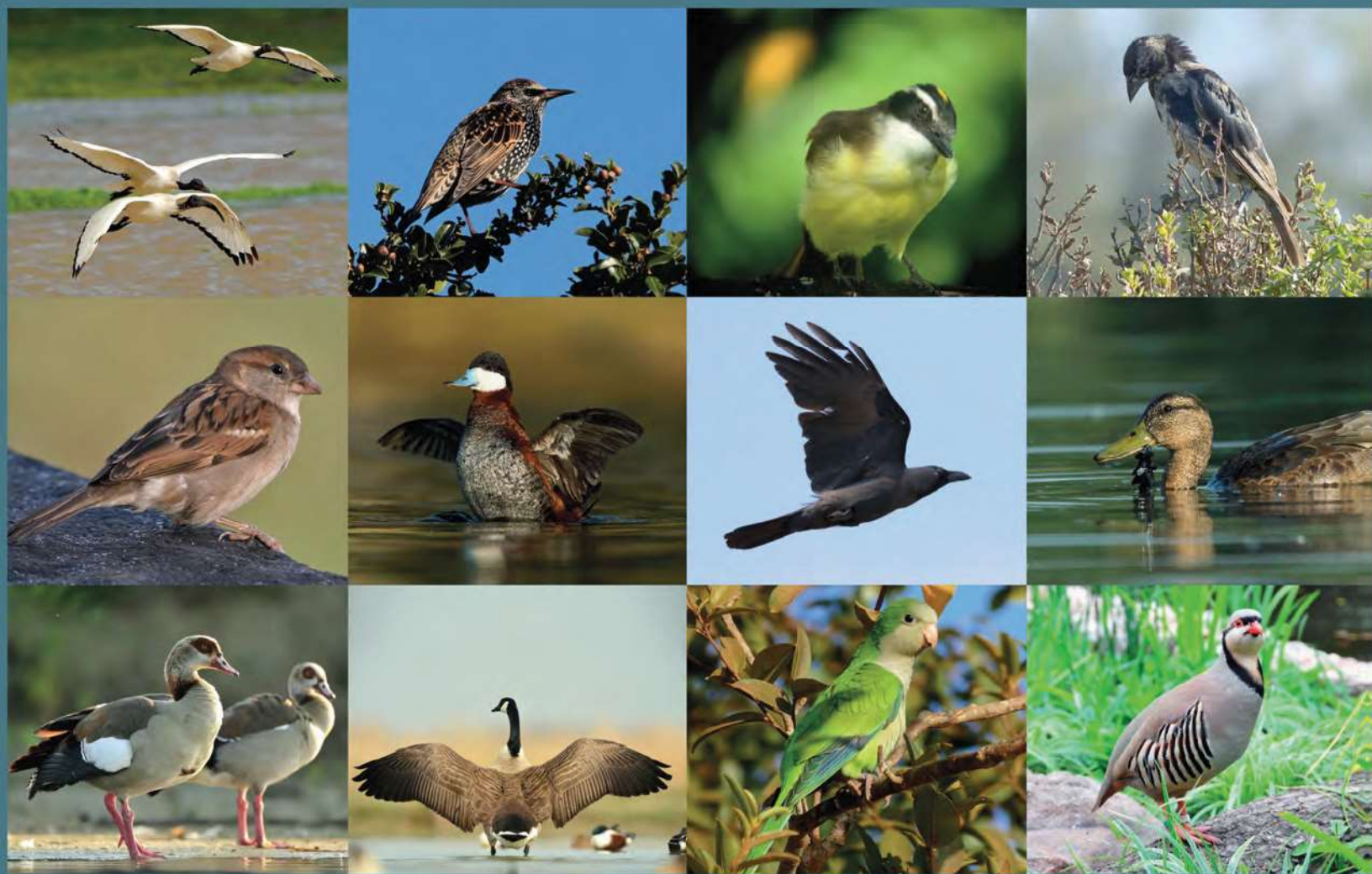


Invasive Birds

Global Trends and Impacts

Edited by **Colleen T. Downs** and **Lorinda A. Hart**



22 Northern Red Bishop (*Euplectes franciscanus* Isert 1789)

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22.1 Common Names

Franciscan Bishop, Orange Bishop, Northern Red Bishop, West Nile Red Bishop.

22.2 Distribution

The native range of the Northern Red Bishop (*Euplectes franciscanus* Isert 1789) is confined to sub-Saharan Africa (Fig. 22.1), reaching south into central Africa (BirdLife International, 2019), specifically, southern Mauritania south to northern Liberia, east to Eritrea, Ethiopia, north-western and southern Somalia, north-eastern Democratic Republic of the Congo, Uganda and Kenya (Lepage *et al.*, 2014). There are only two described subspecies: *E. f. franciscanus* in the western range and *E. f. pusillus* in the eastern range (Lepage *et al.*, 2014). However, the geographical delineation of the subspecies is thought to be unwarranted, making this species monotypic (Craig, 2010). The Northern Red Bishop is often considered a conspecific of the Southern Red Bishop (*Euplectes orix*), which is found in southern Africa, but this is not supported by molecular data (Craig, 2010). The similarities between these species may contribute to sightings of the Northern Red Bishop outside the native range through misidentification.

The Northern Red Bishop was introduced and established in Jamaica, Puerto Rico, Bermuda, Guadeloupe, Martinique and the USA (Florida, Texas, California, Arizona) (Fig. 22.1) (BirdLife International, 2019). Although they were initially introduced to Oahu, Hawaii, in 1965, they did not establish, with only occasional sightings since then around the Pearl Harbor region (Pyle and Pyle, 2017).

Much of the information in this chapter stems from data analysed from the state of Texas, USA, that were collected as part of a Citizen Science programme (Texas Invasive Bird Project: www.hmns.org/invasivebirds, accessed 30 October 2019), with methods similar to those of Conn *et al.* (2017) with dates spanning a decade (June 2008–July 2017). Of 216 sightings of Northern Red Bishops in Texas, 184 (85%) occurred in Houston and the surrounding area (Fig. 22.2). The majority occurred towards west Houston, with the highest concentrations at Addicks Reservoir/Bear Creek Park and Arthur Storey Park (Fig. 22.2).

