

The distribution and ecology of invasive alien vertebrate species in the greater Toamasina region, central eastern Madagascar

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Abstract

A number of organisms introduced to Madagascar have become invasive, dominant, and are now posing threats to native species. Little has been published on their distribution and ecology of invasive alien land vertebrate species on the island. Herein we focus on three introduced species along the coastal zone in the general Toamasina region, from Soanierana Ivongo in the north to Mahanoro in the south, specifically two birds, Common Myna (*Acridotheres tristis*) and House Sparrow (*Passer domesticus*), and one toad, Asian Common Toad (*Duttaphrynus melanostictus*). Based on field surveys across this region, details are presented on the local distribution of these three species, as well as information on their ecology and history of introduction. In the case of *D. melanostictus*, the data presented herein from the Toamasina region indicate important expansions in its previously known distribution, including to the north into the Ivoloïna River system and to the south

into the Nosive River system. This latter locality is the northern portion of the Canal des Pangalanes and with continuous water connections to about 550 km to the south.

In two of the three cases, the lack of direct action by governmental agencies in charge of biodiversity conservation and biosafety and their partner conservation organizations to eradicate these animals at early stages after introduction lead to population explosions and very important range extensions. These invasive alien species pose important threats to agricultural production (*P. domesticus*) and endemic vertebrates (*D. melanostictus* and *A. tristis*). In all three cases, the combination of large populations that are broadly dispersed, and moderate to high reproductive output, renders the current situation to eradicate any of these species nearly impossible.

Recently, the House Crow (*Corvus splendens*), a known invasive alien species in areas of the Red Sea and other portions of the Indian Ocean, was introduced to Toamasina and the population remains small and within a confined geographic area. It is suggested that lessons be learned from the previous lack of action associated with invasive alien vertebrate species on Madagascar, and, despite notable logistic and administrative complications, a program to eradicate the house crows be engaged as soon as possible.

Key words: invasive species, *Passer domesticus*, *Acridotheres tristis*, *Duttaphrynus melanostictus*, distribution, abundance, Région Atsinanana, Région Analanjirofo

Résumé détaillé

De nombreuses espèces introduites à Madagascar sont devenues envahissantes et dominant et menacent maintenant des espèces autochtones. Quant aux espèces de vertébrés terrestres exotiques envahissantes présentes sur l'île, peu d'informations concernant leur distribution et leur écologie, ainsi que leurs impacts sur les espèces autochtones et sur la production agricole sont disponibles. La présente étude a pour objectif de combler ces lacunes afin de disposer d'un outil de base, nécessaire dans

la conception et la mise en œuvre d'un éventuel programme de sensibilisation et de lutte contre la prolifération des espèces exotiques envahissantes. Elle est axée sur trois espèces animales introduites, notamment deux espèces d'oiseaux, le martin triste (*Acridotheres tristis*), le moineau domestique (*Passer domesticus*) et le crapaud commun d'Asie (*Duttaphrynus melanostictus*), le long de la zone côtière de la région de Toamasina, en particulier depuis Soanierana Ivongo au nord à Mahanoro au sud. Basées sur des investigations de terrain relatives à cette région, à partir d'enquêtes, d'observations générales et de méthodes de points d'écoute, des informations sur la répartition, l'écologie et l'histoire de l'introduction de ces trois espèces sont fournies. En effet, les deux espèces d'oiseaux ont une large distribution géographique et sont représentées par des grandes populations. D'après les résultats récoltés dans les villes de Toamasina et de Fénérive-Est, la densité de *P. domesticus* est par exemple estimée à 43,5 à 100,6 individus/ha. L'estimation basée sur la plus faible densité le long de la côte entre Soanierana Ivongo et Mahanoro, sur une bande de 5 km, semble atteindre jusqu'à 7 700 000 individus. Dans le cas de *D. melanostictus*, les données présentées ici indiquent une importante expansion de sa zone d'occurrence originale dont la limite nord observée est la rivière Ivoloïna, et celle du sud se trouve juste au nord de la rivière Ivondro. Cette espèce n'a apparemment colonisé la partie sud de la rivière Nosive constituant l'entrée vers le Canal des Pangalanes, qui continue jusqu'à 600 km au sud. Etant donné que cette espèce se reproduit dans un milieu aquatique et où les têtards se développent jusqu'à la métamorphose complète, les nombreux cours d'eau et points d'eaux qui existent dans cette partie orientale de l'île vont considérablement favoriser son expansion géographique. Ces cours d'eau sont fréquemment employés comme voie fluviale pour le transport en utilisant des bambous, ce qui pourrait augmenter le risque de dispersion au travers de radeaux flottants.

Dans deux, parmi les trois cas étudiés, l'absence d'actions concrètes entreprises par les organes gouvernementaux et en association avec les organisations de conservation à un stade précoce, après la constatation de l'introduction des espèces exotiques envahissantes concernées, est à l'origine de la prolifération des populations de ces espèces et de l'expansion considérable de leur distribution géographique. Ces espèces exotiques envahissantes représentent de sérieuses menaces

pour la production agricole (*P. domesticus*) et pour les animaux autochtones (*D. melanostictus* et *A. tristis*). Dans tous les cas, l'effet conjugué, de la grande taille des populations largement dispersées et de leur succès reproductif modéré à élevé, rendrait impossible dans l'état actuel des moyens techniques l'éradication d'aucune de ces espèces. Récemment, une autre espèce introduite à Toamasina, le corbeau familial (*Corvus splendens*). Cette espèce est connue comme exotique et envahissante dans les zones de la Mer Rouge et dans d'autres parties de l'océan Indien. Pour le moment, la population reste encore relativement petite et confinée à une zone géographique restreinte. Aussi, il faudrait tirer des leçons des cas précédents où aucune action concrète n'a été prise pour lutter contre les espèces exotiques envahissantes à Madagascar. Bien que des complications logistiques et administratives existent, il faudrait entreprendre un programme d'éradication du corbeau familial dans les meilleurs délais.

