Invasion by the red-vented bulbul: an overview of recent studies in New Caledonia

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Abstract New Caledonia is a tropical archipelago of the South Pacific Ocean, and is one of the 36 world biodiversity hotspots. However, its unique biodiversity is increasingly threatened by habitat fragmentation and introductions of invasive alien species. Among these invaders, the red-vented bulbul (*Pycnonotus cafer*) is currently expanding towards the north of the main island. This passerine features in the IUCN-ISSG list of the 100 worst invasive species of the world because of impacts caused by its diet. Thirty-five years after its introduction, we present an overview of data from recent studies conducted in New Caledonia that describe the local status of the red-vented bulbul, its range expansion, and potential impacts on both the local biodiversity and agriculture. Biannual monitoring of the distribution coupled with surveillance at the edges of native forests highlighted a tight association of the bulbul with man-modified habitats. Using a distance sampling method, we estimated that bulbul densities within the distribution core varied from a peak of 200 individuals/ km^2 in the main city of Nouméa, where the species has been introduced, to 30 individuals/km^2 in rural habitats located 50 km away from Nouméa. We conducted a diet analysis on 40 bulbul corpses and found that 82% and 55% of individuals had consumed plant and animal items, respectively. We identified plant and insect species that may be of concern in the contexts of seed dispersal and predation by the red-vented bulbul. Finally, a food colour selection experiment and an open field test showed that the red-vented bulbul had a significant preference for red and sweet fruits. We estimated the economic loss caused by bulbuls to a tomato grower and discuss the result with respect to the development of an adapted management strategy, to prevent further impacts of the red-vented bulbul on the biodiversity and agriculture in the tropical island hotspot of New Caledonia.

Keywords: density, diet, distribution, impacts, invasive bird, *Pycnonotus cafer*

INTRODUCTION

New Caledonia is a tropical archipelago located to the east of Australia, in the SouthPacific Ocean. The archipelago has been classified as one of the world's 36 biodiversity hotspots because of its high levels of endemism in such a small territory (Williams, et al., 2011). Among notable features of local biodiversity in New Caledonia, Myers, et al. (2000) highlighted five endemic families and 112 endemic genera of plants, and one endemic family and three endemic genera of birds. However, a significant proportion of this biological richness is increasingly threatened by human activities and global changes, as is the case for most of the world's biodiversity hotspots (Bellard, et al., 2014). Among factors that foster these changes, habitat fragmentation and climate change are widely recognized (Garcia, et al., 2014; Haddad, et al., 2015), although the best response from scientists and managers to species' introductions is still a matter of debate (Russell & Blackburn, 2017; Davis & Chew, 2017).

The effects of invasive species have been widely documented (Early, et al., 2016). Impacts are accentuated in island ecosystems (Russell, et al., 2017), often because of the naivety of insular species (Gerard, et al., 2016) and environmental, ecological and evolutionary factors associated with geographic isolation (Cabral, et al., 2017). Humans play a key role in the transportation of plant and animal species worldwide (Ricciardi, et al., 2017). Trade in animals (Cardador, et al., 2017; Su, et al., 2016) and the release or escape of cage birds are frequently identified as the main mechanisms for alien bird introductions and the dispersal of wild birds outside of their native ranges (Dyer, et al., 2017).

Tropical bird species, particularly those from South-east Asia, occupy an important place in global bird trade (Nijman, 2010), with bulbuls, starlings, mynas and robins figuring amongst the most traded species from this region (Harris, et al., 2015). As a result, two out of three species considered in the IUCN-ISSG list of 100 worst invasive species are native to Southern Asia: the red-vented bulbul (*Pycnonotus cafer*) and the common myna (*Acridotheres tristis*) (Lowe, et al., 2000). These two species historically were widely transported from India to Pacific Islands (Watling, 1978) and both are now established in New Caledonia (Brochier, et al., 2010). Our global review on the impact and management of alien red-vented bulbuls identified 37 islands in the alien distribution of this species (Thibault, et al., 2018a). This study also highlighted the lack of quantitative data and evidence-based assessments of the impacts associated with this invasive species. The red-vented bulbul was introduced into New Caledonia in 1983 (Gill, et al., 1995) and its local distribution range is currently expanding from Nouméa toward the north and south of the main island. For 25 years following its introduction into Nouméa, no studies were conducted to investigate the ecology, distribution or impacts of the species at a local scale. This lack of information has precluded any detailed assessment of the threats posed by the establishment of the red-vented bulbul in New Caledonia. Consequently, it has not thus far been possible to implement an evidence-based management strategy.

