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ORIGINAL PAPER

# The red-vented bulbul (*Pycnonotus cafer*): serious pest or understudied invader?

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**Abstract** Recently, debate has flourished about inadequacies in the simplistic "worst invasive species" approach and its global scale. Here we investigate the status of the red-vented bulbul (*Pycnonotus cafer*), an Asian passerine bird. This species has been introduced widely across Pacific islands and is commonly blamed for its impacts on agriculture and biodiversity via dispersal of invasive plant seeds and competition with native fauna. This case study evaluates all available data on the impacts and management of this invasive species and identifies priorities for future research. We reviewed the scientific literature and information from three databases (ABBA, GAVIA, eBird) and highlight that the attention paid to this species by scientists and managers varied considerably between islands and contexts and was globally lower than the attention paid to other species on the IUCN-ISSG list. The red-vented bulbul has now established on 37 islands and in seven continental locations outside its native range. We show that three categories of effects are associated with this species: plant damage, seed dispersal and disturbance of fauna. We compiled lists of 110 plant species consumed, 33 plant species dispersed, and 15 species of bird that this bulbul interacts with. However, these lists were mainly made of opportunistic observations rather than specific assessments. Research outputs that focus on better ways to prevent or quantify the impacts of the red-vented bulbul remain scarce. We found very few references exploring potential positive impacts of this species, and only two examples of management actions undertaken against it. The latter are required to inform management actions, especially on sensitive tropical islands where invasions and dispersal of the red-vented bulbul are ongoing. Our analysis of the literature found no clear support for considering this species to be one of the "world's worst" invasive alien species.

**Keywords** Invasive alien bird · Islands · Impact · Biodiversity · Conservation

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## Introduction

Invasive alien species (IAS) are one of the main causes of biodiversity loss (Sala et al. 2000; Keane and Crawley 2002; Pereira et al. 2012; Gren et al. 2016), with associated economic impacts (Bergman et al. 2000; Pimentel et al. 2005; Pimentel 2011) and degradation of ecosystem services (Walsh et al. 2016). The highly ambitious goal of the 2010 Convention for Biological Diversity, Nagoya, Japan, was to ensure that "By 2020, IAS and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment" (Secretariat CBD 2010). Concerns about the impacts of IAS have led to the production of several lists of high priority alien species including the "100 of the World's Worst" from the IUCN Invasive Species Specialist Group (IUCN-ISSG) (Brochier et al. 2010; Burgiel and Perrault 2011; Lowe et al. 2000). Such prioritization attempts have incited intense debate among the scientific community on the definition of an invasive species (e.g. Russell and Blackburn 2017). Some considered invasion as a natural phenomenon and compared the prevention of species dispersal as a kind of racism (Valéry et al. 2013). Others saw the observed impacts of alien species as an important challenge for our developing societies (Richardson and Ricciardi 2013; Simberloff and Vitule. 2014; Blondel et al. 2014; Pereyra 2016). Such debate also applied to species classification methods, as prioritization attempts based on expert assessments is opposed to different classification frameworks based on data analysis and statistics (Donlan and Wilcox 2008; Kumschick et al. 2012; Blackburn et al. 2014; Kumschick et al. 2015). In this study, we consider that an alien species expanding its range in a sensitive territory deserves particular attention from both scientists and managers. For their part, scientists must consider the possibility that a species could be harmless in an alien territory and should produce a local assessment of potential issues associated with that species.

Of the terrestrial vertebrates in the IUCN-ISSG list, 14 are mammals, three are birds and only two are reptiles (Lowe et al. 2000). Unsurprisingly, 10 years after the publication of this "World's Worst" list, authors have commented on the imbalance in attention paid by scientists and managers to mammals in contrast to alien birds (Pyšek et al. 2008; Kumschick and Nentwig 2010). Several studies have called for improvements in the way in which impact values of IAS are assessed beyond experts' "worst" lists, particularly for bird species (Strubbe et al. 2011; Ricciardi et al. 2013; Kumschick et al. 2015; Saxena 2015) and they have stressed that this is vital to better inform management decisions.

The three bird species classified as the world's worst invasive species in the IUCN-ISSG list are the common starling (*Sturnus vulgaris*), the common myna (*Acridotheres tristis*), and the red-vented bulbul (*Pycnonotus cafer*). A recent review of the impact of alien birds on native ecosystems globally (Martin-Albarracin et al. 2015) identified the three species with the highest global impact as being the mallard (*Anas platyrhynchos*, score = 16), the common myna (score = 13), and the red-whiskered bulbul (*Pycnonotus jocusus*, score = 10) whereas the global impact score of the red-vented bulbul in this study should be only 4. Recently, Kumschick et al. (2015) identified important overlaps in the impacts associated with the common myna and the red-vented bulbul. This raises the question as to whether the red-vented bulbul should be considered as one of the three worst invasive bird species on the planet. Local farmers and environment managers need management frameworks in order to deal with the dispersal/impacts of IAS (Blackburn et al. 2011). Biosecurity protocols at frontiers were demonstrated to be the most useful techniques to prevent biological invasions (Edelaar and Tella 2012). However, controlling a newly established invasive species in a territory depends on economic, ecological and social factors and therefore on specific assessment of these factors at local scales (Mack et al. 2000). A synthesis of management programs toward an alien species offers concrete baselines for managers, and this knowledge also helps understanding how the impacts associated with an invasive species give rise to management operations. It is urgent that we review existing assessments of impacts and management programs implemented against the red-vented bulbul.

We review invasion data to determine the nature and severity of the impacts of this species, whether its impacts are consistent throughout its alien range, whether its status as a major invasive species has led to more research and management programs at local scales, and to assess if its current acknowledged pest status is deserved. We present an updated assessment of an invasive species nearly 110 years after it was first record outside of its native range (Fiji in 1903, Watling 1978) and identify priorities for future research.

