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The other subpopulation of Christmas Island White-eye *Zosterops natalis* (Aves: Zosteropidae): a historic introduction has led to an enduring subpopulation on Horsburgh Island, Cocos (Keeling) Islands group

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Abstract. The Christmas Island White-eye *Zosterops natalis* occurs naturally only on the 135 km^2 Christmas Island. Between 1888 and 1900 (remarkably soon after it was first discovered and described), it was introduced to the 1 km^2 Horsburgh Island in the Cocos (Keeling) Islands group. There has been limited subsequent documentation of the fate of this translocated population. Based on transect sampling in 2013, we estimate the population size to be 1084 individuals (with 95% confidence limits of 731 to 1716). This represents a substantially larger estimate than the previous estimate (of 400 individuals in 1941), and indicates a greater abundance than the most recent (1982) non-quantitative record of its status. In contrast to previous documentation, this species is widespread on Horsburgh Island, and abundant in a mosaic of natural and modified vegetation (dominated by coconut *Cocos nucifera* plantation with *Scaevola taccada* shrub layer). Contextualising the conservation significance of this introduced population is difficult because there is no reliable estimate of the population size on Christmas Island, but it is plausible that the Horsburgh Island subpopulation now comprises c. 5% of the species' total population size. However, more importantly, its significance lies in the provision of a second location that may reduce extinction risk.

Key words. Christmas Island, Cocos (Keeling) Islands, conservation, population census, translocation

INTRODUCTION

The passerine family Zosteropidae has an intriguing distribution characterised by an unusually high incidence of occurrence on islands, and rapid speciation leading to high levels of island endemism (Clegg et al., 2002; Warren et al., 2006; van Balen, 2008). The island species in particular have suffered a high rate of decline, typically associated with predation (of eggs, young and possibly adults) by introduced rats (particularly Black Rats *Rattus rattus*): of 75 *Zosterops* species whose conservation status has been assessed by the IUCN, one species is extinct, 12 species are threatened, 11 species are near threatened, and one species is data deficient (http://www.iucnredlist.org).

Of the seven Australian *Zosterops* species, four were confined to single islands: the Robust White-eye *Z. strenuus* occurred only on Lord Howe Island and is now extinct, the White-chested White-eye *Z. albogularis* occurred only on Norfolk Island and is considered Critically Endangered (Possibly Extinct), the Slender-billed White-eye *Z. tenuirostris* occurs only on Norfolk Island and is considered Near Threatened, and the Christmas Island White-eye *Z. natalis* occurs naturally only on Christmas Island (Indian Ocean) and is considered Near Threatened (Garnett et al., 2011).

Since the settlement of the 135 km^2 Christmas Island (10°30'S, 105°40'E; Fig. 1) in 1888, none of its ten endemic bird taxa (five species and five subspecies) has become extinct, but five are now listed as threatened (Garnett et al., 2011). This record of persistence is better than that for other terrestrial vertebrates: at least three and probably four of its five endemic mammal species have become extinct (Woinarski et al., 2014), and at least four of its five endemic reptile species are now close to extinct in the wild (Smith et al., 2012). The island's natural environment is now suffering invasional meltdown, with collapse of much of its ecological structure and function due to the impacts of many invasive species, but particularly of the Yellow Crazy Ant *Anoplolepis gracilipes* (O'Dowd et al., 2003). This renders tenuous the viability of most of its remaining endemic taxa.

Here we report on the persistence of the Christmas Island White-eye on another island, 860 km distant, arising from a deliberate introduction made more than 100 years ago. We also provide an estimate of its population size and habitat use on that island, and note its conservation significance.