The goal of this paper is to present an overview of data from recent studies conducted in New Caledonia to describe the local status of the red-vented bulbul, its

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range expansion, and potential impacts on both the local biodiversity and agriculture. We firstly report the local distribution range of the species, the rate and nature of its range expansion, and its habitat selection and densities in different habitats. We then use diet analysis to explore potential negative effects of the red-vented bulbul on natural and agricultural systems. We present original data on an ongoing invasion process in a tropical island biodiversity hotspot and highlight priority areas for local red-vented bulbul research and risk management.

METHODS

Red-vented bulbul range expansion

Red-vented bulbul dispersal was monitored over time using static 10-min point counts combined with 2-min playback of recorded calls to increase detection probability (Ralph, et al., 1995). Points were sampled within the four hours following sunrise, between November and December in 2008, 2012, 2014 and 2016. Each point was geo-referenced, and the observers accounted for seen and heard individuals. In 2008, 136 points were sampled that covered Nouméa and suburbs as well as borders of the two main roads going to the north and south. Random points were also located in major urban areas along these roads to search for potential pioneering individuals. The method was replicated in 2012, 2014 and 2016, covering 203, 96 and 99 points respectively. Data were compiled and plotted in Qgis software version 2.18.1 (Quantum GIS Development Team, 2016).

In April 2016, we selected six additional sites across native and man-modified habitats to explore the future establishment of the red-vented bulbul in forests. We chose three sites across urban and dry forest habitats, and three across urban and wet forest habitats. These sites were located close to the core of the distribution range, where red-vented bulbul densities were highest. We placed 10 points spaced at least 250 m apart at each site (five points per habitat) and counted red-vented bulbul individuals seen and heard. The method used was the same as for distribution monitoring. Data were compiled in Qgis software version 2.18.1 (Quantum GIS Development Team, 2016) and plotted in R software version 3.4.0 (R Core Team, 2017).

Red-vented bulbul densities

Red-vented bulbul density was measured using a distance sampling method (Thomas, et al., 2010) in four sites located within the core of the red-vented bulbul distribution range. This method relies on three key assumptions: i) individuals at zero metres distance are detected with certainty, ii) individuals are detected once and at their initial location, and iii) distance measurements are exact.

Sites were selected in man-modified habitats, along a distance gradient from Nouméa to Tomo, a village located about 50 km farther north. Three transects of 1 km were established at each site and sampled between October and December 2015. A pair of observers walked along each transect for 30 minutes and counted the number of individuals seen on both sides. The distance of observed individuals from each transect was recorded with a laser telemeter. Transects were sampled three times between 0500 and 0900 hours and data from the three sessions were used independently and pooled to prevent a potential bias due to time of day.

Data were analysed with the "Distance" package (Miller, 2016) using R software version 3.4.0 (R Core Team, 2017). This method considers potential missed observations in the estimated bird densities thanks to the calculation of a detection probability curve. We first estimated the bird density at each site using data from the three sessions separately. Then, we estimated densities at each site using data of the three sessions together, considering the nine transects at each site as independent. Finally, we chose to present the estimates from the pooled dataset as it provided a smoothed estimation of densities regarding the influence of time of day on bird detection.

Red-vented bulbul diet analysis

Gut content analysis was conducted on 40 dead red-vented bulbuls provided by local hunters. There is no morphological dimorphism between male and female red-vented bulbul, so we were only able to determine the sex of sexually mature individuals, using anatomical analysis. Gastrointestinal tracts were excised and the contents removed and washed with tap water through a 0.2 mm sieve. The retained contents were placed in a Petri dish filled with 70% alcohol and examined under a dissecting microscope at 10× magnification (Olympus SZ61). Items were photographed (Toupcam UCMOS camera and Toupview software) for subsequent identification (Lopes, et al., 2005).

Fruit colour selection

According to the literature, damage to cultivated plants is the most frequently reported impact of the red-vented bulbul in its alien range (Thibault, et al., 2018a). This is also the impact category most often reported locally both by professionals (Caplong & Barjon, 2010) and non-professionals. We tackled this issue through two distinct experiments, a colour preference test and an open-field test.