## Methods

### Species description

The red-vented bulbul (*Pycnonotus cafer* Linnaeus, 1766) is a passerine belonging to the family Pycnonotidae. Earlier names include *Molpastes haemorrhous* J.F. Gmelin, 1789 and *Molpastes cafer* Baker, 1930. The genus *Pycnonotus* comprises 47 species (Delacour 1943; Dickinson and Dekker 2002), among which the red-vented bulbul is represented by eight different subspecies (Dickinson et al. 2002). The Pacific sub-species is *P. c. bengalensis*, Blyth 1845 (Watling 1978).

The red-vented bulbul is native to the Indian Subcontinent, Southeast Asia, and Malay Peninsula (Long 1981). It occurs naturally from Eastern Pakistan to southern China and Vietnam, and from Northern India to Sri Lanka. The species also has an historic presence in Bangladesh, Bhutan, Myanmar and Nepal.

### Data collection and analysis

We searched for "*Pycnonotus cafer*" and "red-vented bulbul" keywords on Google Scholar, Web of Science, ScienceDirect and SpringerLink search engines. We looked for information on impacts primarily, and collected references on pathways of invasion, establishment success, and management. We also visited the websites of the Governments, Environment Ministry, Associations and NGOs for each country where the red-vented bulbul was signaled as present. When our searches failed to find the information we sought, we made direct contact with people who had reported the presence of this species in each country. Most of the documents obtained concerned the red-vented bulbul in its alien range. Those that related to this species in its native range were used to extract information on its biology and ecology in countries of origin. We also compared the number of references obtained by searching for each of the species names listed in the IUCN "World's Worst" list in Google Scholar.

In order to update distribution maps, we included records from three international databases. We used the 252 quotations with references from the Global AVian Invasion Atlas Project (GAVIA, Dyer et al. 2017), 150 sightings from the Atlas of Breeding Birds of Arabia (ABBA, Ornithological Society of the Middle East, Jennings 2010) and 40,152 sightings from the participative eBird database (eBird, Sullivan et al. 2009). Maps were designed using the following R software packages: maps (Becker et al. 2015a), mapdata (Becker et al. 2015b), and mapproj (McIlroy et al. 2015) and maptools (Bivand and Lewin-Koh 2016).

We classified the reported impacts of the red-vented bulbul into three categories: (1) plant damage; (2) seed dispersal; and (3) disturbance and impact on fauna. We treated each mention of a species-specific plant or animal impact as one "report". One published article thus often contained several "reports" when listing, for example, species of plants consumed, and the full set of documents potentially contained several reports of impacts on the same species, sometimes at the same location. We chose this index because it facilitates across-taxa comparisons and it is simple to calculate from the large number of references obtained. In addition, the ratio of the number of reports by the number of impacted species provides an informative insight into the attention paid to each impact-category.

## Results

### Sources of the information

We identified 112 published documents on the red-vented bulbul, and obtained comments from seven ornithologists and environment managers about the bulbul from its alien range. The publications comprised 78 academic articles, 15 books, five conference proceedings, five newsletters and nine professional reports. Details about the information obtained are presented in Fig. 1. Among the collected references, 83 addressed the red-vented bulbul in their alien range 74 from islands and nine from continental areas. Three locations (Fiji, Hawaii and French Polynesia) were the focus of 42 documents. We used 12 references that

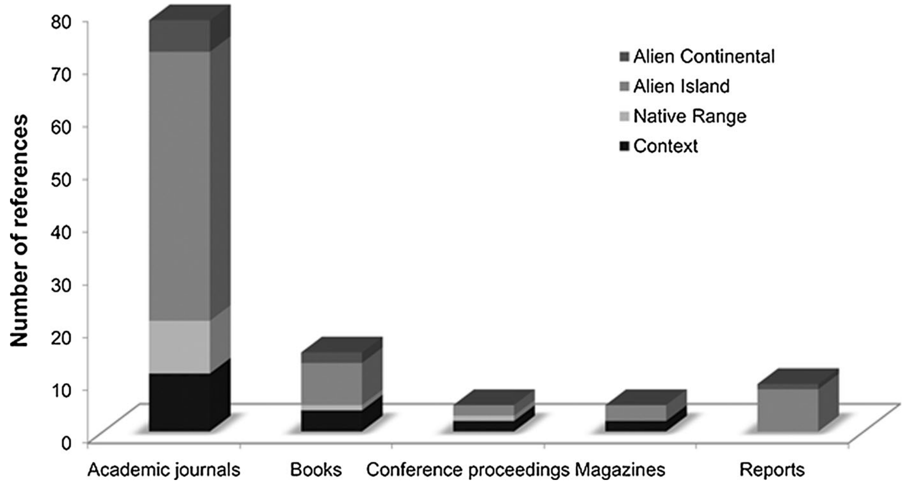


**Fig. 1** Sources of the collected information. The "General information" scope refers to documents dealing with invasion biology at a global scale

focused on red-vented bulbul in their native range. We also used information from 17 documents dealing with biological invasions at a larger scale. These documents cover a period from 1926 to today, but we focus here on documents from 1975 onwards. The cumulative numbers of publications through time are shown in Fig. 2. A full list of the 112 documents is given in Online Resource 1.

Searching for "*Pycnonotus cafer*" in Google Scholar produced 1370 references. Thus, among the 100 species listed by the IUCN, the red-vented bulbul ranked 11th. In comparison, we found 4880 references for "*Acridotheres tristis*", and 36,500 for "*Sturnus vulgaris*", the two other bird species from the list. Searches for "*Pycnonotus jocosus*" and "*Anas platyrhynchos*" resulted 1300 and 24,300 references respectively.

## Pathways of transport and introduction

The red-vented bulbul was first reported in Fiji in ~1903 (Parham 1955), corresponding to the transportation of Indian immigrants from Calcutta harbor to Fiji in the early 1900s (Watling 1978). This species was widely used in bird fights in India (Ali and Ripley 1996) because of its aggressive behavior. Over the following century, the red-vented bulbul was introduced into 19 countries and established in 17 of them (Fig. 3). It is now present in at least 37 islands and seven continental locations, and is anticipated to continue its range expansion in several archipelagos. The first recorded year of observation per country is presented in Table 1. Most introductions of the red-vented bulbul have been in the Pacific and in the Middle East, but the species was recently recorded in southern Europe (Malaga, Spain) and in North America (Houston, Texas, USA) (Fig. 3). The exact reason for introduction is known for only three locations. The red-vented bulbul was deliberately introduced (1940s) to Tongatapu (Tonga) to control unwanted insects (Watling 1978). An American troopship re-routed to Apia took caged birds to Samoa in 1943 instead of New Caledonia that was the intended destination

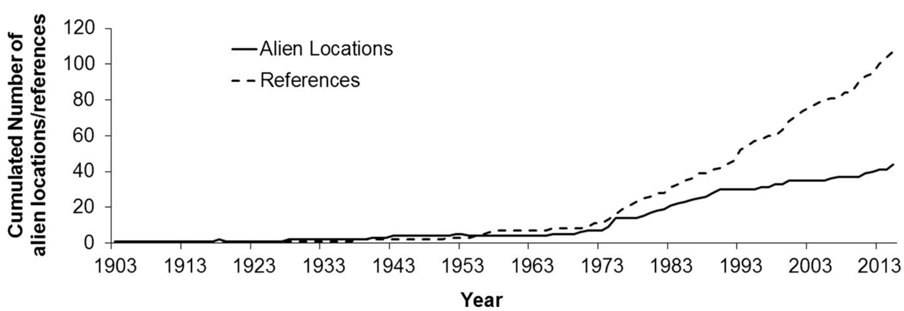


**Fig. 2** Number of alien locations and published references for red-vented bulbul for the period 1903–2013

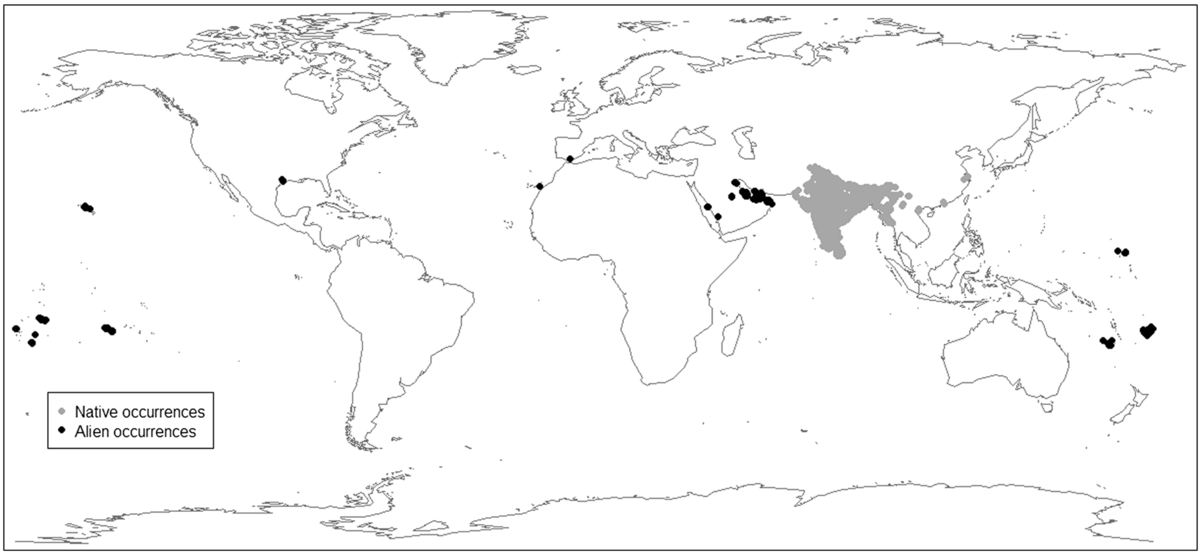


**Fig. 3** Native and alien range of the red vented bulbul

(Watling 1978), and the species was intentionally released in Nouméa (New Caledonia) in 1983 by bird dealers to avoid prosecution (Gill et al. 1995). For 10 other locations, bird trade is most often the suspected reason for introduction. Birds were kept in cages and transported by boat or airplane, with accidental or intentional release occurring commonly around harbors, airports and markets. For the Pacific locations, transportation of caged birds and accidental transport of free birds by boat have been the main introduction pathways, with a few records indicating that some introductions have occurred near airports. The red-vented bulbul remains abundant in Tahiti (French Polynesia) and is expanding its range in the Polynesian archipelago (T. Ghestemme *pers.comm.*). In the Middle East, land and air transport of cage birds between markets is implicated. It is not known how the species got to Houston (Texas, USA), Malaga or Corralejo (Spain).

## Establishment success

The red vented bulbul is currently considered established in 36 of the 46 locations where it has been historically recorded. Up-to-date information is lacking for three small Pacific islands ('Eua, Savai'i and Ailinglaplap). We found mentions of red-vented bulbuls in Melbourne in 1918 and 1942 (Lendon 1952; Watling 1978), but the species has not been reported there since and it was recorded as "Eradicated" in Australia in the global invasive species database (http://www.issg.org/database). It was observed on five islands in the Hawaii archipelago between 1982 and 1989, but it seems that it failed to establish beyond Oahu (Walker 2008). It was eradicated from Auckland, New Zealand, in 1955 (Watling 1978), 3 years after the first observation in 1952 (Turbott 1956).

