New South Wales: State of the Islands

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Summary

NSW islands are important sites for breeding seabirds, and some contain unique or endemic species, many of which do not occur on mainland Australia. Despite their isolation and relatively low visitation, these islands are subject to a broad range of threatening processes. Invasive species are the prime threat, particularly on those islands with human populations or high levels of visitation. The challenge is twofold: to deal with current invasive species, and to develop and implement effective biosecurity measures that prevent the arrival of others.

On the other hand, islands provide great opportunities for habitat restoration and species recovery. The recovery of Gould's Petrel, the restoration of seabird nesting habitat on Montague Island, and the eradication of mammalian pests from many NSW islands demonstrate that it is possible to achieve conservation outcomes on islands that may well be impossible on the mainland. Despite the conservation benefits that can be achieved on islands, there are difficult challenges. Many islands are generally out of sight of the public, hence engendering broad community and political support for island conservation initiatives can be difficult. Also, island communities that rely heavily on tourism often use the natural beauty or pristine state of their island to attract tourists and consequently may not necessarily want to publicise the existence of invasive species or other threats to biodiversity.

Undoubtedly, the jewel in the crown of NSW islands, in terms of its biodiversity values, is the Lord Howe Group. This collection of islands contains an enormous diversity of rare and endemic animals and plants, many of which occur nowhere else in the world. The island's World Heritage status is testament to its global significance. Thus, Lord Howe Island is a high priority for conservation action, not only in NSW, but also within Australia and beyond.

Geography

Within New South Wales (NSW) there are 47 coastal islands that support terrestrial vegetation, a similar number of non-vegetated rocks, and a single oceanic group of 12 islands. Although relatively few in number compared to those of other Australian states, NSW islands are important for the conservation of Australia's biodiversity, either as significant breeding sites for seabirds or critical habitat for threatened, migratory or endemic species.

Coastal islands

All NSW coastal islands of conservation importance, including those that contain significant populations of breeding seabirds, are conservation reserves (Table 1) and, with the exception of Bowen Island, are managed by the NSW National Parks and Wildlife Service (currently part of the Office of Environment and Heritage). Fourteen islands are crown land (Table 1) under the jurisdiction of the NSW Government or local councils, but are generally close to shore and of low conservation value. The Solitary Islands, Five Islands and the Broughton Group are each managed as island groups; all others are essentially managed individually. Thirty-two NSW coastal islands fall within the five coastal marine parks that currently exist in NSW

(Table 1). All these marine protected areas are multiple-use, with specific zonings delineating the various types of use permitted. Cook Island lies within an aquatic reserve. Several islands, such as Bournda and Lennards islands, are connected to the mainland by a sandbar or rock platform, making it possible to walk onto these islands at low tide. Such easy access permits the entry of exotic predators such as dogs, cats and rats, thereby reducing the island's conservation value. There are currently no extractive industries or other forms of non-conservation land use on any NSW coastal island.

All coastal islands in NSW are rocky; some are of volcanic origin (e.g., Cabbage Tree, Montague and Big islands), others are derived from sedimentary rocks (e.g., Green, Broughton and Muttonbird islands). Most are relatively low, with only Cabbage Tree (123 m), Broughton (91 m) and Little Broughton (98 m) containing tall cliffs (Table 1). Aside from Broughton Island (132 ha) and Montague Island (82 ha) no NSW coastal island is greater than 50 ha; 33 are less than 10 ha (Table 1).

Soils on many islands are shallow and of limited extent. Typical vegetation is low, comprising grasses (e.g., Coast Tussock Grass *Poa poiformis,* Blady Grass *Imperata cylindrica* and Sand Couch *Sporobolus virginicus*), succulents (such as Pigface *Carpobrotus glaucescens*) and Spiny-headed Mat-rush *Lomandra longifolia*. Shrubs (such as Coastal Wattle *Acacia longifolia* and Tree Broom Heath *Monotoca elliptica*) and stunted trees (e.g., Tuckeroo *Cupaniopsis anacardioides*) grow to 2–3 m high on some islands. A few of the larger islands support taller shrubs and trees (e.g., Coast Banksia *Banksia integrifolia*, Swamp Oak *Casuarina glauca* and Sydney Red Gum *Angophora costata*). Sub-tropical rainforest occurs in the sheltered gullies of Cabbage Tree Island where the Cabbage Tree Palm *Livistona australis* and fig trees *Ficus* spp dominate.

Oceanic islands

The only oceanic islands in NSW are located within the Lord Howe Group (LHG), situated 780 kilometres north east of Sydney. The LHG comprises the main island (Lord Howe Island; 1,455 ha), 11 smaller islands and islets (Table 1) and a number of non-vegetated rocks. The main island is approximately 12 km long, 1.0–2.8 km wide and rugged. Mount Gower (875 m), Mount Lidgbird (777 m) and Intermediate Hill (250 m) form the southern two-thirds of the island. In the north, the land rises gradually to about 200 m at the top of cliffs that fall precipitously to the sea. The dominant vegetation on the island is closed forest, with rainforest, megaphyllous broad sclerophyll forest (mainly palms) and gnarled mossy forest covering 54%, 19% and 2% of the island respectively (Pickard, 1983). All islands within the group are rocky and volcanic in origin (basalt), with the exception of the central portion of the main island and most of Blackburn Island, which are largely calcarenite derived from coral and shell. The largest, and most striking, of the surrounding islets is Balls Pyramid, a 550 m basalt spire rising from the waters 23 km to the southeast of Lord Howe.