We conducted an experiment on fruit colour selection to test whether the red-vented bulbul was attracted by some fruit colours more than others. We trapped eight adult individuals, maintained them in an aviary for at least a month, and in individual cages for three days. We created false-coloured fruits of four distinct colours, following the method presented in Duan & Quan, (2013). Artificial fruits were made of banana, chicken grain and water, and three quarters of the fruits were coloured with red, green and yellow food colouring. Ten fruits of each colour were placed in four different petri dishes in cages with bulbuls held individually and observed for 25 minutes from a hidden position. Each bird was tested once during five consecutive days, following either two hours or six hours of fasting. For each repetition, the colour of the first fruit eaten as well as the total number of fruit eaten per colour were recorded. ANOVA tests were conducted in R software version 3.4.0 (R Core Team, 2017) with hypothesis H0 being that each fruit colour had the same probability of being eaten first.

Damage to crops

In 2016, we conducted an open field test to explore the range of damage caused by red-vented bulbuls to tomato crops. We planted eight tomato plants inside each of 20 square plots spaced by one metre, and randomly covered half of the plots with bird netting during the flowering stage. During the fruiting period in August and September, each plot was monitored twice a week. Ripe and damaged fruit were harvested and separated in three categories; i) marketable; ii) pecked fruits; and iii) other damage. For each category, the colour, size, and sugar levels (in Brix degrees; Bates, 1942) of fruit were recorded. Tomatoes that were pecked by the birds were easily recognizable by beak marks, and the mark's size together with direct observations were used to determine the fruits that were damaged by red-vented bulbuls. The relative economic loss in marketable tomatoes due to bulbul damage was then calculated as the total weight of pecked tomatoes divided by the total weight of tomatoes harvested in 'unprotected plots'. This percentage was then extrapolated to the national production recorded during the month of our experiment. Data were analysed with the "nlme" package (Pinheiro, et al., 2017) using in R software version 3.4.0 (R Core Team, 2017).

RESULTS

Red-vented bulbul range expansion

The 2008–2016 red-vented bulbul biannual distribution map (Fig. 1) shows a continuous increase in the distribution range occupied by the red-vented bulbul in New Caledonia. Coloured polygons contain all points where red-vented bulbul individuals were observed in 2008, 2012, 2014 and 2016. Conversely, green dots represent all points where red-vented bulbul were not detected either during point-counts or during playback calls. The green triangles and diamonds represent, respectively, absence points located in natural dry forest patches within the city of Nouméa, and in humid forest, which represents the northern border of the capital and its suburbs. This absence data suggests that the species is not yet spreading into natural forest. Indeed, over the 60 point counts conducted at frontiers between urban and forest habitats, we detected red-vented bulbul individuals at 16 points in urban habitats and one point in dry forest habitat. We also received testimonies from local people about red-vented bulbul sightings. These testimonies were rarely confirmed by further observations but sometimes led to new detections. Figure 1 shows a continuous distribution of the red-vented bulbuls with range expansion particularly along main roads. It also presents absence data from another study (Thibault, et al., 2018b) which are consistent with this hypothesis. The two road axes from Nouméa to La Foa (100 km north) and Yaté (95 km south) appeared to be the main dispersal pathways. In 2012, 25 years after its introduction in the city of Nouméa, the red-vented bulbul had reached Tontouta, 42 kilometres north. From 2012 to 2016 the species travelled 35 kilometres north (Fig. 2). Nowadays the red-vented bulbul occupies at least 1,350 km^2 (8% of the New Caledonia territory), mostly restricted to the west coast of the southern province.

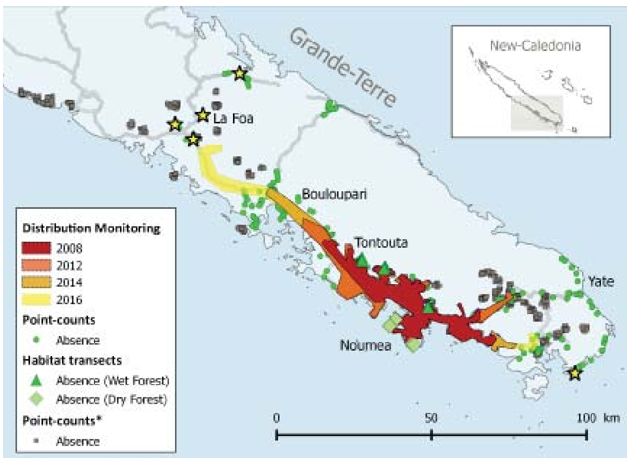

Fig. 1 Map of the expanding distribution of the red-vented bulbul between 2008 and 2016 according to the biannual monitoring. Stars represent observations from local people. Green dots represent point absence data (point counts) from the distribution monitoring. Green triangles and diamonds represent absence data (point counts along transects) in natural forests surrounding the distribution core. Grey dots show absence data (point counts) from another study (Thibault, et al., 2018b).