## Recorded impacts

The red-vented bulbul is commonly blamed for three categories of negative impacts, mostly related to its diverse diet that comprises fruits and berries (Islam and Williams 2000; Brooks 2013), and flowers, buds, insects and small reptiles (VanderVelde 2002). We found 165 reports (110 species) of plants that are eaten by the red-vented bulbul. Among these, 50% concerned the degradation of cultivated plants and 35% related to seed dispersal. The remaining 17% (26 species from 17 families) were reports of consumption without consideration of the impacts. In comparison, we found 22 reports of impacts on local fauna in the bulbul's alien range.

Damage to cultivated plants is the most frequently reported impact of the red-vented bulbul in its alien range (Fig. 4), but these studies were conducted in just four locations. In contrast, the publications reporting

**Table 1** The current alien distribution of the red-vented bulbul *Pycnonotus cafer*, year of first observation (Y.F.O), number of colonized islands, current introduction success, status, range trend, and associated references. (+) Scarce (++) Common (+++) Very common

| Country | Y.F.O | Colonized Islands | Naturalization success | Current status | Range trend | Number of references | Main references |
|---|---|---|---|---|---|---|---|
| Island | | | | | | | |
| Fiji | 1903 | 9 | 9 | ++ | →↗ | 10 | (1) |
| Australia | 1919 | 1 | 0 | – | – | 4 | (2) |
| Tonga | 1928 | 4 | ≥3 | ++ | | 3 | (3) |
| Western Samoa | 1943 | 1 | 1 | ++ | | 7 | (4) |
| New Zealand | 1952 | 1 | 0 | – | – | 1 | (5) |
| American Samoa | >1957 | 2 | ≥1 | | | 7 | (2) |
| United States (Hawaii) | 1966 | 6 | 1 | +++ | → | 20 | (7) |
| French Polynesia | 1979 | 9 | 9 | +++ | ↗ | 12 | (8) |
| New Caledonia | 1983 | 1 | 1 | +++ | ↗ | 5 | (9) |
| Bahrain | 1986 | 1 | 1 | | | 2 | (10) |
| Spain | 1998 | 1 | 1 | + | ↗ | 1 | (11) |
| Marshall Islands | 2000 | 2 | ≥1 | | → | 1 | (12) |
| Iran | 2007 | 1 | 1 | + | | 1 | (13) |
| Continental | | | | | | | |
| Qatar | 1971 | – | 1 | + | | 1 | (14) |
| United Arab Emirates | 1974 | – | 1 | ++ | ↗ | 3 | (15) |
| Kuwait | 1981 | – | 1 | + | ↘ | 1 | (16) |
| Oman | 1987 | – | 1 | ++ | ↗ | 0 | (17) |
| Saudi Arabia | 1980's | – | 1 | + | | 2 | (18) |
| United States (texas) | 1996 | – | 1 | + | → | 1 | (19) |
| Spain | na | – | 1 | + | ↗ | 1 | (11) |

(1) Watling (1978), (2) Lendon (1952), (3) Carlson (1974), (4) Dhondt (1976), (5) Turbott (1956), (6) Clapp and Sibley (1966), (7) Berger (1975), (8) Meyer (1996), (9) Gill et al. (1995), (10)Khamis (2010), (11) MAAMA (2013), (12) VanderVelde (2002), (13) Azin et al. (2008), (14) Nation et al. (1997), (15) Pederson and Aspinall (2015), (16) Gregory (2005), (17) J. Eriksen com.pers., (18) J. Babbington com.pers, (19) Brooks (2013)

the red-vented bulbul to be a problematic seed disperser come from eight locations (six countries), and faunal impacts are reported for 17 species from 11 locations.

## Plant damage

The red-vented bulbul has been reported to cause damage to at least 52 plant species (Table 2) belonging to 25 families with 67% (35 species) being food plants and 33% (17 species) being ornamental plant species. The full list of damaged and dispersed plant species by family and species is given in Online Resource 2.

The impact of the red-vented bulbul appears to be particularly serious on Oahu (Hawaii), where Walker (2008) reported them consuming several species of fruits, vegetables and flowers, leading to considerable economic losses. The estimated value of the damage to Oahu's Orchid industry in 1 year (1989) was $300,000 (Fox 2011) when the red-vented bulbul together with the Japanese white-eye (*Zosterops japonicus*) reportedly destroying up to 75% of Hawaiian orchid and anthurium plantations (Cummings et al. 1994). In New

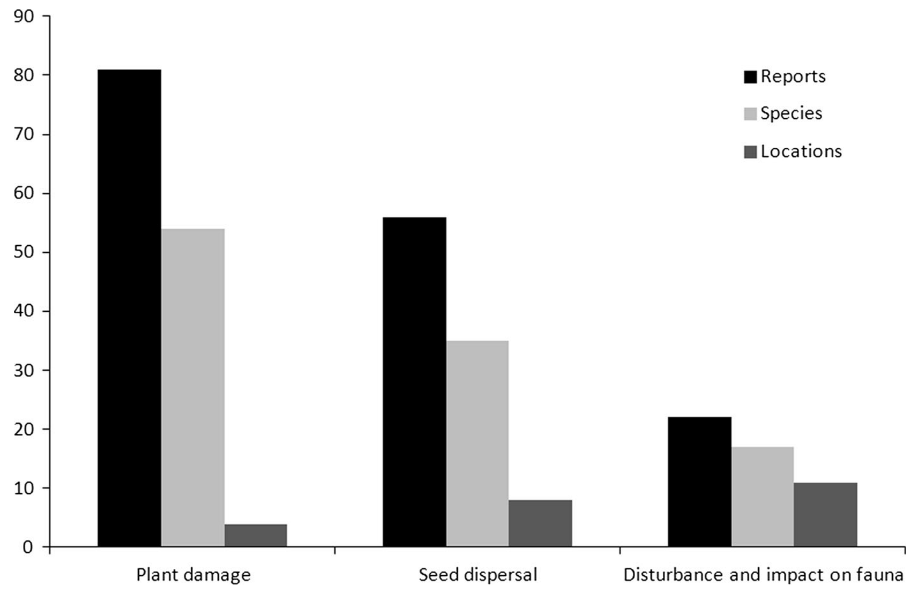


**Fig. 4** Representation of the three impact categories associated with the red-vented bulbul *Pycnonotus cafer*. Each axis corresponds to one category and represents the number of reports, species and location