LHI is the only island within the group that is inhabited. The resident population is now about 350, and the settlement is restricted to the central lowlands, where it covers about 15% of the island. All occupied land on the island is leasehold, with leaseholders being required to reside on the island. Approximately 75% of the main island and all outlying islands, islets and rocks within the LHG are protected under the Permanent Park Preserve, which has similar status to that of a national park. The remaining area, excluding the settlement, accommodates grazing cattle, a golf course and the precincts of the airport.

LHI is administered by the Government of NSW, under the Lord Howe Island Act of 1953, amended in 1981. The local government authority, the LHI Board, is chaired by a nominee of the NSW Minister for the Environment. It has two additional State Government appointees, and four elected representatives of the islanders. The Lord Howe Island Board is responsible for the care, control and management of the LHG in accordance with the LHI Act. A number of planning instruments have been prepared, including a Regional Environmental Plan, a Biodiversity Management Plan and a Plan of Management for the Permanent Park Preserve.

The LHG is surrounded by a marine protected area that extends out to a distance of 12 nautical miles. The area to 3 nautical miles is a NSW marine park that covers approximately 46 000 ha; the area between 3 and 12 nautical miles offshore covers approximately 300 500 ha and falls under Commonwealth authority.

Key Conservation Values

NSW islands have significant conservation value as breeding sites for seabirds (penguins, shearwaters, petrels, storm-petrels, terns and gulls)[1]. No fewer than 22 species of seabirds breed on NSW islands (Table 2). Only two of these species also breed on the Australian mainland. The Silver Gull *Chroicocephalus novaehollandiae*, now a superabundant species and a pest in urban areas, breeds in Sydney Harbour, where there is also a small remnant population of Little Penguin *Eudyptula minor*. The Lord Howe Group of islands contains an enormous diversity of rare and endemic animals and plants, many of which are listed as threatened at the state, national or international level. Some migratory birds that visit NSW islands are also covered by international treaties between the Australian Government and the People's Republic of China (CAMBA), the Government of Japan (JAMBA), and the Government of the Republic of Korea (ROKAMBA).

Coastal islands

The Gould's Petrel *Pterodroma leucoptera leucoptera* is the only seabird that is endemic to NSW; consequently this species has been a focus for research and conservation action. The principal breeding site for Gould's Petrel is Cabbage Tree Island, where birds typically nest in rock cavities amongst boulder scree in two gullies dominated by the Cabbage Tree Palm. In 1991, the entire nesting population of petrels numbered less than 300 pairs (Priddel *et al.* 1995). Breeding success was less than 20%, and the total reproductive output of the species was less than 50 fledglings per annum. The mortality of adults ashore exceeded 50 individuals annually, so clearly the population was unsustainable. Research identified three threats: entanglement in fruits of the Birdlime Tree *Pisonia umbellifera*; predation by Pied Currawongs *Strepera graculina*; and habitat degradation by the European Rabbit *Oryctolagus cuniculus*.

The fruit of the Birdlime Tree grow in clusters or 'umbels' and exude a very viscous sticky substance. When ripe, the fruits fall to the forest floor where they form a sticky covering that the birds must negotiate to get to and from their nest. The result is that birds become hopelessly entangled in the fruits. Just a single fruit across the wing will prevent a bird from

[1] Bird taxonomy and nomenclature follows Christidis, L., and Boles, W.E. (2008) Systematics and taxonomy of Australian birds. CSIRO Publishing, Collingwood.

opening its wing to fly. Unable to feed, the bird slowly starves. To solve the problem, all the offending trees (~50) within the immediate nesting habitat of the petrel were killed with herbicide.

Hunting on the forest floor, Pied Currawongs extract incubating petrels and chicks from the nest to feed to their fast-growing offspring. Most of the petrels killed were breeding adults. To remove this problem, currawongs were shot under licence.

The magnitude of the threat to the petrel population from both the Birdlime Tree and the currawong was a direct result of the absence of rainforest understorey on Cabbage Tree Island due to grazing by rabbits. So now instead of the falling fruits becoming hung up in the vegetation where they are little threat to the petrels, they reach the forest floor, directly in the path of the petrels. Also currawongs tend not to hunt in dense vegetation, but with the understorey removed the currawongs are able to hunt on the forest floor, where they find the nesting petrels.

Rabbits were eradicated using a sequence of three mortality agents (Priddel *et al.* 2000): two biological agents, the myxoma virus and calicivirus, followed by aerial baiting with rodenticide. As a result of this eradication, breeding success of the petrels immediately increased and has been around 50% in every year since. The number of nesting pairs has risen from ~300 to more than 900 pairs currently, and the species has been down-listed from *Endangered* to *Vulnerable* under the NSW Threatened Species Conservation Act 1995 (TSC Act).