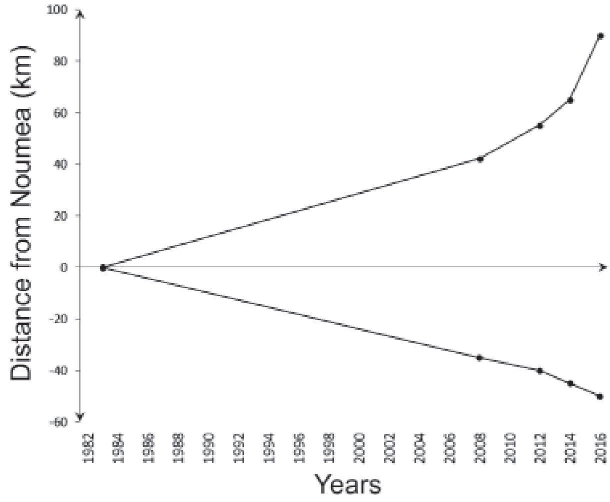

Fig. 2 Rate of red-vented bulbul dispersal toward the North and South of Nouméa.

Red-vented bulbul densities

Most birds were both heard and seen during our sampling sessions in inhabited areas. We fitted our data to a half-normal distribution (Thomas, et al., 2010) to calculate the detection function (Fig. 3**)**. Density estimates from the three sessions and from the pooled data set are presented in Fig. 4. Red-vented bulbul estimated density was six times higher in the city of Nouméa (*d*: 204 ± 23 individuals/km^2) than in the village of Tomo which is located 50 kilometres north (*d*: 31 ± 11 individuals/km^2, Table 1). Estimates from the two suburban areas, Robinson and Paita, were almost identical (*d*: 160 ± 32 individuals/km^2 and *d*: 131 ± 18 individuals/km^2, respectively). The density estimates are corrected by a detection function curve which represents the probability of an observer detecting a red-vented bulbul depending on its distance from the transect. In the four urban habitats we sampled, the average probability of detecting a red-vented bulbul was 50% when the bird was approximately 25 metres from the observer.

Red-vented bulbul diet analysis

We extracted and analysed the gut contents of 40 red-vented bulbuls. Results of the diet study are presented in

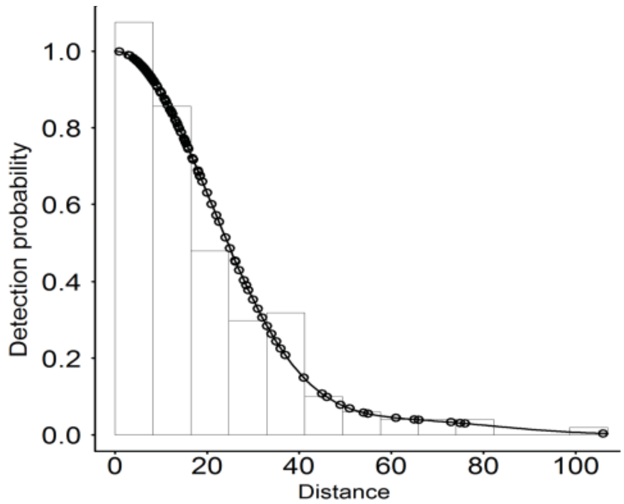

Fig. 3 Probability of detecting a red-vented bulbul individual as a function of distance from the transect in inhabited areas.

Table 1 Sampling statistics and density estimates at four urban sites within the current distribution range of the red-vented bulbuls according to distance from the introduction point. (n) total number of individuals over the three sessions.

Site	Distance (km)	Habitat	Area (m2)	n	Density estimate (ind/km2)	Standard error
Nouméa	0	urban	787.3	117	204	± 23
Paita	10	suburban	816.3	66	160	± 32
Robinson	25	suburban	492.8	65	131	± 18
Tomo	50	rural	993.3	15	31	± 11

Table 2 Occurrences (n) and frequency (%) of food items identified in the gut content of 40 bulbul individuals.

	n	F (n=40)
Fruit parts		
Whole fruit	16	40
Seeds	22	55
Fruit skin	7	17.5
Fruit flesh	17	42.5
Plant families	33	82.5
Myrtaceae	20	50
Passifloraceae	1	2.5
Sapindaceae	2	5
Solanaceae	4	10
Insects	22	55
Coleoptera	8	20
Diptera	1	2.5
Hemiptera	13	32.5
Hymenoptera	3	7.5
Odonata	1	2.5