**Table 2** Numbers of plant species reported as damaged, dispersed or just consumed by the red-vented bulbul *Pycnonotus cafer* in the literature and corresponding number of reports

| Impact | Status | Species | Reports |
|---|---|---|---|
| Damage | | 52 | 81 |
| | Food plant | 35 | 61 |
| | Ornamental plant | 17 | 20 |
| Seeds dispersal | | 33 | 56 |
| | Endemic | 1 | 1 |
| | Native | 8 | 11 |
| | Alien | 10 | 16 |
| | Invasive | 14 | 28 |
| Consumption only | | 25 | 28 |
| Total | | 110 | 165 |

A report corresponds to one mention in one reference. Endemic plants occurred at one location only, native plants are indigenous to the location but also present elsewhere, alien species were introduced in the corresponding location and invasive plants are alien species with negative impacts at the current location

Caledonia, significant impacts have been recorded for some crops and plant nurseries (Metzdorf and Brescia 2008) with up to 35% losses (Caplong and Barjon 2010). Conversely, the red-vented bulbul is not considered an agricultural pest in Fiji (Watling 1979), nor in Houston (Texas, USA) where it was found to consume mainly introduced tropical plant species (Brooks 2013).

## Seed dispersal

We found 56 mentions of problematic seed dispersal by the red-vented bulbul (Table 2) from six countries inside its alien range. The red-vented bulbul is able to spread the seeds of at least 33 plant species from 25 families. Among these species, 30% are considered alien (10 species) and 42% invasive (14 species) in the alien locations. We found records of only one endemic (*Coprosma taitensis*, Tahiti) and eightFdeso native species that are spread by this bird (Spotswood et al. 2012).

The red-vented bulbul is considered a major vector of the invasive tree *Miconia calvescens* in Tahiti (Meyer 1996) and can potentially disperse seven other alien plant species in French Polynesia including *Lantana camara* (Spotswood et al. 2012, 2013). Its ability to disperse *Miconia* and *Lantana* is not unique to the red-vented bulbul, and many other species, both alien and native, also disperse seeds of these plants, and the propensity of the red-vented bulbul to disperse seeds of these plants varies from island to island. For example, the introduced silvereye (*Zosterops lateralis*) also disperses these seeds in Tahiti, but in Moorea the endemic fruit dove (*Ptilinopus purpuralis*) disperses seeds of these alien plants. In Fiji, the red-vented bulbul contributes to the spread of primary colonist weeds (Watling 1979). In New Caledonia, the red-vented bulbul is suspected of spreading seeds of another invasive species: *Schinus terebinthifolius*, as it is often observed feeding on fruits (Spotswood et al. 2012; Thouzeau-Fonseca 2013).

Disturbance and impact on fauna

The list of animal species reported to be impacted by the red-vented bulbul is presented in Table 3. The list comprises 15 species of bird, one reptile and one insect. Only one study addressed the issue of how the aggressive behavior of the red-vented bulbul affected the other bird species (Pernetta and Watling 1978).

On Oahu (Hawaii), direct predation of the monarch butterfly (*Danaus plexippus*) by the red-vented bulbul led to an induced color selection against the orange morph in the monarch (Stimson and Berman 1990). After 10 years, the same authors reported a predation transfer to the larvae, leading to an overall decline in abundance of the butterfly (Stimson and Kasuya 2000). In Tahiti, red-vented bulbuls are considered a threat to the Tahiti monarch (*Pomarea nigra*), an endemic and critically endangered passerine, through competition for nest sites and territory (Blanvillain et al. 2003).

**Table 3** List of animal species reported as being impacted by the red-vented bulbul *Pycnonotus cafer*, with associated locations, inter-specific relationship, reported impact, method and references

| Species | Countries | Islands | Inter-specific relationship | Reported impact | Method | References |
|---|---|---|---|---|---|---|
| Insects | | | | | | |
| *Danaus plexippus* | H | O'ahu | Predation | Decline | Indirect Obs. | (1) |
| Birds | | | | | | |
| *Pomarea nigra* | PF | Tahiti | Competition | Decline | Direct Obs. | (2) |
| *Lamprolia victoriae* | FJ | Vanua Levu | Competition | Decline | Hypothesis | (3) |
| *Myiagra vanikorensis* | FJ | Viti Levu | Aggressivity/competition | Nest parasitism | Monitoring | (4), (5) |
| *Lalage maculosa* | FJ | Viti Levu | Aggressivity | *NA* | Monitoring | (5) |
| *Acridotheres tristis* | FJ | Viti Levu | Aggressivity | *NA* | Monitoring | (5) |
| *Acridotheres fuscus* | FJ | Viti Levu | Aggressivity | *NA* | Monitoring | (5) |
| *Zosterops lateralis* | FJ | Viti Levu | Aggressivity | *NA* | Monitoring | (5) |
| *Amandava amandava* | FJ | Viti Levu | Aggressivity | *NA* | Monitoring | (5) |
| *Streptopelia chinensis* | FJ | Viti Levu | Aggressivity | *NA* | Monitoring | (5) |
| *Foulehaio carnunculata* | FJ, AS | Viti Levu; Tutuila | Aggressivity/competition | *NA* | Monitoring | (5), (6) |
| *Myzomela cardinalis* | AS | Tutuila | Aggressivity/competition | *NA* | Direct Obs. | (6) |
| *Pycnonotus leucogenys* | AE, BH | | Cross-breeding | Setrile hybrids | Obs./ Hypothesis | (7), (8) |
| *Pycnonotus leucotis* | KW, QA, IR | Kish Island | Cross-breeding | *NA* | Obs./ Hypothesis | (9), (10), (11) |
| *Pycnonotus xanthopygos* | UAE | | Cross-breeding | *NA* | Obs./ Hypothesis | (8) |
| *Zosterops xantochroa* | NC | Grande-Terre | Competition | *NA* | Hypothesis | (12) |
| Reptile | | | | | | |
| *Hemidactylus frenatus* | NC | Grande-Terre | Predation | *NA* | Direct. Obs | *Pers. Obs.* |