22.3 Description

The Northern Red Bishop is around 11 cm long and weighs 12–22 g. Adult males during breeding season are all orange-red except for a black crown, mask, belly and flanks (Fig. 22.3). The wings (coverts and flight feathers), tail and thighs are brown. The tail is typically covered by red to orange uppertail and undertail coverts. The bill is thick, conical and black, and the legs are pale brown to flesh-coloured. The adult males during the non-breeding season are brown with dark streaks in the centre and paler edges of the feathers and are indistinguishable from females except in size, with females being smaller. Females also have a yellowish supercilium

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Fig. 22.1. Global distribution of the Northern Red Bishop (*Euplectes franciscanus*) showing the native (green) and introduced (red) ranges. (Data from Dyer *et al.*, 2017; Sullivan *et al.*, 2009).

and brown to buff lores (Fig. 22.3). The throat, belly and undertail coverts of females are white and the breast is buffy with light streaking. Female bills are brown to flesh-coloured. Juveniles are similar to females but have wider buffy feather edges until post-juvenile moult. Males do not moult into their breeding plumage until their second year.

The Northern Red Bishop's song consists of thin, squeaky notes followed by 'zee-zee-zee' buzzing and sizzling sounds. When flying, they make a rattling call and give a high-pitched 'tsip' as a contact call. Their alarm call is a harsh 'chak' sound (description information adapted from Craig, 2010).

22.4 Diet

Northern Red Bishops feed primarily on small grass seeds and some insects (Craig, 2010). They mainly consume seeds from grasses but also some crop seeds. Millet and sorghum (*Sorghum bicolor*) are preferred (Craig, 2010). Rice has been found to be a major component of their diet in regions of its native range, leading the Northern Red Bishop to be labelled as an agricultural pest. They forage mostly on the ground but will take insects in flight (Craig, 2010). During the non-breeding season,

Northern Red Bishops often form mix-species flocks with other seed-eaters such as canaries (*Serinus* spp.), estrildid finches and congeners (Craig, 2010; Brooks and Page, 2012).

In the introduced range, Northern Red Bishops are commonly found at seed feeders, especially in the winter and early spring when seeds are less abundant (Garrett, 1998; Brooks and Page, 2012). In California, they have been observed feeding on emergent aquatic vegetation (e.g. *Polygonum* spp.; Garrett, 1998). They have been observed in mixed-species foraging flocks in both California and Texas (Garrett, 1998; Brooks and Page, 2012). The largest flocks of Northern Red Bishops in Houston occur between May and June, when flock sizes peak, averaging 19 birds in June (Fig. 22.4). Absolute peak flock sizes ranged from 40 individuals (November 2011) in a residential area to 70 (August 2009).

Foraging is the most frequent behaviour of Northern Red Bishops in Texas, accounting for 38% of all behaviour, followed by perching/resting at 26% and other activities (Fig. 22.5).

22.5 Introduction and Invasion Pathways

The Northern Red Bishop is a popular cage bird in the international pet trade and escaped and/or released birds are the

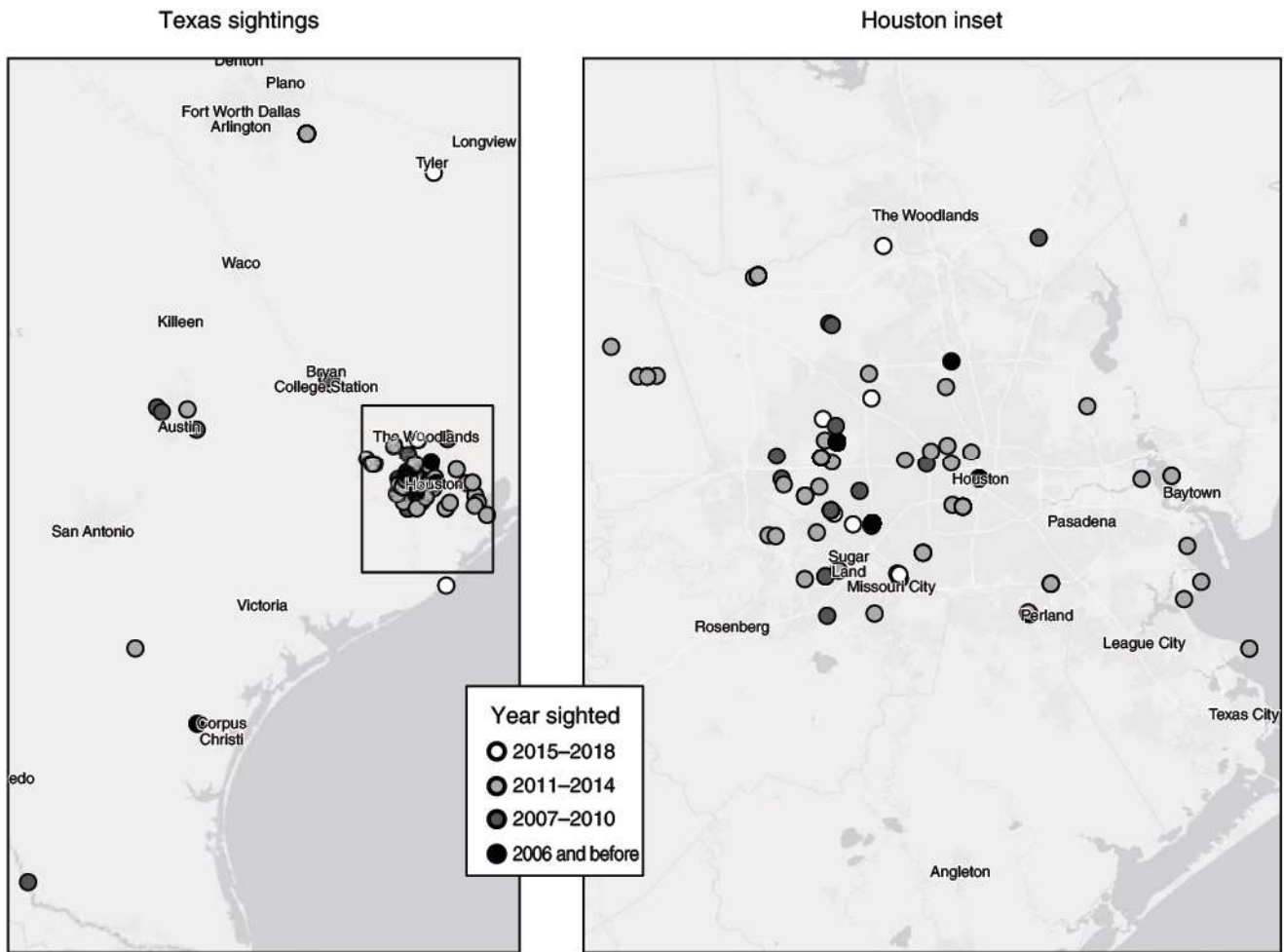


Fig. 22.2. Distribution of Northern Red Bishops in Texas, USA, and the city of Houston (inset), June 2008–July 2017.