Gould's Petrel were purported to also breed on nearby Boondelbah Island Hull (1912) but this was not confirmed until 1992 when a dozen or so nests were located (Priddel & Carlile, 1997). The establishment of a more substantial colony on Boondelbah Island would serve as a safeguard against a catastrophe befalling the colony on Cabbage Tree Island, but nesting opportunities on Boondelbah were limited due to the scarcity of rock scree. This was overcome through the creation of artificial habitat by the installation of nest boxes, and followed up with the translocation of 200 near-fledged nestlings from Cabbage Tree Island in 1999 and 2000 (Priddel *et al.* 2006). This new colony now numbers about 20 breeding pairs, and continues to increase. Recently, Gould's Petrels have also been recorded on Broughton and Little Broughton islands following the eradication of Black Rats *Rattus rattus* from both these islands in 2009 (Carlile *et al.* in-press a; Carlile *et al.* in-press b).

Many NSW islands provide hunting grounds, and in some cases breeding sites, for birds of prey such as the White-bellied Sea-eagle *Haliaeetus leucogaster*, Eastern Osprey *Pandion cristatus,* Swamp Harrier *Circus approximans*, Peregrine Falcon *Falco peregrinus* and Nankeen Kestrel *Falco cenchroides*.

Apart from birds, there are relatively few other vertebrate species on NSW coastal islands. The following amphibian and reptiles have been recorded on one or more islands: Striped Marsh Frog *Limnodynastes peroni,* Eastern Common Froglet *Crinia signifera,* Jacky Lizard *Amphibolurus muricatus*, Water Skink *Eulamprus quoyii*, Southern Water Skink *E. heatwolei*, Striped Skink *Ctenotus robustus,* Garden Skink *Lampropholis guichenoti,* Three-toed Skink *Saiphos equalis*, a blind snake *Anomalopus swansoni*, Golden-crowned Snake *Cacophis squamulosus* and Marsh Snake *Hemiaspis signata*. All of these species occur on the Australian mainland and no island population, except one, are considered to be ecologically significant. The exception is a large population of the *Endangered* (TSC Act) Green and Golden Bell Frog *Litoria urea* that occurs on Broughton Island.

There are few records of native mammals occurring on NSW coastal islands. The White-tailed Water Rat *Hydromys chrysogaster* occurs on Lion Island and the Swamp Rat *Rattus lutreolus*

on Muttonbird Island, but no other islands have any native ground-dwelling mammals. Microchiropteran bats (e.g., Gould's Wattled Bat *Chalinolobus gouldi* and Little Bent-wing Bat *Miniopterus australis*) and flying foxes (*Pteropus* spp) have been reported on some wooded islands. Approximately 300 seals (New Zealand Fur Seal *Arctocephalus forsteri* and Australian Fur Seal *A. pusillus*) haul out on Montague Island, and there is evidence suggesting limited breeding on the island (Pacey, 2001). In line with broad-scale population rises, seals are increasingly appearing on other NSW islands.

Lord Howe Group

The entire LHG was placed on the Register of the National Estate and listed as a World Heritage Area in 1982 in recognition of its exceptional natural beauty and biological values. The inscription described Lord Howe as "an outstanding example of an oceanic island of volcanic origin with a unique biota of plants and animals and important and significant natural habitats for in-situ conservation of biological diversity, including those containing species of plants and animals of outstanding universal significance from the point of view of science and conservation". The island's biodiversity values extend below the waterline, there being a rich diversity of marine algae, fish, coral and other invertebrates, all of which have a high degree of endemism.

Aside from being an important breeding site for seabirds, the LHG also supports a diverse array of flora and other fauna, with a high number of endemics. Of the 800 or more species of terrestrial invertebrates recorded on LHI, at least 50% are endemic, and of the 239 species of native vascular plants, 44% are endemic (DECC, 2007). LHI is home to four endemic land birds: Lord Howe Woodhen *Gallirallus sylvestris*, Lord Howe Currawong *Strepera graculina crissalis*, Lord Howe Golden Whistler *Pachycephala pectoralis contempta* and Lord Howe Silvereye *Zosterops lateralis tephropleura.* The woodhen has been the subject of a successful recovery program (NPWS, 2002) and the population is monitored annually (Olsen, 2008). The currawong population was surveyed in 2006 (Ppriddel & Carlile, 2007), but the most recent estimates of whistler and silvereye numbers date to the early 1970's (Fullagar *et al.* 1974).

Nine endemic bird species (or subspecies) have become extinct since the island was first visited by Europeans (Hindwood, 1938). Many of the endemic species that still survive on LHI are rare or highly threatened. Thirty-five species of terrestrial fauna, two fish, eight plants and three ecological communities are listed as threatened under NSW legislation (TSC Act, Fisheries Management Act 1994). Fifteen faunal species and one floral species are listed as threatened under the Commonwealth legislation—the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

The Lord Howe Woodhen was one of the special features of Lord Howe Island that contributed to its listing as World Heritage in 1982. With the population reduced to less than 30, it was feared that extinction was imminent. Research into the population dynamics of this species revealed that Feral Pigs *Sus scrofa* were responsible for eliminating it from all of LHI apart from the summits of the two mountains, where pigs were absent (Miller & Mullette, 1985). One of the consequent measures taken to conserve the woodhen involved the eradication of pigs from LHI. This was achieved in 1980, and together with a program of captive breeding and release has seen the population increase to about 220 individuals. Today, woodhens can be seen in many parts of the island, and are especially common in the lowland forest around the settlement where they are fed by locals and visitors.