*H* Hawaii, *PF* French Polynesia, *FJ* Fiji, *AS* American Samoa, *AE* United Arab Emirates, *BH* Bahrain, *KW* Kuwait, *QA* Quatar, *IR* Iran, *NC* New Caledonia

(1) Stimson and Berman 1990, (2) Thibault et al. (2002), (3) Williams (2011), (4) Clunie (1976), (5) Pernetta and Watling (1978), (6) Sherman and Fall (2010), (7) Khamis (2010), (8) Kahn (1993), (9) Azin et al. (2008), (10) Gregory (2005), (11) Nation et al. (1997), (12) Hannecart and Letocart (1980)

In Fiji, several authors have reported red-vented bulbuls displaying aggressive behavior and competition for food resources towards other passerine species (Clunie 1976; Pernetta and Watling 1978; Williams 2011). However, Watling (1979) suspected that the observed confinement of native bird species to forest was mainly due to habitat loss rather than the aggressive behavior of the red-vented bulbul in Fiji. On Tutuila (American Samoa), Sherman and Fall (2010) observed that bulbuls competed for access to food resources with two passerine species. Finally, insect and skink predation by red-vented bulbuls is mentioned in several studies (VanderVelde 2002; Walker 2008; Brooks 2013). In the Middle East, cross-breeding between the exotic red-vented bulbul and the three closely related native species (white-cheeked bulbul, *P. leucogenys*; the white-eared bulbul (*P. leucotis*) and the yellow-vented bulbul, *P. xanthopygos*) is often reported as a potential threat for native bulbuls (Khan 1993; Nation et al. 1997; Gregory 2005; Azin et al. 2008; Khamis 2010).

Dispersal of neither endo- nor ecto-parasites by red-vented bulbul is well documented in its alien range (Table 4). In its native range, the red-vented bulbul is known to host *Isospora* spp. (Boughton et al. 1938), *Menacanthus eurysternus* (Price 1975), *Bruelia guldum and Sturnidoecus guldum* (Ansari 1957) and *Pteroherpus pycnonoti* (Constantinescu et al., *unpublished*).

**Table 4** P Parasite load of the red-vented bulbul *Pycnonotus cafer* in the literature

| Type | Species | Host | References |
|---|---|---|---|
| Ecto- | *Isospora sp.* | Yes | (1) |
| | *Menacanthus Eurysternus* | Yes | (2) |
| | *Bruelia guldum* | Yes | (3) |
| | *Sturnidoecus guldum* | Yes | (3) |
| Endo- | *Plasmodium sp.* | No | (4), (5) |
| | *Trypanosoma sp.* | No | (4) |
| | *Atoxoplasma sp.* | No | (4) |
| | *Chlamydia sp.* | Yes | (6) |

Ecto- (Ectoparasites) corresponds to parasites livig outside of the animal body. Conversely Endo- (Endoparasites) corresponds to parasites living inside the animal body

(1) Boughton et al. (1938), (2) Price (1975), (3) Ansari (1957), (4) Atkinson et al. (2006), (5) Jarvi et al. (2003), (6) Blanvillain et al. (2013)

In 1996, Jarvi et al. (2003) detected no avian malaria (*Plasmodium* spp.) in blood smears, and Atkinson et al. (2006) found no evidence of *Plasmodium*, *Trypanosoma*, *Atoxoplasma* or microfilaria. Red-vented bulbuls in Tahiti, however, have been found to carry the zoonotic disease *Chlamydia* sp. (Blanvillain et al. 2013).

## Positive impacts

Red vented bulbuls feed on a variety of native plant species (Trail 1994; Sherman and Fall 2010), and dispersal of native seeds is the only service that has been explored in the bulbul's alien range (Spotswood et al. 2012). Interestingly, in a village-scale survey led by Daigneault and Brown (2013) in Viti Levu (Fiji), 47% of the respondents reported that the red-vented bulbul was good for their community and highlighted three main reasons. First, the bulbul was effective at insect control. Second, the bulbul reduced mongoose attacks on chickens. Third, village focus groups responded that red-vented bulbuls were occasionally eaten by villagers.

## Management

The red-vented bulbul is considered an invasive species and environmental pest under the law in Australia (Tasmanian government 2010), Fiji (Minister of Primary Industries 1985), French Polynesia (Direction de l'environnement de la Polynésie Française 2016), Hawaii (Division of Forestry and Wildlife 2014), New Caledonia (Direction du Développement Economique et de l'Environnement 2008; Direction de l'ENVironnement de la Province Sud 2016), New Zealand (Ministry of Primary Industries 2017), South Africa (Department of Environmental Affairs 2016) and Spain (Ministerio de Agricultura, Alimentacion y Medio Ambiante 2013). In these countries, transportation, trade or possession of this species is forbidden, and hunting is authorized. We found no mention of this species as a pest or invasive species in other countries.