Fig. 22.3. Male Northern Red Bishop in breeding plumage (left) and female (right). (©Photograph: Mark Lear.)

likely introduction pathway, whether as escaped pets or intentionally released as part of ceremonies and rituals. The first recorded sightings of Northern Red Bishops outside the native range were in Hawaii in 1965 (Pyle and Pyle, 2017) but this

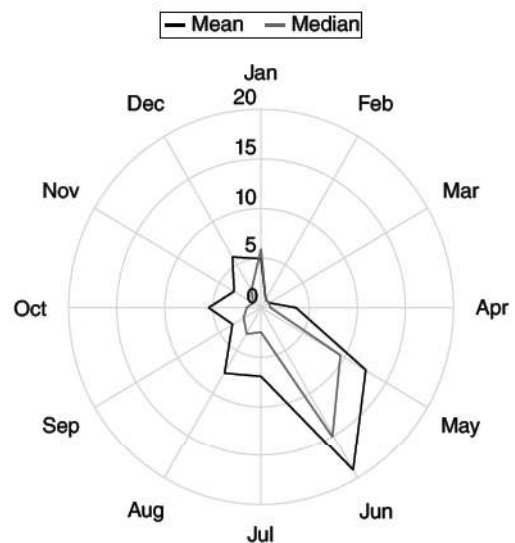


Fig. 22.4. Northern Red Bishop mean flock size by month in Texas, USA, June 2008–July 2017.

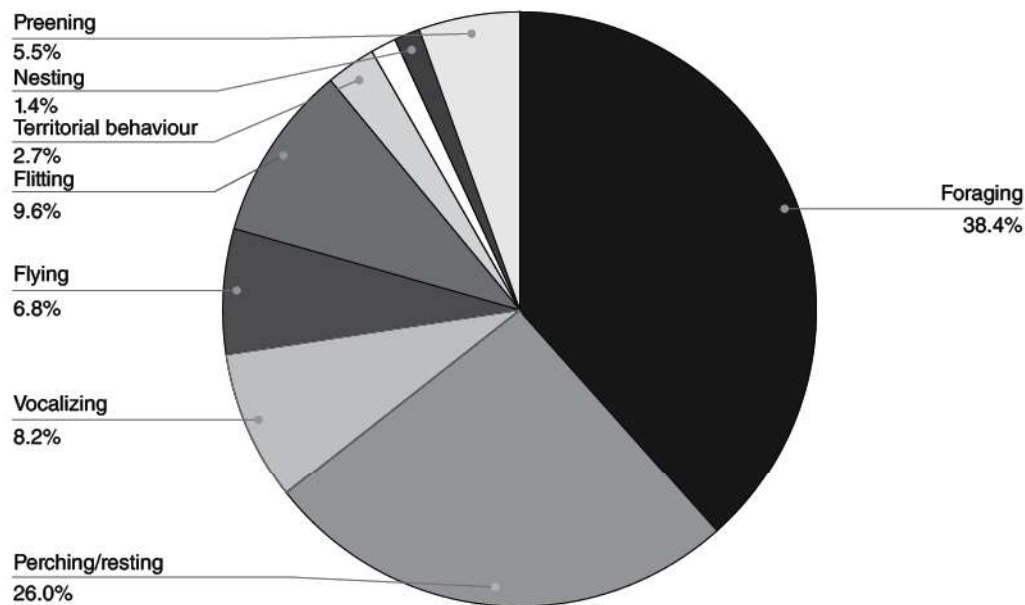


Fig. 22.5. Northern Red Bishop frequency of observed activity patterns in Texas, June 2008–July 2017.

population was unsuccessful at establishing. Later reports of Northern Red Bishops were recorded in Puerto Rico in 1972 (Long, 1981) and southern California in the 1970s (Garrett, 1998), where breeding populations have established. An established population was also reported in Arizona in 1998 (Dunn and Alderfer, 2008). They were not reported in Texas until 2002 and have been suspected of breeding since 2005 (Lockwood and Freeman, 2014). The population in Houston appears to be expanding over time (Fig. 22.2).

22.6 Breeding Behaviour

In their native range, Northern Red Bishops breed during various periods between February and November depending on location. For instance, in the most western part of the range (Gambia and Senegal), they breed from August to November, and the initiation and duration of the breeding season moves earlier in the year and longer along an eastward cline. The furthest eastern populations in Ethiopia breed in May–September. There are a few exceptions to this trend, with populations in Niger breeding in October, populations in Sudan breeding from February to March, and August to November, and populations in Somalia breeding in April and July (native range breeding periods adapted from Craig, 2010). In central portions of their range, the initiation of the breeding period appears to coincide with the end of the wet season, and the peak of breeding occurs during the start of the dry season (Cox *et al.*, 2013).

Northern Red Bishop males are territorial and are thought to be similar in behaviour to the Southern Red Bishop, which often defend their territories through direct confrontations (Craig, 1974). However, territories may be clustered (Craig, 2010). When females are observed in their territories, the male will display by ‘bumble-flying’ – flights within the territory

where the male puffs its feathers and beats its wings slowly (Delacour and Edmond-Blanc, 1933). During these flights, the wings may make distinctive sounds (von Boetticher, 1952). The males of Southern Red Bishops will court any conspecific with brown plumage, regardless of whether it is an immature bird or female (Craig, 1974), and since the courtship of both species is so similar, this may also be the case for the Northern Red Bishop. Indeed, captive males have attempted to copulate with immature males (Craig, 1974). The Northern Red Bishop is polygynous and can have up to five females in a harem (Craig, 2010).

