

Edith Cowan University
Research Online

ECU Publications Post 2013

4-24-2020

Impacts of invasive rats and tourism on a threatened island bird: The Palau Micronesian scrubfowl

Paul M. Radley
Edith Cowan University

Robert A. Davis
Edith Cowan University

Tim S. Doherty
Edith Cowan University

Follow this and additional works at: <https://ro.ecu.edu.au/ecuworkspost2013>

 Part of the [Biology Commons](#), and the [Terrestrial and Aquatic Ecology Commons](#)

[10.1017/S0959270920000246](https://doi.org/10.1017/S0959270920000246)

This article has been published in a revised form in *Bird Conservation International* <http://doi.org/10.1017/S0959270920000246>. This version is free to view and download for private research and study only. Not for re-distribution, re-sale or use in derivative works. © Cambridge University Press.

Radley, P. M., Davis, R. A., & Doherty, T. S. (2020). Impacts of invasive rats and tourism on a threatened island bird: The Palau Micronesian scrubfowl. *Bird Conservation International*, 31(2), 206-218. <https://doi.org/10.1017/S0959270920000246>

This Journal Article is posted at Research Online.
<https://ro.ecu.edu.au/ecuworkspost2013/10033>

1 Impacts of Invasive Rats And Tourism On A Threatened Island Bird:
2 the Palau Micronesian Scrubfowl.

3

4 PAUL M. RADLEY, ROBERT A. DAVIS, and TIM S. DOHERTY

5

6

7

8 Running Head: Effect of Rats and Tourism on a Threatened Island Scrubfowl

9

10 **Keywords:** Invasive predators, island extinction, megapode, *Rattus*, tourist pressure

11

12 Word Count: 6,894 (Summary through Literature Cited)

13 **Summary**

14 Invasive predators have decimated island biodiversity worldwide. Rats (*Rattus* spp.) are
15 perhaps the greatest conservation threat to island fauna. The ground nesting Palau
16 Micronesian Scrubfowl *Megapodius laperouse senex* (Megapodiidae, Aves) inhabits many of
17 the islands of Palau's Rock Island Southern Lagoon Conservation Area (RISL) in the western
18 Pacific. These islands are also heavily visited by tourists and support populations of
19 introduced rats, both of which may act as added stressors for the scrubfowl. Using passive
20 chew-tag and call playback surveys on five tourist visited and five tourist-free islands, we
21 investigated if rats and tourists negatively affect scrubfowl, and if higher rat activity is
22 associated with tourist presence. Rat detection probability and site occupancy were
23 significantly higher on tourist visited (89% and 99%, respectively) compared to tourist-free
24 islands (52% and 73%). Scrubfowl were detected at significantly more stations on tourist-
25 free (93%) than tourist visited (47%) islands and their relative abundance was higher (2.66
26 and 1.58 birds per station, respectively), although not statistically significantly. While rat
27 occupancy probability likewise had a non-significant negative effect on scrubfowl numbers
28 across islands, our results show a negative relationship between tourist presence and
29 scrubfowl in the RISL. Our findings also suggest that rat populations may be augmented by
30 tourist visitation in the RISL. Although this situation may not seriously affect the scrubfowl,
31 it may be highly detrimental to populations of other threatened island landbirds.

32 **Introduction**

33 Invasive predators are a leading cause of biodiversity loss on islands worldwide, having
34 contributed to more than 50% of bird, mammal and reptile extinctions (Doherty *et al.* 2016).
35 Rats (*Rattus* spp.) are perhaps the most successful invasive predator and are established on
36 approximately 80–90% of islands globally (Towns *et al.* 2006). Occurring on 78% of islands
37 known to support highly threatened vertebrates (Spatz *et al.* 2017), rats are well documented
38 to be exceedingly detrimental to island avifauna (e.g., Courchamp *et al.* 2003, Towns *et al.*
39 2006, Tabak *et al.* 2014, Harper and Bunbury 2015). For instance, between Taukihepa and
40 Lord Howe Islands in the South Pacific alone, the ubiquitous black rat *R. rattus* is responsible
41 for the extinction of 10 native and endemic species of birds (Towns *et al.* 2006, Shiels *et al.*
42 2013).

43 The Micronesian Scrubfowl (*Megapodius laperouse*) is a species of ground nesting
44 bird that occurs in the Mariana and Palau archipelagos of western Micronesia (Jones *et al.*
45 1995). A member of the family Megapodiidae, they do not incubate their eggs with body
46 heat but instead use external, environmental sources of heat (Jones *et al.* 1995). The
47 subspecies of scrubfowl in Palau (*M. l. senex*) buries its eggs in large mounds of sand filled
48 with decomposing organic matter, which it constructs predominantly in littoral strand forest
49 that occurs throughout portions of the archipelago (Wiles and Conry 2001, Olsen *et al.* 2016).
50 The largest segment of this population is found in the UNESCO World Heritage listed Rock
51 Islands Southern Lagoon Conservation Area (RISL) (Olsen *et al.* 2016).

52 Citing a small, fragmented distribution, comparatively small population size, and its
53 continued decline, the IUCN (2016) classifies the Micronesian Scrubfowl as Endangered.
54 Documented and potential threats to the species are mostly, but not wholly, deterministic in
55 nature and include hunting, egg collecting for human consumption, and introduced predators
56 (Pratt *et al.* 1980, USFWS 1998, IUCN 2016). Sources suggest that introduced rats are a

57 direct threat to scrubfowl in both the Mariana and Palau archipelagos, but none cite any
58 direct, quantitative evidence as justification (USFWS 1998, Wiles and Conry 2001, Olsen *et*
59 *al.* 2013). Four species of rat have become established in Palau, two of which—the
60 Polynesian rat *R. exulans* and black rat—occur in forested areas of the RISL (Wiles and
61 Conry 1990) and may be detrimental to scrubfowl. Although no other species of scrubfowl is
62 known or believed to be threatened by rats (IUCN 2016), populations of some ground and
63 burrow nesting seabirds have been seriously affected (Jones *et al.* 2008, Ruffino *et al.* 2009).

64 Aside from rats, another potential stressor to wildlife populations on islands is the
65 pressure of tourist visitation. The effect of nature-based tourism and recreation on global bird
66 populations has drawn relatively little attention in either public or academic forums (Steven
67 *et al.* 2011, Steven and Castley 2013). Of the 35 recognized global biodiversity hotspots
68 (Myers *et al.* 2000), Polynesia-Micronesia supports the most bird species threatened by
69 tourism (Steven and Castley 2013, Bellard *et al.* 2014). Steven and Castley (2013)
70 determined that 63 birds listed as Critically Endangered and Endangered by the IUCN (2016)
71 are directly threatened by tourism, and that species occurring in coastal areas are amongst
72 those most at risk. Palau is one of the world's top SCUBA diving destinations (IMF 2016),
73 and the majority of this activity occurs in and around the RISL. Many of the beaches and
74 coastal areas on which Endangered scrubfowl breed are also highly attractive as picnic sites
75 where dive operators bring tourists in large numbers on a daily basis. As a response, the local
76 government has built and maintains facilities on these beaches to support and cater to these
77 activities.