Mots clés : espèces envahissantes, *Passer domesticus*, *Acridotheres tristis*, *Duttaphrynus melanostictus*, distribution, abondance relative, Région Atsinanana, Région Analanjirofo

Introduction

Across the world, particularly on islands, it has been shown that non-native species of plants and animals introduced by direct or indirect human agency pose in certain cases important threats to the native and often endemic biota, as well as public health (Elton, 1958; Atkinson, 1985; Simberloff, 1995; Mooney & Cleland, 2001; Reaser *et al.*, 2007; Simberloff *et al.*, 2013). The impacts of introduced species range from being 1) in direct competition for space or food resources with native taxa, in certain circumstances becoming distinctly dominant, hence, invasive; 2) responsible for different forms of predation; and 3) they or their parasites transmit diseases to immunologically naive organisms. On the basis of these factors, there are documented cases of measurable declines, local extirpation or extinction of the native biota (e.g. Mack *et al.*, 2000; Sanders *et al.*, 2003; Conn, 2014; Gurevitch & Padilla, 2004; Towns *et al.*, 2006; Wyatt *et al.*, 2008; Morand *et al.*, 2015; Doherty *et al.*, 2016). There are also documented cases of native species becoming invasive, for example, on Madagascar (Ratsirarson, 2005).

On islands in the western Indian Ocean, invasive alien species of plants and animals have had impacts

on the native biotic communities and these have been particularly severe on the Mascarenes (Mauritius and La Réunion) and the granitic Seychelles (MacDonald *et al.*, 1991; Strasberg, 1995; Fleischmann 1997; Strahm, 1999; Bullock *et al.*, 2002; Rocamora & Henriette, 2015). These islands have suffered considerably from high rates of human-modification of natural forest ecosystems, which has in turn opened up different non-native habitats, and provided the means for introduced species to become invasive.

Although Madagascar has also been the subject of high levels of deforestation, relatively intact and large forest ecosystems remain and perhaps the threat of invasive species is less than on neighboring islands. Also of importance, different aspects of invasive species have not been brought to the forefront of discussion by researchers involved in different scientific and conservation programs (Carrière *et al.*, 2008; Kull *et al.*, 2014). Madagascar is subject to different aspects associated with climate change and intense anthropogenic pressures resulting in the loss of vast areas of natural ecosystems. As on neighboring islands, these different transformations provide the means for introduced species to get a strong foothold, colonize new areas, and in turn compete with native species in the manners mentioned above. Hence, Madagascar, as on neighboring islands, is not without problems of introduced invasive species, which include a variety of different plants (e.g. Binggeli, 2003; Tassin *et al.*, 2009), invertebrates (e.g. Florens *et al.*, 1998; Jones *et al.*, 2009; Dejean *et al.*, 2010; Feria & Faulkes, 2011; Goodman *et al.*, 2017), and vertebrates (e.g. Benstead *et al.*, 2000; Raselimanana & Vences, 2003; Canonico *et al.*, 2005; Sparks & Stiasny, 2008; Linders & Langrand, 2014).

In the case of introduced land vertebrates on Madagascar, little quantitative published information is available at the regional scale on the distribution of these animals based on ground surveys or aspects of their ecology. Such data are important to track changes in their distribution and possible incursion into native habitats. The purpose of this paper is to document the presence of three invasive alien species, two being birds, Common Myna (*Acridotheres tristis*) and House Sparrow (*Passer domesticus*), and one toad, Asian Common Toad (*Duttaphrynus melanostictus*), in the greater Toamasina region of lowland eastern central Madagascar. This is an area adjacent to Madagascar's largest naval port in the city of Toamasina, and, hence, notably susceptible to accidental introductions of animals arriving via maritime traffic.

Methods

FFR and HAA were responsible for the field surveys conducted in the greater Toamasina area between 2 December 2016 and 2 January 2017. Using road and foot trails, they visited 68 sites between Soanierana Ivongo to Mahanoro, which were grouped in three different portions of this zone, and up to a maximum of 25 km inland to the west of the Indian Ocean coast (Figure 1, Table 1). The surveys were conducted for birds during daylight hours between about 5 h and 10 h and for toads towards dawn or between 17 h and 18h. Given that no work was conducted during the night, when the toads are active, data for this species is limited. Information was registered using a GPS (datum WGS 84) on the latitude, longitude, and elevation of each site (Table 1). For each of the invasive species, information is only presented here on their presence and absence at a given surveyed site. Further, the general habitat around each site was classified as: in the immediate vicinity of a **town** or **village**, at the edge of the sea and along a **beach** or in rural areas next to an **agricultural field** or fallow secondary land referred to as **tanety/savoka**.

Results and Discussion

Invasive alien bird species

Five species of bird have been introduced to Madagascar, which is notably less than on La Réunion and Mauritius with 24 species each, and the Seychelles with 11 species (Safford & Hawkins, 2013). The two invasive alien bird species that are the subject of this study, *Acridotheres tristis* and *Passer domesticus*, are common on islands in the western Indian Ocean, including the archipelagos of the Seychelles, Comoros, and Mascarenes; the period and means of their introduction on these islands are different (Safford & Hawkins, 2013). Details are presented below on different aspects of their ecology, distribution, and introduction history.