Northern Red Bishop nests are globular with a side entrance woven from coarse grass strips by the male. The nest is then lined by the female with grass flower heads (Craig, 2010). The nests are typically placed in grass, weeds and crops 1–2 m from the ground, and occasionally in bamboo, shrubs and small trees 3–6 m from the ground (Craig, 2010). The density of nests in millet is reported to be ten times greater than nest densities found in wild grasses (Craig, 2010). Clutches range from two to four blue eggs and are incubated only by the female for a period of 13–14 days (recorded in captivity; Craig, 2010). Nestlings are also only cared for by the female and typically fledge after 14–16 days.

In the introduced range, Northern Red Bishops breed in August–November in California, with nests averaging 1.1 m high (Garrett, 1998), and may be tied to the seeding *Echinochloa* spp. grasses and other important food resources (Smithson, 1997). Females possibly only produce one clutch of two to three eggs per year in California (Smithson, 1997). In the West Indies, they breed from March to November in grassy edges of sugarcane fields (Craig, 2010). In Texas, the male breeding plumage was observed with greatest frequency during summer and autumn (June–November; Fig. 22.6). While there was a single sighting of partially coloured plumage during winter and spring, the majority were in the autumn (Fig. 22.6). Full-coloured

breeding plumage was only observed during the summer and autumn, with more sightings in the summer (Fig. 22.6).

Instances of territorial behaviour, reproductive behaviour and interspecific interactions were also observed during late summer (July–September) when most breeding plumage males were observed (Fig. 22.7).

22.7 Habitat

In their native range, Northern Red Bishops are commonly found in tall, open grasslands that can have some shrub encroachment (Craig, 2010). They are also found in tall crops and margins of agricultural lands. Some agriculture that they have

been associated with includes rice in Mali, sugarcane in Mauritania, millet in Sudan and maize in Ethiopia (Craig, 2010). In the eastern portion of their native range, they can be found at elevations of between 600 and 1800 m above sea level (a.s.l.) (Stevenson and Fanshawe, 2004), and in Ethiopia they can be observed at up to 2000 m a.s.l. but are also found in lowlands and coastal regions (Craig, 2010).

Northern Red Bishops were never observed in forest habitat during a study in Puerto Rico (Irizarry, 2012), and are thought to be associated mainly with the grassy margins of sugarcane fields in the West Indies (Craig, 2010). In California and Arizona, they inhabit weedy areas, river channels, flood basins and river bottoms (Garrett, 1998; Dunn and Alderfer, 2008). They are especially associated with *Echinochloa* spp.

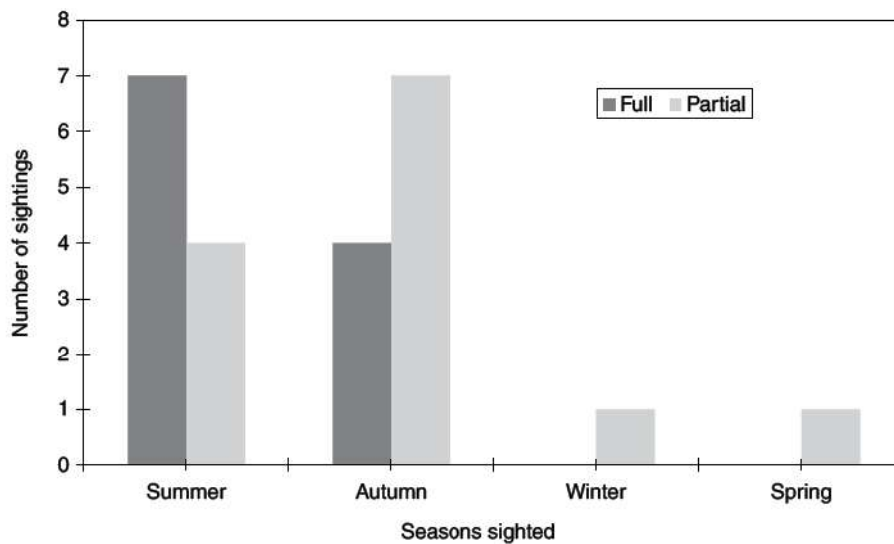


Fig. 22.6. Northern Red Bishop male breeding plumage sightings by season in Texas, June 2008–July 2017.

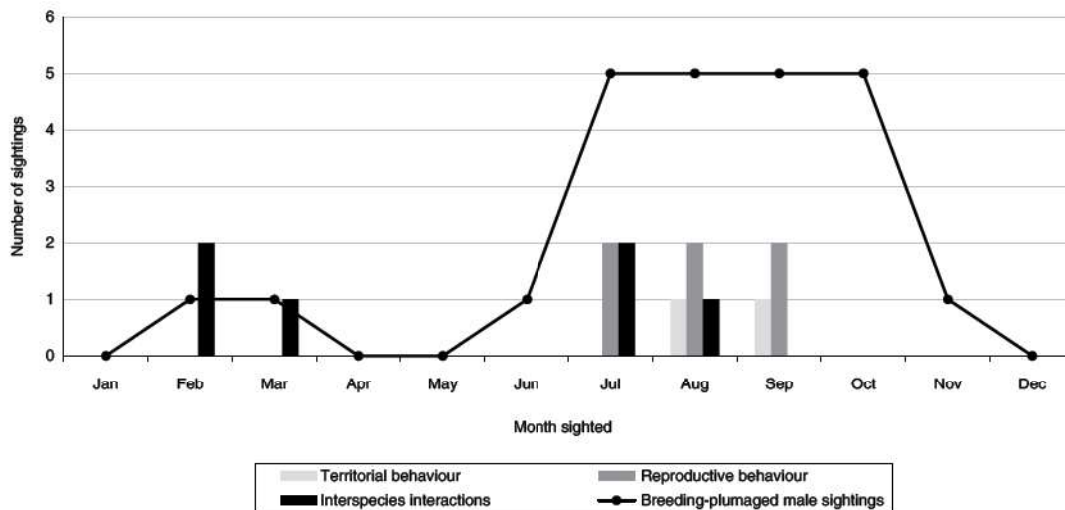


Fig. 22.7. Northern Red Bishop plumage synchronization with behaviour in Texas (June 2008 – July 2017).

grasses in California (Smithson, 1997). In Texas, they have been observed around urban and suburban habitats, including mowed fields, grassy edges of woods and golf courses, and ponds and river banks with high densities of reeds (Brooks and Page, 2012). In Texas, they are now moving away from their preferred habitat with maturing seed heads of approximately 3 m in height to supplementary feeders (Brooks and Page, 2012).