78 In addition to tourist activities and facilities potentially having a direct effect on
79 scrubfowl breeding in the RISL, they may also have an indirect impact by augmenting rodent
80 populations through supplementary food provision (Oro *et al.* 2013, Ruffino *et al.* 2013). In
81 the absence of predators, population densities of rats on tropical islands are generally very

82 high because of greater access to relatively rich food resources (Harper and Bunbury 2015).
83 A consistent availability of anthropogenic food resources further enables these populations to
84 endure environmental variability, further increasing their densities and their threat to native
85 fauna (Russell and Ruffino 2012, Ruffino *et al.* 2013). Understanding the potential effects of
86 tourism and rats on the Palau Micronesian Scrubfowl is essential to their conservation in
87 Palau.

88 Here, we investigate whether rat and tourist presence affect Palau Micronesian
89 Scrubfowl numbers, and whether rat numbers are affected by human presence on islands in
90 the RISL. We undertook active and passive surveys for scrubfowl and rats on uninhabited
91 islands in the RISL that were classified as either visited or not visited by tourists, and aimed
92 to assess the relationships between rats, scrubfowl, and tourist presence. We specifically
93 tested the following hypotheses: 1) rat occupancy is significantly higher on tourist visited
94 compared to tourist-free islands (Oro *et al.* 2013), 2) scrubfowl relative abundance is
95 significantly lower on tourist visited compared to tourist-free islands (Steven *et al.* 2011), and
96 3) scrubfowl relative abundance is significantly lower on islands with high rat occupancy
97 (Harper and Bunbury 2015). We discuss our findings in the context of future research and
98 conservation management for threatened species on the Rock Islands of Palau.

99

100 **Methods**

101 *Study Area and Survey Island Selection*

102 The Palau archipelago (7° 30' N, 134° 35' E; Fig.1) is the westernmost assemblage of islands
103 in Micronesia. It extends 700 km northeast to southwest and is comprised of 12 inhabited
104 islands and over 500 smaller uninhabited islands and islets (Neall and Trewick 2008, Olsen
105 2009). Approximately 87 percent of the archipelago is forested, 75% of which is classified as
106 native tropical lowland rainforest (Kitalong *et al.* 2013). Our research was focused primarily

107 on the uninhabited islands of the RISL that lie between Babeldaob to the north and Peleliu to
108 the southwest (Figure 1), where scrubfowl are relatively abundant (Olsen *et al.* 2016). Unlike
109 other islands in the archipelago, these “rock islands” are ancient, uplifted reefs and are thus
110 coralline in nature (Engbring 1988). The vast majority of islands in the RISL are
111 characterized by nearly vertical, highly fissured and eroded, densely forested karst slopes that
112 protrude abruptly from the water, and are undercut at the water’s edge (Pratt *et al.*, 1980;
113 Engbring, 1988). Despite the heavy forest cover, these uplifted areas exhibit very little soil
114 development and provide no suitable substrate for scrubfowl to construct their mounds (Pratt
115 *et al.* 1980, Olsen *et al.* 2016). The majority of scrubfowl in the RISL breed in the fringing,
116 sandy littoral zones that additionally characterize a relatively small number of these islands
117 (Olsen *et al.* 2016); some of these littoral areas are also heavily visited by tourists (*pers. obs.*,
118 P. Radley).

119
120 (Figure 1 here)

121
122 We selected islands in the RISL for surveys based on the occurrence of sandy littoral
123 areas that supported level, beach strand forest cover. This cover type falls under the category
124 of “Limestone Forest” (Kitalong *et al.* 2013), an ecotype that was consistent in plant species
125 composition and structure at all study sites and was suitable habitat for scrubfowl. Although
126 rats are known to occur in all terrain of the islands in the RISL (*pers. comm.*, T. Hall), areas
127 of strand cover were solely selected for our surveys because of their exclusive use for tourist
128 activities on visited islands, their preferred use by scrubfowl for breeding (Wiles and Conry
129 2001, Olsen *et al.* 2016), and the nearly inaccessible nature of the limestone areas of the
130 islands. Tourist visited islands were additionally characterized by the presence of picnic
131 tables and barbeque facilities, roofed shelters of varying sizes, and restrooms situated in

132 cleared and maintained areas just off the beach. We specifically chose islands for surveys
133 based on 1) the existence of large enough areas of littoral strand forest that were capable of
134 accommodating full length (180 m) rat survey transects, and 2) the level or degree of human
135 visitation they received (Figure 1). Of six islands in the RISL that are regularly visited by
136 tourists, the five we chose for surveys both met the above size criteria and received moderate
137 to heavy tourist visitation. Four of the five selected tourist-free islands were located in the
138 Ngemelis Complex (Figure 1), a local government conservation area from which tourists are
139 prohibited. The fifth, Ngeanges, was known to receive only occasional day visits by locals or
140 kayakers. It should be noted that in this sense, none of the islands in our study were truly
141 unvisited “controls”, but represent a contrast between heavy tourism and very occasional
142 local use.

143

144 *Rat Presence / Absence Surveys*

145 We quantified rat presence with the use of peanut butter scented WaxTags®
146 (www.traps.co.nz). Transects of 10 waxtags spaced 20 meters apart (for a transect length of
147 180 m) (Ruffell *et al.* 2015a, Ruffell *et al.* 2015b) were established in the available and
148 accessible strand forest habitat on all 10 islands selected for surveys, where tags were secured
149 to trees approximately 10 cm above the ground. Each transect was run parallel with the shore
150 roughly equidistant between the beach and the limestone face behind. The lengths of
151 accessible beach habitat for transects was small and ranged from 185 to 680 m ($\bar{x} = 419.5$), a
152 portion of which on tourist visited islands was occupied by the facilities described above.
153 Three beaches on tourist islands were just long enough to accommodate 180 m transects and
154 tourist facilities were by default included in the sampling area. The facilities on the
155 remaining two tourist islands with longer beaches were likewise included in sampling areas
156 to avoid any possible bias in rat detections.

157 Rat surveys were conducted in two replicates over four nights each, from 15–18
158 December 2016 and 19–22 January 2017. Waxtags were deployed for two nights across each
159 island type (i.e., tourist visited and tourist-free) during each survey. Given the size of the
160 RISL and the relatively long travel times between some islands via small motorboat, it was
161 necessary to alternate the days of deployment and retrieval of tags by island type.
162 Specifically, tags were deployed and retrieved on days one and three (respectively) of each
163 replicate on tourist visited islands, and deployed and retrieved on days two and four of each
164 replicate on tourist-free islands.

