Ornithol Sci 3: 57–67 (2004)

SPECIAL FEATURE Invasive bird species

Southeast Asian invasive birds: ecology, impact and management

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ORNITHOLOGICAL SCIENCE

Abstract Invasive birds can have serious impacts on native biodiversity, native ecosystems and humans. However, there is a dearth of literature on the status and effects of invasive birds in Southeast Asia. We review the current available information on the invasive bird species in Southeast Asia, first by discussing characteristics that likely make invasive bird species successful and second by reviewing the impacts of the invasive bird species on Southeast Asian economy and biodiversity. We end by discussing the strengths and weaknesses, as well as the applicability of different management options.

Key words Exotic birds, Invasions, Management, Tropics

The negative impact of invasive species on native biodiversity and ecosystems has been widely recognized for decades (Elton 1958; Lodge 1993a, b; Simberloff 1996). In addition, invasive species can be devastating for human economy (Pimental et al. 2000). Most long-distance introductions of non-native species to new areas are the direct or indirect results of human activities, and social and economic factors are often as critical as biological factors in the introduction of exotic species. Activities such as logging and grazing further enhance establishment of exotics by creating optimal habitat for colonization. Agriculture also facilitates species invasions when pests in agro-ecosystems are exposed to agricultural practices for many generations, resulting in selection for characteristics that make them persistent and noxious (Sakai et al. 2001). Southeast Asia is currently experiencing extensive development through urbanisation and deforestation (Wilson 1988; Myers 1992; Flint 1994). In light of these anthropogenic changes to the environment that can potentially precipitate future invasions of exotic species, it is important to examine the ecology, impact and management of invasive birds in Southeast Asia.

Invasive birds are defined as non-indigenous species that have spread from the point of introduction and become abundant (Kolar & Lodge 2001). Many of these species threaten local economies, human health and native biota (Kolar & Lodge 2001; McNeely 2001). In this paper, we focus on bird species that have invaded Southeast Asian countries, namely Indonesia, Malaysia, Singapore, Vietnam, Thailand, Cambodia, Laos, Burma (Myanmar) and the Philippines. A literature search using key words relevant to the topic was performed using the databases ISI Web of Science^{SM} (1988–2003) and ScienceDirect® (1966–2003), as well as from books concerning this topic. We consider all non-native bird species that have established through either natural range expansion or deliberate release. We refer to the non-native bird species that have spread from the point of introduction and established populations as invasives or exotics. By referring to species accounts by Long (1981), Lever (1987) and Robson (2000), we identified 16 species, which had invaded and established in one or more of the abovementioned countries (Table 1). The small pool of information retrieved suggested a dearth of knowledge on the invasive species of Southeast Asia. This is in contrast to the situation in Australasia (Australia, New Zealand, New Guinea and surrounding islands), which has one of the best-documented and most completely analysed datasets available on biological invasions (Brook 2004).

(Received 31 July 2003; Accepted 18 October 2003)

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Table 1. Characteristics of Southeast Asian invasive bird species.