There are two species of indigenous terrestrial reptile on LHI: the LHI Skink *Oligosoma lichenigera* and the LHI Gecko *Christinus guentheri*. Each is listed as *Vulnerable* under both the TSC Act and the EPBC Act. Both species are restricted to the LHG and Norfolk Island, and their populations at both sites declined soon after rats arrived. Within the LHG they are known to occur on the main island and on several rat-free islands: Balls Pyramid, Blackburn Island and Roach Island (DECC, 2007).

Since the settlement of LHI at least one endemic ant species and ten endemic beetle species may have become extinct. Six endemic ants, nine endemic spiders and 38 endemic beetles are also at risk of extinction (DECC, 2007). The endemic snails *Gudeoconcha sophiae magnifica*, Lord Howe Land Snail *Placostylus bivaricosus*, Masters' Charopid Land Snail *Mystivagor mastersi*, Mount Lidgbird Charopid Snail *Pseudocharopa lidgbirdi* and Whitelegge's Land Snail *Pseudocharopa whiteleggei* are either *Endangered* or *Critically Endangered* under the EPBC Act. Other invertebrates regarded as *Threatened* under the EPBC Act and/or the TSC Act are the Lord Howe Island Wood-feeding Cockroach *Panesthia lata*, the Lord Howe Island Earthworm *Pericryptodrilus nanus* and the Lord Howe Island Phasmid *Dryococelus australis*.

Known locally as the land lobster, the LHI Phasmid or giant stick-insect was once common on the main island, but disappeared soon after rats arrived in 1918. For eighty years or so the species was thought to be extinct, but in 2001 it was rediscovered on Balls Pyramid (Priddel *et al.,* 2003). The population here numbers less than 30 adults and is restricted to a single site where water seeps from a basalt intrusion. This moisture has led to the development of a patch of lush vegetation and an underlying bed of thick peat-like material that provides moist habitat in which the nocturnal phasmids shelter during the day. To protect the species from extinction, two pair were taken from the Pyramid and placed into captivity on the Australian mainland. The local food plant *Melaleuca howeana* was propagated on Lord Howe and also sent to the mainland. The single pair of adults at Melbourne Zoo successfully produced eggs. After difficult beginnings, hatch rates and survival rates gradually improved, and there are now more than 400 adults in captivity and thousands of eggs under incubation. The possibility now exists to reintroduce this species back to LHI, once rats and mice have been removed.

The LHG also provides temporary habitat for numerous migratory species, many of which breed in the Northern Hemisphere. These migrants include Pacific Golden Plover *Pluvialis fulva,* Double-banded Plover *Charadrius bicinctus*, Latham's Snipe *Gallinago hardwickii*, Bar-tailed Godwit *Limosa lapponica,* Whimbrel *Numenius phaeopus*, Ruddy Turnstone *Arenaria interpres,* Red Knot *Calidris canutus*, Red-necked Stint *C. ruficollis* and Sharp-tailed Sandpiper *C. acuminata.*

Community and people

Coastal islands

Many NSW islands have served as larders for aboriginal communities, providing an abundance of shellfish, fish and seabirds (Swanson, 1976; Pacey, 2001). The two largest islands in NSW, Broughton Island and Montague Island have specific links to traditional owners (Pacey, 2001; Clarke, 2009). Broughton Island is regarded as a 'special place' by the Worimi nation; its ceremonial significance makes aboriginal women feel uncomfortable visiting the island. The traditional name for Montague is 'Barunguba' and is regularly visited by traditional owners, although the northern section of the island is again avoided by women. Aboriginal artefacts have been unearthed on several other islands including Cabbage Tree

Island and Big Island, but strong connections with traditional communities on the adjacent coast have not been maintained.

Some NSW islands have historical significance. Lighthouses built on Montague and South Solitary islands during the nineteenth century are still in use today, although now are fully automated. The light-keepers' residences on South Solitary contain asbestos and so are not in use, but those on Montague Island have been preserved and now function as an eco-tourism resort managed by the NSW National Parks and Wildlife Service (NPWS). A small fishing community has been present on Broughton Island since before 1900, and the island continues to have strong cultural and historical links with the Port Stephens fishing community (Clarke, 2009). Although significantly modified from the original dwellings, the six remaining huts are used as temporary accommodation by recreational fishers. Responsibility for these buildings was transferred to the NPWS in 1974, and they are currently managed in conjunction with the Broughton Island Conservation Society Incorporated, a local group established through the Maitland City Offshore Fishing Club and the Newcastle District Anglers Association. Other islands have unofficial monuments to past exploration (e.g., Boondelbah Island) or memorials to fishers who frequented them in the past (e.g., Moon Island).

The most-visited coastal "island" in NSW is Muttonbird Island, which receives approximately 100 000 visitors per year. However, this nature reserve is no longer an island, having been joined to the mainland at Coffs Harbour since 1924 by a substantial rock breakwater built to provide a safe harbour for boats. Visitor impacts have been minimised through the construction of a paved walkway in 1987. Visitors are encouraged to stay on the path and avoid creating new trails, but rock fishers still use unformed tracks to access favoured fishing spots (DECC, 2009). Both the native Swamp Rat and the exotic Black Rat are now present on the island and are causing a decline in the number of breeding Wedge-tailed Shearwaters *Ardenna pacifica*.