165

166 *Scrubfowl Call-playback Surveys*

167 We established and surveyed a total of 48 scrubfowl count stations in the RISL, 19 on tourist
168 visited islands and 29 on islands not visited by tourists. We collected data on scrubfowl
169 presence and relative abundance on six mornings between 9 and 16 January 2017. Scrubfowl
170 surveys consisted of a combination of stationary call playback counts and spot-mapping
171 conducted on the same beaches and in the same habitat as rat surveys. Count stations were
172 established during counts and were spaced 100 m apart in littoral beach strand habitat
173 approximately 10 m inland from the mean high tide mark. We conducted surveys by walking
174 from one end of target beaches to the other, stopping every 100 m to broadcast pre-recorded
175 scrubfowl calls after acquiring a GPS location of each station. Recordings used for surveys
176 were those of Palau Micronesian Scrubfowl that we collected in the Rock Islands in February
177 and March 2016. Call playback was projected towards the limestone face behind the beach
178 as scrubfowl have been observed to not only occur in the littoral strand forest, but also in the
179 dense forest on the face and top of the limestone relief. Surveys at stations consisted of
180 approximately 1 minute of call playback followed by 4 minutes of quiet listening and
181 observation, during which time all scrubfowl seen or heard were recorded and their general

182 locations relative to the observer mapped in field note books. After completion of each 5-
183 minute playback survey period, we slowly walked to the next station, spot mapping all
184 scrubfowl seen and/or heard while in transit between stations to avoid double counting birds
185 at successive stations. Birds mapped in this manner were included in count totals at the
186 stations they were detected closest to if it was determined that they had not already been
187 included in station based counts.

188

189 *Statistical Analysis*

190 We assessed waxtags for evidence of rat chewing for both survey replicates across all islands,
191 recording a '1' for tags that were bitten and '0' for tags that were not. We did not attempt to
192 identify rat species. Site occupancy and detection probabilities for rats were estimated with
193 and without the covariates "Tourist" and "Island" by fitting models in the "unmarked"
194 package in R (Fiske and Chandler 2011). The resulting logit parameter estimates were back-
195 transformed, and model fit and selection were assessed using Akaike's Information Criterion
196 (AIC). To further confirm model fit we compared our occupancy model with a null model of
197 our data using a Likelihood Ratio Test. Occupancy and detection probabilities were then
198 predicted for rats on tourist visited and tourist-free islands as groups and occupancy was
199 further predicted at the island level. Many of these estimates were on the upper boundary (i.e.
200 occupancy = 1), hence meaningful confidence intervals could not be calculated (Hutchinson
201 et al. 2015). We provide standard errors instead. Lastly, averaging the number of waxtags
202 bitten across replicates, we used "Tourist" as a covariate to further test for an effect of tourist
203 presence on rat numbers across islands with a Gaussian family generalized linear model
204 (GLM).

205 To account for small sample sizes and the boundary estimates, we compared our rat
206 occupancy results to those of a Bayesian GLM that provided posterior means and credible

207 intervals for rat occupancy probabilities for treatment and control island groups, as well as at
208 the island level. To represent a lack of knowledge of the true values of these parameters, the
209 prior probability distribution of both the detection and island occupancy probabilities were
210 assumed to be uniform for this inference. Highest posterior density (HPD) 95% credible
211 intervals were generated for the posterior means of the island level inference while 95%
212 equal-tailed credible intervals were produced for the island group inference.

213 As a result of unanticipated and unavoidable logistic constraints, we were able to
214 complete only one round of scrubfowl call playback surveys, and because of this we could
215 neither calculate detection probability nor estimate site occupancy for the species (Knappe and
216 Korner-Nievergelt 2015). In lieu of occupancy modelling, we first used a Fisher's F-test to
217 evaluate scrubfowl survey sample variance between tourist visited and tourist-free islands to
218 verify homoscedasticity and then compared sample means of the two groups with a two
219 sample t-test. We then employed both a Poisson family GLM and a logistic regression (Bates
220 *et al.* 2015) to assess the effect of tourist presence on scrubfowl across islands, using
221 "Tourist" as a covariate and "Island" as a random effect, with survey station used as the
222 observational unit. We applied a Hosmer Lemeshow goodness of fit (GOF) test (Lele *et al.*
223 2016) to determine if there was any difference between this model and our observed data.

224 To test for an effect of rats on scrubfowl, we first calculated island level relative
225 abundances of scrubfowl and compared them to the Bayesian posterior means of island level
226 rat occupancy probability in a Pearson's product-moment correlation. We followed this with
227 a Gaussian family GLM to model island level scrubfowl relative abundance against rat
228 posterior means and tourist presence, using "Rat" and "Tourist" as covariates. All statistical
229 analysis was performed in program R (R Core Team 2015).

230

231 **Results**

232 Rats were detected on all islands surveyed in the RISL, where they chewed a mean \pm SD of
233 44.5 ± 4.9 waxtags on tourist visited islands and 25.5 ± 9.2 on islands not visited by tourists.
234 Occupancy modelling showed that the tourist covariate had a significant positive influence on
235 both rat detection probability ($P < 0.001$) and site occupancy ($P < 0.01$). The probability of
236 detecting rats on the tourist visited islands as a whole (0.89; 95% CI 0.80–0.94) was
237 significantly higher ($P = 0.031$) than on tourist-free islands (0.52; 0.42–0.62). Likewise,
238 occupancy on tourist visited islands (0.99) was significantly ($P = 0.028$) higher than on
239 tourist-free islands (0.73). The Bayesian posterior means for occupancy probability (0.90 and
240 0.69, respectively) were also significantly different ($P = 0.028$) (Table 1). At the island level,
241 occupancy estimates for tourist visited islands ranged from 0.93 to 1.00 and from 0.52 to 1.00
242 for tourist-free islands while Bayesian posterior means ranged from 0.86 to 0.92 and from
243 0.52 to 0.92, respectively (Table 1). In all instances, the Bayesian GLM provided equal-tail
244 and HPD credible intervals that were slightly more accurate when compared to the occupancy
245 generated CI for each island group and each individual island (Table 1). The results of our
246 Gaussian GLM comparing station-level averages of rat detections across tourist visited and
247 tourist-free islands further supports the hypothesis that tourist presence has a significant
248 positive relationship with rat detections (Table 2, model 1).

249
250 (Table 1 and Table 2 here)

251
252 We recorded 107 scrubfowl detections during surveys across all 10 islands, yielding a
253 mean detection rate of 10.7 birds per island (range = 1 – 20) (Table 3). On tourist visited
254 islands, 30 individual detections were recorded from nine of 19 (47%) count stations
255 compared to 77 detections recorded from 27 of 29 (93%) stations on tourist-free islands.
256 Sample variance between the two island groups was confirmed to be homoscedastic ($P =$

257 0.221). The relative abundance (i.e., mean birds per station or BPS) of scrubfowl on tourist
258 islands (1.58 BPS, SD \pm 2.29) was lower than on tourist-free islands (2.66 \pm 1.78), although
259 the difference was not statistically significant ($P = 0.074$; two sample t-test). However, the
260 presence of scrubfowl at survey stations on tourist islands was significantly lower than on
261 tourist-free islands ($P = 0.026$; logistic regression [Table 2, model 2]). The results of the
262 Poisson GLM indicated that although the tourist covariate appears to have a slight negative
263 influence on scrubfowl relative abundance, the coefficient was not significantly different
264 from the intercept (Table 2, model 3). The Hosmer Lemeshow GOF test was non-significant
265 ($P = 0.51$) when comparing the Poisson model and our observed data, thus confirming that
266 the model was a good fit.