In terms of microhabitat selection in Texas, of the 20 identified types of plants used for perching by the Northern Red Bishop, 35% ($n = 7$) were native to Texas, 45% ($n = 9$) were exotic species that occur outside of the native range of the Northern Red Bishop (Table 22.1), and 20% ($n = 4$) were indeterminate. Wild sunflower (*Helianthus* spp.; $n = 4$) and cattails (*Typha* spp.; $n = 4$) were the most frequent types of identified plant used for perching. Feeder perches ($n = 5$; Table 22.1) were the most used of the abiotic perch types

observed. Of the 69 total biotic and abiotic perches, average reported perch height was 2.28 m off the ground. High perches were generally preferred (low perches ≤ 1.5 m: $n = 23$; high perches > 1.5 m: $n = 35$) by Northern Red Bishops.

22.8 Impacts

In some areas of their native range, Northern Red Bishops are considered agricultural pests due to their foraging on and breeding in crops (e.g. Somalia) (Craig, 2010). In Texas, introduced Northern Red Bishops were found to be non-aggressive towards other species in ten interspecific interactions (Table 22.2). Two of the species – the Orange-cheeked Waxbill (*Estrilda melpoda*) and House Sparrow (*Passer domesticus*) – were also introduced (Table 22.2).

Table 22.1. Northern Red Bishop perch use in Texas.

Latin Name	Plant/Object	Origin	Reports	Height (m)	≤ 1.5 m	> 1.5 m	No data
<i>Anisacanthus wrightii</i>	Flame Acanthus	N	1				X
<i>Rhododendron</i> sp.	Azalea	N/EO	1				X
<i>Callistemon</i> sp.	Bottlebrush	EO	1	4		X	
<i>Verbena brasiliensis</i>	Brazilian Vervain	EO	1	1.3	X		
<i>Heterotheca subaxillaris</i>	Camphorweed	N	1	1.3	X		
<i>Typha</i> sp.	Cattails	EO	4	2.65		X	
<i>Triadica sebifera</i>	Chinese tallow	EO	1	1	X		
<i>Trifolium</i> sp.	Clover	N/EO	1		X		
<i>Lagerstroemia</i> sp.	Crape Myrtle	EO	3	3		X	
<i>Cupressus</i> sp.	Cypress	EO	1	1	X		
<i>Chilopsis linearis</i>	Desert willow	N	1				X
<i>Linum</i> sp.	Flax	N/EO					X
<i>Celtis occidentalis</i>	Hackberry	N	2	3.6		X	
<i>Hamelia patens</i>	Hummingbird bush	EO	1				X
<i>Ilex</i> sp.	Holly Bush	N/EO	2	3		X	
<i>Quercus</i> sp.	Oak	N	3	3.5		X	
<i>Nerium oleander</i>	Oleander	EO	2				X
<i>Quercus palustris</i>	Pin Oak	EO	1	2		X	
	Unidentified grass		16	1.01	X		
	Unidentified rose		1				X
	Unidentified shrub		2	3.1		X	
	Unidentified tree		5	1.56		X	
<i>Helianthus</i> sp.	Wild sunflower	N	4	1.57		X	
<i>Salix</i> sp.	Willow	N	2	3		X	
	Abiotic Perches						
	brush pile		1	1.5	X		
	electrical wires		1				X
	feeder		5	2.03		X	
	fence		2				X
	metal post		1				X
	purple martin			4.5		X	
	birdhouse		1				
	shepards hook		1	1.1	X		

N = Native Texas Plant

EO = Exotic plant whose native range lies outside the native distribution of the northern red bishop

Table 22.2. Northern Red Bishop interspecific foraging behaviour in Texas, USA.

Common name	Latin name	No. passive observations	Introduced
House Sparrow	<i>Passer domesticus</i>	2	✓
Orange-cheeked Waxbill	<i>Estrilda melpoda</i>	1	✓
Indigo Bunting	<i>Passerina cyanea</i>	2	
Painted Bunting	<i>Passerina ciris</i>	2	
Northern Cardinal	<i>Cardinalis cardinalis</i>	1	
Unidentified species		2	
Total	5 species	10	

22.9 Control

No control initiatives have been reported for Northern Red Bishops.

22.10 Uses

The Northern Red Bishop is sold in the world pet trade as a cage bird (BirdLife International, 2019).

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23 Warbling White-eye (*Zosterops japonicus* Temminck & Schlegel 1845)

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reclassification and the merger with *Z. montanus*, 15 are now recognized: *Z. j. japonicus*, *Z. j. loochooensis*, *Z. j. diatoensis*, *Z. j. stejnegeri*, *Z. j. alani*, *Z. j. insularis*, *Z. j. montanus*, *Z. j. whiteheadi*, *Z. j. halconensis*, *Z. j. parkesi*, *Z. j. pectoralis*, *Z. j. diuatae*, *Z. j. vulcani*, *Z. j. difficilis* and *Z. j. obstinatus* (Lim *et al.*, 2019; IOC, 2019).

23.1 Common Names

Warbling White-eye, Japanese White-eye, Mountain White-eye, Daito White-eye, Oriental White-eye, Everett's White-eye, Enggano White-eye, Swinhoe's White-eye, Hume's White-eye, Sangkar White-eye, Ashy-Bellied White-eye, Javan White-eye, Mejiro (Japanese).