Commercial tourism operations provide visitor access to three NSW coastal islands. Large passenger boats regularly take visitors to Broughton Island, mostly day-trippers with only a few making use of the limited camping facilities available. Infrequent helicopter trips also operate to South Solitary Island, but overnight stays are not permitted. The most developed tourism operation is on Montague Island where visitors can view the lighthouse and explore the island, and also view Little Penguins *Eudyptula minor* coming ashore in the evening. Two of the three light-keepers cottages are also available for hire, either as self-catered accommodation or as part of an organised tour. Members of organised tours often have the opportunity to participate in ecological restoration activities.

Other NSW islands are rarely visited, and landing on those that are nature reserves is prohibited unless specifically authorised. Permits to land can be issued by the NPWS, but such approvals are largely confined to researchers undertaking relevant studies. Landing on many islands is difficult and can only be affected safely in calm conditions.

Lord Howe Island Group

Lord Howe Island was first visited by humans in 1788 and first permanently settled in 1833. Nowadays, the island has a strong local community of ~350 individuals; some with links back to the 1860s when their forefathers arrived to establish farming and harvesting enterprises to provision passing ships. Blackburn Island was used as a base for an attempt to develop a shark fishing industry in the early 20th century, and as a wind direction indicator for the flying

boats up until 1974. Evidence of both these activities still exists on the island. Roach Island was traditionally used to harvest seabird eggs and fledglings, a practice that declined during the latter part of the 20th century and is now prohibited.

The export of Kentia Palm *Howea forsteriana* seedlings has been a major source of income for the Lord Howe Island community. Palm seed is harvested both from the wild and from small plantations. The seed is germinated locally and exported as seedlings. However, increased competition in recent years has seen the importance of this industry decline. The island has become much more reliant on tourism, which now provides the bulk of local employment. About 16 000 tourists visit the island each year, with numbers regulated; a maximum of 400 tourists are allowed on the island at any one time. The World Heritage listing of Lord Howe Island, along with the island's natural beauty, is a major drawcard for the tourism industry. Other land uses include cattle grazing, small market gardens and an airport.

Current Condition

Coastal islands

Baseline data for most NSW coastal islands are scant. Surveys of seabird populations on NSW coastal islands extend back to the beginning of the twentieth century but, for the most part, visits by ornithologists and other scientists have been rare and infrequent. Current estimates of seabird populations on NSW coastal islands are based largely on ornithological surveys conducted between 1950 and 1980 and published in the Seabird Island Series by the Australian Bird Study Association, initially in the *Australian Bird Bander* and subsequently in *Corella*. These seminal publications are available online at http://www.absa.asn.au/Seabird%20Islands/Front%20Page.htm. Although there is often little information on how the population estimates were derived, the information contained in this series of publications has been fundamental to our understanding of the importance of NSW islands as breeding sites for seabirds. Since 2000, repeat surveys on some islands (Boondelbah, Cabbage Tree, Brush, Wasp, Grasshopper and the Broughton Group) have allowed us to investigate population trends. In addition, there have been a number of replicated surveys of Montague Island that examine temporal and spatial changes in the seabirds that breed there.

With the few notable exceptions mentioned above, NSW islands are rarely visited. Being essentially out-of-sight out-of-mind, the resources allocated to the conservation of NSW islands are meagre. Those islands that are regularly visited by the public receive relatively more resources, but generally management needs exceed current capacity. Priority conservation actions undertaken to date include the eradication of exotic mammals from several islands and the removal of Kikuyu Grass from Montague (see below). Most island conservation reserves are covered by a management plan, albeit often as part of a much larger national park or similar management unit (Table 1). These plans identify threats to biodiversity and consequent management priorities.

Lord Howe Group

In contrast to the limited number and scope of biodiversity surveys undertaken on NSW coastal islands, a broad range of surveys has been completed on Lord Howe Island, encompassing plants (e.g., Pickard, 1983), birds (e.g., Fullagar ,1974), reptiles (e.g., Cogge,r 1971) and terrestrial invertebrates (e.g., Cassis *et al*., 2003). Ornithological records for LHI

have been compiled by McAllan *et al.,* 2004). In addition, a variety of research activities, involving both terrestrial and marine taxa, have been carried out on the island, resulting in a comprehensive range of scientific publications.

The World Heritage status of Lord Howe Island provides the LHI Board with access to Commonwealth funding, leading to this island being far better resourced than other NSW islands. In recognition of an island of such high biodiversity value, numerous planning documents exist, the most relevant being the Lord Howe Island Biodiversity Management Plan, which details all conservation issues, threats, actions and priorities within a single document. Notwithstanding, very little systematic monitoring has been undertaken and the current population numbers of many endemic species are unknown.

Threats and management actions

Coastal islands

Invasive plants

The infestation and spread of invasive plants is the most pervasive threat to the biological integrity of coastal islands in NSW. All islands contain invasive plants, but the level of infestation varies greatly. The most problematic weeds are Bitou Bush *Chrysanthemoides monilifera*, Prickly Pear *Opuntia stricta* and Kikuyu Grass *Pennisetum clandestinum*. The occasional release of the moth *Cactoblastis cactorum* has assisted the control of Prickly Pear, and the release of several biological control agents, including the leaf-rolling moth (*Tortrix* sp), is helping to control Bitou Bush. However, targeted control programs for these weeds on islands are sporadic, waxing and waning in line with interest, funding priorities and opportunities.

In contrast, a systematic approach has been adopted on Montague to eliminate Kikuyu Grass (OEH, 2011). This invasive grass smothers native vegetation to form a dense monoculture than can be a metre or more thick. It was deliberately taken to Montague Island during the 1960s and planted to stabilize areas of erosion. Between 1990 and 2000 the extent of the island covered by Kikuyu increased from 10% to 30%, and it threatened to soon cover the entire island. Of particular concern is that areas of infestation are rendered unsuitable for use by nesting seabirds. Seabirds that nest in Kikuyu can get entangled, with the long tough strands (stolons) of grass wrapping around the bird's wings or legs, trapping it. Unable to escape the bird either starves to death, dies from heat exposure, or falls victim to predatory birds. About 300 Little Penguins were being killed by Kikuyu every year on Montague Island. The first step in removing Kikuyu involved spraying it with herbicide (glyphosate) to kill the bulk of the biomass present. Large or inaccessible infestations were sprayed from the air, and smaller accessible infestations from the ground. Over the next month or so the grass died and cured, and once sufficiently dry (after approximately one month), the grass was burnt to remove the biomass and expose the soil for replanting with native species. Follow-up spraying, initially over the next few months, then annually was undertaken to kill any Kikuyu that resprouted. Discrete management units, typically of one or two hectares, were delineated and a single unit or zone treated each year since 2004 (DECC, 2008).

Burning took place in June every year when there were very few penguins ashore. However, before being fired the area was thoroughly searched and any penguins found were removed and housed overnight. These birds were released into the sea at night after the burn was

completed. A plywood nest box was then placed at each location from where birds had been removed to provide interim nest sites. Burning did not deter the penguins from nesting in these boxes, even though the entire surrounding vegetation had been eliminated. By the time the nest boxes rot and collapse, the vegetation has regrown sufficiently for the birds to simply move into the adjacent vegetation. Adults breeding within nest boxes have similar reproductive success to those nesting in natural nests (Jorgenson, 2003).

Invasive mammals

Mid-size mammalian pests such as goats *Capra hircus* and pigs were removed from most NSW island nature reserves during the 1980s. A long-term program to eradicate the smaller exotics—European Rabbit, Black Rat and House Mouse *Mus musculus*—is nearing completion. Since 1997, rabbits have been eliminated from Cabbage Tree Island, rats from Brush Island, mice and rabbits from Montague Island, and rabbits and rats from the Broughton Group (Priddel *et al.*, 2011). The eradication of mice from South Solitary Island, the last coastal island with invasive mammals, is planned to occur in 2013. The eradication technique involved the distribution of rodenticide (brodifacoum) baits, either aerially or in bait stations. Rabbits were also targeted with biological controls (myxomatosis and rabbit haemorrhagic disease) to reduce their numbers before baiting took place.

The rabbit and rodent eradications have delivered significant biodiversity benefits. For example, since rats were eradicated from Brush Island in 2005 we have observed increased numbers of crabs, as well as an increase in the size of individual crabs. There has also been an increase in numbers of frogs and lizards, and the White-faced Storm-petrel *Pelagodroma marina* has been recorded there for the first time. Small birds like storm-petrels are particularly vulnerable to rodents and this species probably disappeared from the island soon after rats arrived. Since the removal of rats from the Broughton Group in 2009, Gould's Petrel has been recorded breeding on Broughton Island and is suspected of breeding on Little Broughton Island.

Climate Change

Increases in sea level as well as a rise in the severity of storms resulting from climate change (Knutson *et al.,* 2010) are likely to have only minor direct affects on NSW islands. However, the potential effects of rising sea temperatures on the food supply of seabirds are significant and likely to have major impacts on seabird populations. Declining seabird abundance will, in turn, reduce the amount of nutrients that seabirds bring ashore in the form of excrement and failed eggs and chicks. This reduction in marine-derived nutrients may have profound effects on vegetation composition and structure (Anderson & Polis, 1999) as may the decline in soil disturbance from burrowing.

Fire

Wildfire is an infrequent occurrence on NSW islands but it can have a devastating effect on breeding seabirds, including those nesting underground (Carlile *et al.,* in-press a). Although the fuel load is not great, the high level of humus in the soil combined with good ventilation from the burrows can result in ground fires that spread rapidly (DECC, 2009). Wildfires are usually caused by lightning strikes, but on Muttonbird and Broughton islands they have also been lit deliberately (DECC, 2009; Carlile *et al.,* in-press a).

Lighting

Artificial lighting within the Coffs Harbour and Port Kembla urban areas can disorientate shearwaters, particularly fledglings on nearby Muttonbird and Big islands. Birds so affected are often found at the base of streetlights, on sports fields and in the grounds of resorts (Gibson, 1976; DECC, 2009) where they are vulnerable to mainland predators.