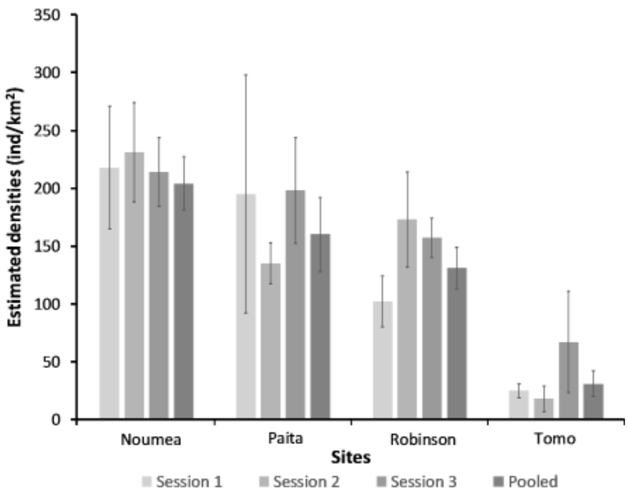

Fig. 4 Densities of red-vented bulbuls at each site calculated from the three sampling sessions, and from the pooled dataset.

Table 2. Mean weight of mature individuals was 38.3 ± 4.9 g for females and 44.1 ± 5.6 g for males. We found plant remains in the gut content of 33 individuals (82.5%) and animal items in 22 (55%). Among plant items, seeds (55%) and fruit flesh (42.5%) were the most frequent. The most frequent plant family was Myrtaceae (20 individuals), and the most consumed insect orders were Hemiptera (13 individuals) and Coleoptera (8 individuals). Identification of the remains highlighted the consumption of one endemic plant species (*Myrtastrum rufopunctatum*), two cultivated species (*Syzygium cumini* and *Lichi chinensis*) and two invasive alien species (*Passiflora foetida* and *Solanum torvum).* Exoskeleton parts from cicada individuals were frequent in this sample (F=32.5%). No vertebrate remains were found during this analysis.

Fruit colour selection

Colour selection tests were replicated 102 times. The first pecked fruit was red in 77% of samples, followed by green (10% of samples). The average number of consumed fruits per colour is presented in Fig 5. Red fruits were the most often consumed (5 ± 0.3), and yellow ones were consumed five times less often (0.9 ± 0.16). Colour explained the consumption of fruits significantly (ANOVA: F: 8.3; p<0.001). In our analysis, fasting period did not contribute to explain the choice of coloured fruits (ANOVA: F: 2.7; p=0.1).

Damage to crops

On our 20 plots, we produced a total of 2,310 tomatoes (345.5 kg). Unfortunately, three plots with nets were damaged by feral dogs just before the beginning of the fruiting season, and were thus considered to be unprotected. Red-vented bulbuls were the only birds that fed on tomato fruit during the experiment. Results are presented in Fig 6. On average, production per plot was homogenous in net-protected pots (18.5 ± 2.1 kg) compared to 'unprotected' ones (16.6 ± 2.3 kg). Losses due to bird damage were recorded almost exclusively in 'unprotected' plots and corresponded to 2.95 ± 0.24 kg per plot (17.5%), as only three tomatoes were pecked at the edge of protected plots (0.5% in weight). These losses were similar to those caused by other pests: 2.63 ± 0.3 kg in unprotected plots, and 3.9 ± 0.3 kg in protected plots. Pecked fruits were mainly red (ANOVA F: 7.6; p=0.009), between 50 and 70 mm in size and with high sugar levels (5°Bx, ANOVA: 5.95; p=0.016). Considering that 34 tons of tomato were sold at 3.18 USD/kg in September 2016 in New Caledonia, the 17.5% loss we recorded because of bird damage would have corresponded to an economic loss of approximately $18,355 USD for September 2016 alone.

