ABANDONED COCONUT PLANTATIONS AS NEW HABITAT FOR THE MOOREA KINGFISHER (*TODIRAMPHUS YOUNGI*)

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Abstract. Island endemics are often particularly susceptible to human threats such as habitat destruction and the introduction of non-native species. One such endemic, the Moorea kingfisher (*Todiramphus youngi*), is already an IUCN listed species. The primary theory for its decline is the loss of its preferred habitat, native forest; additionally, *T. youngi* may be competing with the invasive common myna (*Acridotheres tristis*) for resources. The recent appearance of *T. youngi* on an abandoned coconut plantation suggests that such habitats may be an acceptable alternative to native forest. This study surveyed presence and absence of *T. youngi* and *A. tristis* on coconut plantations of various successional stages to evaluate 1) whether *T. youngi* is present on plantations, and, if so, if the successional stage affected presence, and 2) whether *T. youngi* and *A. tristis* co-occur in these habitats. Presence/absence data was used to model the occupancy of these two species using Program PRESENCE. Results indicate that *T. youngi* is present on late-successional plantations and maybe inhabiting forest edge as well as interior. The best-fitting occupancy model suggests that *T. youngi* is not competitively excluded by *A. tristis*, but that the detectability of *T. youngi* is reduced when both species are present. These results tentatively indicate that *T. youngi* is successfully using this novel habitat.

Key words: Todiramphus youngi*, novel habitat, coconut plantation,* Acridotheres tristis*, Moorea, French Polynesia*

INTRODUCTION

Islands are often bastions of endemism, housing recently evolved species that arose out of extended isolation (e.g. Gillespie 2004). This diversity can be incredibly fragile. Humans have threatened island endemics in many ways; two of the most obvious threats have been the destruction of required habitat and the introduction of non-native species (Seitre and Seitre 1992, Garock et al. 2012). However, without understanding the ecology of endemic species, it can be difficult or impossible to determine major threats to them.

The kingfisher *Todiramphus youngi* is endemic to the island of Moorea, French Polynesia, and is currently listed as near threatened by the IUCN, with recommendations for further study to determine whether or not their numbers are in decline; if their populations are shrinking, they could warrant a listing of vulnerable or endangered (iucnredlist.org 2014). A recent study including population density estimates of the Moorea kingfisher indicated potential habitat saturation, limiting population sizes (Kesler et al. 2010). However, in the last five or so years, *T. youngi* has appeared on UC Berkeley's Gump Station property on Moorea, a former coconut plantation which has returned to thick forest (Brent Mishler, personal communication). It is possible that these birds can use new habitat provided by abandoned plantations as they reach late successional stages.

In addition to habitat loss, Moorean kingfisher abundance may be limited by competition with the island's widespread invasive birds, especially *Acridotheres tristis*, the common myna. A long-term study of native bird abundances in Australia found a decrease in the abundance of the laughing kookaburra, another Alcedine, following the introduction of the common myna (Grarock 2012); these authors suggested it may be due to competition for nesting sites, as both the kookaburra and myna are cavity nesters. The Moorea kingfisher is also a cavity nester (Fry and Fry 1999, Kesler et al. 2010) and may compete with mynas for nesting sites. While the kingfisher is insectivorous and the myna is omnivorous, mynas commonly feed on above-ground insects and may be competing with the kingfisher (Grarock 2012). *Acridotheres tristis* may also be inhabiting overgrown coconut plantations; in Australia, mynas can be found in open forest, but tend to avoid dense forest (Tracey et al. 2007).

The Moorea kingfisher is one of only 8 remaining native terrestrial birds on the island (Manu.pf 2014), and alarmingly little is known about its ecology; it is important that more be understood about their habitat requirements if they are to be protected adequately. This study aimed to determine whether *T. youngi* is able to utilize abandoned coconut plantations as new habitat and whether the forest must be at a particular stage of secondary succession in order to be occupied. It was hypothesized that the kingfishers require the returning forest to be of a mid- to late-successional stage, and that they don't occupy the edges of the forest. This was based on what is known about their current distribution; they are currently found in large blocks of mixed composition forest (Fry and Fry 1999). Additionally, it was hypothesized that common mynas occur in these same habitats, where co-occurrence may indicate that competition from mynas is not a limiting factor for kingfisher distribution. Informal behavioral observations were incorporated in the hope of expanding the knowledge of the Moorea kingfisher's natural history.