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History of introduction and subsequent records. The Clunies Ross clan settled on the isolated Cocos (Keeling) Islands in 1827, and then operated it as a fiefdom for almost 150 years (Clunies-Ross, 2009). In 1888, they also established a very small settlement on Christmas Island, mostly to extract timber and soil, and to pre-empt rival claims. Sometime between that establishment and 1900 (Gibson-Hill, 1949, 1950; Long, 1981), George Clunies Ross translocated an unknown number of Christmas Island White-eyes, Christmas Island Thrush *Turdus poliocephalus erythropleurus* and Christmas Island Imperial-pigeon *Ducula whartoni* to islands in the southern atoll of the Cocos (Keeling) group (and for the thrush also to the isolated North Keeling Island: Gibson-Hill, 1950), for reasons that are not recorded. Remarkably these introductions were more or less contemporaneous with the scientific discovery and formal description of these species (in 1887 for the thrush and pigeon, in 1889 for the white-eye).

The pigeons did not persist long (with the last record as 'practically extinct' in 1906: Wood Jones, 1909), almost certainly because the forests of the Cocos (Keeling) Islands are much more depauperate (with fewer fruit trees) than those on Christmas Island, and perhaps also due to hunting. The thrush persisted at least until 1941, when it was still 'fairly plentiful' on at least three islands (Gibson-Hill, 1950: 254), with an estimate of 500 individuals on the 1 km^2 Horsburgh Island (Pulu Luar) (Gibson-Hill, 1950), but it was recorded as no longer occurring on any island at the next report of the birds of the Cocos group (Stokes et al., 1984).

In 1941, Gibson-Hill reported that the Christmas Island White-eye was present in the Cocos (Keeling) Islands 'only on Pulu Luar, and it is probable that this is the only island on which an attempt was made to establish it' (Gibson-Hill, 1950: 256). He estimated that 'there were about 400 birds present' in 1941 (Gibson-Hill, 1949, 1950: 257).

The distribution of the Christmas Island White-eye on the Cocos (Keeling) Islands was next considered in a 1982 bird survey of all islands (Stokes et al., 1984). This concluded that the Christmas Island White-eye remained restricted to Horsburgh Island, but that it was 'plentiful only in the remnants of the original forest vegetation remaining along the lagoon shore' (Stokes et al., 1984: 27). Subsequently Garnett & Crowley (2001) and Garnett et al. (2011) misinterpreted this assessment as that it 'persists only around the settlement' (Garnett & Crowley, 2001: 606), notwithstanding the then (1982) (and current) lack of any settlement on Horsburgh Island. van Balen (2008: 462) repeated the assertion that, on Horsburgh Island, the white-eye remained abundant 'only in remnants of the original forest vegetation along shoreline of lagoon'.

Gibson-Hill (1949, 1950) noted that Horsburgh Island had several features that offered more conservation security than the other islands in the southern atoll of the Cocos (Keeling) group. Notably it (apparently uniquely) had not been colonised by Black Rats, and it retained a higher proportion of unmodified native vegetation than that of other islands. Furthermore, much human visitation was constrained, with the Clunies-Ross family treating the island as a private retreat and sanctuary with other introductions including deer (that failed to persist), and an enforced and isolated home for adolescent girls, ostensibly 'to prevent them from succumbing to their natural inclinations at too young an age' (Gibson-Hill, 1949: 225).

METHODS

Characteristics of Horsburgh Island. Horsburgh Island (12°50'S, 96°50'E) is the most isolated of the islands in the southern atoll of the Cocos (Keeling) group, being 2.5 km distant from the nearest other island (Direction Island) and c. 4 km and 5 km from the main (and only inhabited) islands of Home (Pulu Selma) and West (Pulu Panjang) respectively. Horsburgh Island is owned collectively by the Cocos Island community, and managed by the Shire of Cocos (Keeling) Islands. While not managed as a conservation reserve, wildlife on Horsburgh Island is given specific protection in regulations under Australia's national environmental legislation, with Schedule 12 defining 'protected species' to include any species 'on the land above the high water mark on Horsburgh Island (Pulu Luar) … other than a fruit or leaf of the species *Cocos nucifera*'.