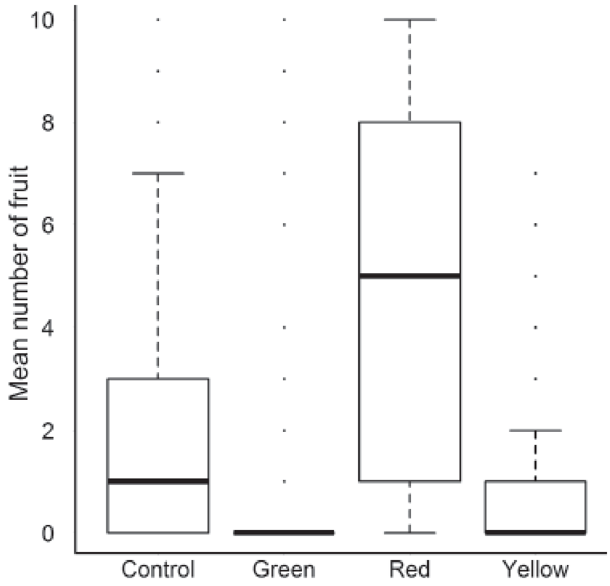

Fig. 5 Result of 102 colour preference tests with red-vented bulbuls. The y-axis represents the average number of fruits consumed by tested individuals during one session.

DISCUSSION

Dispersal along urban corridors

The red-vented bulbul has continuously increased its distribution range in New Caledonia since its introduction 25 years ago. The distribution map suggests that roads and urban habitats are the main dispersal pathways for the species. The dispersal rates we estimated were different depending on the direction. One reason for this may be differences in habitat to the north and south of Nouméa. The south of the main island of New Caledonia is dominated by ultramafic soils and the dominant vegetation type is the "maquis minier", a shrubland characterised by xerophytic plants (Jaffré, et al., 2003; Jaffré, et al., 2004) which may be less attractive in terms of food source for red-vented bulbuls. Considering the dispersal speed, we know that the red-vented bulbul's range expanded 40 kilometres toward the north of its introduction point in 25 years. Its range expansion then increased more quickly, extending a further 35 kilometres in just four years. This is consistent with findings of Aagaard & Lockwood (2014) on growth lag in alien bird populations and suggests that this range expansion could continue to accelerate. Our observation of a lagged expansion in the red-vented bulbul could thus be explained both by a demographic time-lag, inter-specific relationships, or by the carrying capacity of the different habitats.

Study of red-vented bulbul occurrence at the frontiers between urban and forest habitats confirmed the association of the species with man-modified habitats. Our results suggest that the red-vented bulbul is not spreading from invaded urban areas into either dry forest patches or into native rainforests. This is consistent with previous observations of Watling (1979) in Fiji. However, in Tahiti (French Polynesia) the red-vented bulbul is able to colonize native tropical forests with major impacts on native avifauna (Blanvillain, et al., 2003). Further monitoring of the distribution is thus crucial to anticipate potential shifts in the habitat occupancy and resulting threats on forest bird communities. A specific effort could be dedicated by managers to prevent future establishment of pioneer individuals out of the current range, toward the north, the Loyalty Islands or specific areas of high conservation/agricultural value. Quick detection coupled with control actions at the edges of the red-vented bulbul range will reduce the colonisation speed and prevent future negative effects.