METHODS

Study site

This study was conducted on the north and northeastern edge of Moorea, French Polynesia (17°38´S 149°30´W and 17°32´S 149°50´W). A total of seven sites were surveyed during this investigation (Figure 1). Sites were selected based on preliminary scouting in order to maximize the range of secondary succession. Sites range from active coconut plantations to plantations that have

TABLE 1. Study site map key.

Site	Stage	Key
Garden Cafe	1	A
Public Beach	2	B
Temae Young	2	C
Jetski	3	D
Temae Old	4	E
Mari Mari	5	F
Gump Station	5	G

been abandoned for over forty years. Successional stages were assigned to each site based on species richness and structural complexity rather than historical age, as the length of abandonment was only known for three of the sites; the stages were defined as follows. Stage 1 – active plantation with no trees or shrubs present other than *Cocos nucifera*. Stage 2 – sites still heavily dominated by *C. nucifera*, but additional trees were present that made up approximately 25% of trees at the site. Stage 3 – Decreased dominance of *C. nucifera*, comprising approximately 50% of the trees present. Stage 4 – Trees other than *C. nucifera* dominated the site, with *C. nucifera* still comprising about 25% of trees present. Stage 5 – Scattered *C. nucifera* made up less than 10% of trees present; undergrowth of young trees and/or brush present (no undergrowth present in Stages 1-4).

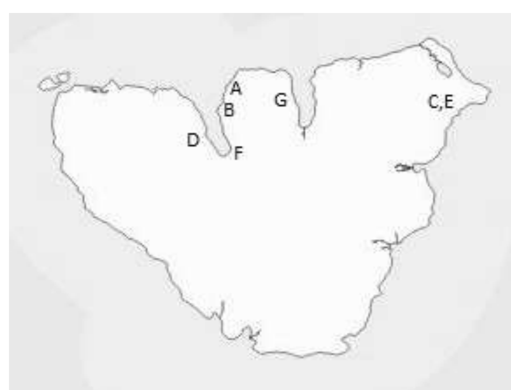

FIG. 1. Moorea, French Polynesia, and the location of each study site. Source: Wikimedia Commons.

Bird surveys

One transect was laid out per site, ranging from 104 to 265 m in length and containing between three and five observation stations. Transect lengths were determined by the size of each coconut plantation, traversing the longest distance from one edge to the opposite edge when possible. The distances between transect stations ranged from 50 to 70 m, in order to maximize the number of stations per transect. A total of 34 stations were surveyed. Additional survey effort was expended at one site (Gump Station), where I surveyed a grid rather than a single transect. The grid was comprised of 12 stations, roughly 3x4, covering an area of approximately 54,000 m^2. Gump site stations were also placed 50 to 70 m apart, and covered the whole of the forest between the station's library and the visitor bungalows up the hill. Because *T. youngi* was already known to be present on the Gump Station, the site provided the opportunity to more thoroughly investigate where on the plantation the kingfishers could be found.

Each transect was surveyed five times between from 21 October to 15 November 2014 in order to estimate probability of detection of the birds. Based on preliminary observations, both the kingfisher and myna are active throughout the day, and surveys were conducted whenever was possible between 7:00 and 17:00. No transect repetitions at a single site were ever done on the same day; the five surveys were spaced out over several days, from five days at the Mari Mari site to 23 days at the Public Beach site. Observations at each station lasted seven minutes, as per recommendation from Erica Spotswood (UC Berkeley). Presence or absence of the Moorea kingfisher and common myna within a 25 m radius of the station were recorded during each observational period. Identification was based on bird sightings, aided by binoculars, and calls heard. Calls were learned both by observing the two bird species on the Gump Station as well as by listening to recordings from xeno-canto.org. In addition to occupancy surveys, informal observations of *T. youngi* behavior were made on Gump Station.

Data analysis

Occupancy modeling of the kingfisher and myna was done using Program PRESENCE 7.3 (Hines 2006) using the Ψ^{Ba}/r^{Ba} parameterization of single-season, two-species models with each observation station defined as an independent site (Richmond et al. 2010; parameters define in Table 2). In this model species A is assumed to be the dominant species and here represents *A. tristis*; species B is assumed to be subordinate and represents *T. youngi*. Detection parameters were manipulated first to establish the best fit models for the detection of the myna and kingfisher. The best fit models for detection were then maintained while occupancy parameters were manipulated to find an overall best fit model for both occupancy and detection. This approach was based on

TABLE 2. Definitions of parameters used with Program PRESENCE.

Parameter	Description
Ψ^{A}	Probability of occupancy for species A
Ψ^{BA}	Probability of occupancy for species B, given species A is present
Ψ^{Ba}	Probability of occupancy for species B, given species A is absent
p^{A}	Probability of detection for species A, given species B is absent
p^{B}	Probability of detection for species B, given species A is absent
r^{A}	Probability of detection for species A, given both species are present
r^{BA}	Probability of detection for species B, given both species are present and species A is detected
r^{Ba}	Probability of detection for species B, given both species are present and species A is not detected

suggestions by Steve Beissinger (UC Berkeley, personal communication).

RESULTS

Bird surveys

My hypothesis that *T. youngi* would only be found in mid- to late-successional plantations was partially supported. Kingfishers were only located at the two sites that had been abandoned the longest (over 40 years), Gump Station and Mari Mari Kellum's property. Both of these sites differed from the others, having soil rather than sand substrate as well as the presence of undergrowth. These sites were also farther removed from the coast and at higher elevations than the others. While the kingfishers were expected to be found in the interiors of the sites, at the Gump site they were almost exclusively found at an edge station, where mynas were also observed. Mynas were largely limited to edges of two of the three densest sites (Mari Mari's and Temae Old), but were found throughout the interiors of the remaining sites, including Gump.

During behavioral observations, one to three kingfishers were seen on Gump Station. They appeared to be an adult male (solid chest band present), adult female (lacking chest band; tawny streaks on breast), and juvenile male (patchy chest band present). While kingfishers were looked for across the Gump property, the birds were only ever observed in a grass clearing downhill from the Gump Station director's bungalow. The clearing, approximately 25m by 50m and at an elevation of 30m, was bordered on opposite ends by the director's bungalow and one of the guest bungalows with trees along about half its edge (predominately the native *Hibiscus tiliaceus* and introduced *Albizia falcatoria*). Almost all observations were of a single individual; a pair was seen on one occasion, and three individuals were seen on a separate occasion. A very young *Terminalia catappa* was located at the center of the clearing, and was used by a kingfisher as a perch on at least three occasions. From this perch, kingfisher(s) were observed to quickly sally out to either one of the neighboring trees or the grass, then immediately return to the *Terminalia*. On two occasions, following the sallying behavior, the kingfisher was observed striking its bill against the branch it was perched upon, presumably to stun or kill the prey it had caught.

Simultaneous or alternating calls from two to three kingfishers were heard on several occasions when one or no birds were visible. Many vocalizations were heard, but almost exclusively when the kingfisher(s) were out of sigh. The most common was a rapid, mewling *kew-kew-kew-kew-kew* with a changeable number of syllables, the pace of which was also variable. Occasionally one or more syllables would be lengthened and trail off in a shuddering manner, especially at the end of calls, although some calls were exclusively comprised of these "shuddering *kews*." A sharp screech and a hoarse croak were also heard from visible kingfishers.