267

268 (Table 3 here)

269

270 A Pearson's product-moment correlation conducted at the island level showed a weak
271 but non-significant negative relationship between rat occupancy and scrubfowl relative
272 abundance (-0.49 , 95% CI -0.85 – 0.20 ; $P = 0.152$). The results of the Gaussian GLM
273 indicated that while both the covariates rats and tourists appeared to have a slight negative
274 influence on scrubfowl relative abundance, the coefficients were not significantly different
275 from the intercept (Table 2, model 4).

276

277 **Discussion**

278 We did not find a strong negative relationship between rats and scrubfowl presence on islands
279 in the RISL. This outcome is at odds with numerous other studies that have attributed island
280 bird extinction and extirpation to invasive rats (e.g., Tabak *et al.* 2014, Harper and Bunbury
281 2015) and conservation advice naming rats as a threat to the Palau Micronesian Scrubfowl

282 (USFWS 1998, Wiles and Conry 2001, Olsen *et al.* 2013). Rats (particularly black rats)
283 affect island landbird populations primarily at the level of productivity by predating eggs,
284 hatchlings or chicks in nests, but they also opportunistically take adults of some smaller
285 species (Shiels *et al.* 2013, Harper and Bunbury 2015). Unlike other avian species, scrubfowl
286 eggs and hatchlings are not outwardly visible and vulnerable to predation for days to weeks
287 on end within an open nest. Instead, their eggs are buried under up to a meter of sand or soil
288 and organic matter, through which hatchlings dig their way to the surface after hatching
289 (Jones *et al.* 1995). A young scrubfowl would be most vulnerable for a relatively brief period
290 just as it erupts from the incubation mound, after which it emerges as a “super-precocial”
291 chick that cannot only run but is immediately capable of flight (pers. comm., R. Dekker).
292 The window of opportunity for predation by rats is therefore relatively very narrow and any
293 scrubfowl young taken by rats may likely be more so by chance. The lack of an obvious or
294 significant effect in our study may be due to the fact that rat predation is negligible on larger
295 sub-adult and adult birds.

296 Some studies show that other island birds are able to coexist with introduced rats with
297 no apparent negative effects at the population level. Larger, ground nesting seabirds (e.g.,
298 albatrosses, frigatebirds, and gulls) tend to be far less affected by rats than smaller, burrow
299 nesting seabirds (e.g., storm petrels and some Alcids), a result that may stem from the size of
300 the former and their likely adeptness at defending their eggs and young from predators (Jones
301 *et al.* 2008). Populations of larger burrow nesting shearwaters that breed almost exclusively
302 on rat infested islands in the Mediterranean were found to be limited less by rats than the
303 smaller, resident storm petrels, and more so by physical characteristics of the islands
304 themselves (Ruffino *et al.* 2009). Tabak *et al.* (2014) found that the occurrence of three
305 mostly ground-dwelling passerines, the Falkland Pipit *Anthus correndera*, Long-tailed
306 Meadowlark *Sturnella loyca*, and Dark-faced Ground Tyrant *Muscisaxicola maclovianus*,

307 were unaffected by the presence of Norway rats *R. norvegicus* in the Falkland Islands,
308 regardless of island size. While the endemic pipit avoids areas of tussock grass *Parodiochloa*
309 *flabellata*, a habitat preferred by Norway rats, the above-ground feeding behaviours of the
310 latter two may reduce their exposure to rats (Hall *et al.* 2002).

311 There is the possibility that rats act as a competitor for food resources (Shiels *et al.*
312 2013), but our data are not appropriate to test this hypothesis. Although there is little in the
313 literature pointing to rats as direct resource competitors for avian species (Shapiro 2005,
314 Tabak *et al.* 2016), Shiels *et al.* (2013) suggest that those birds relying on either arthropods or
315 fruit as a major component of their diet may experience direct competition with rats. The
316 Palau Micronesian Scrubfowl is omnivorous, with a diet consisting of a variety of fruits,
317 seeds and other plant matter, various insects and land crabs (Jones *et al.* 1995). Likewise,
318 both species of rat that occur in the RISL are known to be highly opportunistic, exploiting
319 virtually any available food source, but relying heavily on plant matter, with insects
320 providing the majority of animal protein in their diets (Shiels *et al.* 2013, Harper and
321 Bunbury 2015). The broad dietary intake of scrubfowl in the RISL may serve to minimize
322 the chances of direct resource competition, and as primarily a scratch feeder the species may
323 fill a functionally different foraging niche than rats (Jones *et al.* 1995).

324 Our results further suggest that tourists may have a negative impact on scrubfowl, as
325 shown by lower relative abundance and detection rates at tourist compared to tourist-free
326 islands. Aside from negative consequences to individual physiology and reproductive
327 success, other studies (e.g., Otley 2005, Ma and Cheng 2008, Steven *et al.* 2011, Steven and
328 Castley 2013) show that the behaviour, distribution and movement patterns of some bird
329 species in tourist visited areas are affected by human presence, while their apparent
330 abundance or numbers are not. Otley (2005) further found that up to 80% of Gentoo
331 *Pygoscelis papua*, King *Aptenodytes patagonicus*, and Magellanic *Spheniscus magellanicus*

332 Penguins at a tourist visited sites in the Falkland Islands avoided traveling between beach and
333 colony areas during daylight hours when most human visitors were present. Indeed,
334 scrubfowl on tourist visited islands in the RISL tended to be more skittish upon approach
335 than on islands that experience little or no human presence (pers. obs., P. Radley). From a
336 statistical standpoint, however, our Poisson GLM does indicate a slight negative effect of
337 tourism on scrubfowl relative abundance. The relatively high number of birds detected on
338 Ulong (Table 3), a tourist visited island, may have prevented this model from showing a
339 significant result. This may leave the result of our logistic regression to be a more accurate
340 reflection of the effect of tourists on scrubfowl.

341 Lastly, our results suggest that tourist presence may positively influence rat numbers.
342 The probability of detecting rats on islands that routinely receive high levels of tourist
343 visitation was 42% greater than on islands that were tourist-free. While occupancy on
344 tourist-free islands was relatively high and the difference between these islands and tourist-
345 visited islands is lower than the difference between detection probabilities, occupancy on
346 tourist islands approached 1.00. We cannot rule out that these differences are not the result of
347 historical visits by local people for the purpose of fishing or hunting coconut crabs (*Birgus*
348 *latro*). One likely reason for this disparity, however, is that high tourist presences often
349 equates to the greater availability of food waste that may supplement the diet of rats on
350 islands routinely and heavily visited by tourists (e.g., Sealey and Smith 2014). Depending on
351 the season, an island's infrastructure, and its proximity to popular dive sites in and around the
352 RISL, several dozens to near a hundred tourists could be fed buffet style at the picnic
353 facilities on a single beach every day (pers. obs., P. Radley). The resulting waste was often
354 left at these facilities in plastic bags for the local government clean-up crews to remove for
355 disposal. In some instances, smaller portions of organic waste were simply discarded by
356 locals, tourist and tour operators in the vegetation adjacent to picnic facilities.

