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1 **All the eggs in one basket: are island refuges securing an endangered passerine?**

2

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24

25 **Abstract**

26 Refuges for threatened species are important to prevent species extinction. They provide
27 protection from a range of environmental and biotic stressors, and ideally provide
28 protection against all threatening processes. However, for some species it may not be clear
29 why some areas are refuges and others are not. The forty-spotted pardalote (*Pardalotus*
30 *quadragintus*) is an endangered, sedentary, cryptic and specialized bird endemic to the
31 island of Tasmania, Australia. Having undergone an extreme range contraction over the past
32 century the species is now mostly confined to a few small offshore island refuges. Key
33 threatening processes to the species include habitat loss, wildfire, competition and
34 predation. The ways in which these processes have molded the species' contemporary
35 range have not been clearly evaluated. Furthermore, the security of the remnant population
36 within refuges is uncertain. To overcome this uncertainty we assessed key threats and
37 established the population status in known refuges by developing a robust survey protocol
38 within an occupancy modelling framework. We discuss our results in the context of planning
39 trial reintroductions of this endangered species in suitable habitat across its former range.
40 We found very high occupancy rates (0.75-0.96) at two refuges and in suitable conditions,
41 the species was highly detectable (p , 0.43-0.77). At a third location our surveys indicated a
42 local extinction, likely due to recent wildfire. We demonstrate that all refuges are at high
43 risk of one or more threatening processes and the current distribution across island refuges
44 is unlikely to secure the species from extinction. We identified large areas of potential
45 habitat across the species' former mainland range, but these are likely too distant from
46 source populations for natural recolonization. We propose that establishing new
47 populations of forty-spotted pardalotes via reintroduction is essential to secure the species
48 and that this is best achieved while robust source populations still exist.

49 **Key words**

50 Forty-spotted pardalote *Pardalotus quadragintus*, refuges, conservation biology,
51 threatening processes

52 **Introduction**

53 The identification of refuges for at risk species is increasingly important to conservation
54 biology (Keppel and Wardell-Johnson Grant 2012). In the Australian context, refuges can
55 generally be defined as locations or habitat within a landscape that facilitate survival of
56 species after disturbance events (e.g. fire, drought) or protection against introduced
57 predators (Pavey *et al.* 2017). Refuges can originate through geographic isolation (e.g.
58 islands), topographic position and vegetation types less prone to fire, or anthropogenic
59 activities such as predator control, fencing and fuel reduction burning (Taylor *et al.* 2005).
60 There are numerous cases where a species' survival hinges on its persistence within refuges
61 (Atkinson 2002; Morris 2000; Webb *et al.* 2016). Understanding the processes that form
62 refuges is critical to conservation management. Moreover, understanding the spatial and
63 temporal nature of these processes is important to evaluate if the protection provided by a
64 refuge is short-term (e.g. fire refuges, invasive species), or potentially long-term security
65 (e.g. islands) (Woinarski *et al.* 2011). This will ultimately determine what actions can be
66 undertaken to increase their effectiveness (e.g. fire management, reservation, biosecurity)
67 (Caughley 1994).

68

69 For small or rapidly declining populations, failure to act can quickly lead to extinction
70 (Martin *et al.* 2012; Woinarski 2016). When a species has reached this critical stage, its
71 distribution has often contracted to refuges (Lomolino and Channell 1995) and by default,
72 these areas often become foci for conservation planning (Webb *et al.* 2016; Stojanovic *et al.*

73 2017). In such cases, conservation actions usually focus on the reservation of occupied
74 habitat, increasing habitat area (Smith 2008) and evaluating how best to expand or protect
75 refuges depending on spatial and temporal factors related to extinction risk (McCarthy *et al.*
76 2005; Schultz Courtney *et al.* 2013).

77

78 Typical approaches for threatened species in conservation are increasing population size
79 (McCarthy *et al.* 2005); managing specific threats (Wilson *et al.* 2007), and ex situ
80 conservation or translocations (Seddon 2015). If populations are viable but local habitat is at
81 carrying capacity, creating 'new' populations (or restoring locally extinct populations) in
82 suitable but unoccupied habitat may provide greatest cost-benefits rather than attempting
83 to enlarge existing populations (McCarthy *et al.* 2005).