23.2 Nomenclature

It should be noted that White-eyes (*Zosterops* spp.) from the eastern hemisphere are regarded as having the fastest diversification rates among birds, which gave rise to naming the family as the 'great speciators' by Cornetti *et al.* (2015). The Warbling White-eye (*Zosterops japonicus* Temminck & Schlegel 1845) has recently been rearranged along with two other white-eye species from the eastern hemisphere: the Oriental White-eye (*Z. palpebrosus*) and Mountain White-eye (*Z. montanus*) (IOC, 2019; Lim *et al.*, 2019). These species, originally set apart by plumaged features, have now been shown to have phylogenetic variability and have undergone a rearrangement into five species: the Oriental White-eye (*Z. palpebrosus*), Swinhoe's White-eye (*Z. simplex* – *Z. japonicus* and *Z. palpebrosus* variations merged), Javan White-eye (*Z. melanurus* – variation split off from *Z. palpebrosus*), Citronella White-eye (*Z. citronella* – variation split off from *Z. palpebrosus*) and Warbling White-eye (*Z. japonicus* – *Z. montanus* merged into the *Z. japonicus* group) (Fig. 23.1) (Lim *et al.*, 2019). There were previously eight subspecies of *Z. japonicus*, and the

23.3 Distribution

The natural distribution of the Warbling White-eye extends from Japan and east Asia to the Greater Sundas, Lesser Sundas and Philippines, Borneo and Indonesia, as recent merges in species variations have suggested (Fig. 23.2) (Lim *et al.*, 2019). Previously, distribution ranges included parts of mainland China and Thailand (Lim *et al.*, 2019), which is now the distribution for the suggested new species *Z. simplex*. The Warbling White-eye (*Z. japonicus*) was introduced into Korea and on to the islands of Hawaii where it has become invasive, with the potential to invade other parts of the Central Pacific and Australasia (Scott *et al.*, 1986).

23.4 Description

As with all white-eyes, the Warbling White-eye has a diagnostic bold, white eye-ring with an overall greenish appearance and shows no sexual dimorphism (Fig. 23.3) (Lekagul and Round, 1991). The throat and undertail coverts are a pale lemon yellow, with the upper-parts of the bird being olive-green with less yellow (Smythies, 1953). The feet and legs are black, with a black slightly down-curved bill that extends from a narrow yellow band on the forehead (Smythies, 1953; King and Dickinson, 1991). Juvenile birds are similar to adults; however, they have a fainter eye-ring (Robson, 2015). They are small songbirds, 10–12 cm in body length and weighing

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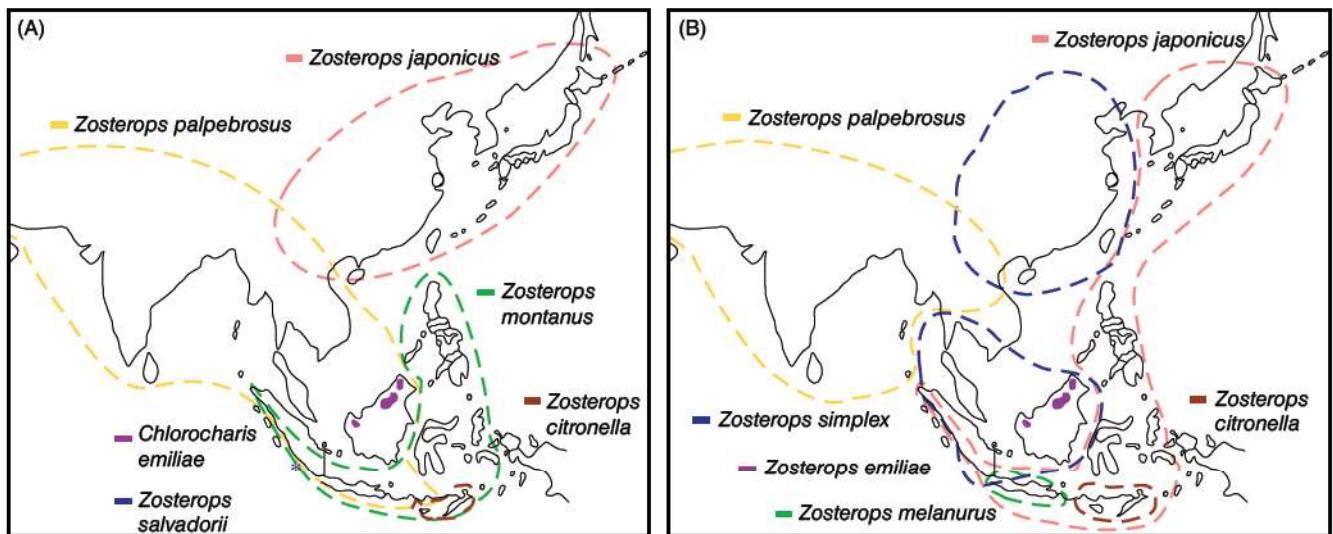


Fig. 23.1. (A) Natural distribution range of the three known *Zosterops* spp. affecting the reclassification of *Z. japonicus* (*Z. palpebrosus*, *Z. japonicus*, *Z. montanus*), with other species depicted that underwent similar reclassification. (B) ranges of the new suggested species with *Chlorocharis emiliae* and *Z. salvadorii* being classified under *Z. emiliae* and still separated from *Z. japonicus*. (From Lim *et al.*, 2019.)