357 There are numerous published studies illustrating the effect of tourism, particularly
358 nature-based tourism, on wildlife populations (e.g., Steven *et al.* 2011, Steven and Castley
359 2013). Surprisingly, however, we could find little pertaining to the possible direct effects of
360 tourism activities on populations of invasive rats, particularly in tropical island ecosystems.
361 Only Sealey and Smith (2014) describe high concentrations of rats at tourist facilities as a
362 result of the availability of solid food waste generated by tourist based operations on Great
363 Exuma Island, Bahamas. That study, however, focused specifically on large facilities or
364 resorts on the island, and sheds no light on its broader ecological effects on rats at the
365 ecosystem level (Sealey and Smith 2014). Resource subsidies across numerous ecosystems,
366 however, have been found to increase individual fitness and resilience of various
367 opportunistic species, leading to increases in densities and decreases in temporal variability
368 of some populations (Oro *et al.* 2013). Insular rodents with access to allochthonous resources
369 tend to grow larger, occur at higher densities, and their populations tend to persist in the
370 longer-term in part because they are better able to withstand local environmental stress (Stapp
371 and Polis 2003, Ruffino *et al.* 2013). Our field observations strongly indicate that food
372 subsidies are routinely made available to rats on islands in the RISL, and that this is likely to
373 present a significant challenge to rat-sensitive species inhabiting these islands.

374

375 *Habitat and Scrubfowl Detectability*

376 While Palau supports the richest assemblage of native flora and the highest rate of plant
377 endemism in Micronesia (Costion *et al.* 2009), plant diversity across islands in the RISL is
378 relatively homogenous (Kitalong 2014). Based on this, and on the fact that the RISL
379 supports the majority of breeding scrubfowl in the archipelago, with incubation mounds
380 occurring on all islands surveyed, we assumed that habitat would not be a factor in our
381 analysis of scrubfowl relative abundance.

382 The only comprehensive survey of scrubfowl in the Palau archipelago was conducted
383 by Olsen *et al.* (2016), in which a combination of 15-minute passive counts and broad area
384 searches (for birds and mounds) were used to survey 122 beach / island sites. They detected
385 350 individuals at 61 (50%) of the sites surveyed, for a detection rate of 2.9 scrubfowl per
386 beach or island included in the surveys. Olsen *et al.* (2016) suggested one confounding factor
387 that could have decreased their detections is the possibility of “commuting” by scrubfowl
388 between their nesting and feeding grounds, a phenomena documented in other species
389 (R.W.R.J. Dekker pers. comm., Jones *et al.* 1995). As a result, birds may have at times been
390 detected on return visits at sites where they had not previously been encountered, or not
391 detected at sites they previously had (Olsen *et al.* 2016).

392 By comparison, our surveys yielded a mean detection rate of 10.7 scrubfowl with at
393 least one bird detected at every one of the 10 beaches or islands surveyed in the RISL. This
394 difference may likely have been the result of our use of a targeted active survey, employing
395 call-playback from fixed stations at survey sites. Many of our detections were of birds that
396 responded from a distance from habitat atop the limestone relief, birds we would not have
397 detected without call-playback. Given our relatively high detection rates, and the fact that we
398 detected birds at every site surveyed, commuting by scrubfowl may not have been
399 encountered on the islands we surveyed during our work.

400

401 *Conservation Implications*

402 In March 2017, Island Conservation executed an eradication of rats from the island of
403 Ngeanges and was developing plans with the local government to do likewise for other
404 islands in the RISL (pers. comm., T. Hall). This is inarguably the optimal approach to
405 conservation of tropical island landbird species threatened by rats (e.g., Russell and Holmes
406 2015, Jones *et al.* 2016, Spatz *et al.* 2017). While our results suggest that rats do not

407 detrimentally affect scrubfowl, other species of native and endemic landbirds that share
408 forested habitat with scrubfowl in the RISL may be at threat (e.g., Harper and Bunbury
409 2015). These species include the Endangered Palau Ground Dove (*Alopecoenas canifrons*)
410 and perhaps the Palau Fantail (*Rhipidura lepida*), and Micronesian Imperial and Nicobar
411 Pigeons (*Ducula oceanica* and *Caloenas nicobarica*, respectively). Aside from some point-
412 count based inventories (e.g., VanderWerf 2007), few studies have been carried out on
413 Palau's terrestrial avifauna and little is known about population trends for most species in the
414 RISL. Given the significantly higher level of rat detection probability and occupancy on
415 tourist visited islands relative to tourist-free islands, a study comparing the vital rates of
416 landbirds across the two island types would be beneficial (e.g., Saracco *et al.* 2014). The
417 threat of rats to island landbirds suggests that quantitative studies concerning the effect of
418 tourism on rat populations would be an asset to other insular nature-based tourism
419 destinations globally.

420 To further manage rat numbers in the RISL, a good first step would be managing
421 tourist waste by enforcing a "pack-it-out" policy that requires tourist operations to remove all
422 their food waste from the islands they visit. Adequate signage, education and onsite
423 enforcement of removal of all food refuse by tourist operators would go a long way to
424 decrease supplementary food sources that may be helping to sustain or augment rat
425 populations on tourist visited islands in the RISL.

426

427 **Acknowledgements**

428 Edith Cowan University School of Science provided financial, administrative, and logistical
429 support, and project ethics approval (which conforms to the requirements of the "*Australian*
430 *code of practice for the care and use of animals for scientific purposes*", 8th Edition, Ref. No.
431 EA28). The Palau National and Koror State Governments provided all necessary research

432 permits, and the latter further permitted access to restricted conservation areas. We are
433 grateful to Clarence Kitalong for all boat transport and whose vast local knowledge of the
434 islands made our work possible. Mike Lohr assisted with scrubfowl surveys. Greg Budney,
435 Cornell Lab of Ornithology, provided sound recording equipment to record megapode calls.
436 Jim Baldwin, a Statistician at the U.S. Forest Service Pacific Southwest Research Station,
437 provided the Bayesian estimates of occupancy probability. Richard Camp and Marcos
438 Gorresen, U.S. Geological Survey, Hawaii, provided valuable input pertaining to analytical
439 approach and methods. Fred Amidon, U.S. Fish and Wildlife Service, Hawaii Field Office,
440 provided technical insight with Figure 1. We thank two anonymous reviewers for their
441 comments on an earlier version of this manuscript.

442

443 **Financial Support**

444 This work was supported by the Rufford Small Grants for Nature Conservation (grant no.
445 G1002201), Club 300 Bird Protection (G1002235), and the World Pheasant Association
446 (G1002935).