Data analysis

Of the five models tested where only the parameters linked to the detectability of the two birds were manipulated, two had very similar Akaike's Information Criterion (AIC) values and were weighted nearly equally (Table 3). These were the simplest and most complex detectability models allowable using this parameterization. They were both used in the next round of modeling, where the parameters for occupancy were manipulated (Table 4). The overall best-fitting model equated the two parameters Ψ^{BA} and Ψ^{Ba}, indicating that the probability of a station being occupied by a king fisher was not dependent on the presence or absence of mynas. It also included all possible parameters for detectability, meaning the probability of a kingfisher being detected at a site was dependent upon both the presence and the absence of mynas, and the probability of detecting the mynas was dependent upon the presence and absence of kingfishers (Parameter estimates in Table 5).

TABLE 3. Models with manipulated detection parameters ordered from best to worst fit.

Occupancy model	Detection model	*K*	ΔAIC	*w*
$\Psi^A\Psi^{BA}\Psi^{Ba}$	$p^A p^B r^A r^{BA} r^{Ba}$	8	0.00	0.3146
$\Psi^A\Psi^{BA}\Psi^{Ba}$	p^A	4	0.08	0.3023
$\Psi^A\Psi^{BA}\Psi^{Ba}$	$p^A p^B$	5	0.62	0.2307
$\Psi^A\Psi^{BA}\Psi^{Ba}$	$p^A p^B r^A$	6	2.46	0.0920
$\Psi^A\Psi^{BA}\Psi^{Ba}$	$p^A p^B r^A r^{BA}$	7	3.30	0.0604

Note: *K* is the number of parameters in each model, ΔAIC is the difference between the AIC value of each model and the best-fitting model, and *w* is the relative weight of each model.

DISCUSSION

Although kingfishers were found in late-successional coconut plantations, the fact that they were only found at two sites makes it challenging to make claims about their use of this type of habitat. Additionally, with only two sites where kingfishers were seen, and only one site where both species were found to be present, it is difficult to say anything meaningful about potential competition between the kingfishers and mynas. Where they were seen together, there were no interactions observed. More observations would be needed to make any definitive statements about how and if these two species may affect each other.

The presence of kingfishers almost exclusively at an edge site at Gump Station, during both surveys and informal observational periods, is very interesting. While the kingfishers are known to occupy dense native forest, the feeding observations made during this study indicate that the kingfishers can successfully forage in open spaces. The presence of the kingfishers on the two oldest plantations paired with this feeding location may indicate not only that *T. yougi* is able to successfully persist in these habitats, but may have a wider or more flexible range of acceptable habitat than previously thought, encompassing forest edges as well as interiors.

The association of three kingfishers on the Gump Station supports the findings of a recent paper calling the Moorea kingfisher a cooperative breeder; Kesler et al. (2010) proposed that this cooperative breeding could be indicative of habitat saturation. The grouping of what appeared to be an adult male and female pair with a juvenile male makes this particularly convincing, but all three were only seen together once. Additional observations on the station could potentially reveal more about the dynamics of these kingfisher family groups and how they communicate.

The best-fitting Program PRESENCE model has interesting implications for kingfisher occupancy. Due to the limited sample size of this study, many of the parameter estimates have very wide 95% confidence intervals. While the majority of the estimates are not meaningful, there are two aspects of the model that may accurately reflect the occupancy and detectability of mynas and kingfishers in these plantations.

TABLE 4. Models with manipulated occupancy parameters using the top two best-fitting detection parameters, ordered from best to worst fit.

Occupancy model	Detection model	*K*	ΔAIC	*w*
$\Psi^A\Psi^{BA}$	$p^A p^B r^A r^{BA} r^{Ba}$	7	0.00	0.4622
$\Psi^A\Psi^{BA}\Psi^{Ba}$	$p^A p^B r^A r^{BA} r^{Ba}$	8	2.00	0.1701
$\Psi^A\Psi^{BA}\Psi^{Ba}$	p^A	4	2.08	0.1634
Ψ^A	$p^A p^B r^A r^{BA} r^{Ba}$	6	2.13	0.1593
$\Psi^A\Psi^{BA}$	p^A	3	4.66	0.0450
Ψ^A	p^A	2	33.72	0.0000

TABLE 5. Parameter estimates for the overall best-fitting model.