We found only three examples of management action taken against the red-vented bulbul in its alien range. The first one is the successful eradication program implemented in New Zealand between 1952 and 1955 (Turbott 1956). This program allowed the early detection and shooting of bulbuls thanks to a reward associated with a call for information and led to an announcement of eradication in 1955 (Watling 1978). This management strategy remains in place in New Zealand and it helped prevent establishment following two more recent introduction events (September 2006 and February 2013).

Second, a cage test conducted in Hawaii on bird repellant showed that Ziram, Methiocarb and Methyl anthranilate reduced the consumption of treated papaya mash by red-vented bulbuls (Cummings et al. 1994). In an open-field test, the same authors showed that Methiocarb significantly reduced damages on orchids.

The third location where management actions have been implemented against the red-vented bubul is the island of Tahiti in French Polynesia. In Tahiti, a management program that was not focused on red-vented bulbul management specifically, but rather on Tahiti monarch conservation, aimed to control alien birds. Pilot control campaigns were implemented twice, in 2012 and 2013 (Saavedra 2012, 2013), against the red vented-bulbul and the common myna. These actions resulted in 1035 red-vented bulbuls being trapped in 2012, and 849 in 2013 and led to an increase in the breeding success of the Tahiti monarch (Saavedra 2013). Elsewhere in the French Polynesia archipelago, bulbul removal programs are in progress in Bora–Bora, Makatea and Nuku Hiva, three islands where the species is still rare but that are located near uninvaded parts of the archipelago.

In Fiji, a recent cost–benefit analysis of controlling the red-vented bulbul recommended "taking no action against the bulbul until such time as other benefits and or means of control have been field tested" (Daigneault and Brown 2013).

## Discussion

The red-vented bulbul is still expanding its range into islands and continental areas across a wide geographic range between latitudes 22°N and 36°S. The number of references associated with this species outside its native range is also growing, but remains low compared to other species listed in the IUCN "100 world's worst list". As an example, searching for "*Acridotheres tristis*" in Google Scholar results in a four times larger output than the keywords "*Pycnonotus cafer*". Based on this metric, the mallard and the red-whiskered bulbul could have been included in the IUCN list in the same way as suggested in Martin-Albarracin et al. (2015). This reflects the heterogeneity in the attention paid to this "world's worst invasive species". In fact, more than half of the information we obtained came from just three island locations: Fiji, where the species was first transported; Hawaii, where it was responsible for huge economic losses; and French Polynesia, where it was considered to contribute to pressures on endemic biodiversity. Dispersal of the red-vented bulbul is strongly linked to human activities, as is the case for other bird species (Cassey et al. 2015). In Assam in the north-east of India, bulbul fights were part of a traditional and religious annual celebration until this was banned in January 2016. Wild bulbuls were trapped, kept in cages and prepared for the fights, and finally released if they won (Shalet 2016). The long and close relationship with humans led to the transportation of caged birds across the Pacific Ocean by Indian migrants from the early 20th century, first by boat, and then by airplane from the 1950s, certainly fostered the bulbul expansion (Hulme 2009). This was also a key period for invasion biology, with the publication of the Elton's book (1958) marking the start of an increasing scientific interest in this field. While we found just eight references to this species between 1926 and 1966, 15 were published between 1967 and 1978. This species is still sold in local markets in several countries of the Arabic Peninsula (J. Babbington *pers.com.*), and bird trade remains the suspected principal vector of red-vented bulbul in this region.

Precise historical data are lacking regarding the propagule pressure, exact pathways of introduction, and dates associated with each introduction event, and we found very few records of this species being introduced but failing to establish. Globally, the establishment success recorded from Pacific islands to the USA or Europe suggests a better latitudinal plasticity of this species toward climate than expected when looking at the native distribution only. Moreover, its populations are considered to be self-sustaining or increasing in most of the tropical islands to which it has been introduced. Conversely, in most of the alien continental areas, population trends are considered steady or decreasing (ABBA database, Jennings 2004). This global pattern is consistent with the finding of Cassey et al. (2004) who showed that without consideration of the propagule pressure, islands are significantly associated with introduction success and increased geographical range in birds.

Interest in introduced red-vented bulbuls grew rapidly in response to the considerable damage it caused on orchid production on Oahu, Hawaii, following its arrival in 1966. However, except for a few mentions of the cost associated with this issue (Cummings et al. 1994; Fox 2011), all references that reported damage to plant production referred only to species lists, inducing a lack in quantitative data on this impact category (Martin-Albarracin et al. 2015). Impact scores attributed to the red-vented bulbul in the study of Martin-Albarracin et al. (2015) were based on the two other impact categories. Seeds dispersal was demonstrated in three studies that explored the dispersal pattern of invasive plants such as *M. calvescence*. But these studies were all conducted in French Polynesia, and concluded that seed dispersal networks are complex and the interactions between native and alien plants and birds depend on both the frugivore community and on the relative abundance of available fruit (Spotswood et al. 2012). Negative impacts through competition also gain mention in three studies. Particularly, the aggressive behavior of red-vented bulbul was reported in Fiji and French Polynesia. In Tahiti, its aggressiveness toward adults of Tahiti monarchs (*P. nigra*) combined with predation by black rats (*Rattus rattus*) has contributed substantially to the decline in abundance of the critically endangered monarch species (Thibault et al. 2002). However, the same author reported that the main cause of the Tahiti monarch decline was predation by the black rat. The red-vented bulbul was blamed as a strong competitor because of its aggressive behavior, but rats, cats, and other bird species such as the common myna are also recognized as chick predators or nest competitors (Blanvillain et al. 2003; Ghestemme 2011). According to Saavedra (2012), the combined effects of the myna and red-vented bulbul were responsible for 35% of the nest failing of the Tahiti Monarch in 2012. Except for observed hybridization with its native cousins from the Pycnonotidae family in the Middle-East (Khan 1993; Nation et al. 1997), there are no reported impacts of red-vented bulbuls in continental areas (Khamis 2010; Brooks 2013). However, we reported some other potential impacts of the red-vented bulbul such as predation, hybridization, and dispersal of ecto- and endoparasites that were not included in any previous impact scoring attempts. This highlights a large knowledge gap about how the inter-specific behavior of the red-vented bulbul impacts other species. Therefore, we believe that the role of the red-vented bulbul in the decline of plant or animal species is still to be demonstrated, or at least quantified, as has been done for other major invasive bird species such as the common myna (Lowe et al. 2011).