Common Myna, *Acridotheres tristis*

Ecology and reproduction

In India, the clutch size is 4-6 eggs, the incubation period from 17-18 days, and the young fledge between 22-24 days (Ali & Ripley, 1989). On Madagascar, this species, which occurs in colonies of several hundred individuals, is known to nest in holes in trees and exposed banks, as well as an assortment of human structures. *Acridotheres tristis* is aggressive and at nest sites occupied by other bird species and that this species wants to usurp, it will

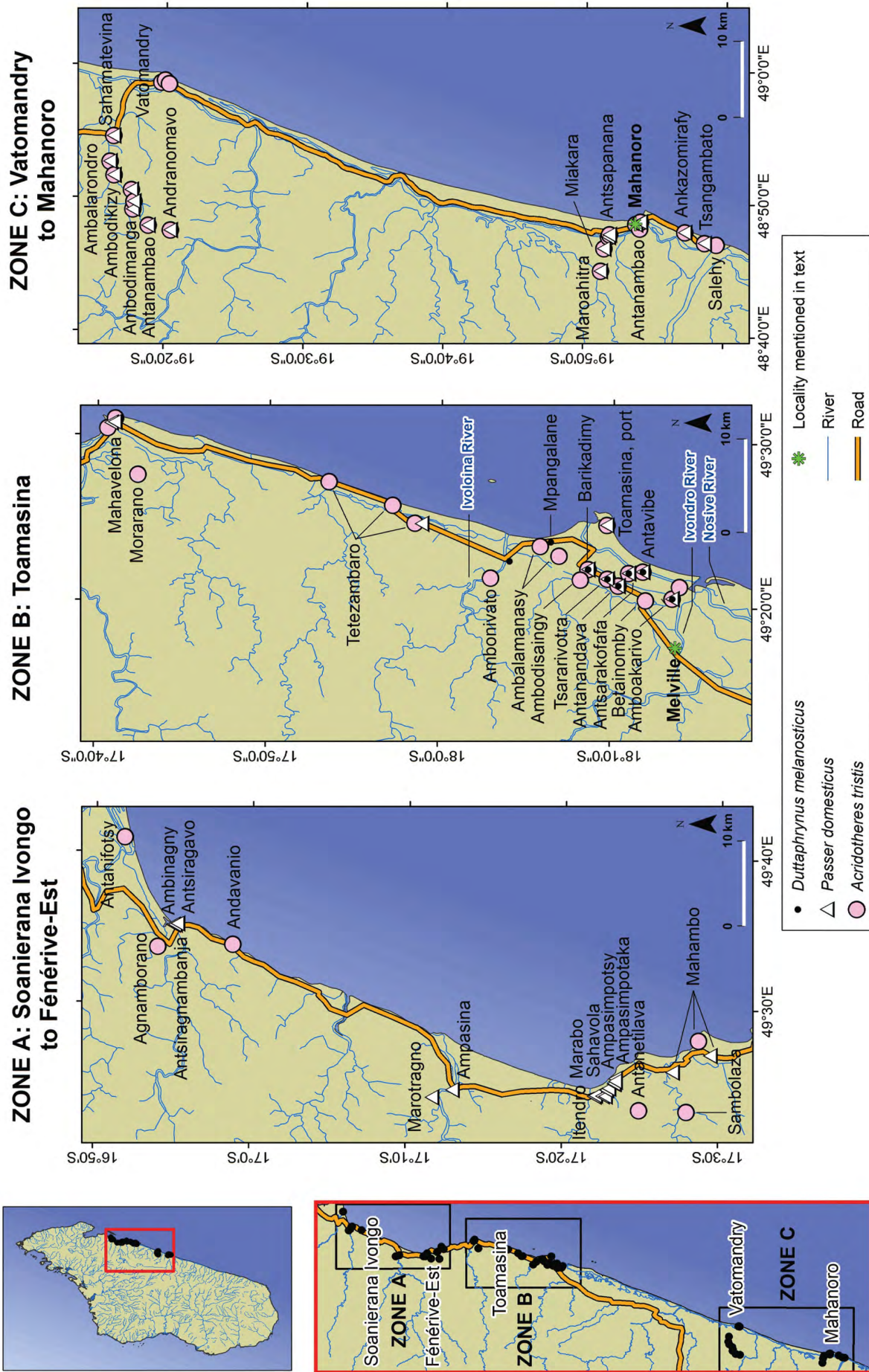


Figure 1. Map of the distribution of three invasive alien species in the general Toamasina region based on field surveys conducted in December 2016 and January 2017. The surveys were not continuous across the coastal area of the region, but were grouped in the area between 1) Zone A - Soanierana Ivongo and Fénérive-Est, 2) Zone B - greater Toamasina area south to the Ivondro River, and 3) Zone C - Vatomandry to Mahanoro.

Table 1. Inventoried sites in the greater Toamasina area, ranging from Soanierana Ivongo in the north to Mahanoro in the south and the species of introduced birds and road recorded. + = present at a site.