447

448 **Literature Cited**

- 449 Bates, D., Maechler, M., Bolker, B. and Walker, S. (2015) Fitting linear mixed-effects
450 models using lme4. *J. Stat. Softw.* 67: 1–48.
- 451 Bellard, C., Leclerc, C., Leroy, B., Bakkenes, M., Veloz, S., Thuiller, W. and Courchamp, F.
452 (2014) Vulnerability of biodiversity hotspots to global change. *Global Ecol.*
453 *Biogeogr.* 23: 1376–1386.
- 454 Costion, C., Kitalong, A. H. and Holm, T. (2009) Plant endemism, rarity, and threat in
455 Palau, Micronesia: A geographical checklist and preliminary red list assessment.
456 *Micronesica* 41: 131–164.

- 457 Courchamp, F., Chapuis, J. L. and Pascal, M. (2003) Mammal invaders on islands: Impact,
458 control and control impact. *Biol. Rev. Camb. Philos.* 78: 347–383.
- 459 Doherty, T. S., Glen, A. S., Nimmo, D. G., Ritchie, E. G. and Dickman, C. R. (2016)
460 Invasive predators and global biodiversity loss. *P. Natl. Acad. Sci. USA.* 113:
461 11261–11265.
- 462 Engbring, J. (1988) *Field Guide to the Birds of Palau*. Conservation Office, Koror, Palau.
- 463 Fiske, I. and Chandler, R. (2011) unmarked: An R package for fitting hierarchical models of
464 wildlife occurrence and abundance. *J. Stat. Softw.* 43: 1–23.
- 465 Hall, J. R., Woods, R. W., de L. Brooke, M. and Hilton, G. M. (2002) Factors affecting the
466 distribution of landbirds on the Falkland Islands. *Bird Conserv. Int.* 12: 151–167.
- 467 Harper, G. A. and Bunbury, N. (2015) Invasive rats on tropical islands: Their population
468 biology and impacts on native species. *Global Ecol. Conserv.* 3: 607–627.
- 469 Hutchinson, R. A., Valente, J. J., Emerson, S. C., Betts, M. G., and Diettrich, T. G. (2015)
470 Penalized likelihood methods improve parameter estimates in occupancy models.
471 *Methods Ecol. Evol.* 6: 949–959.
- 472 IMF (2016) *Republic of Palau: Staff report for the 2016 Article IV consultation*. IMF
473 *Country Report No. 16/328*. U.S. International Monetary Fund, Washington DC,
474 USA.
- 475 IUCN (2016) *The IUCN Red List of Threatened Species. Version 2016.3*. Available at:
476 <http://www.iucnredlist.org> [accessed 20 March 2017].
- 477 Jones, D. N., Dekker, R. W. R. J. and Roselaar, C. S. (1995) *The megapodes*. Oxford
478 University Press, Oxford, U. K.
- 479 Jones, H. P., Holmes, N. D., Butchart, S. H. M., Tershy, B. R., Kappes, P. J., Corkery, I.,
480 Aguirre-Muñoz, A., Armstrong, D. P., Bonnaud, E., Burbidge, A. A., Campbell, K.,
481 Courchamp, F., Cowan, P. E., Cuthbert, R. J., Ebbert, S., Genovesi, P., Howald, G.

- 482 R., Keitt, B. S., Kress, S. W., Miskelly, C. M., Opper, S., Poncet, S., Rauzon, M. J.,
483 Rocamora, G., Russell, J. C., Samaniego-Herrera, A., Seddon, P. J., Spatz, D. R.,
484 Towns, D. R. and Croll, D. A. (2016) Invasive mammal eradication on islands
485 results in substantial conservation gains. *P. Natl. Acad. Sci.* 113: 4033–4038.
- 486 Jones, H. P., Tershy, B. R., Zavaleta, E. S., Croll, D. A., Keitt, B. S., Finkelstein, M. E. and
487 Howald, G. R. (2008) Severity of the effects of invasive rats on seabirds: a global
488 review. *Conserv. Biol.* 22: 16–26.
- 489 Kitalong, A. H., DeMeo, R. A. and Holm, T. (2013) *A Field Guide to the Native Trees of*
490 *Palau*. Kitalong, DeMeo, and Holm, Palau.
- 491 Kitalong, C. (2014) *Ethnomedical, Ecological and Phytochemical Studies of the Palauan*
492 *Flora*. Ph.D. Thesis, City University of New York.
- 493 Knape, J. and Korner-Nievergelt, F. (2015) Estimates from non-replicated population
494 surveys rely on critical assumptions. *Methods Ecol. Evol.* 6: 298–306.
- 495 Lele, S. R., Keim, J. L. and Solymos, P. (2016) ResourceSelection: Resource selection
496 (probability) functions for use-availability data. R package version 0.2-6. Available
497 at: <http://CRAN.R-project.org/package=ResourceSelection>.
- 498 Ma, J. Z. and Cheng, K. (2008) Impacts of ecotourism on wildlife in nature reserves:
499 Monitoring and management. *Shengtai Xuebao/ Acta Ecol. Sin.* 28: 2818–2827.
- 500 Myers, N., Mittermeyer, R. A., Mittermeyer, C. G., Da Fonseca, G. A. B. and Kent, J. (2000)
501 Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.
- 502 Neall, V. E. and Trewick, S. A. (2008) The age and origins of the Pacific islands: a
503 geological overview. *Philos. T. Roy. Soc. B* 363: 3293–3308.
- 504 Olsen, A., Eberdong, M., Ketebengang, H. and Chen, P.-h. (2013) *Nesting mounds and*
505 *status of an endemic subspecies of the endangered Micronesian Megapode,*
506 *Megapodius laperouse senex Hartlaub 1867 (Megapodiidae), in the Rock Islands*

- 507 *Southern Lagoon World Heritage Site, Palau Islands, Oceania*. Report: Belau
508 National Museum, Koror.
- 509 Olsen, A. R. (2009) Palau. In R. G. Gillespie and D. A. Clague, eds., *Encyclopedia of*
510 *Islands*. University of California Press, Berkeley and Los Angeles, CA, USA.
- 511 Olsen, A. R., Eberdong, M., Ketebengang, H., Blailes, P. and Chen, P.-h. (2016) Survey of
512 megapode nesting mounds in Palau, Micronesia. *West. Birds* 47: 27–37.
- 513 Oro, D., Genovart, M., Tavecchia, G., Fowler, M. S. and Martinez-Abraín, A. (2013)
514 Ecological and evolutionary implications of food subsidies from humans. *Ecol.*
515 *Letters* 16: 1501–1514.
- 516 Otley, H. M. (2005) Nature based tourism: experiences at the volunteer point penguin
517 colony in the Falkland Islands. *Mar. Ornithol.* 33: 181–187.
- 518 Pratt, H. D., Engbring, J., Bruner, P. L. and Berrett, D. G. (1980) Notes on the taxonomy,
519 natural history, and status of the resident birds of Palau. *Condor* 82: 117–131.
- 520 R Core Team (2015) R: A Language and Environment for Statistical Computing. R
521 Foundation for Statistical Computing. Vienna, Austria.
- 522 Ruffell, J., Innes, J., Bishop, C., Landers, T., Khin, J. and Didham, R. K. (2015a) Using pest
523 monitoring data to inform the location and intensity of invasive-species control in
524 New Zealand. *Biol. Conserv.* 191: 640–649.
- 525 Ruffell, J., Innes, J. and Didham, R. K. (2015b) Efficacy of chew-track-card indices of rat
526 and possum abundance across widely varying pest densities. *New Zeal. J. Ecol.* 39:
527 87–92.
- 528 Ruffino, L., Bourgeois, K., Vidal, E., Duhem, C., Paracuellos, M., Escribano, F., Sposimo,
529 P., Baccetti, N., Pascal, M. and Oro, D. (2009) Invasive rats and seabirds after 2,000
530 years of an unwanted coexistence on Mediterranean islands. *Biol. Invasions* 11:
531 1631–1651.