With the exception of three rarely used holiday cottages ('pondocks'), Horsburgh Island is uninhabited and little visited, and has been largely so since the Second World War. Its vegetation comprises a complex mixture of remnant native and introduced plant species (Williams, 1994). About 25% of the Island (in the east) was cleared to grassland during the Second World War, with this clearing retained subsequently through occasional fires, but now including patches of shrubs (mostly *Scaevola taccada*) (Fig. 1c). Stands of coconut *Cocos nucifera* were planted over much of the area intermittently over the Clunies-Ross' period, but have been unmanaged for at least 30 years, and are now characterised by a dense understorey of coconut saplings, *Scaevola* and *Premna serratifolia*, with this vegetation type merging into dense shrublands with fewer or no emergent coconuts. There is one relatively large (0.9 ha) and several small connected lagoons, and the margins of these support a dense low forest of *Cordia subcordata* and a small stand of mangroves *Rhizophora apiculata*. The extent of the three vegetation types (grassland, coconut forest with *Cordia* understorey, and remnant forest at the lagoon margins) was estimated from a recent satellite image.

Recent sampling by R. Palmer (Western Australia Department of Environment and Conservation) has confirmed that apparently alone of all the islands in the southern atoll, Horsburgh Island still has no introduced *Rattus* species, but does have an introduced population of House Mouse *Mus musculus*.

The bird fauna of Horsburgh Island is species-poor, with no native resident passerines, raptors or potential competitors (Gibson-Hill, 1949, 1950; Stokes et al., 1984).