Locality (District)	Habitat	Latitude (S)	Longitude (E)	Altitude (m)	<i>Acridotheres tristis</i>	<i>Passer domesticus</i>	<i>Duttaphrynus melanostictus</i>
Antanifotsy (Soanierana Ivongo)	<i>Tanety/savoka</i>	16.86355°	49.68232°	8	+		
Soanierana Ivongo, Agnamborano (Soanierana Ivongo)	Town	16.90032°	49.56185°	11	+		
Soanierana Ivongo, Ambinagny (Soanierana Ivongo)	Town	16.91630°	49.58620°	9		+	
Soanierana Ivongo, Antsiragnambanja (Soanierana Ivongo)	Town	16.91825°	49.58608°	12		+	
Soanierana Ivongo, Antsiragavo (Soanierana Ivongo)	Town	16.92113°	49.58752°	8		+	
Soanierana Ivongo, Andavano (Soanierana Ivongo)	Agricultural field	16.98025°	49.56560°	15	+		
Marotragno (Fénériver-Est)	Village	17.19457°	49.39937°	23		+	
Ampasina (Fénériver-Est)	Village	17.21637°	49.40803°	19		+	
Fénériver-Est, Itendro (Fénériver-Est)	Town	17.36763°	49.40320°	16		+	
Fénériver-Est, Sahavola (Fénériver-Est)	Town	17.36903°	49.40417°	16		+	
Fénériver-Est, Ampasimpotaka (Fénériver-Est)	Town	17.37627°	49.40373°	18		+	
Fénériver-Est, Ampasimpotaka (Fénériver-Est)	Town	17.37965°	49.40328°	15		+	
Fénériver-Est, Marabo (Fénériver-Est)	Town	17.38084°	49.41040°	15		+	
Fénériver-Est, Ampasimpotsy (Fénériver-Est)	Town	17.38328°	49.41213°	11		+	
Fénériver-Est, Ampasimpotsy (Fénériver-Est)	Town	17.38832°	49.41750°	14		+	
Fénériver-Est, Ampasimpotsy (Fénériver-Est)	Town	17.38880°	49.41778°	14		+	
Fénériver-Est, Ampasimpotsy (Fénériver-Est)	Town	17.38995°	49.42315°	18		+	
Fénériver-Est, Ampasimpotsy (Fénériver-Est)	Town	17.39020°	49.42027°	25		+	
Fénériver-Est, Antanetilava (Fénériver-Est)	<i>Tanety/savoka</i>	17.41530°	49.38800°	70	+		
Mahambo, Antsikafoka (Fénériver-Est)	Village	17.45077°	49.43102°	19		+	
Mahambo, Sambolaza (Fénériver-Est)	Beach	17.46590°	49.38693°	24	+		
Mahambo (Fénériver-Est)	Beach	17.47810°	49.46618°	13	+		
Mahambo (Fénériver-Est)	Village	17.49075°	49.45000°	22		+	
Mahavelona, Parcelle 1 (Toamasina II)	Agricultural field	17.67635°	49.50698°	14	+		
Mahavelona, Parcelle 3 (Toamasina II)	Beach	17.67948°	49.51200°	8		+	
Mahavelona Parcelle 4 (Toamasina II)	Town	17.68323°	49.512667°	8		+	
Mahavelona, Parcelle 4 (Toamasina II)	Beach	17.68373°	49.51672°	6	+		
Mahavelona, Morarano (Toamasina II)	Beach	17.70632°	49.46013°	23	+		

Locality (District)	Habitat	Latitude (S)	Longitude (E)	Altitude (m)	<i>Acridotheres tristis</i>	<i>Passer domesticus</i>	<i>Duttaphrynus melanostictus</i>
Tetezambaro, Vohitsara (Toamasina II)	Village	17.89163°	49.45597°	9	+		
Tetezambaro, Vohitsara (Toamasina II)	Village	17.95378°	49.43310°	6	+		
Tetezambaro (Toamasina II)	Village	17.97550°	49.41513°	10	+		
Tetezambaro, Vohibendrana (Toamasina II)	Village	17.98212°	49.41487°	10		+	
Ambonivato (Toamasina II)	Agricultural field	18.04960°	49.36083°	6	+		
Ivoloina (Toamasina II)	Village	18.06730°	49.37822°	10			+
Ambalamanasy (Toamasina II)	Village	18.09718°	49.39377°	9	+		
Mpangalane (Toamasina II)	Village	18.10742°	49.39812°	9			+
Ambalamanasy (Toamasina II)	Village	18.11550°	49.38413°	11	+		
Ambodisaigny (Toamasina II)	Agricultural field/village	18.13648°	49.36043°	17	+		
South of Barikadimy (Toamasina I)	Village	18.14385°	49.37114°	27	+	+	+
Toamasina, port (Toamasina I)	Town	18.16151°	49.41616°	12	+	+	
Tsararivotra (Toamasina I)	Agricultural field/village	18.16270°	49.36166°	20	+	+	+
Antanandava (Toamasina I)	Village	18.17324°	49.35484°	22	+	+	+
Antsarakofafa (Toamasina I)	Village	18.18307°	49.36776°	19	+	+	+
Near Antavibe (Toamasina I)	Agricultural field/village	18.19698°	49.36926°	20	+	+	+
Between Betainomby & Ampirasantany	Agricultural field/village	18.19976°	49.34020°	20	+		
Amboakarivo (Toamasina I)	Agricultural field/village	18.22581°	49.34243°	24	+	+	+
South of Ivondro River	<i>Tanety/savoka</i>	18.23257°	49.35428°	21	+		
Ambalarondro (Vatomandry)	Village	19.26775°	48.87819°	35	+	+	
Sahamatevina (Vatomandry)	Village	19.27177°	48.91046°	24	+	+	
Ambodikizy (Vatomandry)	Village	19.27296°	48.86118°	37	+	+	
Ambodimanga (Vatomandry)	Village	19.29368°	48.84303°	22	+	+	
Antanana (Vatomandry)	Village	19.29562°	48.81891°	32	+	+	
Bemita (Vatomandry)	Village	19.29708°	48.82823°	37	+	+	
Antanambao Mahatsara (Vatomandry)	Village	19.31436°	48.79868°	45	+	+	
Vatomandry, CARE (Vatomandry)	Town	19.32813°	48.97776°	19	+		
Vatomandry, FLM (Vatomandry)	Town	19.33263°	48.98085°	10	+		
Vatomandry, Gare Routière (Vatomandry)	Town	19.33722°	48.97617°	25	+		
Andranomavo (Vatomandry)	Village	19.34077°	48.79286°	50	+	+	
Maroahitra (Mahanoro)	Village	19.85380°	48.74.837°	25	+	+	
Ekar (Mahanoro)	Village	19.85741°	48.77665°	20	+	+	
Miakara (Mahanoro)	Village	19.86268°	48.79156°	14	+	+	
Antsapanana (Mahanoro)	Village	19.86410°	48.79454°	15	+	+	
Antanamborizano (Mahanoro)	Village	19.89481°	48.80780°	14	+	+	
Antanambao II (Mahanoro)	Village	19.89956°	48.80196°	19	+		
Ambalamangahazo (Mahanoro)	Village	19.90060°	48.81050°	12	+	+	
Ankazomirafy (Mahanoro)	Village	19.95359°	48.79824°	19	+	+	
Tsangambato (Mahanoro)	Village	19.97713°	48.78478°	24	+	+	
Salehy (Mahanoro)	Village	19.99109°	48.78307°	15	+		

readily destroy or remove the nest contents. These different nesting and behavioral characteristics partially account for this species being considered as an invasive alien species. It is one of only three bird species listed among the “100 of the world’s worst invasive alien species” (Lowe *et al.*, 2007). *Acridotheres tristis* has a largely animalivorous diet, feeding on a wide variety of food types, including commercially important fruits, and different types of domestic animal food. On Madagascar, it is known to be very aggressive towards and presumably in competition with sympatrically occurring endemic vertebrates, such as the chameleons *Furcifer lateralis* and *F. oustaleti* (M. J. Raherilalao, unpublished data). In the Seychelles, it is known to feed on the eggs of nesting seabirds (Feare *et al.*, 2015).

Introduction history on Madagascar

There is good evidence that *A. tristis* was introduced to the east coast of Madagascar during the first half of the 19th-century (Milon, 1951; Decary, 1962), and it was observed in mid-September 1862 at Fénériver-Est and near Mahavelona (Foulepointe) (Newton, 1863). By the first third of the 20th-century, this species was common in the Toamasina area, and to the north as far as Fénériver-Est and to the south to at least Brickaville (Rand, 1936). Hence, it has occurred across the inventory zone reported on herein for at least 80 years, where today it is a dominant member of the local non-forest-dwelling bird community. With respect to Madagascar, by 2000, *A. tristis* had colonized nearly the complete coastal region and portions of the Central Highlands from sea level to 1,985 m (Hawkins & Goodman, 2003). Today, it can be encountered across the island in areas disturbed by human activities, in heavily degraded forests with open canopy, and at the ecotone between natural forest and open habitat.

Distribution in the survey zone and associated ecology

Acridotheres tristis was present at 46 of the 68 sites surveyed, in all of the different habitats, and often sympatric with *Passer domesticus*. Across the Toamasina region and for that matter much of Madagascar, this species can regularly be seen in areas degraded by anthropogenic pressures and at the edge of disturbed or relatively intact forest.

In villages close to Vatomandry, young *A. tristis* taken from nests and hand-reared by humans were

found at Bemita (n=30 birds), Ambodimanga (n=15 birds), and Ambodikizy (n=4 birds). When the birds reach adult size, they are carried to Vatomandry and sold as pet birds (without cages) for what was reported to be about 1,500 Malagasy ariary (approximately \$0.50 in late February 2017). The same captive rearing system was found at a smaller scale in and around Fénériver-Est. In rural zones around Vavatenina, to the north of Toamasina, young boys can be seen with pet *A. tristis*.

House Sparrow, *Passer domesticus*

Ecology and reproduction

Across portions of its introduced range, the average clutch size is 4–6 eggs, the incubation period is 10–14 days, and the birds fledge about 14 days after hatching (Lowther & Cink, 2006). Generally, at least two clutches are produced in a calendar year, but up to seven clutches have been recorded in the tropics. In tropical areas, individuals still in juvenile plumage are capable of breeding, although with lower reproductive success than older birds (Anderson, 2006). This species is known to nest in a variety of cavity types, ranging from rock cliffs, vertical banks, and an assortment of human structures, as well as in branches of trees and in the nests of large birds. The aggressive behavior of *P. domesticus* and competition for nest sites have been cited as the basis for the decline of bird species that are in direct contact (Bennett, 1990). These different life-history traits explain why this taxon has so successfully colonized different temperate and tropical areas of the world. This mixed granivore-animalivore species is known in other portions of its range to feed extensively on agriculture grains, including rice (Dhindsa & Toor, 1980; Ubaidullah, 2004).

Introduction history on Madagascar

The previously reported first evidence of *Passer domesticus* on Madagascar was in the mid-1980s and in close proximity to the Toamasina port (Langrand & Sinclair, 1994); the population that resulted in its successful colonization is presumed to have arrived as stowaways on an ocean-going vessel. Information provided in an apparently unpublished report of Jaonina & Dra (no date) and associated with a letter to SMG from Dr. Wolfgang Zehrer (dated January 1997), provides further information on the introduction of this species to Madagascar. Therein it is reported that in 1975 agents associated with the Service Phytosanitaire observed in the Toamasina

port several individuals of *P. domesticus* that arrived by a sea-faring boat carrying Pakistani rice. Thereafter, this source population of birds established themselves in the Club Nautique, which is adjacent to the port. During the period from mid-1985 to early 1987, the estimated local population in central Toamasina was about 20 individuals (D. Halleux and O. Langrand, pers. comm.). Hence, the presence of *P. domesticus* in the region covered by this survey is about four decades as compared to slightly less than a century for *A. tristis*.

In 1987, Olivier Langrand, then the Technical Advisor of WWF, Madagascar, seconded to the Direction des Eaux et Forêts in Antananarivo submitted a written proposal to WWF-International to undertake an eradication of this invasive alien species, which at that point was composed of a small population in central Toamasina. WWF and the Malagasy authorities rejected this proposal, as it was considered not a priority in the context of the conservation of Madagascar biodiversity (O. Langrand, pers. comm.). National authorities did not heed this suggestion and no further action was taken by WWF. Subsequently the *Passer* population rapidly grew, dispersed, and expanded its geographic range. As shown by the results presented below, today it is abundant in the greater Toamasina region, the means to eliminate the population is outside the realm of possibility, and even population control would be notably difficult.

Distribution in the survey zone and associated ecology

This species was present at 43 of the 68 sites surveyed, in a wide variety of habitats, and often co-occurring with *A. tristis*. Across the Toamasina region, from at least Soanierana Ivongo to Mahanoro (Figure 1), it can regularly be seen in areas occupied by people, including city centers, villages, agricultural areas, and degraded areas or fallow fields.

In 2016, point count surveys were conducted in Toamasina and Fénériver-Est to estimate population densities of this species in these urban environments. Density measurements of *P. domesticus* in Toamasina varied from 43.5 to 87.6 individuals/ha (Sylvestre, in prep.) and in Fénériver-Est from 49.2 to 100.6 individuals/ha (Gauthier, in prep.). Using these figures, it can be estimated that approximately 233,000 to 469,000 *Passer* occur in greater Toamasina (5,355 ha) and 16,000 to 32,000 in greater Fénériver-Est (320 ha). In both of these two urban centers, point counts were established in three different anthropogenic habitats ranging from areas

with relatively dense garden vegetation to those with little plant cover and the results indicate that densities vary as a function of vegetational cover (Gauthier, in prep.; Sylvestre, in prep.). In both of these urban centers, the density of *Foudia madagascariensis*, an endemic and not strictly granivorous species, often found in degraded forest or open habitats and a serious pest of rice (Andriatsilavo, 1997; Sama, 1999), was distinctly lower than *P. domesticus* (Gauthier, in prep.; Sylvestre, in prep.).

In an attempt to estimate the number of *P. domesticus* occurring in the greater Toamasina region, that is a band from the Indian Ocean coast to 5 km inland in the zone from Soanierana Ivongo in the north to Mahanoro in the south; we employed the lowest density estimate per hectare in Toamasina and Fénériver-Est. The following figures can be suggested: total surface area of zone is 177,850 ha x 43.5 *P. domesticus*/ha, yields something approaching 7,700,000 individuals in this narrow coastal strip of about 350 km in length.

In the general Toamasina area, *P. domesticus* was found on several occasions in 2015 and 2016 in agricultural areas and flocks of up to 50 individuals were observed in areas of rice paddy (S. M. Goodman, unpublished data). It is reasonable to imagine that this species together with *F. madagascariensis*, a known large scale rice consumer, have or will soon have an important impact on rice production in the greater Toamasina region (see below). Groups of 600 individuals have been observed in Toamasina around rice grain stores, where they are able to pierce rice sacks to obtain rice (Jaonina & Dra, no date).

To explore possible negative impacts this species might be having as an agricultural pest, some other figures can be presented. On the basis of experiments in captivity, it has been estimated that a single *P. domesticus* eats at least 6 gm of seeds per day (Jaonina & Dra, no date; El-Danasory & Abouamer, 2012). If 25% of the daily food consumption of this species in the Soanierana Ivongo to Mahanoro area is rice, either taken from grain stores, vendor stalls, or agricultural areas, the following figures can be presented: 7,700,000 individuals x 1.5 gm/day = 11.6 tons/day or nearly 4100 tons/year. Regardless of the precision of these estimates, the impact these birds have on agricultural production is measurable. Clearly, more research needs to be conducted on this subject in the greater Toamasina region.

Over the past decade, this species has also colonized the port cities of Antsiranana and Mahajanga via international boat traffic, presumably

independent of its occurrence in Toamasina. In March 2017, it was abundant in Antsiranana and dominated the city's bird fauna, together with *A. tristis* (S. M. Goodman, unpublished data). There are recent records of this species in Antananarivo, mostly within the railroad yard of the principal train station and it presumably reached this city from Toamasina via the train line connecting these two cities (Safford & Hawkins, 2013; S. M. Goodman, unpublished data). If this is indeed the case, it is easy to imagine that this species also occurs in numerous towns and villages along the Toamasina-Antananarivo railway line, a point recently verified with its presence in close proximity to the Andasibe train station, close to halfway point between these two cities (K. Behrens, pers. comm.). Train wagons parked near certain stations remain immobile for relatively long periods, with birds making their nests within, and then with the possibility of being transported to other stations.

Since the mid-1980s, about a decade after *P. domesticus* were first discovered in Toamasina and numbered about 20 individuals, the situation rapidly evolved. They are now present in substantial numbers in different areas of the island and have a broad and dense distribution in portions of lowland central Madagascar. Given the estimates of the number of individuals presented above in the coastal strip from Soanierana Ivongo to Mahanoro, combined with unknown population estimates of this species elsewhere on the island, we deem its eradication as no longer possible, but perhaps a program of population control can be advanced. From the level of damage these birds might cause to agricultural production and possible competitive exclusion with endemic Malagasy animal species, it is simply a shame that the alarm bell launched by Olivier Langrand for action some 30 years ago was not heeded.