84

85 Despite islands being disproportionately represented in species extinctions (Blackburn *et al.*
86 2004; Tershy *et al.* 2015), conversely they can also provide critical refuges if threatening
87 processes are absent (Heinsohn *et al.* 2015; Lentini *et al.* 2018; Taylor *et al.* 2005). Here we
88 examine the benefits of focusing management actions on the protection of refuges
89 compared to actions that target threats, both historic, current and future. We use the case
90 study of an endangered bird that now only occurs in refuges, primarily on islands
91 (Threatened Species Section 2006). The forty-spotted pardalote (*Pardalotus quadragintus*) is
92 a small, cavity nesting, leaf gleaning passerine dependent on white gums (*Eucalyptus*
93 *viminalis*) for food, and primarily nests in tree cavities of eucalyptus species (Woinarski and
94 Bulman 1985). Historically the species was widely distributed across Tasmania (Fig 1) and it
95 is now presumed extinct across most of its former range (Brown 1986; Rounsevell and
96 Woinarski 1983). This range contraction has been occurring at least since the early last

97 century and has continued over recent decades (Bryant 2010; Rounsevell and Woinarski
98 1983; Threatened Species Section 2006). Three decades ago the species' area of occupancy
99 was estimated to be <50 km², mostly on Bruny, Maria and Flinders Islands off the Tasmanian
100 coast and a mainland location, Tinderbox Peninsula. Tinderbox Peninsula is < 1.5 km from
101 Bruny Island (Fig. 1; Figs. S1 & S2), and based on genetic evidence is likely supported by
102 birds dispersing from Bruny Island (Edworthy 2017) . These locations are foci for the species'
103 conservation, and 77% of refuge habitat has some level of statutory protection (Bryant
104 2010). Importantly, an implicit assumption of this approach is that the species can be
105 secured from extinction at these locations.

106

107 The probable causes of the species' range contraction are diverse (Table 1). Likewise, it is
108 not known whether forty-spotted pardalotes are now restricted to island refuges, or if they
109 are capable of recolonizing parts of their historical range on mainland Tasmania either
110 naturally or through translocation (Threatened Species Section 2006). Here, we aim to: (1)
111 quantify current threats to refuges and their security, and (2) provide baseline population
112 data. We use our results to examine management options to prevent further range
113 contraction and evaluate potential for range expansion through reintroductions.

114

115 **Methods**

116 *Aim 1: quantifying the historical and future impact of threats and updating conservation*
117 *assessments of refuge habitat*

118 We focus on widespread threatening processes with strong evidence of direct impacts: (i)
119 deforestation, (ii) wildfire, (iii) noisy miner *Manorina melanocephala* competition, and
120 climate change (see Table 1), but also consider threats where impacts are more uncertain

121 such as a newly discovered parasitic fly that can cause high nestling mortality (Edworthy
122 2018). For each threat, we evaluated the potential risk of it impacting refuges.

123

124 To assess the impact of recent deforestation, we quantified the area of core forty-spotted
125 pardalote refuge habitat using two data sources: (i) a 30-year-old spatial layer of core refuge
126 habitat (Brown 1986; habitat (Natural Values Atlas www.naturalvaluesatlas.tas.gov.au,
127 accessed 1 September 2015) and (ii) a recent map of vegetation types TASVEG 3.0
128 (Department of Primary Industries, Parks Water and Environment 2013) to identify key
129 forest habitats. We assessed contemporary habitat loss/disturbance using a spatial layer of
130 forest loss derived from Landsat imagery at 30 x 30 m resolution (Hansen *et al.* 2013).

131 Hansen *et al.* (2013) classifies ‘forest loss’ as the result of land clearing, timber harvesting
132 and wildfire. Here, we defined the cumulative area of impact of these processes as
133 deforestation area. Using ArcMap 10.2, we estimated the total area of potential habitat of
134 the forty-spotted pardalote and the total area of habitat affected by recent deforestation.

135

136 The forty-spotted pardalote’s current and historical distribution is highly fire-prone (Fig S3
137 and S4). To assess the potential historical impacts of fire on refuges, we used a spatial layer
138 of fires in Tasmania (1969 – 2016) (Tasmanian Fire Service 2017) to estimate the area of
139 forty-spotted pardalote habitat affected by wildfire during this period. We also assessed the
140 future risk of fires occurring in refuges using the Tasmanian Bushfire Risk Assessment Model
141 (Parks and Wildlife Service, unpublished) by quantifying the area of each refuge and its
142 respective ‘fire ignition potential’. Ignition potential in this model is based on the number of
143 historical fires, lightning probability and Bureau of Meteorology observations.