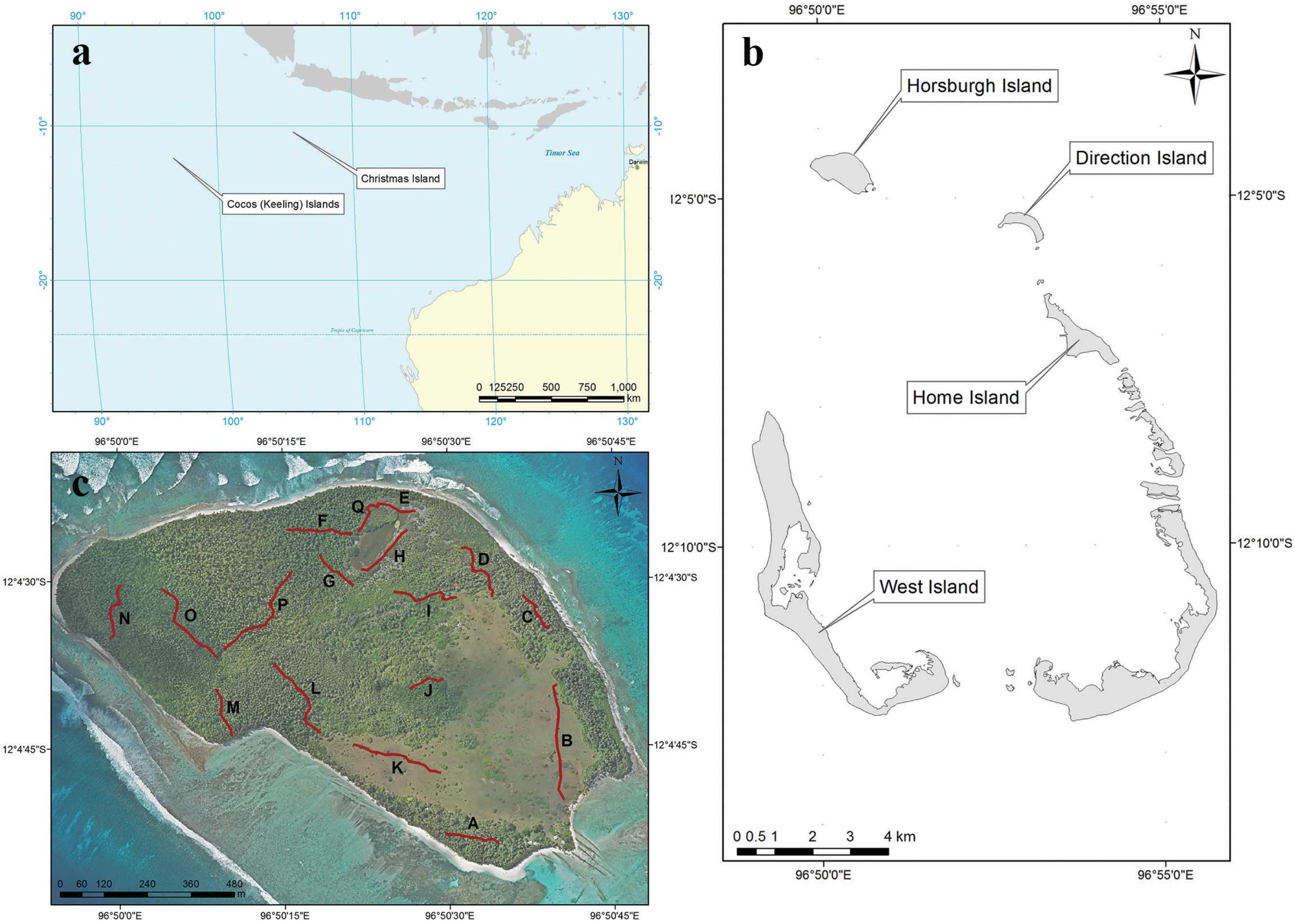

Fig. 1. a, General location of Christmas Island and Cocos (Keeling) Islands; b, map of southern atoll of the Cocos (Keeling) Islands, showing Horsburgh Island and other islands mentioned in text; c, satellite image of Horsburgh Island showing marked variation in vegetation, and transects established for censusing White-eyes.

Sampling. We estimated the population size of Christmas Island White-eyes on Horsburgh Island, using a series of variable-width belt transects, placed more or less evenly across the island and sited to represent the range of vegetation types present (Fig. 1; Table 1). In April 2013, we censused every transect one to three times and recorded the number of White-eyes seen or heard along the route, along with their distance from the central axis of the transect. The total length of transects sampled (including multiple samples of the same transect) was 7.49 km. Counts were undertaken by JW, TD, IM, Caitlin Pink, Neil Hamilton, Razali Zainiel and Mohammed Aslie Woren. There are no other passerine birds on the island, so there is no risk of inter-observer variability in identification.

Detection distances varied amongst the three main vegetation types, being notably less in the dense understorey of coconut-*Scaevola* scrub than in the grasslands. Density estimates were calculated using the programme DISTANCE (Buckland et al., 2001) for the three vegetation types: grasslands (with total area of 24.2 ha), coconut forest-*Scaevola* shrubland (70.3 ha), and lagoon-edge forest (3.4 ha).

RESULTS

A total of 398 White-eyes (in 67 groups) were recorded on the transect sampling. White-eyes were recorded from 16 of the 17 transects sampled (Table 1). Density was appreciably higher in the coconut forest-*Scaevola* shrubland and in the lagoon edge forest than in the grasslands (Table 2). Confidence limits were broad, probably largely because of occasional incidence of large groups (>10 individuals). The total population size for Horsburgh Island was estimated to be 1084 individuals.

DISCUSSION

This study has confirmed the persistence of a translocated population of Christmas Island White-eyes on one small island for >100 years. The sampling indicates that Horsburgh Island now supports an appreciably larger population size than the previous (1982) reporting (Stokes et al., 1984), although that previous reporting was not based on systematic sampling. In particular, our study demonstrates that white-eyes now are widespread and abundant in the modified habitat of coconut plantation forest with *Scaevola* understorey, rather than being restricted to the small areas of remnant native habitat around the lagoon edge as reported by Stokes et al. (1984). It is not clear whether this represents a habitat