Moreover, positive effects or ecosystem services brought by introduced red-vented bulbuls have been poorly studied in its alien range, but may compensate to some degree for noxious impacts at the local scale (Daigneault and Brown 2013). Studies conducted in the bulbul native range confirmed part of this assessment. For example, it was shown that the bulbul was effective at insect control, including eating the widespread and highly polyphagous agricultural pest *Helicoverpa armigera* (Rana et al. 2014, 2017). By doing so, they improved curd and seed yields of cauliflower. The bulbul was also found to be an efficient pollinator of *Erythrina variegata* in India (Raju et al. 2004). Finally, an anti-predator response strategy that relies on eavesdropping of the bulbul's alarm call may also benefit other species such as *Emoia cyanurea*, a species of skink that is widespread throughout Pacific islands (Fuong et al. 2014). These few examples suggest that positive impacts may partly counterbalance the three categories of negative impacts attributed to the red-vented bulbul depending on the environment where the species occur.

For this reason, local-scale surveys led by Daigneault and Brown (2013) are crucial to inform local farmers and environment managers. We found few published studies dealing with the local management of the red-vented bulbul in its alien range. One is the biosecurity protocol currently in place in New Zealand (Watling 1978) that illustrates the efficiency of locally preventing alien species introductions on reducing their dispersal (Edelaar and Tella 2012). A test of bird repellents on Hawaiian orchids and papaya production demonstrated the efficiency of three chemicals (Cummings et al. 1994). In their study exploring the efficiency of bird repellent methods in the bulbul native range, Patyal and Rana (2003) highlighted nets as the most efficient methods although it can be costly to implement on large orchards. In their overview of birds impacts on Indian agriculture, Kale et al. (2012) reviewed the existing repellant techniques used against birds including the red-vented bulbul, and underlined two main limits to their use being (1) social and ecological issues associated with killing birds and (2) danger of most chemical repellants for the biodiversity. This suggest that preventing damages of the red-vented bulbul on plants is feasible and that the investment intensity and the method used mostly depends on local communities. On the other hand, preventing impacts on seed dispersal and native fauna will rely on bird control programs and we found no feedbacks of such operations from the red-vented bulbul alien range yet. Results of the control programs currently in course in French Polynesia will certainly contribute to fill this gap (Saavedra 2013). In comparison, 13 eradication programs were conducted on islands against the common Myna and two against the red-whiskered bulbul that were mostly successful (DIISE 2015). Thus, more research is needed in the countries were the bulbul was introduced to evaluate threats associated with this species and guide adapted management strategies. Priority should be given to captive and field assessments of its diet and foraging ecology in its alien range. This would allow more accurate determination of the range of resources it uses and its prey (Bhatt and Kumar 2001), its role in seed dispersal (Spotswood et al. 2012), and its interspecific relationships (Bates et al. 2014).

Management strategies often rely on rigorous expert assessment and are mostly "restricted only to species for which there is already some suspicion of a threat, often an agricultural one" (Simberloff 2003). Even for suspected pests, risk assessment is often based on "anecdotal observations relating to small areas only" rather than direct scientific research (Strubbe et al. 2011). The alien range of the red-vented bulbul, mostly consisting of tropical islands, could have also contributed to the negative reputation of the bird as island ecosystems are especially sensitive to the arrival of alien species (Sax and Gaines 2008; Tershy et al. 2015). The high endemicity and naivety of insular species accentuates their vulnerability (Gerard et al. 2016; Walsh et al. 2012). This sensitivity of tropical islands towards alien species may also be reinforced with the risk that a newly established population becomes a stepping stone for further introduction events through short-distance colonization (Gillespie et al. 2012). The information we present here supports this claim, with most reported impacts of red-vented bulbul on biodiversity and plant production being from tropical islands, but even here the bulbul's reported impacts are heterogeneous and typically non-specific. This work reveal that the red-vented bulbul remains highly understudied considering its invasive and pest status. The species' long and close associations with people in its native range and subsequent transportation around the world as a cage-bird, coupled with its competitive foraging behavior (Sherman and Fall 2010), have surely contributed to its presence among the UICN-ISSG list of the world's worst invasive species, but this may well be overstated. Detailed and specific knowledge of this bulbul's impacts and the threats it poses is essential, and Kumschick et al. (2015) recently insisted on the need for such information to inform the construction of global prioritization lists. In comparison, the red-whiskered bulbul or the mallard, for example, apparently attracted a more attention from both scientists and managers.

In conclusion, we found few references on the red-vented bulbul, reflecting a less attention paid by scientists to this species compared to the other world's worst invasive species. The consideration of its negative impacts is largely influenced by few island locations whereas it is considered elsewhere as harmless, which prevent us from considering the bulbul as an absolute pest. Negative impacts led to the implementation of management programs in only one country and crop protection methods exist but are not necessarily used by local communities. Therefore, we suggest that the red-vented may not always be a dangerous pest.

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**Compliance with ethical standards**

**Conflict of interest** The authors state that they have no conflict of interest.

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