

Reservation and Management of Seabird Breeding Islands in New South

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Abstract

Thirty-nine islands along the New South Wales coast are used as breeding sites by a total of 12 seabird species. Twenty-eight of the islands are current or impending conservation reserves. Because of the small size and confined nature of these island reserves, preservation of their seabird colonies will depend on careful management. Introduced animals and plants, fire, and direct human disturbance are obvious, though often complex, problems. There are also less direct effects of human activities. The basis for management should be regular monitoring of the seabird colonies, so that major problems and long-term trends can be identified.

INTRODUCTION

The coastline of New South Wales is dotted with numerous offshore islands, the majority of which are used as breeding sites by seabirds. A total of 39 islands are used by a total of 12 seabird species (Appendix 1.). These seabird colonies have long been a subject of scientific and general interest (e.g. Hull 1911, 1912, 1916; Hindwood 1958; Lane 1979a). In this paper we review the progress made in reservation of these breeding sites, and consider the problems posed in management of such small and vulnerable reserves. The protection of breeding sites is seen as the major role of the N.S.W. National Parks and Wildlife Service in seabird conservation (Smith 1985).

Seabird Species

The 12 species of seabirds that breed on the islands along the New South Wales coast are listed in Table 1. Four of these species also breed on the mainland - the Little Penguin and Eastern Reef Egret on rocky sea-coasts, and the Silver Gull and Australian Pelican on estuaries and inland lakes. The other species breed only on islands.

None of the species is endemic to New South Wales, nor even to Australia. However, Cabbage Tree Island is the only known breeding site for the nominate subspecies of Gould's Petrel (another subspecies, *caledonica*, breeds in New Caledonia). Six species are true seabirds, spending most of their time and obtaining most of their food at sea - Little Penguin, Gould's Petrel, Wedge-tailed Shearwater, Sooty Shearwater, Short-tailed Shearwater and White-faced Storm-Petrel. The remainder are coastal

species - Australian Pelican, Eastern Reef Egret, Sooty Oystercatcher, Silver Gull, Kelp Gull and Crested Tern, with the Australian Pelican and Silver Gull also found along inland rivers and lakes.

Historical changes in the breeding seabirds of New South Wales are apparent from a series of surveys during this century (Hull 1911, 1912, 1916; Hindwood 1958; Lane 1979a). It is noteworthy that in spite of considerable disturbance on many of the islands, no species appears to have ceased nesting in the State during this period. In fact, three species are recent colonists. The Short-tailed Shearwater and Kelp Gull were first recorded breeding in New South Wales in 1958 (Davies 1959; Gwynne and Gray 1959) and have been steadily increasing in numbers since then (Lane 1979a). The Australian Pelican was first recorded breeding on offshore islands of the State only in 1983 (Battam *et al.* 1986).

Reservation of Breeding Islands

The 39 islands along the New South Wales coast that are used by breeding seabirds are listed in the Appendix. The most important is Cabbage Tree Island, which contains the only known breeding colony of the nominate subspecies of Gould's Petrel. The islands with the largest populations of breeding seabirds are Montagu Island (33 650 pairs, 7 species), Big Island (20 900 pairs, 5 species), Tollgate Islands (19 709 pairs, 7 species), Broughton Island (13 160 pairs, 6 species), Muttonbird Island (12 400 pairs, 1 species) and North Solitary Island (10 516 pairs, 4 species).

In the mid 1950s, at the instigation of Dr R. Carrick of the CSIRO Division of Wildlife Research,

Table 1.

Seabirds known to breed on offshore islands in New South Wales (from Lane 1979a, Floyd & Swanson 1983, Battam *et al.* 1986).

	Species	Breeding population (pairs)	Comments
1.	Little Penguin <i>Eudyptula minor</i>	16 800	c.74% of this population is found on Brush, Tollgates and Montagu Islands off the south coast. Some birds breed on rocky sea-coasts on the mainland.
2.	Gould's Petrel <i>Pterodroma leucoptera</i>	250-300	Confined to Cabbage Tree Island.
3.	Wedge-tailed Shearwater <i>Puffinus pacificus</i>	52 000	c.77% of this population is found on Solitary group, Muttonbird, Broughton group, Cabbage Tree and Boondelbah Islands off the north coast.
4.	Sooty Shearwater <i>P. griseus</i>	250	c.60% of this population is found on Montagu Island.
5.	Short-tailed Shearwater <i>P. tenuirostris</i>	25 700	c.84% of this population is found on Tollgates and Montagu Islands off the south coast.
6.	White-faced Storm-Petrel <i>Pelagodroma marina</i>	10 700	c.65% of this population is found on the Tollgates Islands.
7.	Australian Pelican <i>Pelecanus conspicillatus</i>	9	Big and Martin Islands. Most breeding in NSW occurs on inland lakes.
8.	Eastern Reef Egret <i>Egretta sacra</i>	5	Also breeds on rocky sea-coasts on the mainland.
9.	Sooty Oystercatcher <i>Haematopus fuliginosus</i>	20-25	Breeds only on islands.
10.	Silver Gull <i>Larus novaehollandiae</i>	30 000	c.70% of this population is found on Big, Bass and Martin Islands off the central coast. Also breeds on estuaries and inland lakes.
11.	Kelp Gull <i>L. dominicanus</i>	13	Restricted to islands off the central coast.
12.	Crested Tern <i>Sterna bergii</i>	13 000	c.62% of this population is found on North Solitary Island.