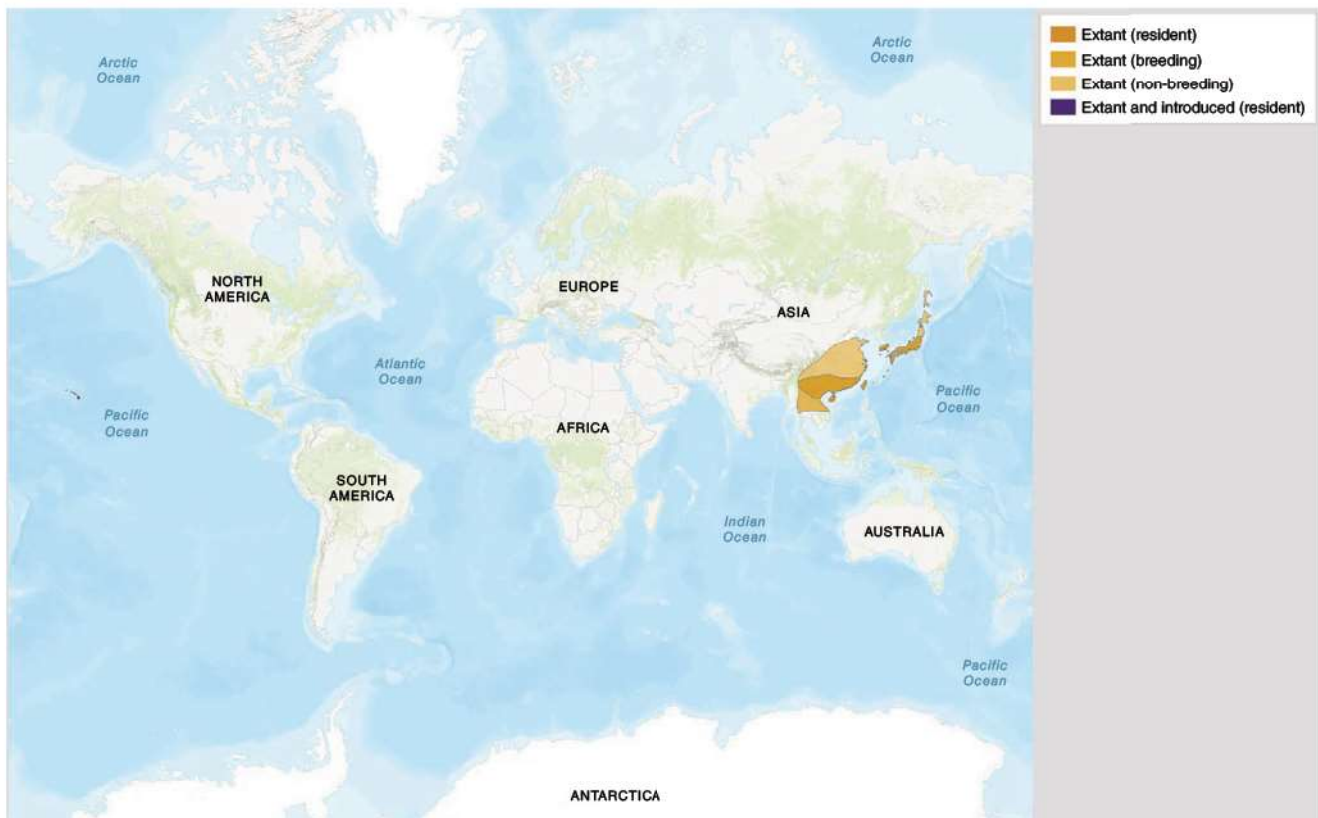


Fig. 23.2. Global distribution of the Warbling White-eye (*Zosterops japonicus*) and its introduced distribution depicted in the Central Pacific Islands including Hawaii (IUCN 2020). The distribution of the new arrangement is slightly different here compared with previous analysis, and because of the recent rearrangement, few databases have been updated (see Lim *et al.*, 2019 and Fig. 23.1).



Fig. 23.3. An adult Warbling White-eye. (©Photograph: James Eaton, Birdtour Asia.)

9.75–12.75 g (Brazil, 2018). Tables of morphological variations can be found in Lim *et al.* (2019). They often occur in flocks of five to 20 birds and are noisy with a simple high-pitched call (Pratt *et al.*, 1987). They are active and acrobatic by nature as they glean leaves and twigs in the canopy of trees and shrubs (Robson, 2015).

23.5 Diet

Warbling White-eyes are predominantly insectivorous, their stomach contents have shown them to be opportunistic with a diverse diet including, insect larvae, tiny fruit and nectar from flowers (MacKinnon and Phillipps, 2000; Gruner, 2004; Wada *et al.*, 2012).

23.6 Introduction and Invasion Pathways

All Asian white-eye species are regularly captured from wild populations across their range for the pet trade as a sought-after songbird (Scott *et al.*, 1986; Eaton *et al.*, 2015; Lewis 2017). This is jeopardizing wild populations of other white-eye species, particularly the Javan White-eye, which is regarded as the most heavily traded bird species in the world and is being threatened to extinction through trade (Lim *et al.*, 2019). The pet trade has brought the Warbling White-eye to many of the South and Central Pacific Islands (Kawakami and Higuchi, 2003). The invasive populations on the Hawaiian Islands are said to have come originally from the Warbling White-eye species group (*Z. japonicus*), introduced in 1929 as a pest control for crops on the islands. They have since invaded the surrounding islands in the Central Pacific through natural dispersion (Ely, 1971; Shallenberger, 1978).

23.7 Breeding Behaviour

Guest (1973) gave a detailed record of the breeding biology of Warbling White-eyes within an urban environment. The breeding season ranges from February to December, with a heightened period in July and August, where they form monogamous pairs and are highly territorial when nesting. Pairs are said to form during the non-breeding season where flocks of 20 can be seen together (Robson, 2015). They will lay two to five (average 3.1) pale blue eggs that take around 11 days to incubate, and both sexes share parental responsibility (Guest, 1973). The fledging period is approximately 20 days. Their nests are found at various heights above the ground in trees neatly nestled into a fork of a branch resembling a woven basket (average 56 mm in diameter, 41 mm deep) (Guest, 1973). Nesting material is diverse composing of grass, string, tin foil, leaves, moss and spider webs/cocoons. Nesting pairs hold on average an area of 6.5 ha, which is variable based on the availability of food to them; this could be smaller in natural areas where food is in higher abundance. Nesting pairs are tolerable to disturbances around the nest and unphased by the presence of other bird species nesting in proximity. The success rate from egg to fledging is high for such a small, altricial, tropical bird at 58.6% (Guest, 1973). Failure of nesting can be attributed to bad weather, poor nest construction, and interference by animals and humans. Furthermore, the adaptability of bettering a nest location after interference has been shown for this species (Guest, 1973; Horie and Takagi, 2012). Tables of nest measurements can be found in Guest (1973).