Table 1. Characteristics of sampling transects on Horsburgh Island

Transect ID	Habitat description	Length (m)	Mean no. of White-eyes recorded (no. of counts)
Grasslands			
B	Grassland with scattered shrubs to 2 m (mostly *Scaevola taccada*)	332	18 (1)
K	Mixed grassland and open shrubland (to 3 m) of *Premna serratifolia*, *Dodonaea viscosa* and *Scaevola* (c. 20% cover)	263	4.3 (3)
Lagoon edge remnant native forest			
E	Patchily mixed *Cordia subcordata* forest (10 m, 50% cover), *Sesuvium portulacustrum* herbland and mangrove *Rhizophora apiculata* forest (10 m, 50% cover)	113	2.0 (3)
H	Dense *Cordia* forest (10 m, 70% cover), with some gaps of *Sesuvium* herbland	176	15.3 (3)
O	Mixed (i) tall dense (15–20 m, 50% cover) coconut forest, with open understorey (1–2 m, 20% cover) of coconut; and (ii) lagoon pools, forest of *Cordia* forest (10–15 m, 30% cover) and coconut (10–15 m, 30% cover) with open coconut understorey (2–3 m, 30% cover)	273	13.3 (3)
Q	Patchily mixed forest of mangroves (*Rhizophora*) (90% cover, 5 m) and *Cordia* (70% cover, 5–10 m)	112	9.0 (2)
Mixed coconut forest with *Scaevola* tall shrub understorey			
A	Tall coconut forest (15 m, 80% cover) with dense shrubby understorey (3–5 m, 50% cover), mostly coconut with some *Dodonaea* and *Scaevola*	153	8.0 (3)
C	Open coconut forest (15–20 m) with dense *Scaevola* (1–3 m) understorey	127	13 (1)
D	Mixed height coconut forest (10–15 m), with dense shrubby understorey (to 3 m) of *Scaevola*, *Cassytha filiformis* and coconut	203	0 (1)
F	Dense tall shrubland of *Scaevola* (5–10 m, 70% cover) and coconut, with emergent coconut (15 m, 20% cover)	186	10.7 (3)
G	Dense shrubland of *Scaevola* (3–5 m, 90% cover) and coconut, with occasional emergent coconut (10 m, <5% cover)	130	8.3 (3)
I	Dense tall (3–5 m) *Scaevola* shrubland with occasional emergent coconut (5% cover, 15 m)	205	9.0 (2)
J	Coconut forest (10–15 m, 70% cover); dense tall shrub layer (5–10 m, 70% cover) of coconuts, with occasional *Morinda citrifolia*. Occasional *Calophyllum inophyllum* trees (to 15 m)	105	3.5 (2)
L	Mixed (i) *Premna* forest (10 m, 50% cover) with occasional emergent coconut (to 15 m), understorey (to 3 m) of coconut, *Scaevola*, *Morinda*; some damp areas; and (ii) tall dense coconut forest (15–20 m, 80% cover), with coconut understorey (1–2 m, 50% cover)	262	20.3 (3)
M	Mixed forest of *Premna* (10 m, 40% cover), coconut (15 m, 25% cover), with tall understorey of coconut (to 5 m, 30% cover) and *Premna* (to 3 m, 20% cover)	142	12.5 (2)
N	Open coconut forest (15–20 m, 20% cover), with dense (5 m, 80% cover) *Scaevola* understorey	175	9.0 (3)
P	Coconut forest (10–20 m, 40% cover) with *Premna* (10 m, 20% cover), *Scaevola* (5–10 m, 20% cover) and coconut (3–5 m, 50%) mid-storey	318	4.5 (2)

Table 2. Number of observations, density and population estimates for Christmas Island White-eye on Horsburgh Island. Density estimates are mean no. of individuals/ha, with 95% confidence limits in brackets.

Total no of individuals (no. of groups) recorded	Density estimate			Estimated population size
	Grasslands	coconut-*Scaevola*	Lagoon edge forest	
398 (67)	2.0 (0.5–8.8)	14.1 (9.9–20.3)	12.3 (6.9–21.9)	1084 (730.6–1715.5)

expansion or is based on insufficient sampling in 1982. Our study also indicates a larger population size than the previous quantitative assessment, of 400 individuals in 1941 (Gibson-Hill, 1949, 1950), although the basis for this earlier estimate was not described.

There are two conservation management implications from this study. The first relates to the current and potential role of islands in the Cocos (Keeling) group as conservation lifeboats for the Christmas Island biota, and the second relates to management of Horsburgh Island itself.