Appendix 1.

Offshore islands used by breeding seabirds in New South Wales.

Islands are listed in geographical order, north to south. Figures in parentheses are the estimated numbers of breeding pairs. Question-marks indicate that breeding is unconfirmed, at least in recent years.

1. Cook Island

Location: 28°12'S 153°35'E. Area: 4.7 ha.
Status: Cook Island Nature Reserve.
Breeding seabirds: Wedge-tailed Shearwater (2000), Crested Tern (?).
Sources: Lane (1973c, 1979a).

2. Julian Rocks

Location: 28°37'S, 153°36'E. Area: 1.3 ha.
Status: Julian Rocks Nature Reserve.
Breeding seabirds: Wedge-tailed Shearwater (?), Crested Tern (300).
Sources: Lane (1976a, 1979a).

3. North Solitary Island

Location: 29°55'S, 153°23'E. Area: 17.4 ha.
Status: North Solitary Island Nature Reserve.
Breeding seabirds: Wedge-tailed Shearwater (2500), Sooty Oystercatcher (1), Silver Gull (15), Crested Tern (8000).
Sources: Lane (1974a, 1979a).

4. North Rock, Solitary Islands

Location: 29°59'S, 153°15'E. Area: 4 ha.
Status: North Rock Nature Reserve.
Breeding seabirds: Wedge-tailed Shearwater (100), Sooty Oystercatcher (?), Silver Gull (?).
Sources: Morris (1975b), Lane (1979a).

5. North-west Solitary Island

Location: 30°02'S, 153°16'E. Area: 1.9 ha.
Status: North-west Solitary Island Nature Reserve.
Breeding seabirds: Wedge-tailed Shearwater (100), Sooty Oystercatcher (1).
Sources: Morris (1975a), Lane (1979a).

6. South-west Solitary Island

Location: 30°09'S, 153°14'E. Area: 6.8 ha.
Status: South-west Solitary Island Nature Reserve.
Breeding seabirds: Wedge-tailed Shearwater (1500).
Sources: Lane (1975a, 1979a).

7. South Solitary Island

Location: 30°12'S, 153°16'E. Area: 17.4 ha.

Status: Commonwealth land - lighthouse site.

Breeding seabirds: Little Penguin (20), Wedge-tailed Shearwater (100), Sooty Shearwater (?), Silver Gull (300), Crested Tern (300).

Sources: Lane (1975c,d, 1979a).

8. Split Solitary Island

Location: 30°14'S, 153°11'E. Area: 5.2 ha.

Status: Split Solitary Island Nature Reserve.

Breeding seabirds: Wedge-tailed Shearwater (100).

Sources: Lane (1974b, 1979a).

9. Little Muttonbird Island

Location: 30°18'S, 153°08'E. Area: 1.1 ha.

Status: Vacant Crown land.

Breeding seabirds: Wedge-tailed Shearwater (20), Silver Gull (?).

Sources: Roberts (1976), Lane (1979a).

10. Muttonbird Island

Location: 30°18'S, 153°09'E. Area: 8 ha.

Status: Muttonbird Island Nature Reserve.

Breeding seabirds: Black-winged Petrel *Pterodroma nigripennis* (?), Wedge-tailed Shearwater (12 400), Sooty Shearwater (?), Short-tailed Shearwater (?), White-faced Storm-Petrel (?).

Sources: Swanson (1976), Floyd & Swanson (1983), Lane (1970, 1979a), Lane & White (1983), Holmes (1975).

11. Korff's Islet

Location: 30°19'S, 153°09'E. Area: 0.9 ha.

Status: Vacant Crown land.

Breeding seabirds: Silver Gull (100), Crested Tern (100).

Sources: Lane (1976j, 1979a).

12. Sawtell Islet

Location: 30°23'S, 153°06'E. Area: 3 ha.

Status: Vacant Crown land.

Breeding seabirds: Wedge-tailed Shearwater (10), Sooty Oystercatcher (1), Silver Gull (100).

Sources: Holmes (1976b), Lane (1979a).

13. Green Islet

Location: 30°55'S, 153°05'E. Area: 2.3 ha.

Status:	Vacant Crown land.	
Breeding seabirds:	Wedge-tailed Shearwater (80).	
Sources:	Holmes (1976a), Lane (1979a).	
14. Delicate Nobby		
Location:	31°16'S, 152°58'E.	Area: 4.5 ha.
Status:	Vacant Crown land.	
Breeding seabirds:	Little Penguin (20), Wedge-tailed Shearwater (500).	
Sources:	Lane (1976i, 1979a).	
15. Statis Rock		
Location:	32°26'S, 152°32'E.	Area: 2.2 ha.
Status:	Vacant Crown Land.	
Breeding seabirds:	Little Penguin (5), Silver Gull (100), Crested Tern (10).	
Sources:	Holmes (1979), Lane (1979a).	
16. North Rock, Broughton Group		
Location:	32°36'S, 152°19'E.	Area: 4.7 ha.
Status:	Forms part of Stormpetrel Nature Reserve.	
Breeding seabirds:	Wedge-tailed Shearwater (1000), White-faced Storm-Petrel (1000), Silver Gull (20).	
Sources:	Lane (1976d, 1979a).	
17. Inner Rock, Broughton Group		
Location:	32°36'S, 152°18'E.	Area: 1.2 ha.
Status:	Forms part of Stormpetrel Nature Reserve.	
Breeding seabirds:	Wedge-tailed Shearwater (100), White-faced Storm-Petrel (100).	
Sources:	Lane (1976e, 1979a).	
18. Broughton Island		
Location:	32°37'S, 152°19'E.	Area: 138 ha.
Status:	Forms part of Myall Lakes National Park.	
Breeding seabirds:	Little Penguin (20), Wedge-tailed Shearwater (12 000), Sooty Shearwater (10), Short-tailed Shearwater (1000), White-faced Storm-Petrel (?), Silver Gull (80), Crested Tern (50).	
Sources:	Lane (1976b, 1979a,b), van Gessel (1978).	
19. Little Broughton Island		
Location:	32°37'S, 152°20'E.	Area: 36 ha.
Status:	Little Broughton Island Nature Reserve.	
Breeding seabirds:	Wedge-tailed Shearwater (4500), Sooty Shearwater (5), Short-tailed Shearwater (1000)	

Sources:	Lane (1976c, 1979a).	
20. Cabbage Tree Island		
Location:	32°42'S, 152°14'E.	Area: 26 ha.
Status:	John Gould Nature Reserve.	
Breeding seabirds:	Little Penguin (300), Gould's Petrel (300 - only known breeding site of the nominate subspecies), Wedge-tailed Shearwater (2500), Sooty Shearwater (50), Short-tailed Shearwater (20).	
Sources:	Fullagar (1976), Lane (1979a).	
21. Little Island		
Location:	32°42'S, 152°15'E.	Area: 1.2 ha.
Status:	Vacant Crown Land.	
Breeding seabirds:	Silver Gull (50), Crested Tern (40).	
Sources:	Lane (1976k, 1979a).	
22. Boondelbah Island		
Location:	32°42'S, 152°14'E.	Area: 9.3 ha.
Status:	Boondelbah Nature Reserve.	
Breeding seabirds:	Little Penguin (1000), Gould's Petrel (?), Wedge-tailed Shearwater (3500), Sooty Shearwater (10), Short-tailed Shearwater (500), White-faced Storm Petrel (100).	
Sources:	Morris (1976), Lane (1979a).	
23. Shark Island		
Location:	32°45'S, 152°12'E.	Area: 1.5 ha.
Status:	Vacant Crown land.	
Breeding seabirds:	Wedge-tailed Shearwater (10), Eastern Reef Egret (1).	
Sources:	Lane (1976l, 1979a).	
24. Moon Island		
Location:	33°05'S, 151°41'E.	Area: 2.3 ha.
Status:	Moon Island Nature Reserve.	
Breeding seabirds:	Little Penguin (15), Wedge-tailed Shearwater (?), Sooty Oystercatcher (1), Silver Gull (1000), Kelp Gull (2), Crested Tern (700).	
Sources:	Gray & Gwynne (1974), Lane (1979a).	
25. Bird Island		
Location:	33°14'S, 151°36'E.	Area: 12 ha.
Status:	Bird Island Nature Reserve.	
Breeding seabirds:	Little Penguin (5), Wedge-tailed Shearwater (1000), Sooty Shearwater (5), Short-tailed	