Species	Colonised Location	Mode of Colonization	Some Species Characteristics	Relationship with humans or other species of birds
Spotted Dove *Streptopelia chinensis*	Indonesia; Philippines	Unknown.	Inhabits open forest, secondary growth, wooded and cultivated country, parks, rivers, residential and urban areas; can occur in flocks; mainly sedentary; its diet includes seeds, grain, green shoots and food scraps; multi-brooded and probably breeds throughout the year; adaptable in choice of nest site; lays 2 eggs.	Potential crop pest.
Peaceful Dove *Geopelia striata*	Thailand; Borneo; Indonesia; Philippines; Laos.	Deliberate introduction by natives.	Common cage bird; inhabits dry forest, arid scrubland, open country, cities, villages, gardens, farms and cultivated areas; can occur in flocks; sedentary and nomadic; its diet includes seeds, grain (including cultivated grain), insects, small invertebrates and food scraps; lays 2 eggs; multi-brooded, probably breeding throughout the year.	Confiding and allows close approach by humans; well-adapted to exploit human-altered habitats.
Feral Pigeon *Columba livia*	Most of Southeast Asia (with possible exception of Vietnam).	Feral.	Inhabits cities, towns, villages, farms, cliffs; can occur in flocks; sedentary; its diet includes seeds, grain, green shoots, berries, earthworms, slugs, snails; multi-brooded and breeds most of the year; lays 2 eggs; feeds young cropmilk; breeds from young age of six months.	Strong commensal ties with humans; considered nuisance because of fouling of buildings and other structures and grain with its droppings; agricultural pest; useful as food, bioindicator and for study of avian biology.
Moustached Parakeet *Psittacula alexandri*	Borneo; Singapore.	Escapee from cage.	Inhabits secondary jungle, forest, woodlands near cultivation and mangroves; can occur in flocks; sedentary; its diet includes seeds, nuts, fruits, berries, nectar blossom and leaf buds; hole-nester; lays 3 to 4 eggs.	Potential rice crop pest.
Yellow-crested Cockatoo *Cacatua sulphurea*	Singapore.	Unknown.	Inhabits open woodlands, cultivated fields and forest edges; can occur in flocks; its diet includes seeds, nuts, berries, fruits; hole-nester; lays 2 to 3 eggs (in captivity).	
House Crow *Corvus splendens*	Malaysia; Singapore.	Released as a biological controller of pests; Natural expansion.	Inhabits plains, mangroves, villages, towns and cities; can occur in flocks; sedentary; its diet is omnivorous and includes insects, termites, locusts, grain, nectar, fruit, offal, carrion, eggs, and young birds; useful scavenger; lays 3 to 6 eggs; solitary or colonial nester; nests on variety of substrates; roosts communally in hundreds.	Potential crop pest; attacks small birds and eats their eggs; competes with native species and destroys their nests and eggs; communal roosts annoy residents.
Common Myna *Acridotheres tristis*	Vietnam; Malaysia; Singapore; Thailand.	Natural expansion; Introduction.	Inhabits primarily human habitation, also open country, forest edges, agricultural land, gardens, orchards, towns, cities and villages; can occur in flocks; roosts communally in large flocks; sedentary; its diet is omnivorous and includes fruits, grain, seeds, berries, insects, earthworms, flower nectar; multi-brooded; hole-nester; lays 3 to 6 eggs.	Possible crop pest; largely commensal with man; considered possible biological controller of insect pests, but at other times cause damage to orchard fruit and standing cereal crop but does not affect cultivated fruits much; may compete for nesting holes with native bird species

Table 1. (Continued)

Species	Colonised Location	Mode of Colonization	Some Species Characteristics	Relationship with humans or other species of birds
White-vented Myna *Acridotheres javanicus*	Singapore; Malaysia.	Escapee from cage; Natural expansion from Singapore.	Inhabits cities and cultivated areas; opportunistic and its diet is omnivorous including seeds, fruit (including cultivated fruit), nectar, insects, animal matter, human refuse; sedentary; can occur in flocks; hole-nester; adaptable in choice of nest site; roosts communally in hundreds; adaptable in choice of nest substrate; lays 2 to 5 eggs.	Tolerant of humans; disturbs human residents near communal roosts; faecal droppings foul buildings and cars.
Crested Myna *Acridotheres cristatellus*	Malaysia; Philippines.	Released as a biological controller of pests.	Common cage bird in native range; inhabits plains, cultivated areas, fields, open country, parklands, villages, suburban gardens, orchards; mainly found on the ground where it frequently feeds in grassland, often among cattle; can occur in flocks; sedentary; its diet includes insects, worms, slugs, snails, mussels, fruits, nuts, grains; multi-brooded; hole-nester; may sometimes nest colonially; lays 4 to 7 eggs; roosts communally, sometimes in hundreds.	Considered by some to be a crop pest.
Sooty-headed Bulbul *Pycnonotus aurigaster*	Sumatra.	Unknown.	Common cage bird; inhabits secondary growth, open forest, scrub, gardens, parks, roadsides; can occur in flocks; its diet includes insects, fruits, nuts; multi-brooded; lays 2 to 6 eggs.	Has both beneficial and harmful impacts on the agricultural and forestry industry.
Red-whiskered Bulbul *Pycnonotus jocosus*	Singapore.	Escapee from cage.	Common cage bird; inhabits forest edges, secondary growth, woodlands, cultivation, parklands, gardens, villages; can occur in loose flocks; roost communally; sedentary; its diet includes fruits, berries, seeds, flowers, nectar, insects, caterpillars, ants, seedlings; multi-brooded; lays 2 to 4 eggs.	Causes some damage to fruits and vegetable gardens in Thailand and other countries; but also destroys insects in other countries; has both beneficial and harmful impacts on agriculture.
White-crested Laughingthrush *Garrulax leucolophus*	Singapore.	Unknown.	Inhabits thickets, forest undergrowth, secondary growth, bamboo jungle, scrub country bordering cultivation; can occur in flocks; sedentary; insects, berries, seeds, small reptiles, nectar; multi-brooded; lays 2 to 6 eggs.	
Eurasian Tree Sparrow *Passer montanus*	Philippines; Indonesia; Malaysia.	Accidental.	Inhabits wooded regions, open fields, grasslands, parks, gardens, orchards, villages, towns; can occur in flocks; roosts communally; mainly sedentary in Asia; its diet includes seeds, rice and other grains, insects; multi-brooded; lays 4 to 8 eggs; often colonial nester; versatile in nest site selection.	Potential grain crop pest.
Red Avadavat *Amandava amandava*	Sumatra.	Escapee from cage.	Common cage bird; inhabits wet grasslands, reeds, secondary growth, scrub, gardens, villages, cultivation (especially rice fields); can occur in flocks; sedentary; its diet includes seeds, grains, insects; lays 4 to 10 eggs.	Potential rice crop pest.