- 532 Ruffino, L., Russell, J. and Vidal, E. (2013) Anthropogenic subsidies mitigate
533 environmental variability for insular rodents. *Oecologia* 172: 737–749.
- 534 Russell, J. C. and Holmes, N. D. (2015) Tropical island conservation: Rat eradication for
535 species recovery. *Biol. Conserv.* 185: 1–7.
- 536 Russell, J. C. and Ruffino, L. (2012) The influence of spatio-temporal resource fluctuations
537 on insular rat population dynamics. *P. Roy. Soc. B-Biol. Sci.* 279: 767–774.
- 538 Saracco, J. F., Radley, P., Pyle, P., Rowan, E. and Taylor, R. (2014) *Vital rates of landbirds*
539 *on saipan and links to remote-sensed habitat data: A summary of five years (2008-*
540 *2012) of the Tropical Monitoring Avian Productivity and Survivorship (TMAPS)*
541 *program on Saipan, Northern Mariana Islands.* The Institute for Bird Populations,
542 Point Reyes Station, California, USA.
- 543 Sealey, K. S. and Smith, J. (2014) Recycling for small island tourism developments: Food
544 waste composting at Sandals Emerald Bay, Exuma, Bahamas. *Resour. Conserv.*
545 *Recy.* 92: 25–37.
- 546 Shapiro, M. L. (2005) *Diet Overlap and Potential Competition between North Island Brown*
547 *Kiwi Chicks (*Apteryx mantelli*) and Ship Rats (*Rattus rattus*) for Limited Resources on*
548 *Ponui Island, New Zealand.* M.Sc. Thesis, Massey University.
- 549 Shiels, A. B., Pitt, W. C., Sugihara, R. T. and Witmer, G. W. (2013) Biology and Impacts of
550 Pacific Island Invasive Species 11. The Black Rat, *Rattus rattus* (Rodentia: Muridae).
551 *Pac. Sci.* 68: 2–94.
- 552 Spatz, D. R., Zilliacus, K. M., Holmes, N. D., Butchart, S. H. M., Genovesi, P., Ceballos, G.,
553 Tershy, B. R. and Croll, D. A. (2017) Globally threatened vertebrates on islands with
554 invasive species. *Sci. Adv.* 3: e1603080.
- 555 Stapp, P. and Polis, G. A. (2003) Marine resources subsidize insular rodent populations in
556 the Gulf of California, Mexico. *Oecologia* 134: 496–504.

- 557 Steven, R. and Castley, J. G. (2013) Tourism as a threat to critically endangered and
558 endangered birds: global patterns and trends in conservation hotspots. *Biodivers.*
559 *Conserv.* 22: 1063–1082.
- 560 Steven, R., Pickering, C. and Castley, J. G. (2011) A review of the impacts of nature based
561 recreation on birds. *J. Environ. Manage.* 92: 2287–2294.
- 562 Tabak, M. A., Anderson, O .R. J., Robb, G., Poncet, S., Passfield, K., Martinez, M. G. and
563 Martinez Del Rio, C. (2016) Comparative isotopic natural history of two native
564 passerines (*Troglodytes cobbi* and *Cinclodes antarcticus*) and the invasive rats (*Rattus*
565 *norvegicus*) that extirpate them. *Austral Ecol.* 41: 622–632.
- 566 Tabak, M. A., Poncet, S., Passfield, K. and Martinez Del Rio, C. (2014) Invasive species
567 and land bird diversity on remote South Atlantic islands. *Biol. Invasions* 16:
568 341–352.
- 569 Towns, D. R., Atkinson, I. A. E. and Daugherty, C. H. (2006) Have the harmful effects of
570 introduced rats on islands been exaggerated? *Biol. Invasions* 8: 863–891.
- 571 USFWS (1998) *Recovery Plan for the Micronesian Megapode (Megapodius laperouse*
572 *laperouse)*. U. S. Fish and Wildlife Service, Portland, OR, USA.
- 573 VanderWerf, E. A. (2007) *2005 bird surveys in the Republic of Palau: final report*. Pacific
574 Rim Conservation, Honolulu, Hawaii, USA.
- 575 Wiles, G. J. and Conry, P. J. (1990) Terrestrial vertebrates of the Ngerukewid Islands
576 Wildlife Preserve, Palau islands. *Micronesica* 23: 41–66.
- 577 Wiles, G.J. and Conry, P.J. (2001) Characteristics of nest mounds of Micronesian Megapodes
578 in Palau. *J. Field Ornithol.* 72: 267–275.
- 579
- 580
- 581

582 PAUL M. RADLEY*¹, ROBERT A. DAVIS^{1,2}, TIM S. DOHERTY^{1,3}

583

584 ¹ School of Science, Edith Cowan University, 270 Joondalup Drive, Joondalup WA, 6027,

585 Australia

586

587 ² School of Biological Science, University of Western Australia, 35 Stirling Highway,