There is no reliable estimate of the number of Christmas Island White-eyes on Christmas Island. The most recent estimate is c. 20,000 individuals (Garnett & Crowley, 2001; van Balen, 2008; Garnett et al., 2011), however this is considered to be of low reliability (Garnett et al., 2011). A previous estimate of 100,000 to 1,000,000 individuals (van Tets, 1975) has no systematic sampling basis, and divergence of recent estimates from that earlier estimate may or may not represent real population decline. It is difficult to contextualise the conservation significance of the Horsburgh Island subpopulation given this uncertainty about the population size on Christmas Island, but it is plausible that the Horsburgh Island population now represents about 5% of the total population. Of more importance than the relative population size is that Horsburgh Island constitutes a separate and isolated location, and hence reduces the risk of rapid extinction arising from a novel threat introduced to Christmas Island.

Relative to other Christmas Island endemic species, the Christmas Island White-eye may be an unrepresentatively good candidate for translocation. Like most other *Zosterops* species (e.g., Catterall, 1985; Scott et al., 2003), it is a habitat and dietary generalist, and can sustain high population densities. The rapid failure of the attempted translocation of Christmas Island Imperial-pigeon to the Cocos (Keeling) Islands group, and the eventual failure of the translocated population of Christmas Island Thrush are outcomes that may be more likely for other Christmas Island species. The failure of the thrush, after establishment for at least several decades, is intriguing, given that it was abundant on Horsburgh Island in 1941 (Gibson-Hill, 1949, 1950), but had disappeared by the next reported account (1982: Stokes et al., 1984). The period of this disappearance also coincided with the loss of the Cocos-endemic subspecies of Buff-banded Rail *Gallirallus philippensis andrewsi* from Horsburgh Island (and also from other islands in the southern atoll) (Reid & Hill, 2006). The factor that caused these losses from Horsburgh Island sometime between 1941 and 1982, but did not affect the White-eye, is undocumented and unknown.

Nonetheless, given the rapid decline of many Christmas Island endemic animal species (Smith et al., 2012; Woinarski et al., 2014), the successful and enduring translocation of the Christmas Island White-eye does indicate that translocation options are worth considering for some additional Christmas Island species, and may provide some medium-term conservation security.

Of the islands in the southern atoll of the Cocos (Keeling) group, Horsburgh has the largest area of natural vegetation and alone has not been colonised by Black Rats (or, at least, Black Rats have not persisted on it). These features may account for the fact that White-eyes have not colonised successfully from Horsburgh to other islands in the group. An alternative explanation is that the Horsburgh White-eyes may simply have not sought to cross the sea between these islands, although this hypothesis is unlikely given the propensity of other *Zosterops* species to disperse between islands (e.g., Clegg et al., 2002). Indeed, IM has reported occasional records of white-eye individuals on the main Cocos (Keeling) Islands of West and Home over the last 10–20 years.

The persistence over more than a century of this subpopulation on a very small island from a presumably small founder population is noteworthy, but not entirely unexpected. Brook & Kikkawa (1998) used population viability modelling for a smaller population (of c. 380 individuals) of *Z. lateralis* on the smaller (17 ha) Heron Island (Great Barrier Reef area of Australia), and reported that it had only a 15% probability of extinction over 100 years. The likelihood of extinction of that subpopulation was most influenced by major disturbance (cyclones), novel disease and increases in predation pressure, but was moderated by possibilities of recolonisation from nearby islands or mainland areas, a relief that is not realisable for the isolated Horsburgh Island subpopulation.

The introduced Horsburgh Island population of White-eyes has survived at least five major cyclones in which much of its forest habitat was felled (in 1893, 1902, 1909, 1968 and 1992) (Clunies-Ross, 2009). The subpopulation has apparently been resilient to this disturbance, perhaps because of the relative lack of other threats, notably predation pressure.

On Christmas Island, White-eyes have persisted despite the introduction of Black Rats more than 100 years ago (Wyatt et al., 2008). However it may be that this is at substantially reduced population size than prior to the rat's introduction, and such persistence may be unlikely on a far smaller island.

If so, rat introduction to Horsburgh Island may imperil this translocated White-eye subpopulation (and hence the conservation security that it offers to the species as a whole). Thus, biosecurity (particularly with respect to reducing the risk of rat introduction) should be a prime focus for the conservation management of Horsburgh Island.

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