Table 1. (Continued)

Species	Colonised Location	Mode of Colonization	Some Species Characteristics	Relationship with humans or other species of birds
Scaly-breasted Munia *Lonchura punctulata*	Singapore.	Escapee from cage.	Common cage bird; inhabits secondary growth, open and timbered grassland, cultivated areas, ricefields, gardens, villages; will also feed in rubbish dumps and on roadkills; can occur in flocks; roosts communally; sedentary and nomadic; its diet includes seeds, rice, berries, insects; multi-brooded; colonial nester; adaptable in choice of nest-site; lays 4 to 10 eggs.	Rice crop pest.
Java Sparrow *Padda oryzivora*	Vietnam; Burma (Myanmar); Thailand; Indonesia; Philippines.	Escapee from cage.	Common aviary bird; inhabits rice fields, villages, cities, mangroves, scrub; largely associated with humans; can occur in flocks; sedentary; its diet includes corn, seeds, cultivated grains, insects; colonial nester; lays 4 to 8 eggs.	Potential rice crop pest.

NB: The information in the table was compiled from the following sources: Pinowski & Kendeigh (1977); Long (1981); Hails (1985); Lever (1987); Kang et al. (1990); Dickinson et al. (1991); Kang (1992); Madge & Burns (1994); Johnston & Janiga (1995); Pell & Tidemann (1997); Restall (1997); Feare & Craig (1999); Robson (2000); Gibbs et al. (2001); Peh & Sodhi (2002).

SOME COMMON CHARACTERISTICS OF INVASIVE SPECIES

Life history and ecological attributes are important influences on introduction success, and an understanding of them can be useful in the development of management strategies for invasive bird populations and of predictive models for bird invasions, which can identify high-risk species that require more attention concerning their intentional introduction (Johnston & Janiga 1995; Cassey 2002). Specific characteristics can assist a species in establishing in a new area (Mayr 1965; Duncan et al. 2003). The invasive birds listed in Table 1 show some characteristics that individually or collectively enhance the survival and reproductive success of invasive bird species and thus may have helped in their colonization, establishment and spread. We discuss these characteristics with reference to Southeast Asian invasive bird examples.