Invasive alien toad species

Two species of amphibian are known to have been introduced to Madagascar, *Hoplobatrachus tigerinus* often referred to as the Asian Bullfrog, and *Duttaphrynus melanostictus* or Asian Common Toad. The latter species is in the state of explosive expansion centered in the Toamasina region and details are presented below on aspects of its ecology, distribution, and introduction history.

Asian Common Toad, *Duttaphrynus melanostictus*

Ecology and reproduction

Duttaphrynus melanostictus has considerable reproductive capacity, producing what has been proposed up to 40,000 eggs per breeding bout and having two breeding sessions per year (Csurhes, 2010). This species is well adapted to living in relatively open areas, with little or no canopy cover, as well as near human habitation. They breed in different ecological conditions, including pools of stagnant water and channels, often associated with submerged aquatic vegetation, which is important during reproduction for mating sites and deposition of egg masses. Tadpoles undergo their metamorphosis into adult form after 34 to 90 days (Jørgensen *et al.*, 1986; Csurhes, 2010). On Madagascar, specifically the Toamasina area, populations of this species at a given site include animals at different stages of development and reproduction, which gives the impression that it is not a strict seasonal breeder (A. P. Raselimanana, unpublished data). *Duttaphrynus melanostictus* is considered an opportunistic predator, consuming a wide variety of animal prey, for example, in India ground-dwelling Hymenoptera and Isoptera being the most prevalent taken of the 13 different groups identified (Jamdar & Shinde, 2013). A study conducted south of Toamasina on the diet of this species found similar results, with a variety of invertebrates being identified (Diplopoda, Coleoptera, and Mollusca) (Narivony, in prep.). These toads are known to survive in the wild to the age of 12 years (Nayak *et al.*, 2007). When an adult toad is disturbed, the parotoid glands produce a toxic substance and it has been proposed that larger individuals may poison different predators (Daniels, 2005; Brown *et al.*, 2016).

Introduction history on Madagascar

Exactly when *D. melanostictus* was introduced to Madagascar is uncertain, but this took place in the immediate vicinity of Toamasina. In the scientific literature the date of invasion has been proposed as early 2014 (Kolby, 2014), but the colonization event may have taken place as early as 2010 (Moore *et al.*, 2015) or perhaps a few years earlier. In November 2013, a tree nursery worker associated with the Ambatovy mining company, which has refinement facilities to the south of Toamasina, found evidence of this species in the village of Marovato and by March

2014, it was found at several different areas in and around Toamasina (Ambatovy, 2016).

Distribution in the survey zone and associated ecology

Several different scenarios have been proposed as to the means this species was introduced to the Toamasina area, but with little doubt this was associated with maritime traffic and imported goods, and mostly likely living animals within a shipping container arriving from southeastern Asia (McClelland *et al.*, 2015). As this species is not known to occur in the immediate vicinity of the port, its release into the Toamasina environment is presumed to have taken place after the displacement of a shipping container to the southern periphery of the city. Soon thereafter, the local toad population expanded rapidly and this problem received considerable attention in high profile scientific journals (Andreone, 2014; Kolby, 2014; Mecke, 2014). By November 2014, this species was found during systematic surveys as far south as Amboakarivo and north to the vicinity of Barikadimy (Figure 1), several sites within 1 km from the Indian Ocean coast, and across a total surface area of 108 km² (Moore *et al.*, 2015). During this approximate period, density estimates based on fieldwork in portions of its range were calculated at about 400 toads/ha, bringing the population to about 4,000,000 toads (McClelland *et al.*, 2015). These same authors calculated that the population was expanding at the rate of 2 km ground distance/year.

Toamasina is the northern terminus of an extensive waterway, known as the Canal de Pangalanes, which commences at Farafangana, about 700 km to the south. Approximately, 15 km south of Toamasina is an extensive wetland where the Ivondro River, descending from forested zones to the west, and further south the Nosive River, which marks the entrance into a north-south aligned canal (Figure 1). Data on the distribution of *D. melanostictus* gathered until May 2016 (Moore *et al.*, 2015; Rakotonandrasana, in prep.) indicate that this toad had colonized areas within the branches of the Ivondro River (around Mahatsara), but not south of the Nosive River. However, there are unconfirmed reports that it occurs in the Mahanoro area (Raharisoa, 2014), much further to the south (Figure 1).

On the basis of data gathered during the late 2016-early 2017 survey, this species was not found further south than Amboakarivo, north of the wetlands leading into the Canal de Pangalanes. Once it reaches south of the entrance into the canal

system, it will have access to extensive waterways and many westward draining feeder rivers with their origins in the eastern highlands; these are zones with considerable numbers of endemic frog species. Of considerable importance with respect to the late 2016-early 2017 field data is the expansion of this species' range about 10 km to the north of the Toamasina city center, in the region of Ivoloina, and in a river basin of the same name that has its origin in large forested zones to the west.

During our surveys, this species was found in a variety of habitats, which included towns, villages, and rural communities in the general vicinity of Toamasina, and agricultural fields. Its behavior of using secluded sites as day resting places and out of the direct sun, such as underneath piles of wood, leaves, and bamboo increases the possibility of dispersal through human intervention via boat and land traffic. In all cases, it was associated with different types of water bodies ranging from small stagnant pools to larger agricultural irrigation systems; further, it was abundant in the oil palm plantations south of Toamasina near Melville (Figure 1). These are the same habitats it has been previously cited to occur (Moore *et al.*, 2015). Given the rapid and massive increase in the numbers and range of this species, combined with different interconnections of regional water and road systems, it would appear that eradication of this invasive alien species is no longer possible and perhaps the best strategy is local control of population numbers.

Lessons to be learned

In the three cases of invasive alien species discussed herein, all introduced in the immediate vicinity of Toamasina, two being birds and the third a toad, and during different periods of time, relatively small founder populations rapidly expanded and reached the point that any exercise aimed at their total eradication is now futile. The reproductive potential of the two birds is notably less than the toad; the latter in the past few years has undergone rapid population increases and expansion of its geographic range. In any case, a program needs to be rapidly put in place to control toad populations, which in order to be effective would have to be at both the national and local levels, with strong participation at the local administrative level (*fokontany*) down to individual neighborhoods where it occurs.

The question of a bounty of some sorts to reduce the number of *Duttaphrynus melanostictus* in the greater Toamasina region has received

mixed opinions from individuals and organizations concerned with the rapid expansion of this species. One reason being that local people would raise toads in semi-captivity to profit from the bounty and perhaps transport them to rearing zones outside the current incursion area. Clearly, this possibility needs to be weighed against reduction of local toad populations. An eradication or control program to reduce the number of introduced *Rattus rattus* raiding rice fields in western Madagascar was put in place by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). The simple approach used was a person in possession of a rat tail was given an entrance ticket for free to enter a local festival; this action resulted in the death of thousands of rats during a month. Some ingenuity will be needed, but perhaps a similar approach can be used in the Toamasina region to reduce numbers of this invasive toad species by using a system of benefits, rather than direct monetary gain.

Within island ecosystems such as Madagascar that contain a high percentage of endemic species, many presumably naive to aggressive introduced alien species, immediately after a potential invasive species has been identified, governmental organizations need to be quickly notified and action taken, preferably in association with scientists, conservation groups, and local communities to eliminate the founder population. The case with the rapid expansion of *Passer domesticus* in the greater Toamasina area is a case in point. If action had been taken in the late 1980s when their presence was first recorded, the situation today would be notably different. While certain aspects remain unclear as to the population level and geographic scale of the toad invasion had extended when the problem was announced to the scientific world (Kolby, 2014), relatively quick action during that period may have at least dampened the subsequent rapid expansion of this species. Now several years later, after extended discussions on removal or control procedures and some trial tests, the situation is beyond eradication. Most importantly, and the scale of the invasion is notably greater than any previous successful removal of an invasive amphibian any where in the world (Beachy *et al.*, 2011; K. Freeman, pers. comm.).

Certain members of the Malagasy scientific community have been frustrated by the approach of the international scientific community in spending what they consider large sums of money for feasibility analyses over several years. During delays of many months between different phases of the feasibility studies and associated analyses,

there was a continued population explosion of this toad and considerable range extension. For reasons associated with diverse views of needed actions, differences between regional and national perspectives, and the lack of direct funding to advance projects, a national committee created to address the invasion of this toad never advanced at the needed level. Of critical importance is the national government has the ultimate decision to implement action, but in the case of the toad invasion, the government showed no clear commitment to this problem, which in turn is part of the reason that the national committee was ineffective. As a direct corollary to this problem, we are unaware of any national governmental organization responsible for the control and surveillance of invasive species and at a larger scale biosecurity issues in and around maritime ports.

In the cases of *P. domesticus* and *D. melanostictus*, they have become invasive alien species in quick order, even though at a certain stage, it may have been possible to curtail their spread and eradicate local populations. The period when the *P. domesticus* problem was identified, was one at the start of scientific and conservation coordination across Madagascar and specifically in the Toamasina region. For a variety of different reasons associated with bureaucratic, logistic, negative public image, and perhaps a lack of understanding of the long-term implications of this possible invasion, no action was taken, which, once again, has lead to a very unfortunate situation. The case of *D. melanostictus* is different in that the conservation and scientific communities became aware of the problem a few years after the original introduction and the question of its possible invasion of the Toamasina region received considerable attention in the scientific literature and popular international and local press (e.g. Andreone, 2014; Crottini *et al.*, 2014; Kolby, 2014; Mecke, 2014; Raharisoa, 2014; Moore *et al.*, 2015; Pearson, 2015; Ambatovy, 2016). Part of this discussion concerned the importance of quick action to subdue this potentially invasive alien species, the type of trial experiments to be conducted, and what procedures to follow. However, even given the ecology and reproductive potential of this species, no control steps have yet to be taken at the regional level. Based on the explosive expansion of the population, the question of eradication in the opinion of the authors is no longer an option. Time will tell what impact the three invasive alien species discussed herein may have on agricultural losses and declines or local extirpation of the native biota

associated with competition, predation, and disease transmission.

In early 2014, a small population of an estimated 15 House Crows, *Corvus splendens*, was found in downtown Toamasina, in the park adjacent to the port and Club Nautique (Linders & Langrand, 2014). It is an invasive alien species at numerous sites in the western Indian Ocean (Puttoo & Archer, 2003; Ryall, 2016; Shimba & Jonah, 2017) and after initial colonization, it rapidly expands its range and has negative effects on agriculture, including fruit and grain crops, tourism, human health, and local biodiversity (Kamel, 2014). The most likely explanation for its introduction in Toamasina is as a stow-away on an ocean-going vessel arriving from a port where this species is known to occur, such as Mauritius, the east African coast, or elsewhere. In April 2016, in the park next to the Club Nautique, approximately 25 individuals were counted. At that time, on the basis of incomplete surveys of other coastal areas in Toamasina and within 5 km to the north and south, no other population of this species was located (S. M. Goodman & M. J. Raherilalao, unpublished data). Hence, we strongly suggest that immediate action be taken by the government, in collaboration with scientists and conservation organizations, to extirpate the *C. splendens* population of Toamasina before they become locally invasive, as witnessed in other regional areas they have been introduced.

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