588 Crawley WA, 6009, Australia

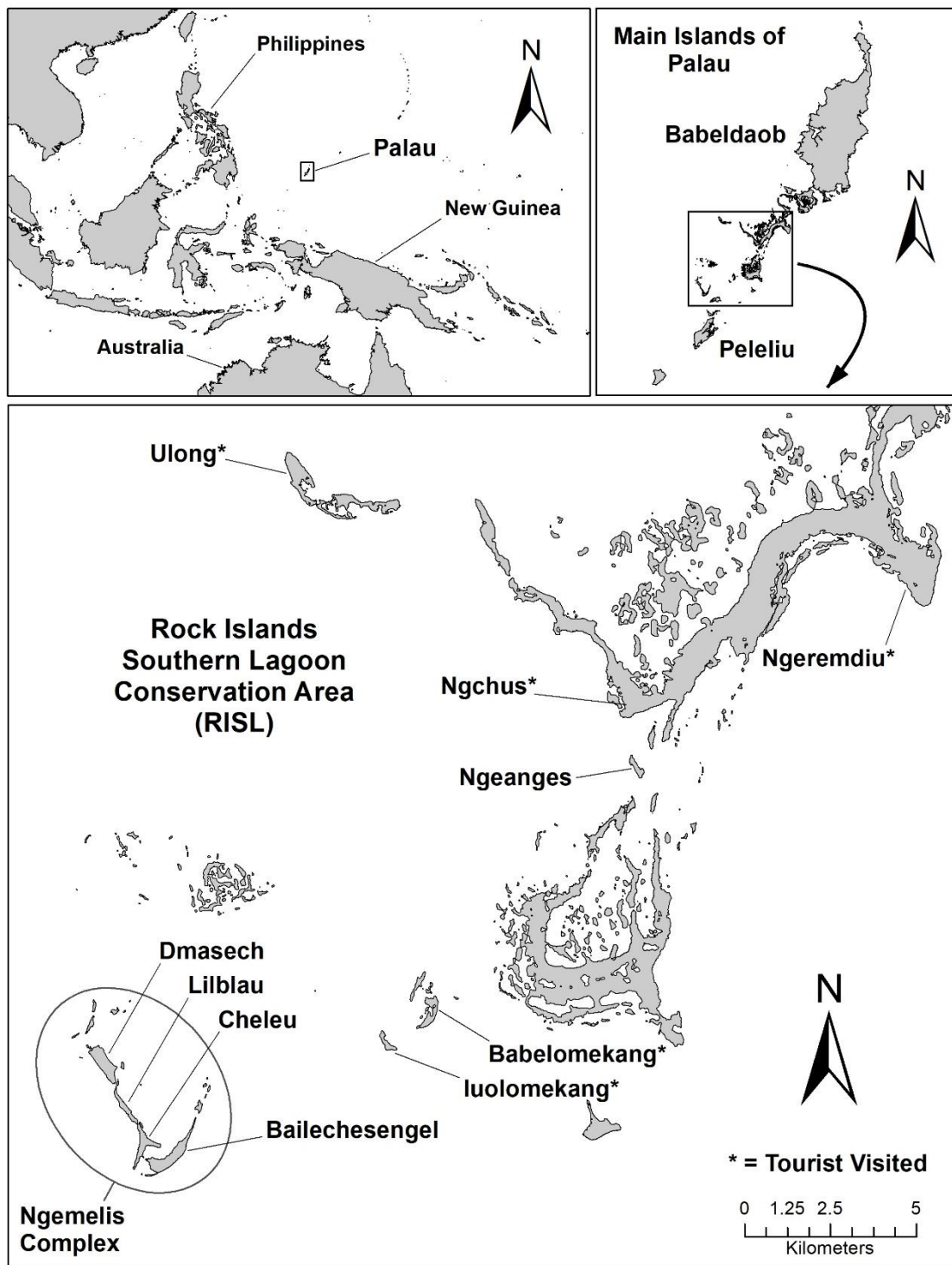
589

590 ³ Deakin University, School of Life and Environmental Sciences, Centre for Integrative

591 Ecology (Burwood campus), Geelong VIC, 3220, Australia

592

593 * Author for correspondence; e-mail: pratincola@hotmail.com



594

595 Figure 1. Map of the study area within the Rock Islands Southern Lagoon Conservation Area

596 (RISL), Palau, and the locations of five tourist visited and five tourist-free islands surveyed

597 for rats and scrubfowl between 15 December 2016 and 22 January 2017.

598 Table 1. Island level rat occupancy estimates and standard errors compared to island level occupancy probability Bayesian posterior means and
 599 95% credible intervals for tourist visited and tourist-free islands in the Rock Islands Southern Lagoon Conservation Area (RISL) of Palau.

Island	Occupancy		Posterior		HPD Credible Intervals	
	Estimate	SE	Mean	SD	Lower 95%	Upper 95%
<i>Tourist Visited</i>						
Babelmokang	1.00	0.00041	0.9167	0.0767	0.7616	1.0000
Ngchus	0.93	0.09883	0.8553	0.1038	0.6548	1.0000
Ngeremdiu	1.00	0.00003	0.9167	0.0767	0.7616	1.0000
Ulong	1.00	0.00003	0.9167	0.0767	0.7616	1.0000
Ioulomokang	1.00	0.00003	0.9167	0.0767	0.7616	1.0000
<i>Tourist-Free</i>						
Bailechesengel	0.52	0.16378	0.5192	0.1442	0.2424	0.7961
Cheleu	0.72	0.15026	0.6921	0.1358	0.4278	0.9418
Dmasech	0.72	0.15026	0.6921	0.1358	0.4278	0.9418
Lilblau	0.62	0.16053	0.6058	0.1422	0.3299	0.8743
Ngeanges	1.00	0.00002	0.9167	0.0767	0.7616	1.0000

601 Table 2. Results for four models used to assess the effect of tourist presences on rats (model
 602 1) and Palau Micronesian Scrubfowl (model 2 and 3), and the effect of rats on scrubfowl
 603 (model 4) on tourist visited and tourist-free islands in the Rock Islands Southern Lagoon
 604 Conservation Area (RISL) of Palau.

Parameter	Estimate	SE	t/z-value	Pr (>t/z)
<i>Model 1, Gaussian GLM – Rats on tourist visited vs tourist-free islands</i>				
Intercept	0.5100	0.0464	11.004	0.0000
Tourist Visited	0.3700	0.0655	5.645	0.0000
<i>Model 2, Logistic Regression – Megapode presence / absence on tourist visited vs tourist-free islands</i>				
Intercept	3.064	1.067	2.871	0.0041
Tourist Visited	-2.798	1.259	-2.223	0.0262
<i>Model 3, Poisson GLM – Megapode relative abundance on tourist visited vs tourist-free islands</i>				
Intercept	0.9559	0.2744	3.484	0.0005
Tourist Visited	-0.7276	0.4341	-1.676	0.0937
<i>Model 4, Gaussian GLM – Effect of rats on Megapodes across islands</i>				
Intercept	5.766	3.414	1.689	0.142
Rats	-4.285	4.893	-0.876	0.415
Tourist Visited	-21.777	24.093	-0.904	0.401
Rat: Tourist Visited	23.788	26.810	0.887	0.409

605

606 Table 3. Total counts and relative abundances during call playback surveys for Palau
 607 Micronesian Scrubfowl on tourist visited and tourist-free islands in the Rock Islands Southern
 608 Lagoon Conservation Area (RISL) of Palau. No. of Stations is the number of survey stations
 609 per island, and Count Total is the total number of scrubfowl counted per island.

Island	No. Stations	Count Total	BPS	% Stations w/ Detections
<i>Tourist Visited</i>				
Babelmokang	2	5	2.50	50%
Ngchus	3	2	0.67	33%
Ngeremdiu	6	1	0.17	17%
Ulong	5	19	3.80	100%
Ioulomokang	3	3	1.00	33%
<i>Not Tourist Visited</i>				
Bailechesengel	4	20	5.00	100%
Cheleu	6	14	2.33	100%
Dmasech	7	19	2.71	100%
Lilblau	7	12	1.71	86%
Ngeanges	5	12	2.40	80%

610