All the identified invasive species show social behaviour, such as facultative colonial nesting, communal roosting, and congregation at food sources. The likely benefits of this social behaviour include enhancement of predator avoidance, foraging, reproductive and locomotive efficiency (Johnston & Janiga 1995). Among colonists in man-made habitats, granivores are conspicuously more successful than insectivores. For example, the Feral Pigeon *Columba livia*, Scaly-breasted Munia *Lonchura punctulata*, Spotted Dove *Streptopelia chinensis*, Peaceful Dove *Geopelia striata* and Eurasian Tree Sparrow *Passer montanus* are largely granivorous. This suggests that seeds may be a more amply available food resource in areas modified by humans. The birds listed show flexibility in the use of nest-sites. The White-vented Myna *Acridotheres javanicus* and the Common Myna *A. tristis* for example, use a wide variety of nest holes such as holes in the trunk of trees, drainage holes in retaining walls, holes in buildings, bridges and crevices in other structures such as lamp-posts, air-conditioners, ventilators and disused vehicles (Kang et al. 1990). All the identified species show habitat flexibility, a character that has been shown to increase the likelihood of successful avian invasion (Cassey 2002). Most of them can be found in man-altered habitats, such as agricultural land, villages and towns, or other disturbed habitats such as secondary growth, scrub and wooded country. This is in contrast to the invasion pattern seen in Hong Kong, another part of tropical East Asia, where most of the recent invaders are forest species. These differences in colonized habitat have been attributed to differences in recent patterns of habitat change by humans in Southeast Asia and Hong Kong (Leven & Corlett 2004). Many of the Southeast Asian invasive species, such as the Crested Myna and the White-crested Laughingthrush, are multi-brooded and sedentary, resulting in high bird densities. Jones (1996) suggested that successful invasive birds had high reproductive rates and maintained high flock densities. Some species such as the Feral Pigeon are capable of breeding throughout the year, partly because they rely on seeds as their major food source, which are available throughout the year. They can also breed successfully at an early age (Dorzhiev 1978; Johnston & Johnson 1990). Breeding at an early age and throughout the annual cycle may result in high reproductive rates and help these species to spread in colonized areas. Columbids such as the Feral Pigeon also feed their young on regurgitated crop milk (seeds mixed with secretions from the crop). This habit bypasses the routines of normal altricial birds of hunting for high-protein arthropods, whose availability may vary stochastically, to feed their young (Johnston & Janiga 1995).

Ricklefs (1969a, b) pointed out that hole-nests suffer less mortality, both in terms of individual and whole nest losses, than do open nests. The Eurasian Tree Sparrow, for example, is a hole-nester, and it likely experiences little predation pressure, in contrast with open-nesting birds. Hole-nesting species also do not experience stress due to severe micro-climatic changes (Dyer et al. 1977). Therefore, this habit may have assisted in the successful reproduction of some hole nesting species such as the Eurasian Tree Sparrow in newly colonized areas. Some species such as the Eurasian Tree Sparrow also possess a functional crop, which allows them to eat rapidly, minimising actual feeding time and thereby maximising the time available for searching for patchily distributed seed concentrations, and further allows an individual to take as much as possible from a localized food source before other individuals discover it (Wiens & Johnston 1977). The crop also allows birds to store large quantities of seeds temporarily for efficient transport to safer locations such as cover (Wiens & Johnston 1977). Hence, the presence of a crop may have allowed some invaders to compete better with the native species.

IMPACT OF INVASIVE BIRDS ON HUMANS

The establishment of invasive bird populations may affect the humans living there, since many of these species are found in human-altered habitats. This section outlines some known negative effects of invasive bird species recorded for Southeast Asian countries.

Where the Java Sparrow *Padda oryzivora* has been introduced in eastern Malaysia, it has been causing damage, particularly on Labuan Island, since the late 1800s. It is said to cause serious damage to paddy *Oryza sativa* (Long 1981). According to Boosey (1958), it is a much-dreaded perennial curse in the rice fields of Southeast Asia, descending in hordes to devour the ripening grains. When the rice is ripening, it gathers in large flocks and obviously is capable of consuming considerable amounts, which naturally leads to its persecution. It would also feed on small fruits and possibly insects (Bernstein 1861). Like many species of munias, the Scaly-breasted Munia flocks to the paddy fields when the rice is ripening, feeding heavily from the laden panicles. In the Philippines, it causes damage to crops, principally rice (Long 1981). The Red-whiskered Bulbul *Pycnonotus jocosus* is reported to do a certain amount of damage in fruit and vegetable gardens in Thailand and is probably a pest throughout most of its range (Deignan 1945). Baker (1922) recorded damage to fruits such as raspberries *Rubus idaeus*, oranges *Citrus* spp. and plums *Prunus* spp. by this species. It is regarded as exhibiting much potential as a pest, particularly in fruit growing areas (Long 1981). According to Cheng (1963), the Red-whiskered Bulbul also destroys insects; it is considered both good and harmful.

In Singapore, there is much concern about the nocturnal roosting behaviour of House Crows *Corvus splendens*, and the accompanying fouling of gardens, pedestrian paths, buildings, and vehicles beneath or near roosts. Excessive noise from roosts, especially in the early morning hours, has also caused annoyance. A public perception also exists that the House Crow may spread pathogens to humans. The accumulation of their faecal droppings is thus perceived as a health hazard (Peh & Sodhi 2002), although Cooper (1996) has found no evidence that the House Crow plays a role in pathogen dissemination. It is a useful scavenger and probably eats many injurious insects, but also attacks small birds and eats their eggs. According to Fitzwater (1967), it flies in and out of houses without restrain and pilfers anything edible.