144

145 Noisy miners do not currently occur in forty-spotted pardalote refuges. However, they are
146 widespread on the Tasmanian mainland, having expanded with land clearance (MacDonald
147 and Kirkpatrick 2003). To examine possible historical impacts of noisy miners on pardalote
148 populations and assess the future risk of noisy miner colonization of refuge habitat, we
149 compared noisy miner environmental suitability of forty-spotted pardalote refuges and their
150 historical range. We modeled environmental suitability for noisy miners across Tasmania
151 using MaxEnt (Phillips *et al.* 2006). We used verified occurrence data with a location
152 accuracy < 500 m downloaded from the Atlas of Living Australia (ALA,
153 <http://www.ala.org.au>, downloaded 4/9/2016). We also included unpublished data
154 collected by the authors, resulting in a total of 1550 noisy miner records for modeling.
155 Predictor variables were total rainfall during the driest quarter, mean temperature of the
156 warmest quarter, minimum temperature of the coldest period, temperature seasonality,
157 vegetation cover (cleared or not), and ecosystem type (11 categories, reclassified from the
158 Major Vegetation subgroups from the National Vegetation Information System v4.1,
159 Australian Government 2012); these variables are known to relate to noisy miner
160 prevalence and abundance (Maron *et al.* 2013; Thomson *et al.* 2015). Based on model
161 outputs, we assessed the environmental suitability of forty-spotted pardalote refuges for
162 noisy miners. We reclassified the Maxent logistic output into predictions of noisy miner
163 presence or absence using equal sensitivity and specificity threshold values for each year
164 (Liu *et al.* 2013). This resulted in a map of predicted suitable or unsuitable environments.
165 This map aimed to represent current suitability and did not account for potential expansion
166 of the species resulting from future disturbance or a changing climate. The potential
167 impacts of climate change were considered in the context of the species' highly restricted
168 distribution and likely exacerbation of other known threats (e.g. fire).

169

170 Using the information outlined above and the combined expert knowledge of the authors
171 we used a standard threat risk assessment process (Hart *et al.* 2005) to identify the relative
172 future risk posed by each threat to each refuge (and habitat in the historical range) over a
173 30-year period. Each threat was assessed for the consequence to the species and the
174 likelihood of that consequence happening (Supplementary Material). Consequence was
175 defined by the expected magnitude of the impact of a threat and the overall threat
176 footprint. For example, habitat clearance in reserved refuges would be major but only small
177 areas (i.e. threat footprint) are likely to be affected. Overall risk posed by each threat was
178 then assessed using the consequence and likelihood ratings in a standard risk matrix
179 (Supplementary Material).

180

181 *Aim 2: develop a monitoring protocol to provide baseline population data for refuges*

182 There is currently no systematic monitoring program for the forty-spotted pardalote. To
183 account for false absences (i.e. imperfect detection) we adopted a standard occupancy
184 modelling approach (MacKenzie *et al.* 2002). We undertook baseline surveys on known
185 pardalote refuges Maria Island, North Bruny Island and Flinders Island (Figs. S1, S2 & S3),
186 which combined supports ~79 % of the species contemporary area of occupancy, with the
187 remainder occurring on South Bruny Island and Tinderbox Peninsula (calculated in ArcMap
188 10.2 using the spatial layer of habitat outlined above (Natural Values Atlas 2015). The
189 number of sites and site visits is summarized in Table 5. As our objective was to estimate
190 occupancy in critical habitat (i.e. forest containing white gum, *E. viminalis*), we used the
191 spatial layer of refuge habitat outlined above as a guide for site selection. All sites had at
192 least one white gum present, and were selected as follows: from a random starting point

193 the nearest white gum was located which became the first sampling site. Subsequent sites
194 were established by following a random compass bearing to the nearest white gum $\geq 200\text{m}$
195 from the previous site. For logistical reasons the locations of sites on North Bruny Island
196 were influenced by access and on Maria Island sites were restricted to within $\sim 100\text{m}$ of
197 existing walking tracks (Fig. S1). We used repeated five-minute visits to record the
198 presence/absence of birds within 100m of the site (based on calls and observation).
199 Monitoring was conducted intermittently between 2010 and 2016. Other locations in the
200 historical range were surveyed opportunistically.

201

202 The forty-spotted pardalote is extremely cryptic owing to its soft call, small size, and two
203 other sympatric pardalote species (*P. striatus* and *P. punctatus*) (Rounsevell and Woinarski
204 1983). During the species' breeding season (i.e. spring/summer), several avian migrants and
205 other resident species, can form noisy aggregations that can drown out the soft
206 vocalizations of the forty-spotted pardalote. To increase and control for variation in
207 detectability, we restricted our surveys to still, clement weather in the non-breeding season
208 (i.e. autumn/winter, when migratory species had left the study area) to maximize the
209 likelihood of detecting the soft calls of the target species. We used occupancy modelling to
210 estimate overall occupancy (ψ) in critical habitat for each refuge. We fitted simple constant
211 occupancy models using the package *unmarked* in R (Fiske and Chandler 2011; R
212 Development Core Team 2011). We used estimates of detectability (p) to assess the
213 reliability of absences at other locations where data were too sparse.

214

215 **Results**

216 *Aim 1: quantifying the historical and future impact of threats and updating conservation*
217 *assessments of refuge habitat*

218 The species' area of occupancy based on mapped habitat (Natural Values Atlas
219 www.naturalvaluesatlas.tas.gov.au, accessed 1 September 2015) was estimated as ~ 42 km²,
220 but only 35.5 km² of this area is currently eucalypt forest and woodland. According to our
221 overall risk assessment, all refuges face high, very high, or extreme risks from multiple
222 threats (Table 2). Consequence and likelihood ratings for each threat in each refuge are
223 provided in Appendix A.

224

225 Only 0.82 km² (< 2 %) of refuge habitat has been affected by deforestation since ~1996.
226 Overall, deforestation through habitat clearance is likely to be relatively low risk to refuge
227 populations, as 77% (Bryant 2010) of refuges has some level of statutory reservation and
228 risk level was identified to vary depending on the location (Table 2). Furthermore, fire is
229 likely the cause for ~75% of the disturbance classified as deforestation (Hansen *et al.* 2013).

230

231 Historical fire mapping indicates that of all refuge habitat has burned since 1969 (17 %, 7.1
232 km²), with most of this (62 %, 4.1 km²) attributable to the 2003 fire on Flinders Island (Fig.
233 S3). Other fires in refuge habitat were smaller (mean 0.12 km²; range 0.0002 – 1.2 km²) and
234 83% of extant habitat has not burned for > 45 years. The Tasmanian Bushfire Risk
235 Assessment Model identifies 83% of refuge habitat as having a moderate to very high
236 ignition potential (Table 3).

237

238 Our MaxEnt model of noisy miner distribution indicates that an area of 10,587 km² across
239 Tasmania is climatically suitable for the generalist noisy miner (see Supplementary Material

240 for model details). Environmental suitability for noisy miners is high across most of the
241 former and present distribution of the forty-spotted pardalote and they are well established
242 < 4km from all refuges except Flinders Island (Fig 2). The percentage area above the
243 threshold value of noisy miner environmental suitability for each pardalote refuge varied
244 from 0 – 81% (Table 4).

245

246 *Aim 2: develop a monitoring protocol to provide baseline population data for refuges*

247 On North Bruny Island and Maria Island estimates of pardalote ψ were high in all years
248 (range 0.75-0.96, Table 5). Detectability for a single site visit was also high but more variable
249 (0.43-0.77). Over the entire study period the species was recorded at 59 of 67 sites (88 %)
250 on Maria Island, 55 of 61 sites (90 %) on Bruny Island, and only 7 of 115 of sites (6 %) on
251 Flinders Island. The mean number of birds counted at a site (given presence) was 2.2 (range
252 1-6).

253

254 No birds were detected at any previously known forty-spotted pardalote sites on Flinders
255 Island despite visiting these sites more often than other areas (up to 5 site visits in each
256 year). A 'new' location was discovered on Flinders Island but is separated from the
257 previously known refuge by >20 km of primarily agricultural land (Fig. S3). The species was
258 also found in small patch of habitat (~10 ha) near Southport, on the Tasmanian mainland
259 (Fig. 1). The last record of the species in the vicinity of Southport was > 120 years ago. Too
260 few data (and birds) were available to model ψ or p at these locations (Table 5).

