Diet preference of common mynas (*Sturnus tristis*) in urban areas of Pietermaritzburg and Durban, KwaZulu-Natal

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ABSTRACT

Urbanization is one of the anthropogenic land use changes with a negative impact on biodiversity generally. However, some species are persisting well in urban areas and are termed urban exploiters. One of these species is the common myna (*Sturnus tristis*). It is also considered amongst the 100 worst alien invasive birds globally. As relatively little is known about the factors that affect common mynas invasive ability and urban persistence, aspects of their diet were investigated. Consequently, the main aims of this project were to investigate the macronutrient preference, sugar type and concentration preference, and assimilation efficiency of captive common mynas in the laboratory from July 2016 to March 2017. In addition, patterns of occurrence of common mynas in urban areas of Pietermaritzburg and Durban, KwaZulu-Natal, South Africa, and the influence of supplementary feeding and anthropogenic foods on their diet were investigated using questionnaires.

Common mynas (n = 10) macronutrient preference was investigated in the laboratory where they were offered pairwise choices of three different diets (high in lipids diet, high in soluble carbohydrates (including sucrose) diet, and high in protein diet). Common mynas significantly preferred the high in lipids diet compared with either the high in protein diet or the high in carbohydrate diets. Common mynas (n = 7) were offered pairwise choices of three nectars (glucose, fructose and sucrose) to investigate their sugar type and concentration preference. Birds showed a significant preference for diluted glucose when given a choice of nectars. The sugar content of their excreta showed that they were unable to digest and absorb sucrose in nectar.

Responses from the questionnaires showed that common mynas were found in the two study cities and were abundant year around. Results also showed that they were feeding mostly on anthropogenic foods compared with natural foods. Anthropogenic supplementary feeding has likely influenced the occurrence of common mynas because they follow food resources (human food waste) in urban areas and therefore successfully persist through lean periods. Further research is needed to help understand the ecology and behaviour of common mynas in order to get insights on how to monitor and control them in urban areas, in particular in South Africa where their range is expanding. Common mynas behaviour is currently poorly documented in South Africa. Since these are alien invasive birds with negative impacts in other countries, more research, especially on their behaviour, is required to prevent their negative impacts occurring in South Africa.

Keywords: Urban areas, diet preference, common mynas, invasive, supplementary feeding

PREFACE

The data described in this thesis were collected in the urban areas of Pietermaritzburg and Durban, Republic of South Africa, from July 2016 to March 2017. Experimental work was done while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, under the supervision of Professor Colleen T. Downs.

This thesis, submitted for the degree of Master of Science in the College of Agriculture, Engineering, and Science, University of KwaZulu-Natal, Pietermaritzburg campus, represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others, it is duly acknowledged in the text.

……………………………………

Silindile T. Gumede

September 2017

I certify that the above statement is correct and as the candidate's supervisor, I have approved this thesis for submission.

…………………………….

Professor Colleen T. Downs (Supervisor)

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DECLARATION 1 – PLAGIARISM

I, Silindile Thobeka Gumede, declare that

1. The research reported in this thesis, except where otherwise indicated is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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DECLARATION 2 – PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis.

Manuscript 1

S Gumede & CT Downs

Dietary preference of the invasive alien bird, the common myna (*Sturnus tristis*) in South Africa.

Author contributions:

SG conceived paper with CTD. SG collected and analysed data, and wrote the paper. CTD contributed valuable comments to the manuscript.

Manuscript 2

S Gumede & CT Downs

Sugar preference of the alien invasive bird, common myna (*Sturnus tristis*) in South Africa

Author contributions:

SG conceived paper with CTD. SG collected and analysed data, and wrote the paper. CTD contributed valuable comments to the manuscript.

Manuscript 3

S Gumede, L Patterson and CT Downs

Diet preference and the occurrence of an alien invasive bird the common myna in urban areas of South Africa.

Author contributions:

SG and LP conceived paper with CTD. SG collected and analysed data, and wrote the paper, LP collected data and CTD contributed valuable comments to the manuscript.

Signed: …………………………………………………………

Silindile Thobeka Gumede

September 2017

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Chapter 1

Introduction

Many researchers are convinced that many recent species extinctions are due to non-native species invasions (Gurevitch and Padilla, 2004). The introduction of non-native invasive species is a problem worldwide (Gurevitch and Padilla, 2004; Hui and Richardson, 2017). However, not all non-native species are necessarily a problem in their new environment. There are a number of non-native species used for agricultural purposes (crops and livestock) which contribute importantly to food security (Pimentel et al., 2001). Non-native species with a negative impact on the environment are those replacing native species by predating and/or outcompeting them for resources, and then dominating the environment (Pimentel et al., 2001). Alien invasion is highly associated with the extinction of native species and loss of biodiversity (Gurevitch and Padilla, 2004; Hui and Richardson, 2017). Invasive species poses a major threat to economies and ecosystems across the globe, especially as the invasion results in habitat loss and fragmentation of the landscape (Richardson et al., 2000; Allendorf and Lundquist, 2003; Yap and Sodhi, 2004; Grarock et al., 2013; Hui and Richardson, 2017). The term 'invasive species' refers to organisms that have been introduced accidentally or intentionally outside their normal distribution ranges (Richardson et al., 2000; Fraser et al., 2014). These organisms in their new environment establish a breeding population, and eventually spread rapidly (Richardson et al., 2000). In the United States approximately 50,000 of non-native species have established and caused environmental and economic loss of estimated ~US$ 125 billion p.a. (Allendorf and Lundquist, 2003). The establishment of introduced species in the new environment is determined by many factors including the availability of natural enemies, habitat suitability and essential resources to survive (Sol et al., 2012a; Grarock et al., 2013; Duduś et al., 2014). Food availability is generally an essential factor for reproduction and survival of any species (Sol et al., 2012a; Grarock et al., 2013).

Most alien invasive species show flexibility in behaviour and habitat selection, causing them to be successful in different environmental conditions and landscapes (Yap et al., 2002; Yap and Sodhi, 2004). Generally, urban landscapes are unsuitable for wildlife, however, some species persist successfully in urban areas and they are called urban exploiters (Adams et al., 2013; Paker et al., 2014). These species are often the alien species rather than native species (Galbraith et al., 2014; Haythorpe et al., 2014). Generally, the increase in urbanization levels results in more opportunities for alien invading species because they are able to tolerate human-modified environments (Yap and Sodhi, 2004; Paker et al., 2014). Alien invasive birds are the mostly advantaged species because of their ability to fly and access new areas (Klasing, 1998). Common pigeons (*Columbia livia*), English sparrows (*Passer domesticus*), European starlings (*Sturnus vulgaris*) and common myna (*Sturnus tristis*) are among the most well-known bird-pest invaders around the globe and have had major impacts on ecosystems (Dean, 2000; Pimentel et al., 2001). High availability of anthropogenic food sources generally influences the survival rates of alien species in urban areas and in turn generally supports high densities of such populations (Duduś et al., 2014; Galbraith et al., 2014).

1.1 Supplementary feeding

Generally, anthropogenic supplementary feeding and edible human refuse determine the feeding ecology of local species (Galbraith et al., 2014). Supplementary bird feeding is a popular human activity globally (Goddard et al., 2013, Reynolds et al., 2017). Supplementary feeding stations have been made available for different purposes; including to avoid and/or reduce the decline of endangered species in many parts of the world such as southern Europe and southern Africa (Bijleveld, 1974). In some instances, people feed birds to engage with wildlife (Murray et al., 2016). Supplementary feeding may result in improved population recovery, as found in the bearded (*Gypaetus barbatus*) and Egyptian (*Neophron percnopterus*) vultures in the Pyrenees and southern France, respectively (Oro et al., 2008; Lieury et al., 2015). However, supplementary feeding also has negative impacts such as increased disease transmission, foraging shifts in the behaviour of individual animals, and/ or the facilitation of invasions (Goddard et al., 2013; Cortes-Avinda et al., 2016). For example, blackcaps, *Sylvia atricapilla* in Britain changed their winter distributions due to the provision of supplementary foods in gardens (Plumer et al., 2015). Food availability is known to be a primary driver of avian distribution (Galbraith et al., 2015; Plummer et al., 2015). The interpretation of potential effects of anthropogenic supplementary feeding is different depending on whether the species is native or introduced (Galbraith et al., 2015). Enhancement of native species would have a positive impact on biodiversity whereas the enhancement of introduced species might have negative impact. Generally, supplementary food that is provisioned by humans includes seeds, bread and left overs which are likely to be exploited by omnivorous birds (Galbraith et al., 2015). Invasive bird species are generally omnivorous and opportunistic, and scavenge on novel foods (Sol et al., 2002). Therefore, they are likely to be enhanced by anthropogenic supplementary feeding or edible refuse. According to Chamberlain et al., (2009) the accessibility of anthropogenic food is likely to have a significant effect on avian demography in urban areas. Discarded foods from humans are often high in lipids and carbohydrates (Machovsky-Capuska et al., 2015). It is important to understand and determine the contribution of different diets and how consumers switch between resources of different nutrients.

1.2 Nutrient preference in birds

Lipids, carbohydrates and proteins are macronutrients supplying the kilojoules needed for the body's energy supply (Nicklas et al., 2014). These macronutrients are obtained from food (fruits, nectar, seeds etc.) birds eat. Lipids are hydrophobic and must be emulsified and hydrolyzed prior to absorption by passive processes, whereas carbohydrates (sugars) are soluble in water and readily absorbed by active and passive mechanisms (Witmer and Van Soest, 1998). Avian species have adapted to their diets with changes in body size, beak and tongue structure, protein requirements (Gartrell, 2000; Witteveen and Brown, 2014), metabolic activities, and gastrointestinal tract physiology (Downs, 1997; Klasing, 1998; Avery et al., 1999). These adaptations have influenced the food preferences in different avian species (Downs, 1997; Klasing, 1998; Avery et al., 1999). Birds select their diet according to nutrient composition and concentration they prefer (French et al., 2005). Studies have shown that fruits with high water content and high concentrations of monosaccharides but low lipid and protein contents, are often preferred by birds lacking enzymes for digesting sucrose (del Rio and Restrepo 1993; Malcarney et al. 1994; