
Wonga pigeon	*Leucosarcia picata*			100									
Yellow thornbill	*Acanthiza nana*			50						50			
Yellow-faced honeyeater	*Lichenostomus chrysops*			6.3	21.9	53.1	9.4	6.3	3.1				
Yellow-tailed black-cockatoo	*Calyptorhynchus funereus*				9.1	90.9							
Yellow-throated scrubwren	*Sericornis citreogularis*			86.7	6.7	6.7							
Yellow-tufted honeyeater	*Lichenostomus melanops*					80			20				
Mammals													
Black rat*	*Rattus rattus**								#				
Brown antechinus	*Antechinus stuartii*					#							
Bush rat	*Rattus fuscipes*			#									
Cat*	*Felis catus**				#								
Chocolate wattled bat	*Chalinolobus morio*			17.6	5.9	70.6		5.9					
Common brushtail possum	*Trichosurus vulpecula*					50			50				
Common dunnart	*Sminthopsis murina*		x										
Common ringtail possum	*Pseudocheirus peregrinus*			16.7	8.3	58.3			16.7				
Common wallaroo	*Macropus robustus*		x										
Common wombat	*Vombatus ursinus*		x										
Dog*	*Canis lupus familiaris**		x										
Eastern bentwing-bat	*Miniopterus schreibersii oceanensis*	x		25	25	50							
Eastern broad-nosed bat	*Scotorepens orion*			#									
Eastern freetail-bat	*Mormopterus ridei*		x										
Eastern horseshoe-bat	*Rhinolophus megaphyllus*			35.7	14.3	42.9	7.1						
Eastern pygmy-possum	*Cercartetus nanus*	x				#							
Feathertail glider	*Acrobates pygmaeus*			33.3		66.7							
Fox*	*Vulpes vulpes**					#							

Gould's long-eared bat	*Nyctophilus gouldi*			10		70		10		10	
Gould's wattled bat	*Chalinolobus gouldii*			11.1	19.4	50	8.3	8.3	2.8		
Greater broad-nosed bat	*Scoteanax rueppellii*	x				100					
Grey-headed flying-fox	*Pteropus poliocephalus*	x				81.8			18.2		
House mouse*	*Mus musculus**		x								
Koala	*Phascolarctos cinereus*	x	x								
Large forest bat	*Vespadelus darlingtoni*			12.5		87.5					
Large-eared pied bat	*Chalinolobus dwyeri*	x		14.3		85.7					
Lesser long-eared bat	*Nyctophilus geoffroyi*					#					
Little bentwing-bat	*Miniopterus australis*	x									
Little forest bat	*Vespadelus vulturnus*			8.2	14.8	65.6	3.3	1.6	4.9	1.6	
Long-nosed bandicoot	*Perameles nasuta*			100							
Mountain brushtail possum	*Trichosurus cunninghami*		x								
New Holland mouse	*Pseudomys novaehollandiae*	x	x								
Rabbit*	*Oryctolagus cuniculus**				#						
Rusa deer*	*Cervus timorensis**			28.6	14.3	14.3		14.3	28.6		
Short-beaked echidna	*Tachyglossus aculeatus*		x								
Southern myotis	*Myotis macropus*	x		60		40					
Sugar glider	*Petaurus breviceps*			16.1	29.1	41.9			12.9		
Swamp rat	*Rattus lutreolus*		x								
Swamp wallaby	*Wallabia bicolor*			6.7	20	60		6.7	6.7		
White-striped freetail-bat	*Tadarida australis*			18.2	18.2	63.6					

APPENDIX 2. SPECIES PREVIOUSLY RECORDED BUT NOT DURING THE CURRENT SURVEY

Sources: Atlas of NSW Wildlife (OEH 2012), Anyon-Smith (2006), M. Schulz (unpublished data), Robinson (1987, 1988), Andrew (2001), B. Sullivan OEH staff at Royal NP (pers. comm.).

Introduced species are denoted by *.

Common name	Scientific name	Threatened species listed under the TSC Act and/or EPBC Act	Status in the study area
Amphibians			
Broad-palmed frog	*Litoria latopalmata*		Status uncertain
Brown toadlet	*Pseudophryne bibronii*		Status uncertain
Green and golden bell frog	*Litoria aurea*	x	Locally extinct
Green tree frog	*Litoria caerulea*		Status uncertain
Jervis Bay tree frog	*Litoria jervisiensis*		Winter-vocalising
Stuttering frog	*Mixophyes balbus*	x	Locally extinct
Verreaux's tree frog	*Litoria verreauxii*		Winter-vocalising
Birds			
Apostlebird	*Struthidea cinerea*		Rare or vagrant
Australian brush turkey	*Alectura lathami*		Rare or vagrant
Australian little bittern	*Ixobrychus dubius*		Rare or vagrant
Australian pied oystercatcher	*Haematopus longirostris*	x	Winter visitor
Australian shelduck	*Tadorna tadornoides*		Rare or vagrant
Australian spotted crake	*Porzana fluminea*		Rare or vagrant
Baillon's crake	*Porzana pusilla*		Rare or vagrant
Barking owl	*Ninox connivens*	x	Status uncertain
Beach stone-curlew	*Esacus magnirostris*	x	Rare or vagrant
Black falcon	*Falco subniger*		Rare or vagrant
Black honeyeater	*Sugomel niger*		Rare or vagrant
Black kite	*Milvus migrans*		Rare or vagrant
Black-chinned honeyeater	*Melithreptus gularis*		Rare or vagrant
Black-eared cuckoo	*Chalcites osculans*		Rare or vagrant
Black-winged stilt	*Himantopus himantopus*		Rare or vagrant
Blue-faced honeyeater	*Entomyzon cyanotis*		Rare or vagrant
Brown honeyeater	*Lichmera indistincta*		Rare or vagrant
Brown songlark	*Cincloramphus cruralis*		Rare or vagrant
Bush stone-curlew	*Burhinus grallarius*	x	Locally extinct

Caspian tern	*Hydroprogne caspia*		Sporadic visitor
Cattle egret	*Ardea ibis*		Sporadic visitor
Common sandpiper	*Actitis hypoleucos*		Rare or vagrant
Common tern	*Sterna hirundo*		Rare or vagrant
Diamond firetail	*Stagonopleura guttata*	x	Rare or vagrant
Double-banded plover	*Charadrius bicinctus*		Winter visitor
Double-barred finch	*Taeniopygia bichenovii*		Rare or vagrant
Eastern bristlebird	*Dasyornis brachypterus*	x	Locally extinct
Eurasian blackbird*	*Turdus merula**		Sporadic visitor
Fairy martin	*Petrochelidon ariel*		Sporadic visitor
Forest kingfisher	*Todiramphus macleayii*		Rare or vagrant
Freckled duck	*Stictonetta naevosa*	x	Rare or vagrant
Gang-gang cockatoo	*Callocephalon fimbriatum*	x	Sporadic visitor
Glossy black-cockatoo	*Calyptorhynchus lathami*	x	Rare or vagrant
Great crested grebe	*Podiceps cristatus*		Rare or vagrant
Grey-tailed tattler	*Tringa brevipes*		Rare or vagrant
Ground parrot	*Pezoporus wallicus*		Locally extinct
Hardhead	*Aythya australis*		Sporadic visitor
Hoary-headed grebe	*Poliocephalus*		Rare or vagrant
Intermediate egret	*Ardea intermedia*		Sporadic visitor
Jacky winter	*Microeca fascinans*		Rare or vagrant
King quail	*Excalfactoria chinensis*		Status uncertain
Little friarbird	*Philemon citreogularis*		Rare or vagrant
Mangrove gerygone	*Gerygone levigaster*		Status uncertain
Masked woodswallow	*Artamus personatus*		Rare or vagrant
Musk duck	*Biziura lobata*		Sporadic visitor
Oriental cuckoo	*Cuculus optatus*		Rare or vagrant
Pacific golden plover	*Pluvialis fulva*		Rare or vagrant
Pacific gull	*Larus pacificus*		Rare or vagrant
Painted honeyeater	*Grantiella picta*	x	Rare or vagrant
Pallid cuckoo	*Cacomantis pallidus*		Rare or vagrant
Peaceful dove	*Geopelia striata*		Rare or vagrant
Pied butcherbird	*Cracticus nigrogularis*		Rare or vagrant
Plumed whistling-duck	*Dendrocygna eytoni*		Rare or vagrant
Red-capped plover	*Charadrius ruficapillus*		Rare or vagrant
Red-capped robin	*Petroica goodenovii*		Rare or vagrant
Red-rumped parrot	*Psephotus haematonotus*		Rare or vagrant

Regent bowerbird	*Sericulus chrysocephalus*		Locally extinct
Regent honeyeater	*Anthochaera phrygia*	x	Rare or vagrant
Restless flycatcher	*Myiagra inquieta*		Rare or vagrant
Rock dove*	*Columba livia**		Sporadic visitor
Rose-crowned fruit-dove	*Ptilinopus regina*	x	Rare or vagrant
Rufous songlark	*Cincloramphus mathewsi*		Rare or vagrant
Satin flycatcher	*Myiagra cyanoleuca*		Rare or vagrant
Sharp-tailed sandpiper	*Calidris acuminata*		Rare or vagrant
Spangled drongo	*Dicrurus bracteatus*		Winter visitor
Speckled warbler	*Chthonicola sagittata*	x	Locally extinct
Spectacled monarch	*Symposiachrus trivirgatus*		Rare or vagrant
Spiny-cheeked honeyeater	*Acanthagenys rufogularis*		Rare or vagrant
Spotted harrier	*Circus assimilis*	x	Rare or vagrant
Spotted quail-thrush	*Cinclosoma punctatum*		Rare or vagrant
Square-tailed kite	*Lophoictinia isura*	x	Rare or vagrant
Striated pardalote	*Pardalotus striatus*		Sporadic visitor
Stubble quail	*Coturnix pectoralis*		Rare or vagrant
Superb fruit-dove	*Ptilinopus superbus*	x	Rare or vagrant
Swift parrot	*Lathamus discolor*	x	Sporadic visitor
Tawny grassbird	*Megalurus timoriensis*		Rare or vagrant
Torresian crow	*Corvus orru*		Rare or vagrant
Wandering tattler	*Tringa incana*		Rare or vagrant
White-bellied cuckoo-shrike	*Coracina papuensis*		Rare or vagrant
White-headed pigeon	*Columba leucomela*		Sporadic visitor
White-throated gerygone	*Gerygone albogularis*		Rare or vagrant
White-winged triller	*Lalage sueurii*		Rare or vagrant
Yellow-billed spoonbill	*Platalea flavipes*		Rare or vagrant
Yellow-rumped thornbill	*Acanthiza chrysorrhoa*		Rare or vagrant
Mammals			
Australian fur-seal	*Arctocephalus pusillus*	x	Sporadic visitor
Dusky antechinus	*Antechinus swainsonii*		Status uncertain
Eastern quoll	*Dasyurus viverrinus*	x	Locally extinct
Feral dog*	*Canis lupus familiaris**		Status uncertain
Feral pig*	*Sus scrofa**		Status uncertain
Greater glider	*Petauroides volans*		Status uncertain
Leopard seal	*Hydrurga leptonyx*		Rare or vagrant
New Zealand fur-seal	*Arctocephalus forsteri*	x	Sporadic visitor

Parma wallaby	*Macropus parma*	x	Locally extinct
Platypus	*Ornithorhynchus anatinus*		Status uncertain
Red-necked pademelon	*Thylogale thetis*		Locally extinct
Southern elephant seal	*Mirounga leonina*	x	Rare or vagrant
Spotted-tailed quoll	*Dasyurus maculatus*	x	Locally extinct
Water rat	*Hydromys chrysogaster*		Status uncertain
Yellow-bellied sheathtailed-bat	*Saccolaimus flaviventris*	x	Status uncertain