In Southern Asia, the Common Myna is not generally considered a pest. It is largely a commensal of man and is frequently abundant around towns where it roosts communally. It feeds on fruits, berries and insects, but does not appear to affect cultivated fruits much (Long 1981). According to Sengupta (1968) and Ali & Ripley (1968–74), the species is a friend of the farmer doing immense good by eating many insect pests, but Ali & Ripley (1968–74) also state that they often cause damage to orchard fruits and standing cereal crops. Because of their fruit-eating habits, the species is regarded by many as being a potential pest in areas where it has been introduced (Long 1981). Like the House Crow, the White-vented Myna and the Common Myna are considered pests in Singapore primarily because of their habit of roosting communally at night, often close to humans, where they disturb and irritate the residents with their noise and faecal droppings (Hails 1985).

The Feral Pigeon has become a nuisance in most of the larger cities in the world because of their fouling of buildings and statues with droppings. Few large cities and towns lack Feral Pigeons. It is also generally regarded as a potential health hazard to humans in urban environments (Long 1981). Pigeon droppings deface and accelerate deterioration of buildings, statues and automobiles, render fire escapes hazardous, sometimes land on unwary pedestrians, and produce objectionable odours especially when deposited in ceilings and on sills. There appears to be reasonable evidence that it provides a reservoir for ornithosis and plays some part in the transmission of such diseases as encephalitis and histoplasmosis (Shuyler 1963; Morris 1969). It is a common contaminator of grain destined for human consumption. Its nests can clog drainpipes. It is a granivorous bird and is a candidate for being a pest on human row-crops (e.g. wheat *Triticum aestivum*, barley *Hordeum* spp., maize *Zea mays*, milo *Sorghum bicolour* and peas *Pisum* spp.; Long 1981).

IMPACT OF INVASIVE BIRDS ON NATIVE BIRDS

The avifauna of Southeast Asia is currently threatened by habitat loss (Ehrlich & Ehrlich 1981; Myers 1979, 1992; Brook et al. 2003a). The presence of invasive birds could compound the survival pressures on the avifauna through predation, disturbance or competition for resources. This section considers the known and potential detrimental effects of invasive birds on native birds in Southeast Asia.

The Common Myna nests in tree hollows and may compete for these resources with native hollow-nesting species (Pell & Tidemann 1997). Huong and Sodhi (1997) postulated that one of the factors in the decline of the hole-nesting Oriental Magpie Robin *Copsychus saularis* in Singapore might be the spread of the mynas there. The nesting of the Common Myna on the same trees was also known to disturb the nesting of the threatened Seychelles Magpie Robin *Copsychus schellarum* on Fregate Island in the Seychelles. These nest disturbances had an adverse effect on the breeding success of the robins (Komdeur 1996).

In Kenya, the House Crow was observed to raid the nests of ploceid weavers and other small bird species (Ryall 1992); hence it might be possible that the House Crow in Southeast Asia could pose a similar threat (for instance to White-vented Mynas; Kang 1989). Available evidence shows that where the Feral Pigeon has been abundant, the feral and wild forms (i.e. the Rock Pigeon) interbreed, and the wild pigeon is genetically consumed by the Feral Pigeon eventually. Johnston and Janiga (1995) anticipated that the number of Feral Pigeon colonies and individuals would increase, perhaps in some proportion to the increasing human population. Feral Pigeon increases might allow it to occupy a greater distributional range, which could promote contact with the wild Rock Pigeon in regions where it was formerly isolated. Johnston and Janiga (1995) hypothesize that such contacts will be a challenge to the continued existence of the primordial, because the Feral Pigeon has both survival and reproductive advantages relative to the wild Rock Pigeon.

MANAGEMENT OF INVASIVE BIRDS

Some of the invasive species listed are crop pests, while other species are undesirable because of their communal roosting behaviour or fouling of buildings and other property. Yet others have a potential for competing with native birds. The possibility of a need for the control and management of these birds may arise with the establishment of populations in pest proportions now or in the future. It is timely therefore, to discuss the possible methods of controlling bird populations and a few studies of habitat modification as feasible long-term control programmes in Southeast Asia and beyond.