23.8 Habitat

Warbling White-eyes are habitat generalists. They occupy a wide range of tropical woody habitats and even persist in vegetated urban environments (Guest, 1973; Robson, 2015). Within their natural range, they occupy deciduous forest through to tropical rain forests but prefer open wooded habitats (Kurosawa and Askins, 2003). They frequent tree tops and canopies of rain forests, extending into secondary forest and shrubs and even coastal mangroves (Robson, 2015). They occur over a wide range of altitudes extending from sea level up to the treeline between 1525 and 1820 m in elevation, provided there is enough woody structure available to them (Robson, 2015).

23.9 Impacts of Species

23.9.1 Economic impact

Ironically, the Warbling White-eye, originally introduced on to the Hawaiian Islands to control insect pests on crops is now regarded as a crop pest itself, receiving the second highest number of complaints from farmers and affecting a wide range of crops from fruits to orchids (Koopman and Pitt, 2007).

23.9.2 Interspecific relationships with native species

The Warbling White-eye is considered to be the most abundant bird species in Hawaii and is regarded as a habitat generalist (Scott *et al.*, 1986; Boelman *et al.*, 2007). As a consequence, the Warbling White-eye competes directly for resources with native birds with similar niche guilds, many of which are faced with extinction, such as the Maui Creeper (*Paroreomyza montana*), the Hawaiian Amakihi (*Hemignathus virens*), the Hawaii Creeper (*Loxops mana*) and the Hawaii Akepa (*Loxops coccineus*) (Gruner, 2004; Samuel *et al.*, 2011; Rozek *et al.*, 2017). In some studies, this has been shown to negatively affect the juvenile growth rates of these native species and thus outcompete them (Freed and Cann, 2009; Rozek *et al.*, 2017). Interspecific competition was shown to negatively affect native birds because of limited resources rather than the Warbling White-eye negatively affecting their prey species (insects in this case) (Gruner, 2004). Their high abundance on the islands can be attributed to being habitat generalist and that the males improve the nest site selection over time to avoid nest predation (Horie and Takagi, 2012).

Warbling White-eyes are not specific to feeding off native plants and aid in the spread of the alien invasive plants that they frequent, threatening the native habitat suitable for native birds (Boelman *et al.*, 2007; Wu, 2012). Warbling White-eyes are found to be the most common visitor to the alien invasive fire-tree (*Myrica faya*) when in fruit (LaRosa *et al.*, 1985). Over one-third of faecal matter from Warbling White-eyes contains fertile seed from the fire-trees (Smathers and Gardner, 1979; LaRosa *et al.*, 1985; Woodward *et al.*, 1990). One positive interaction is that Warbling White-eyes, along with some other invaders, are replacing the endemic avifauna pollinators, ensuring the survival of certain endangered plants species (e.g. *Metrosideros polymorpha*) that have lost their avi-pollinators through extinctions (Chimera and Drake, 2010). Furthermore, on some islands, evidence suggests that the Warbling White-eye teaches native birds to feed off foreign food as part of their diet, as was the case for the Ogasawara Islands Honeyeater (*Apalopteron familiare*; Kawakami and Higuchi, 2003).

23.9.3 Spread of diseases to native species (avian malaria and pox)

Along with the introduction of non-native birds came avian-borne diseases to islands not adequately adapted to these diseases. The Warbling White-eye serves as a vector aiding in the spread of these diseases into isolated populations of native species, due to their high dispersal nature (Warner, 1968; Atkinson *et al.*, 2014). This is primarily in the case of avian malaria and pox (van Riper and Hansen, 2002; Woodworth *et al.*, 2005; Samuel *et al.*, 2011).

Overall, the Warbling White-eyes, because of their abundance on Hawaii and their nature as a habitat generalist, have negative effects on the islands' endemic species (Mountain-spring and Scott, 1985; Gruner 2004). In a study by Baker *et al.* (2014), the Warbling White-eye was one of ten cases where

non-native birds have been shown to drive extinction of native species, in this case due to direct competition with food resources. These effects, however, cannot be taken in isolation and are compounded by other factors such as habitat loss, invasion of mammalian species (rats) and other factors associated with island ecology (Mack *et al.*, 2000). In contrast, Lewis (2017), on the topic of naturalizing a non-native species, argued that, due to their high abundance, their presence in every habitat and their diverse food supply, the Warbling White-eye may be filling a role that might otherwise cause the loss of something not anticipated.

23.10 Control

The combination of local plants and native birds buffers the expansion of invasive plants and Warbling White-eyes, and thus intact native habitats are less susceptible to invasion by Warbling White-eyes (Boelman *et al.*, 2007). The idea behind ecological restoration through invasive eradication and minimization can limit the impact of Warbling White-eyes (Mack *et al.*, 2000; Boelman *et al.*, 2007). Predation on nests and individual birds is unlikely, unless in the presence of domestic cats (*Felis catus*), rodents and other small predatory mammals. Studies showed that native birds were more likely to be preyed on than Warbling White-eyes, as these birds have been known to adapt to predator avoidance techniques to increase their survival (Guest, 1973; Horie and Takagi, 2012). Bird trapping is being developed for the eradication of pest birds in Hawaii, where the Warbling White-eye is considered one of them (Koopman and Pitt, 2007).

23.11 Uses

Primarily, the Warbling White-eye makes an attractive caged bird as it tames well because of its gregarious nature, it has a melodious call and is a small bird (Lim *et al.*, 2019). The introduction to Hawaii, however, was because of their flocking and vigorous feeding nature that initially saw the species as a biological control for insects on the Hawaiian Islands. Its invasiveness has since then made the species unsuitable as a biological control agent (Scott *et al.*, 1986; Koopman and Pitt, 2007).

23.12 Notes

In the 1960s, the Warbling White-eye was sighted between Oahu and Johnston Atoll and on Johnston Atoll itself. These sightings were attributed as having come from the established population of Warbling White-eyes on the Hawaiian Islands (Ely, 1971). This is a remarkable distance for a bird of its size (400–1000 km depending on which part of the Hawaiian Islands), and through island hopping, it has occurred on other islands in the Central Pacific. Another interesting study on the species determined how the Warbling White-eye assisted in the dispersal of a snail species (*Tornatellides boeningi*) by ingesting these snails; the study by Wada *et al.* (2012) showed that around 14.3% of ingested snails passed through the digestive system unharmed.

23.13 References

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