Biosecurity

Exotic rodents reached many NSW coastal islands either in fodder brought ashore to feed stock or aboard ships that wrecked. With the removal of stock from islands and the advent of clean modern ships and electronic navigation equipment, these threats are now minimal. Consequently, once islands have been cleared of rodents, reinvasion is unlikely. However, the transfer of other biological material, particularly seeds, by visitors is an ever-present biosecurity risk and is growing in line with the increased emphasis on tourism. NSW coastal islands currently have few biosecurity measures in place.

Lord Howe Group

Despite its geographical isolation, the biodiversity of Lord Howe Island is subject to a broad range of threatening processes, presently the most significant being invasive plants and animals (DECC, 2007).

Invasive plants

There are more than 670 species of exotic plants on Lord Howe Island (DECC, 2007), many of which were taken to the island as garden plants. Some species, such as Cherry Gauva *Psidium cattleyanum*, form dense thickets displacing native plant species and communities. Asparagus Fern *Asparagus* spp can encroach into the nesting grounds of shearwaters and tropicbirds, preventing these birds from gaining access to traditional nest sites. The thickly matted growth form of Rhodes Grass *Chloris gayana* poses an impenetrable barrier to the Lord Howe Island Wood-feeding Cockroach, and the establishment of this grass on Blackburn Island, one of two remaining strongholds of the cockroach, is of significant concern (DECC, 2007; NSW Scientific Committee, 2008). The climbing Coastal Morning Glory *Ipomoea cairica* is a problem on Balls Pyramid where it is smothering the food plants of the *Critically Endangered* Lord Howe Island Phasmid. A control programme is now in place for this species in this location.

Conservation issues for the vascular flora of Lord Howe Island have been reviewed by Auld & Hutton (2004). Seventeen species of introduced plants have been declared noxious weeds, and 15 targeted for eradication through an extensive and highly successful programme of weed eradication (DECCW, 2010). Ecotourists and volunteers are major contributors to this programme, with the Friends of Lord Howe Island running several volunteer weeding trips each year.

Invasive animals

Several species of invasive mammals have been eradicated from LHI. Feral cats *Felis catus* were eradicated in the 1970s. Subsequently, the acquisition of cats as domestic pets was

banned and there are now no cats on the island. Pigs were eradicated in 1979, and feral goats in 1999. Aside from pets and stock, the only exotic mammals that now remain on LHI are the Black Rat and the House Mouse. Rats are a major threat to many endemic birds, reptiles, invertebrates and plants. Predation by Ship Rats on LHI is listed as a Key Threatening Process under both NSW State and Australian Government legislation. Although the impacts of mice are less well understood, it is likely that they have similar (and cumulative) effects on the island's fauna and flora, as well as affecting nutrient-recycling processes.

Black Rats arrived on LHI in 1918, with the grounding of a cargo ship, and were widespread on the island by 1920. The House Mouse probably arrived before 1870. Densities of up to 94 rats and 200 mice per ha have been reported (Miller & Mullette, 1985; Billing & Harden, 2000). Rats are implicated in the extinction of at least 11 species of endemic invertebrates and five endemic bird taxa (the Island Thrush (LHI subspecies, Turdus *poliocephalus vinitinctus*), the Robust White-eye (*Zosterops strenuus*), the Lord Howe Gerygone (*Gerygone insularis*), the Tasman Starling (LHI subspecies, *Aplonis fuscus hullianus*) and the New Zealand (Grey) Fantail (LHI subspecies, *Rhipidura fuliginosa cervina*) (Hindwood,1940). While many of these extinctions occurred within only a few years of rats arriving, the detrimental effect of rodents on the island's biodiversity is ongoing, with at least 13 species of birds, two reptiles, seven invertebrates, 49 flowering plants, two non-flowering plants, and 12 vegetation communities currently at risk of extinction because of the presence of rodents (Ponder, 1997; DECC, 2007). Rats are suspected of causing the extirpation of the White-bellied Storm-petrel *Fregetta grallaria* and Kermadec Petrel *Pterodroma neglecta* from the main island. These species nest above ground and are highly vulnerable to rat predation. Both species now breed only on offshore islets where rats are not present. A strategy to eradicate exotic rodents from LHI has been prepared (LHIB, 2009) and funding ($9 million) allocated, on a 50/50 basis, by the State and Commonwealth governments. At present, the eradication is not expected to take place before 2015. When completed, it will be possible to re-introduce onto the main island several invertebrate species that are currently restricted to rat-free islets. Subsequent introductions of analogue bird species could also be considered.

The Masked Owl *Tyto novaehollandiae* was introduced to LHI in a failed attempt to control rats. Although these owls are known to prey on woodhen and several species of seabird, the degree of threat they pose to these species is unknown. However, if rats are eradicated the owls will need to prey on native species, and this prey switching may have deleterious consequences, particularly for those species with small populations like the woodhen. Consequently, the rodent eradication programme includes a complementary programme to eradicate owls.