Sources:	Shearwater (25), White-faced Storm-Petrel (500), Eastern Reef Egret (1). Lane (1973a, 1979a).	
26. Lion Island		
Location:	33°33'S, 151°20'E.	Area: 8 ha.
Status:	Lion Island Nature Reserve.	
Breeding seabirds:	Little Penguin (300), Wedge-tailed Shearwater (300), Sooty Shearwater (7), Short-tailed Shearwater (?).	
Sources:	Lane (1975b, 1979a).	
27. Flinders Islet, Five Islands		
Location:	34°27'S, 150°56'E.	Area: 2.8 ha.
Status:	Forms part of Five Islands Nature Reserve.	
Breeding seabirds:	Little Penguin (30), Wedge-tailed Shearwater (5), White-faced Storm-Petrel (20), Eastern Reef Egret (1), Sooty Oystercatcher (3), Kelp Gull (1).	
Sources:	Battam (1976b), Lane (1979a).	
28. Bass Islet, Five Islands		
Location:	34°28'S, 150°57'E.	Area: 2.3 ha.
Status:	Forms part of Five Islands Nature Reserve.	
Breeding seabirds:	Little Penguin (5), Silver Gull (2000), Kelp Gull (6), Crested Tern (?).	
Sources:	Battam (1976c), Lane (1979a).	
29. Big Island, Five Islands		
Location:	34°29'S, 150°56'E.	Area: 19 ha.
Status:	Forms part of Five Islands Nature Reserve.	
Breeding seabirds:	Little Penguin (500), Wedge-tailed Shearwater (500), Short-tailed Shearwater (100), White-faced Storm-Petrel (?), Australian Pelican (2), Silver Gull (17 800), Crested Tern (2000).	
Sources:	Gibson (1976), Lane (1979a), Battam <i>et al.</i> (1986)..	
30. Martin Islet, Five Islands		
Location:	34°29'S, 150°56'E.	Area: 2.5 ha.
Status:	Forms part of Five Islands Nature Reserve.	
Breeding seabirds:	Little Penguin (30), Wedge-tailed Shearwater (30), Short-tailed Shearwater (40), White-faced Storm-Petrel (10), Australian Pelican (7), Silver Gull (1000), Kelp Gull (4), Crested Tern (500).	
Sources:	Battam (1976d), Lane (1979a), Battam <i>et al.</i>	
31. Stack Islet		
Location:	34°38'S, 150°52'E.	Area: 1.4 ha.

Status:	Vacant Crown Land.	
Breeding seabirds:	Wedge-tailed Shearwater (10).	
Sources:	Battam (1976a), Lane (1979a).	
32. Drum and Drumsticks		
Location:	35°03'S, 150°50'E.	Area: 2.5 ha.
Status:	Vacant Crown Land.	
Breeding seabirds:	The only likely seabird breeding island in the State not yet surveyed (Lane 1979a). Inaccessible except by helicopter.	
33. Bowen Island		
Location:	35°07'S, 150°46'E.	Area: 50 ha.
Status:	Commonwealth land - forms part of Jervis Bay Nature Reserve, administered by the A.C.T. Parks and Conservation Service.	
Breeding seabirds:	Little Penguin (1000), Wedge-tailed Shearwater (100), Sooty Shearwater (10), Short-tailed Shearwater (200).	
Sources:	Lane (1976f, 1979a).	
34. Brush Island		
Location:	35°32'S, 150°25'E.	Area: 35 ha.
Status:	Brush Island Nature Reserve.	
Breeding seabirds:	Little Penguin (2500), Wedge-tailed Shearwater (400), Short-tailed Shearwater (750), Sooty Oystercatcher (2).	
Sources:	Morris (1974), Lane (1979a).	
35. Belowla Island		
Location:	35°33'S, 150°24'E.	Area: 4 ha.
Status:	Belowla Island Nature Reserve.	
Breeding seabirds:	Little Penguin (800), Wedge-tailed Shearwater (?), White-faced Storm-Petrel (1500), Sooty Oystercatcher (3).	
Sources:	Lane (1973b, 1977, 1979a).	
36. Grasshopper Island		
Location:	35°38'S, 150°20'E.	Area: 3.5 ha.
Status:	Forms part of Murrumbidgee National Park.	
Breeding seabirds:	Little Penguin (50), Wedge-tailed Shearwater (200), Short-tailed Shearwater (400), White-faced Storm-Petrel (10).	
Sources:	Lane (1976g, 1979a).	
37. Wasp Island		
Location:	35°40'S, 150°19'E.	Area: 5 ha.

Status: Forms part of Murramurrang National Park.

Breeding seabirds: Little Penguin (200), Wedge-tailed Shearwater (50), Short-tailed Shearwater (200), White-faced Storm-Petrel (50).

Sources: Lane (1976h, 1979a).

38. Tollgate Islands

Location: 35°45'S, 150°16'E. Area: 23 ha.

Status: Tollgate Islands Nature Reserve.

Breeding seabirds: Little Penguin (5000), Wedge-tailed Shearwater (1200), Sooty Shearwater (5), Short-tailed Shearwater (6500), White-faced Storm-Petrel (7000), Eastern Reef Egret (2), Sooty Oystercatcher (2).