1) Direct control of bird populations

Direct methods to reduce bird populations (e.g. killing and scaring) are not effective in the long term. A common reason is that an equilibrium in the number of birds is reached when control mortality is balanced by recruitment and juveniles, either by reproduction or by immigration of juveniles from other populations, taking the places of those removed by the control programme (Murton et al. 1972; Martin &

Martin 1982; Haag-Wackernagel 1993b). Further, the impacts of some methods (e.g. poisons, baits and explosives) on the ecosystem are not often adequately assessed in the control programmes (Dyer & Ward 1977).

Use of guns is common in rural environments, but not always feasible in cities, which is why urban control killing is done after having trapped or netted the birds. Trapping and netting are expensive, hands-on activities. Chemical products that either kill or stupefy the birds are likewise fractionally effective in most populations, being dose-dependent and dependent on the birds contacting toxic perches or feeding on toxic or stupefying baits. Detailed knowledge of the birds' biology is critical when using chemicals. Some repellents are toxic in excess and may kill birds that were intended to be merely stupefied. Toxic chemicals may not kill immediately, but incapacitate the birds for some time prior to death. Dead or dying birds and the toxic substances themselves are threats to the public health when children and household pets contact them (Johnston & Janiga 1995). The dying birds can also be a public relations problem for the wildlife managers (Weber 1979). Further, effects of reduction or elimination of the pest on the community of animals, such as the replacement of the target by another (and possibly worse) pest species should be considered (Dyer & Ward 1977).

2) Sterilization of birds

Other methods such as the sterilization of birds have been tried. Chemosterilants have been reported in birds such as starlings *Sturnus* spp. The problems with field use of chemicals lie in guaranteeing the action of the chemical, in the delivery of the material to the wild population and in the lack of species-specificity (Dyer & Ward 1977).

3) Scaring and bioacoustic techniques

Use of sounds (e.g. recorded distress calls, periodic explosions from acetylene cannons) and scarecrow dummies (e.g. plastic owls, snakes) are known to be effective in sending the Feral Pigeon and White-vented and Common Mynas elsewhere for short periods. However, birds habituate to such stimuli within a few days, and these techniques prove unsatisfactory ultimately (Hails 1985; Johnston & Janiga 1995).

4) Habitat Modification

Habitat manipulation has long been espoused as the proper way to manage wildlife species (Leopold 1939). Comprehensive information about the entire biology of birds (e.g. the feeding, nesting, breeding, roosting requirements and behaviour) is required for an effective habitat control programme (Johnston & Janiga 1995). The type of information required would depend on the nature of the disturbance caused by the invasive species. Habitat modification can take many forms, such as exclusion (e.g. blocking entrances to holes to prevent roosting or nesting, and installing netting to protect high-value crops), agricultural and horticultural methods (e.g. removing roost sites and planting bird resistant varieties of crops) and food removal (e.g. restricted feeding) (Fitzwater 1994; Johnston & Janiga 1995). Below we examine a few such studies aimed at developing appropriate pest bird control programmes employing habitat modification in Southeast Asia and elsewhere.

Control of House Crow populations: The global range of the House Crow has increased in the past 100 years, an expansion that either happened naturally or through deliberate release by humans (Ryall 1994). The House Crow is now established in many urban areas throughout Asia, where it roosts communally in large numbers (e.g. $>$20,000 birds; Siew et al. 1980). In Singapore, the House Crow population is estimated to be 130,000 birds (Brook et al. 2003b). Urban managers have faced great public concern over the nocturnal roosts of these birds (Peh & Sodhi 2002). Since 1973, the sole management measure carried out by the government of Singapore to control urban House Crow roosts has been periodic shooting at known roost sites to disperse roosting birds (Peh & Sodhi 2002). However, this management technique has proven ineffective in achieving long-term control. In a recent study by Peh & Sodhi (2002), it was found that the House Crow preferred roosting in tall, old trees such as *Pterocarpus indicus* with large dense crowns surrounded by tall buildings and located in areas of much human activity. Their study recommended the following habitat modification measures to discourage the crows from roosting in affected areas: (a) avoid planting well-spaced tall trees (18m tall) in urban area; (b) making existing roost sites less attractive (e.g. by tree pruning); and (c) establishing alternative roost sites. A study of the nest site selection of the House Crow in Singapore by Soh et al. (2002) found that it preferred nesting in *Peltophorum pterocarpum*, in trees with greater crown volume and diameter at breast height, in urban open habitats, with higher disturbance, and nearer to bin centres and food centres. They recommended the following habitat modification measures to discourage crows from nesting in affected areas: (a) minor changes to the design of existing bin centres (i.e. food source) to restrict access by crows; (b) planting alternative, less suitable tree species; and (c) regular pruning of trees with large and dense crowns. Brook et al. (2003b) argued that if applied simultaneously, both population control and habitat management might work effectively for the long-term control of House Crows in Singapore.