261

262 **Discussion**

263 The forty-spotted pardalote is now predominantly confined to island refuges. The species is
264 at risk from multiple threats across this highly restricted range . We have established
265 baseline population data and quantified the historical impacts and future potential risks of
266 threats to refuge populations. We demonstrate that occupancy rates are very high at two
267 refuges (Maria and Bruny Islands) and that the Flinders Island population is almost extinct.
268 This provides the first standardized quantitative assessment of refuge populations providing
269 a baseline for assessing change in population size using ψ as a surrogate for abundance
270 (MacKenzie and Nichols 2004). Deforestation in refuges has abated in recent decades and
271 these areas appear to currently support viable populations. However, our threat risk
272 assessment (Table 2) found all refuges are extremely vulnerable to multiple threats
273 including wildfire, colonization by the hyper-aggressive noisy miner and climate change.
274 Islands have clearly provided critical refuges from threatening processes; however, our
275 results indicate that these refuges are not secure from these threats despite being
276 extensively reserved.

277

278 Fire frequency, intensity, and extent are expected to increase with climate change in this
279 ecosystem (Fox-Hughes *et al.* 2014; Grose *et al.* 2014). In this case, the islands have clearly
280 provided protection from fire; however, most refuge habitat has not burnt for a long
281 time (and therefore currently support high fuel loads) and has a high ignition potential
282 suggesting severe fire(s) are likely under suitable weather conditions (Table 3 & Fig. S4).
283 Hence, refuges have only provided temporary protection at different spatial scales, but not
284 security. The impact of fire will depend on fire severity, frequency and the spatial
285 configuration and extent of burned and unburned habitat (Prowse *et al.* 2017). For example,

286 a single severe fire on Flinders Island in 2003 (Fig. S3) that burned an entire patch of refuge
287 habitat has likely resulted in another local extinction. Despite some forest recovery, the
288 location remains unoccupied by forty-spotted pardalotes over a decade later. In contrast,
289 several decades ago a fire burned all of south Maria Island (Fig. S1), but was recolonized two
290 years later likely due to immigration from nearby refuge habitat (< 1 km) on the north of the
291 island (Rounsevell and Woinarski 1983). Importantly, when compared to the size of many
292 large fires the small size of refuges means they are all at risk of being totally destroyed with
293 little chance of recolonisation.

294

295 The value of a refuge for forty-spotted pardalotes post fire will also depend on interactions
296 with other biota including competition, predation, and parasitism (Kirkpatrick *et al.* 2011;
297 Lindenmayer *et al.* 2006). Under post-fire conditions introduced herbivores may suppress
298 regrowth and structural complexity of forest (Driscoll *et al.* 2010; Kirkpatrick *et al.* 2011),
299 thus increasing environmental suitability for noisy miners (MacDonald and Kirkpatrick 2003;
300 Maron and Kennedy 2007; Maron *et al.* 2011) or result in increased predator abundance
301 (Hradsky *et al.* 2017). While high nestling mortality is caused by the newly discovered native
302 parasitic fly (Edworthy 2018) it is unknown what the overall potential threat this poses.

303 However, its effect likely varies in time and space depending on environmental conditions
304 (e.g. Antoniazzi *et al.* 2010) and may be exacerbated under post fire conditions and climate
305 change (Møller *et al.* 2014). Longitudinal (and larger scale) studies are required to
306 determine the role of the parasitic fly on population dynamics for the forty-spotted
307 pardalote..

308

309 We identify a large area of climatically suitable habitat for noisy miners across Tasmania
310 (Fig. 2). The high bioclimatic suitability of most forty-spotted pardalote refuges for noisy
311 miners, and their proximity to refuges (< 4 km) suggests there is a very high likelihood of
312 colonization. Given that noisy miners favor fragmented environments (MacDonald and
313 Kirkpatrick 2003; Maron *et al.* 2013), the impacts of colonization of refuges may vary
314 depending on local forest fragmentation (Fig. S1 & S2). Since most occupied habitat on
315 Bruny Island is adjacent to fragmented agricultural land, noisy miners could penetrate most
316 pardalote refuges. By contrast, forest on Maria Island is more intact providing less
317 opportunities for miner expansion, but historically cleared areas maybe ideal for noisy
318 miners. Furthermore, intense grazing by introduced herbivores across large parts of Maria
319 Island severely suppresses understory vegetation, reducing (or eliminating) cover which may
320 advantage noisy miners (Maron and Kennedy 2007; Maron *et al.* 2011). Thus, our use of
321 vegetation mapping likely provides an optimistic view of the area of 'intact' forest.

322

323 ***Historical range contraction***

324 Failure to account for historical processes that have resulted in a species' current range can
325 lead to misleading inferences about a species' ecological niche (Warren *et al.* 2014). Since
326 European settlement, waves of local extinctions caused by large scale land clearance,
327 subsequent habitat fragmentation and stochastic events (e.g. wildfire) and habitat
328 fragmentation most likely resulted in no refuge populations to recolonize recovering
329 habitat. We argue these processes probably disrupted pre-existing extinction-colonization
330 dynamics, causing the species' range contraction. Some potential habitat in the species'
331 historical range appears to be suitable forty-spotted pardalote habitat (M.H.W personal
332 observations). However, the threatening processes (outlined above) allowed the

333 concomitant expansion of noisy miners (and other aggressive birds with a similar niche),
334 thus preventing dispersal through the agricultural matrix and recolonization of suitable
335 habitat. Considering the spatial and temporal nature of the processes that caused the
336 species range contraction, We suggest that suitable habitat may be available, but natural
337 recolonisation is no longer possible.

338 ***Translocations in the species historical range***

339 We call for immediate action to identify and prioritize potential reintroduction sites for the
340 forty-spotted pardalote and attempt to establish new populations while apparently viable
341 source populations exist within refuges. Moreover, reintroducing individuals from wild
342 sources can be more effective since even small amounts of genetic adaptation in captive-
343 bred individuals may negatively impact long-term wild population size and genetic diversity
344 (Willoughby & Christie 2018). We propose that any attempt would undertake a structured
345 decision-making process to identify an optimal source population (as per Wauchope et al. *in*
346 *press*). There are well established protocols to inform conservation reintroductions
347 (IUCN/SSC 2013) and many precedents to inform a pardalote program (e.g. Taylor et al.
348 2005; Ortiz-Catedral & Brunton 2010; Collen et al. 2014).

349

350 Revegetation programs usually result in small areas of the landscape being revegetated
351 (Thomson *et al.* 2015), require large investments (Atyeo and Thackway 2009; Menz *et al.*
352 2013) and take many years to achieve their objectives. Targeted revegetation programs
353 (Understorey Network 2011) at refuges may eventually increase the area of occupancy, but
354 this will not address the immediate threats to these refuges.

355

356 The creation of new populations via translocation may provide substantial opportunities to
357 secure the species, particularly we are proposing reintroductions into the species former
358 range. There is currently >1100 km² of white gum forest across the species former range,
359 610 km² of which occurs in patches >1 km² in area (mean, 3.1 km²; S.D. 4.4 km²) and often
360 form part of larger forest remnants (Harris and Kitchener 2005) (Fig. S5). Despite the high
361 climatic suitability of much of the former range for noisy miners, they rarely occur in the
362 intact interior of larger forest patches (Maron *et al.* 2013); these areas may be ideal for
363 creating new populations. In this context, a common failure in conservation planning is that
364 locations designated as critical habitat rarely include suitable but unoccupied locations
365 (Camaclang *et al.* 2014) and currently unoccupied potential habitat within the species'
366 former range is afforded no legislative protection.

367

368 While reintroductions may be perceived as a 'risky' strategy (Ricciardi and Simberloff 2009)
369 and the outcomes uncertain in some instances (e.g. persistence, population growth rate),
370 they may be essential for the species' long-term survival and knowledge gained from
371 undertaking such actions may be extremely valuable (Rout *et al.* 2009). Because of the
372 current threats to refuges we believe any risks associated with translocations far outweigh
373 the risks of not acting. Moreover, our assessments show this opportunity could rapidly be
374 lost due to collapse of refuge populations (e.g. Flinders Island), or clearance of potential
375 reintroduction sites and action must be undertaken promptly.

376

377 **Conclusion**

378 Our study highlights the need to consider the processes that create refuges for endangered
379 species, and if they provide long-term security or merely represent the final locations to be

380 affected by threatening processes. Diagnosing the processes that have led to a species
381 current distribution is extremely valuable because previous local extinctions does not
382 necessarily mean these sites remain permanently unsuitable, and vice-versa.

383

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