Sources: McKean & Fullagar (1976), Lane (1979a).

39. Montagu Island

Location: 36°15'S, 150°14'E. Area: 49 ha.

Status: Commonwealth land (lighthouse site) being transferred to state for dedication as a Nature Reserve.

Breeding seabirds: Little Penguin (5000), Wedge-tailed Shearwater (5000), Sooty Shearwater (150), Short-tailed Shearwater (15 000), Sooty Oystercatcher (3), Silver Gull (7500), Crested Tern (1000).

Sources: Fullagar (1973), Lane (1979a).

the Fauna Protection Panel of N.S.W. moved to protect all offshore islands of value to nesting seabirds. John Gould Nature Reserve, covering Cabbage Tree Island, was in fact the forerunner of the entire N.S.W. nature reserve system.

Because of the general absence of competing land uses, considerable progress has been made by the Fauna Protection Panel and its successor, the N.S.W. National Parks and Wildlife Service. All 39 seabird islands are Crown land - 36 State and three Commonwealth (Appendix). Twenty-seven now have national park or nature reserve status. Most are managed by the N.S.W. National Parks and Wildlife Service. Bowen Island forms part of Jervis Bay Nature Reserve and is managed by the A.C.T. Parks and Conservation Service.

Montagu Island, which has the largest population of breeding seabirds of all, is not yet formally reserved. A lighthouse site, the island is Commonwealth land in the process of transfer to the State for dedication as a nature reserve. South Solitary Island is another Commonwealth-owned lighthouse site which is the subject of negotiations for transfer to the State as a nature reserve. Some 720 pairs of four seabird species breed on South Solitary Island.

The 10 State-owned islands that remain unreserved are, in order of their seabird populations, Delicate Nobby (520 pairs, two species), Korff's Islet (200 pairs, two species), Statis Rock (115 pairs, three species), Sawtell Islet (111 pairs, three species), Little Island (90 pairs, two species), Green Islet (80 pairs, one species), Little Muttonbird Island (20 pairs, one species), Shark Island (11 pairs, two species), Stack Islet (10 pairs, one species) and Drum and Drumsticks (seabird population unknown). At least the first six are sufficiently important breeding sites to warrant nature reserve status.

Management Problems

Preservation of seabird breeding islands is by no means assured simply by formal reservation. Because of their small size and confined nature, island reserves require careful management. Various problems facing the managers of seabird island reserves in New South Wales are discussed below.

Introduced Animals

Environmental changes resulting from the spread of alien animals to islands, particularly mammals, have been a major problem throughout the world (Bourne 1975; Merton 1978). Breeding seabirds may be affected directly by introduced predators, or

indirectly through vegetation changes that result from introduced herbivores.

On Muttonbird Island the construction of a breakwater in 1925 allowed access for feral cats *Felis catus*, dogs *Canis familiaris* and foxes *Vulpes vulpes*. Cats were found to be resident on the island in 1972-73 and were killing White-faced Storm-Petrels (Roberts 1974). An 'animal-proof' fence was subsequently erected across the breakwater but proved to be of limited value. For example, a fox was shot on the island in 1975 after reports of predation on Wedge-tailed Shearwaters (Swanson 1976). After rusting completely several years ago, the fence has not been replaced. Trapping programs following detection are now regarded as more effective.

The only other known island population of the larger introduced predators is the feral cat population on Broughton Island (Lane 1976b). However, introduced rats *Rattus* spp., which are potential egg predators, have been reported from a number of islands. On Lion Island, surveys of breeding Wedge-tailed and Sooty Shearwaters from 1957 to 1968 showed considerable egg damage and very low breeding success, for which introduced rats were considered largely responsible (Lane 1962, 1974c). A series of drought years in the late 1960s have now apparently eliminated the rat population - none was trapped during a survey in 1968 and no egg damage was recorded in subsequent surveys (Lane 1974c). Nevertheless, the shearwater colony has continued to decline, apparently as a result of rough seas washing away large quantities of soil in the lower part of the colony, and a thickening of the vegetation, including the introduced shrub *Lantana camara*, in the upper part of the colony (Lane 1974c, 1975b).

Introduced herbivores, particularly rabbits *Oryctolagus cuniculus* and goats *Capra hircus*, have had a considerable effect on the vegetation of several New South Wales islands and, consequently, on the breeding seabirds of those islands. A goat population persists on Montagu Island and populations formerly occurred on South Solitary, Broughton and Big Islands. Rabbit populations persist on Cabbage Tree, Broughton and Big Islands, and formerly occurred on South Solitary and Bowen Islands.

Rabbits and goats were introduced to South Solitary Island as a reserve food supply after lighthouse keepers set up residence in 1879. The goats did not survive long but the rabbits persisted until they were shot out in 1975, when the lighthouse became automatic. While being grazed, the vegetation of the island was dominated by the wiriest and most unpalatable species, including both introduced grasses such as Whisky Grass *Andropogon*

virginicus, and hardy native grasses such as Prickly Couch *Zoysia macrantha*. The net effect was a dry, brown-coloured landscape in comparison with the lush green of the adjacent, rabbit-free Birdie Island, where the vegetation continued to be dominated by Wandering Jew *Commelina cyanea* and Variable Groundsel *Senecio lautus* ssp. *dissectifolius* (Floyd 1984).

Changes in the vegetation of South Solitary Island following removal of the rabbits in 1975 have been monitored by Floyd (1984). From 1976 to 1984 there was a dramatic reduction in the tough grasses such as Whisky Grass and Prickly Couch, and a corresponding increase in Wandering Jew and Variable Groundsel. This change has undoubtedly been enhanced by the proximity of Birdie Island as a source of seeds.

Wandering Jew - Variable Groundsel communities are favoured nesting sites for burrowing Wedge-tailed Shearwaters (Floyd and Swanson 1983; Floyd 1984) but the removal of rabbits from South Solitary Island has not yet resulted in a build-up of the shearwater colony from its low numbers under grazing. It is likely, however, that the colony will slowly increase in size as a friable, humus-rich topsoil gradually develops (Floyd 1984).

The surface-nesting Crested Terns and Silver Gulls also favour the soft, cushion Wandering Jew - Variable Groundsel communities, laying their eggs on top of the trampled foliage (Floyd 1984). Their dense nesting colonies destroy most of the vegetation but the birds change their nesting site from year to year and there is a vigorous regeneration of the vegetation after nesting, which is enhanced by the fertilising effect of the nesting activities. Before removal of the rabbits, Crested Tern and Silver Gull colonies in the South Solitary Island complex were restricted to Birdie Island (Lane 1975c). However, in January 1981, and again in 1984, Crested Terns nested on South Solitary Island itself, occupying particularly luxuriant patches of Wandering Jew and Variable Groundsel (Floyd 1984).

Rabbits have also had a significant effect on the very different vegetation of Cabbage Tree Island (Dodkin 1978; Floyd and Dodkin 1978; Werren and Clough 1984). This is the only known breeding site of the nominate subspecies of Gould's Petrel, which nests mainly in two rocky gullies on the western side of the island. The vegetation of the two gullies is rainforest dominated by Cabbage Tree Palms *Livistona australis*. The nest-sites are almost invariably crevices amongst the rocks, usually with fallen palm fronds forming the only cover (Fullagar 1976).

The rabbits on this island were derived from the release of a single pair in 1906 as part of a myxomatosis research program. By the 1960s it was apparent that the rainforest canopy was becoming progressively thinner and the understorey more sparse, which has generally been attributed to heavy browsing of the regeneration by rabbits. Exclosure plots were established on the island in 1979 and a flush of new seedlings was recorded in the following 18 months. Increases in the number of Cabbage Tree Palm seedlings after the exclusion of rabbits were particularly dramatic (Werren and Clough 1984).

These observations suggest that browsing of seedlings by rabbits is preventing the regeneration of Cabbage Tree Palms and other rainforest plants. While rabbits remain, the rainforest may gradually be eliminated as the existing trees age and die without replacement. In view of the close association of the Gould's Petrel colonies with the stands of rainforest, and the importance of the fallen Cabbage Tree Palm fronds in providing suitable nest-sites, the loss of the rainforest may also mean the loss of the petrels.

Not only are the rabbits indirectly affecting the status of the Gould's Petrel, but they may also be competing directly for nest sites with the island's burrowing seabirds - the Little Penguin and the shearwaters (Dodkin 1978). On Bowen Island, eradication of the rabbit population in 1981 rapidly led to an increase in shearwater and Little Penguin populations as the birds took over burrows previously occupied by rabbits (Martin and Sobey 1983).

Eradication of the rabbit population has been established as a management priority for Cabbage Tree island and is being undertaken through baiting with 1080 and carrots. The island is currently visited at least twice a year to monitor progress.

Introduced Plants

Vegetation changes resulting from the introduction of alien plants may affect breeding seabirds. The vegetation of Muttonbird Island at various times since 1954 has been mapped from aerial photos and ground inspections (Floyd 1984; Floyd and Swanson 1983). Tall Burr Grass *Cenchrus caliculatus*, which is native to Australia but not to Muttonbird Island, was present in 1954 and has continually expanded its distribution since then, particularly after fires. By 1980 this species occupied 17% of the island. Floyd and Swanson (1983) found that areas of this robust grass, which grows to 2m tall, contained no active Wedge-tailed Shearwater burrows. As a result, the National Parks and Wildlife Service instituted a spray program in 1982 using Roundup, which appears to be controlling the Tall Burr Grass well and allowing

native species to take over once more. The Tall Burr Grass now occupies only about 5% of the island (P. Evans pers. comm.).

The introduced Kikuyu Grass *Pennisetum clandestinum* has also been found to be a hazard to breeding shearwaters (Lane 1978). During the wet summer of 1975-76 this grass spread rapidly on Big Island and formed deep carpets over large areas. In subsequent breeding seasons, numbers of Wedge-tailed Shearwaters were found dead after becoming entangled in Kikuyu Grass runners at the entrances of their burrows. During one visit in December 1977, 30 shearwaters were found to have been killed in this manner. Little Penguins were less troubled, being able to extricate their short flippers and force their way through the Kikuyu Grass. The native grass, Prickly Couch *Zoysia macrantha* does not pose the same problems as its runners are much thinner than those of the Kikuyu Grass and more easily broken.

Other introduced plants that are found on a number of the islands and are a potential problem are Lantana *Lantana camara* and Prickly Pear *Opuntia stricta*. Thickening of the vegetation, due in part to Lantana, is one factor blamed for the decline of the shearwater colony on Lion Island (Lane 1975b). However, Lantana is not always a serious problem. The survey of vegetation changes on Muttonbird Island since 1954 found that although Lantana was present in 1954, there has been little expansion in the last 30 years, the thickets being periodically cut back by salt scorch (Floyd 1984).

Fire

Fire is generally absent from seabird islands, especially those that are well offshore and seldom visited. When fires do occur, their effects can be long-term. In 1973 fishermen stranded on South-west Solitary Island lit a fire to attract attention. When the fishermen were rescued, the fire was not completely extinguished. It penetrated the deep humus layer and continued to smoulder underground, breaking out again the following day to burn some 2000 m² of the Wedge-tailed Shearwater breeding area before being finally controlled (Floyd 1984; Lane 1975a). The original vegetation was dominated by Wandering Jew and Variable Groundsel. For the first two years after the fire it regenerated well but was then overwhelmed by Prickly Couch. Eleven years after the fire there was still no clear recovery of the Wandering Jew-Variable Groundsel community on the burnt area (Floyd 1984).

The density of breeding Wedge-tailed Shearwaters was high before the fire and remained high in the

unburnt part of the island. However, not a single burrow was located in the burnt area in the 11 years after the fire (N. Swanson in Floyd 1984). The dense Prickly Couch community was unsuitable for burrowing shearwaters because of the strong tussocky bases of the plants and their dense root systems, compared with the sparse, weak roots of the Wandering Jew-Variable Groundsel community. Thus, a single fire on South-west Solitary Island has had long-lasting effects whose final duration cannot yet be estimated.

A shorter recovery period has been recorded for Muttonbird Island. Being close to the mainland and connected by a breakwater since 1925, this island has had a long history of burning every 5-10 years up until the last fire in 1970, which was deliberately lit to improve access to fishing spots. Since that time the National Parks and Wildlife Service and local conservationists have been able to prevent the island being burnt again. In spite of this history of fires, the Wandering Jew-Variable Groundsel community has remained the most extensive type of vegetation on the island, and the Wedge-tailed Shearwater colony, which is closely associated with this community, is apparently the largest along the New South Wales coast (Floyd and Swanson 1983; Floyd 1984).

After the fire in 1970 the burnt areas were colonised by Smooth Summer Grass *Digitaria ciliaris* and Soldier Vine *Kennedia rubicunda*. The annual Smooth Summer Grass was soon replaced, while the woody Soldier Vine persisted longer. Nevertheless, some four years after the fire the original vegetation of the burnt area had substantially recovered (Floyd 1984) and was being fully utilised again by the Wedge-tailed Shearwaters (Swanson 1976).

Broughton Island, the largest of the offshore islands of New South Wales, is also the one most frequently burnt, dating back well before European settlement, when the island is known to have been occupied by Aborigines. The various fishermen who live on the island or visit regularly continue to burn frequently to improve access to favoured fishing spots and provide greater safety from snakes. The effects of this burning regime are evident from the vegetation (Dodkin 1981; Lane 1976b). Much of the island is dominated by Kangaroo Grass *Themeda australis*, Blady Grass *Imperata cylindrica* and Bracken *Pteridium esculentum*, all species characteristic of sandy, fire-prone sites. It appears, however, that the slopes around the highest point of the island once supported rainforest vegetation, as indicated by the presence of a few persistent low clumps of rainforest plants (Dodkin 1981). The island may even have provided suitable nesting sites for Gould's Petrels in the past.

The regular fires on Broughton Island, compounded by considerable human disturbance and introduced predators (feral cats and rats) and herbivores (feral goats until 1972 and a persistent rabbit population) have doubtless reduced the breeding seabird populations. For such a large island, Broughton Island has only a small seabird population (Appendix). Furthermore, White-faced Storm-Petrels were reported as breeding on the island "literally in thousands" in the first decade of this century (Hull 1911). This species no longer breeds on the island, the last reported breeding being in 1957 (Hindwood and D'Ombrain 1960).

Human Visits

Human visits to seabird islands may seriously disrupt breeding seabirds, whether the visitors are tourists, educational groups, scientists or vandals (Anderson and Keith 1980). A New South Wales example is Sawtell Islet, where the number of breeding Wedge-tailed Shearwaters has declined from 50-100 pairs in the 1950s to 5-10 pairs in the 1970s, with only a very low breeding success rate among the remaining pairs (Holmes 1976b). This decline has corresponded with increasing interference from people and dogs. Formerly, access to the island from nearby Sawtell Beach was by wading through strongly flowing waist-deep water. The island has gradually become more easily accessible from the beach and is now separated at low tide by only ankle-deep water.

The most frequently visited island in the State is Muttonbird Island, which lies just off Coffs Harbour and is connected to the mainland by a breakwater. The number of visitors to the island in February 1985 was estimated at over 26 000. In spite of this high visitation, the island still supports what is probably the largest Wedge-tailed Shearwater colony along the coast (Floyd and Swanson 1983). A significant number of visitors come primarily to observe the shearwater colony and the island is an important educational resource. A seasonal ranger program has been in operation for several years and attracts large groups to a guided tour along an established walking track. Signposts have been erected to explain the importance of the island for nesting shearwaters and to prevent unnecessary trampling of the burrows. These measures have reduced the impact that unaware visitors were having on the burrows. Monitoring of both shearwaters and people is continuing in order to identify and reduce the effects of the high visitation rate.

Indirect Human Disturbance

Introduced animals and plants and changed fire regimes are all examples of indirect human

disturbance. However, an example of a more insidious problem is the effect of the urbanisation of the Sydney-Wollongong region on the seabirds of Big Island. Silver Gulls were first recorded breeding on the island only in 1940 but have increased greatly since then and now number some 17 800 pairs (Gibson 1976; Lane 1979a). Rubbish tips are a major source of food for this species and the increase in the Silver Gull population is a result of the increasing human population on the adjacent mainland.

Big Island was well vegetated prior to colonisation by the surface-nesting Silver Gulls, but large areas have become denuded as gull number have increased. There has been some recovery in the last decade, helped by the spread of various self-introduced plants, notably the exotic grasses, Kikuyu Grass *Pennisetum clandestinum* and Crowsfoot Grass *Eleusine indica* (Gibson 1976). However, the loss of vegetation has allowed the soil to be severely eroded. The nesting area available to burrowing species has been reduced and the numbers of Little Penguins, Wedge-tailed Shearwaters and White-faced Storm-Petrels have declined markedly since the 1960s. The White-faced Storm-Petrel apparently no longer breeds on the islands.

CONCLUSIONS

Although considerable progress has been made in reserving seabird breeding islands along the New South Wales coast, a number of islands of moderate importance remain unreserved. These islands are Crown land with no competing land uses. They should be reserved and managed. The first priority should be South Solitary Island.

The potential problems faced in management of offshore islands to preserve their seabird breeding colonies are many. Obvious, though often complex, problems are introduced animals and plants, fire and direct human disturbance. Human activities may also have more subtle, less direct effects on seabird colonies. No seabird species appear to have ceased breeding in New South Wales since European settlement. In fact, three species, the Short-tailed Shearwater, Australian Pelican and Kelp Gull, are recent colonists. Nevertheless, breeding populations have been lost from individual islands, notably the former colonies of White-faced Storm-Petrels on Broughton Island and Big Island.

Because of their small size and confined nature, islands are particularly vulnerable to disturbance and environmental change. Formal reservation is not sufficient to guarantee preservation of seabird colonies on islands. Careful management of the island reserves is crucial. Broad goals can be easily

formulated, such as eradication of populations of introduced animals and plants, exclusion of fire, and restriction of human visits to a minimum. However, limited staff and resources make it necessary to determine priorities.

Some immediate priorities can be identified for the existing and impending New South Wales reserves - the eradication of rabbits and cats and reduction of fire frequency on Broughton Island; the eradication of rabbits on Cabbage Tree Island; and the eradication of rabbits and rehabilitation of the vegetation and soil on Big Island; and the eradication of rabbits and goats on Montagu Island. In the long term, however, regular monitoring of the seabird colonies is needed as a basis for management, so that major problems and long-term trends can be identified. Whilst a number of individual island reserves are currently being monitored, a more general and more systematic program of monitoring needs to be instituted for the island reserves of New South Wales.

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