Control of Common and White-vented Mynas: These two species of mynas are well established and common in Singapore, where their populations are estimated to exceed 100,000 birds and 25,000 birds, respectively (Lim et al. 2003). They are considered pests in Singapore primarily because of their communal nocturnal roosts, which frequently occur in residential areas, where their noise and faecal droppings disturb neighbouring residents. This has led to calls for management, and to attempts by authorities in Singapore to remove the birds by scaring, poisoning, and thinning or removing the trees (Hails 1985; Kang et al. 1990). These measures were partially effective short-term solutions to the problem, probably because they were not integrated with serious efforts by the authorities to provide alternative roosting sites for the mynas in less humanly populated areas (Kang et al. 1990). Schmidt & Johnson (1984) proposed that the difficulties of roost dispersal might be reduced if stress was imposed on the birds by removing sources of food, water or shelter from the vicinity of the roost. Kang et al. (1990) argued that this strategy would be unsuccessful with the mynas because they had a highly diverse diet and choice of nesting sites, and they could range over a large area (e.g. 308.0 ha [Kang 1989] and 14.0 ha [Yap 2003]). Ecological studies have been carried out on mynas in Singapore with the aim of formulating habitat modification programmes to discourage mynas from roosting in affected areas. These studies found that mynas preferred to roost in tall, old trees with dense canopies, such as *Pterocarpus indicus* and *Eugenia grandis*, in urban areas sheltered from winds by nearby buildings or embankments, situated closer to food centres (i.e. open-air eateries) and surrounded by more vegetation than random non-roost trees (Hails 1985; Kang & Yeo 1993; Yap et al. 2002). Their studies recommended these management strategies: (a) roosts should be discouraged from forming in undesirable areas through a combination of bioacoustic and habitat modification control measures such as thinning of canopies; (b) attractive alternative sites should be created in other areas (such as roadside verges or roundabouts situated away from residential areas) in numbers that kept pace with the myna population; (c) refuse should be stringently controlled at food centres; (d) planting of mono-specific rows of tall trees with dense canopies such as *Pterocarpus indicus* and *Eugenia grandis* in urban areas, especially near to food centres should be avoided, and trees with flattened, less dense canopies, or with leaves that close at night, such as *Samanea samanea* should be planted instead; and e) all these measures should be adopted on a long-term basis for effective control of myna roosts. Hails (1985) also recommended that roosts should not be disturbed unless they posed a serious nuisance, because of the costs and logistics involved in roost dispersal, and that public education be carried out at the same time.

Control of pigeon populations: A possible method of control of Feral Pigeon populations using modification of habitats would involve the elimination of food sources (including deliberate feeding of pigeons by people), and the cleanup of food waste and spillage. The control of food supply was the basis for a successful control programme of a Feral Pigeon population in Basel, Switzerland (Haag-Wackernagel 1993a). Prior experience in Basel showed that the population of Feral Pigeons was about 20,000 individuals, which numbers had been maintained in the face of the inadequate trapping and shooting of 100,014 birds in the period 1961 to 1985 (Haag-Wakernagel 1993b). The new programme envisioned population reduction, not elimination, by means of highly restricted feeding of just a few birds. A loft was created and the birds were fed nearby in a public place. A bird-keeper maintained the loft and took eggs and young when the population exceeded a certain predetermined number. The programme included public education on the advantages of population control, and the public advantages of having healthy, unstressed birds.

CONCLUSION

There are 16 established invasive bird species in Southeast Asia. These species may have some negative impacts on the native biodiversity and human economy. However, we need more research to assess the impacts of these species precisely. Control of invasive bird species in Southeast Asia is possible, but it requires a multi-pronged approach including both population and habitat management.

ACKNOWLEDGMENTS

Our research on invasive bird species in Singapore was supported by the Ministry of National Development and Agri-food & Veterinary Authority of Singapore. We thank Malcolm Soh, Lian Pin Koh, Tien Ming Lee and two anonymous reviewers for their comments.

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