The introduced Common Blackbird *Turdus merula* and Song Thrush *T. philomelos* prey on native invertebrates, and compete with native birdlife for food. Although suspected of being a significant threat to endemic invertebrates, particularly the LHI Land Snail, this has not been confirmed. It is possible that the combined effect of these two introduced species may be no worse than any previous competition posed by the now-extinct LHI subspecies of Island Thrush. A Recovery Plan (NPWS, 2001) has been prepared for the LHI Land Snail and components of the Plan are being implemented when resources are available.

Approximately 5% of invertebrate species on LHI are introduced (Cassis *et al.,* 2003), and several likely impacts have been identified. The African Big-headed Ant *Pheidole megacephala* established a population on LHI about ten years ago. This species is capable of out-competing and displacing native invertebrates, particularly other ants, and has caused major disruption to the biota of islands it has colonised. An eradication programme is currently

underway on LHI. A population of a large, exotic, carnivorous slug has established in the lowland forests of LHI. This species preys upon smaller endemic snails and slugs (Hutton, 2001) and may be having a significant impact on native species, including the *Endangered* LHI Land Snail. An introduced earthworm can potentially compete with native soil fauna, and is thus a threat to the endemic earthworm *Pericryptodrilus nanus* (DECC, 2007). The chrysomelid *Arsipoda* is likely to have been introduced with exotic species of *Ipomoea* and feeds on the *Endangered* vine *Calystegia affinis,* affecting flower and seed production.

Land-use conflicts

Loss of habitat through clearing of lowland forest has reduced the habitat of some endemic species, but particularly the Flesh-footed Shearwater *Ardenna carneipes*, LHI Land Snail and LHI Wood-feeding Cockroach. Shearwaters can be noisy at night and those birds that excavate burrows near buildings risk being illegally killed by homeowners. There have also been instances of currawongs being illegally shot because some islanders see them as a threat to other birds such as the White Tern *Gygis alba*. The use of snail bait around gardens to control the introduced garden snail *Cantareus aspersus* may also kill the LHI Land Snail.

Climate change

The summits of Mt Gower and Mt Lidgbird are enveloped in cloud for much of the time. This semi-permanent cloud layer provides a rich source of precipitation and maintains the humidity on the summits at very high levels, giving rise to a unique vegetation community—Gnarled Mossy Cloud Forest. This unique ecological community has been listed by the NSW Scientific Committee as *Critically Endangered* (NSW Scientific Committee, 2011) (due to the potential impact of climate change, which is likely to affect the process of cloud formation on the mountains (Pounds *et al., 1997;* Pounds *et al*., 1999; Still *et al.,* 1999; Auld & Hutton*,* 2004*).* Reduced moisture will have profound negative impacts on those species occupying the cloud forest, which in turn may affect critical ecological processes (Garnaut, 2008). For example, epiphytes are very sensitive to changes in microclimate (Benzing,1998) yet they play a key role in light regimes and in hydrological and nutrient cycling processes (Foster, 2001). Restricted to two summits, there is no bioclimatic zone for component species of the cloud forest to retreat to as temperatures warm.

Changing global temperatures will also affect the marine environment, including the marine park surrounding the LHG. Changes in the marine food web will have direct consequences on seabirds and, in turn, the nutrients they contribute to the terrestrial environment in the form of excrement and failed eggs and chicks. A decrease in the influx of marine-derived nutrients due to decreased seabird activity on Norfolk Island has led to forest ill-health (Holdaway & Christian, 2010).

Biosecurity

There are strict regulations in place for the importation of plants and animals to LHI, and a biosecurity plan is in operation. However, recent arrivals suggest there is considerable opportunity for improvement, particularly given the high biodiversity value of the island. Two reptile species (Snake-necked Tortoise *Chelodina longicollis* and Grass Skink *Lampropholis delicata*) and a frog (Bleating Tree Frog *Litoria dentata*) have been introduced to LHI from the Australian mainland. The ecological impact of these species on native biota is unknown.

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Table 1. Location, size and tenure of the islands of New South Wales

[1] Bowen Island forms part of the Jervis Bay Territory (67 km^2) administered by the Commonwealth Government. It was surrendered by the state of NSW in 1915 to provide the Federal capital of Canberra with access to the sea.

[2] Name of this island is currently under consideration by the Geographical Names Board.

[3] Muttonbird Island is now joined to the mainland by a substantial rock breakwater, built to construct a safe harbour for boats, and is strictly no longer an island.

[4] Area taken from various sources including the Seabird Island Series; or calculated from GIS data (a).

[5] Height taken from various sources including the Seabird Island Series; or GPS data (b).

[6] Permanent Park Preserve under the Lord Howe Island Act 1981.

[7] Much of the LHI is Permanent Park Preserve under the Lord Howe Island Act 1981; other areas of the settlement are leasehold and special purpose areas.

Table 2. Seabirds breeding on New the islands of South Wales

EPBC Act, Commonwealth Environmental Protection and Biodiversity Conservation Act 1999; TSC Act, NSW Threatened Species Conservation Act 1995; E, Endangered species; M, Migratory species; V, Vulnerable species; B, breeding; A, recorded breeding in the mid 20th century but absent in subsequent surveys.

Data for coastal islands taken from the Seabird Island Series published in Corella (http://www.absa.asn.au/Seabird%20Islands/Front%20Page.htm); data for the Lord Howe Group taken from McAllan *et al.* (2004).