Parameter	Estimate	Std. err.	95% conf. int.
Ψ^A	0.8453	0.0918	0.5800-0.558
Ψ^{BA}	0.5681	0.2079	0.2079-0.8683
p^A	0.3226	0.2165	0.0640-0.7684
p^B	0.5936	0.1314	0.3343-0.8095
r^A	0.8218	0.0849	0.5970-0.9349
r^{BA}	0.0299	0.0226	0.006-0.1244
r^{Ba}	0.1379	0.1417	0.0152-0.6233

The first interesting aspect of the model is the detectability of the kingfishers. The parameters r^{BA} and r^{Ba}, estimating the probability of detection of the kingfisher given that both species are present and the myna is or is not detected, respectively, are both very low with narrow 95% confidence intervals. Both of these parameters indicate that myna presence significantly decreases the probability of detecting kingfishers compared to their detectability in the absence of mynas, p^B, even after taking the wide confidence interval of p^B into account. This drop in detectability should be taken into account in single-species surveys of kingfisher occupancy, as the myna is so prevalent across Moorea. The second interesting aspect of the model is the absence of the parameter Ψ^{Ba}, meaning that the model estimates the probability of the kingfisher occupying a site to be the same whether or not mynas are present at that site. The independence of the probability of the kingfisher's occupancy from the presence of mynas indicates a lack of competitive exclusion of the kingfishers by the mynas. While the two birds may still compete for resources, this model suggests that mynas do not affect kingfisher occupancy of these coconut plantations.

Methodology

There were several potentially confounding factors across the site surveys. Weather was highly variable across the course of the study, including periods of heavy rain, high wind, and a dry spell that lasted several weeks. Due to time constraints, surveys were performed whenever possible, and although none were conducted in the rain, several were conducted just following rain when the birds may still have been sheltering and not visible or audible. High winds could also have resulted in the birds sheltering, and the dry spell may have altered food resources and caused the birds to change locations.

There were also many site-specific factors that could have affected these results. Some sites were located directly alongside a road, exposing them to higher levels of vehicle traffic and human activity than sites that were set back from the road. All but the two oldest sites (Gump Station and Mari Mari) had a sandy substrate; the presence of dirt could potentially be due to the later successional state of these sites, but they were also located further from the shore than many of the other sites and the plant species present were very different.

Future directions

Additional late-succession coconut plantations should be surveyed to confirm whether or not kingfisher occupancy is a common occurrence. While the sites for this study were found by driving around the island's main road, site choice based on land use maps would be much more efficient. As abandoned land, this habitat is at high risk of being developed, and these surveys should be conducted in the immediate future if possible. If these late-succession plantations are found to be novel habitat for *T. youngi,* the government of Moorea may want to consider land management policies protecting these sites. Surveys of the kingfishers' abundance and population trends should also be conducted in order to determine whether their numbers are declining. These studies are required to reevaluate the IUCN listing status of *T. youngi.* If this endemic warrants a listing of threatened or endangered, it is important that the status is conferred as soon as possible to ensure that the Moorea kingfisher receives proper protection.

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APPENDIX A

SITE LOCATIONS AND CANOPY DATA

Site	No. of stations	Latitude	Longitude	% canopy openness (edge)	% canopy openness (center)	Canopy height (m)
Gump Station	12	17°29'27.41"S	149°49'40.28"W	80.76	11.18	11.75
Mari Mari	3	17°30'49.40"S	149°50'44.80"W	n/a	11.70	11.00
Jetski	5	17°30'23.85"S	149°51'32.27"W	52.26	11.96	7.00
Public Beach	3	17°29'31.00"S	149°50'58.67"W	72.28	54.60	8.75
Garden Cafe	4	17°29'15.74"S	149°50'48.58"W	76.18	55.90	14.50
Temae Young	4	17°29'51.84"S	149°45'36.10"W	100.00	91.00	11.75
Temae Old	3	17°29'45.26"S	149°45'39.87"W	61.36	2.34	8.00