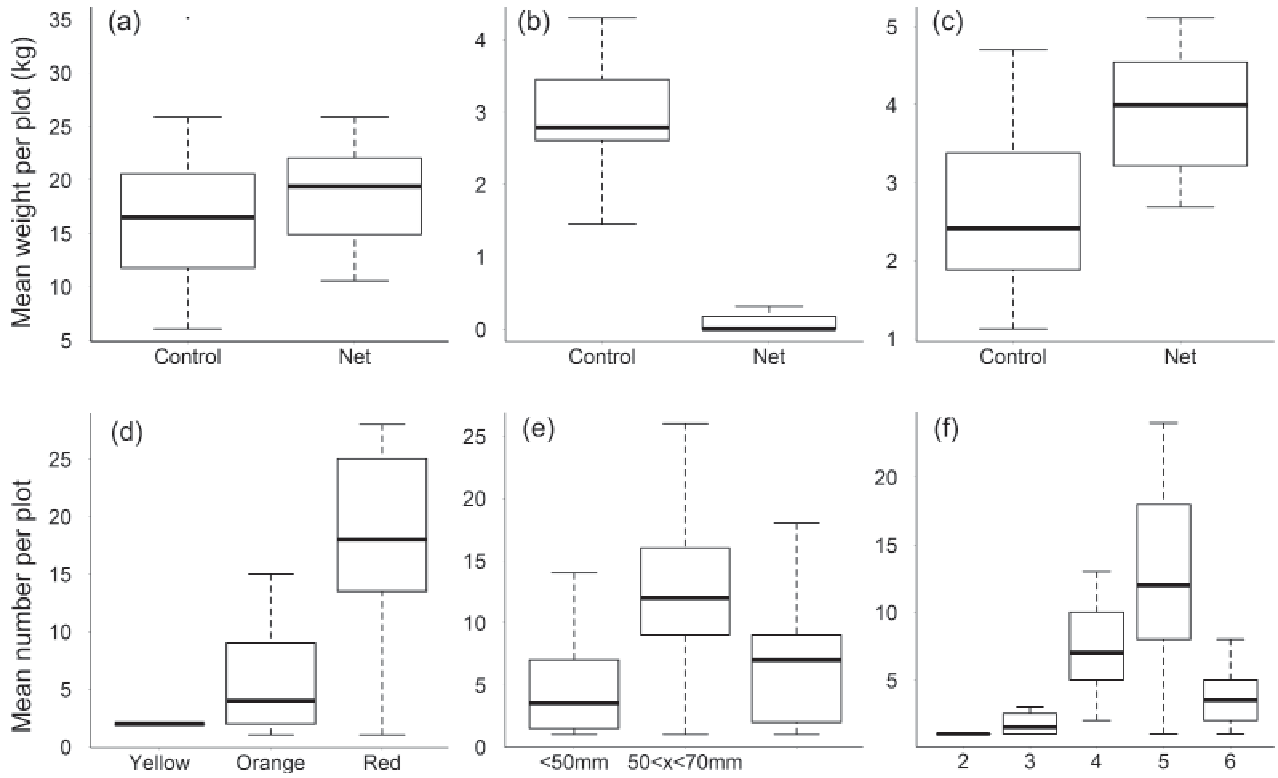

Fig. 6 Result of the open field test conducted with tomato plants. (a) Represents the global production weights for "net-protected" and "unprotected" treatments, (b) and (c) represent the mean weight of fruit damaged per plot by birds and other pests. (d), (e) and (f) represent the average number of damaged fruit depending on fruit colour, size, and sugar content, respectively.

Density gradient

Dispersal of bird species is partly related to population densities (Matthysen, 2005), so the anticipation of future dispersal events may be facilitated by the knowledge of bird density in specific locations. Our density estimates showed a density gradient in the red-vented bulbul, depending on the degree of urbanisation and the distance from the introduction point. This has been frequently observed in alien bird populations (Chace & Walsh, 2006). The density level we estimated in the rural village of Tomo was similar to those reported by Radhakrishanan & Asokan (2015) in two villages of the Cauvery delta region in Southern India, to which the red-vented bulbul is native. However, our estimates for the centre of Nouméa and suburbs are similar to those found for common bird species in European/ American urban centres (Clergeau, et al., 1998). High bird densities in urban habitats are often associated with low bird-community species richness (Matthysen, 2005). Regarding its density, the red-vented bulbul is already a predominant species in Nouméa. Monitoring the change in red-vented bulbul densities over time will contribute to a better understanding of the species' dynamics. It will also allow the estimation of the density-impact relationship in further management programmes (Yokomizo, et al., 2009), as management of invasive alien species populations often relies on abundance/density reductions (Genovesi, 2005; Simberloff, et al., 2005). For example, control operations could be feasible at low densities, whereas mitigation of specific impacts could be more cost-efficient at high-density levels.

Predation and frugivory

Results of the diet analysis were consistent with previous observations elsewhere in both the alien and native range of the species (Watling, 1978; Bhatt & Kumar, 2001; Brooks, 2013 Bates, et al., 2014). The diet comprised mostly fruits and a significant part of animal remains. We observed several red-vented bulbul individuals feeding on house geckos (*Hemidactylus frenatus*) and skinks in the field, but we did not find any reptile or gastropod remains in the gut contents we analysed. Such food items have been reported in the red-vented bulbul native range (Bhatt & Kumar, 2001). Much of the gut contents we analysed (n=13, F=32.5%) contained remains from cicadas. Considering the periodic lifecycle of these insects (May, 1974), this observation suggests that red-vented bulbuls can adapt their diet to this temporary resource. Levels of endemism are high in New-Caledonia, with approximately 92% of reptiles and nearly 100% of cicadas (Smith, et al., 2007; Grandcolas, et al., 2008; Delorme, et al., 2016) being endemic. Predation by alien species such as the red-vented bulbul could thus represent an additional threat for these species of high conservation value.

Seeds and whole fruits were found in 50% of individuals. This observation emphasizes the red-vented bulbul's capacity to participate in seed dispersal, particularly in association with invasive alien plant species like *Miconia calvescens* or *Lantana camara* (Meyer, 1996; Spotswood, et al., 2012; Spotswood, et al., 2013). In our diet study, we identified several candidates for red-vented bulbul-mediated dispersal. Most of them were invasive or cultivated species, but we also identified one endemic (*Myrtastrum rufopunctatum*) that is used for mining-site restoration (Lemay, et al., 2009). Consumption of native species by the red-vented bulbul could result in a service, by improving the dispersal capacity of some species (Kawakami, et al., 2009). However, it can also lead to competitive interactions with native avifauna (Sherman & Fall, 2010; Thibault, et al., 2018b) which can turn into a conservation issue (Blanvillain, et al., 2003). New Caledonia is considered a biodiversity hotspot (Myers, et al., 2000) thanks to its plant diversity, with 3060 species of flowering plants recorded (78% endemic; Munzinger, et al., 2016). Exploring variations in the red-vented bulbul diet over different habitat, seasons and maturity stages will contribute to better prediction of the dispersal of both alien and native plants as well as potential negative interactions with endemic species. At a wider scale, such quantitative and qualitative data will contribute to the assessment of impacts caused by red-vented bulbuls (Thibault, et al., 2018a).

Colour selection and damages on crops

Diet and preference for specific resources plays a key role in impacts caused by vertebrate pest species (Herrero, et al., 2006; Gebhardt, et al., 2011). Sometimes, these preferences can be strong enough to aid bait selection for both hunters and environment managers. In our experiment, the red-vented bulbul preferred red, consistent with colour preference in the red-whiskered bulbul (*Pycnonotus jocosus*) (Duan & Quan, 2013). In a French Polynesian study, authors concluded that preference may sometimes be stronger than abundance in fruit selection by birds, including the red-vented bulbul (Spotswood, et al., 2013).

Such preference for specific fruits implies that red-vented bulbuls are likely to disperse or damage the fruit of some species more than others, and that predictions can be made about species that are likely to be most vulnerable. Observations made during our open field experiment were consistent with this hypothesis, with red tomatoes being damaged more than orange or yellow ones. In unprotected plots, damage caused by birds was equivalent to that of all the parasites and corresponded to 17.5% loss in weight of marketable fruit. This corresponds to the average losses presented in Oerke (2006) in their global estimation of economic losses due to animal pests over 11 production types including tomato, between 2001 and 2003. In this study, recorded losses attributed to animal species and other pathogens on unprotected crops were of 18% and 15%, respectively. Oerke suggested that pest control operations allowed a 39% reduction in losses due to animal pests. Here we showed that protecting tomato plants with nets efficiently protected 99% of fruits, reducing by 97% the loss in weight of marketable fruit. This early assessment of colour selection and damage on production suggests that red and sweet fruit/flower crops could be more sensitive to red-vented bulbul damages. Such information is already used in the development of trapping systems dedicated to this species. Indeed, fruit and fresh vegetables represented 5115 and 6292 tons, respectively, of production in New Caledonia in 2012, corresponding to 25% and 30% of the total plant production that year (ISEE, 2012). The red-vented bulbul is currently restricted to suburban areas in a limited range, but up to 35% loss has already been recorded on fruit production there (Caplong & Barjon, 2010). Future establishment of the species in cultivated areas of the main island could thus represent an additional risk to crop productivity.

CONCLUSION

The global distribution and population trends of red-vented bulbul have been poorly reported, relative to many other tropical invasive birds. The potential overlap in the impacts associated with tropical passerine species from south Asia, suggested by Kumschick et al. (2015), has not been explored either. Authors have claimed that introduced populations of red-vented bulbuls were harmless (Watling, 1979), while in other locations their role in noxious seed dispersal (Meyer, 1996), competition with native birds

(Blanvillain, et al., 2003, Thibault, et al., 2018b) and damage to crops (Walker, 2008) was suggested. New Caledonia must deal with the current dispersal of this species on its territory with only a few quantitative data available from the literature (Thibault, et al., 2018a). However, the establishment, on-going dispersal, and impacts of the red-vented bulbul deserve attention from conservation biologists, environment managers and local people. Perceptions of this invasive species differ across groups of people (Fischer, et al., 2014), but a coordinated joint effort is required to improve our knowledge of invasion mechanisms for the red-vented bulbul in the New Caledonia archipelago. New Caledonia recently produced a list of priority invasive species for management actions, and the studies we presented here contributed to the consideration of the red-vented bulbul among the six species on this list.

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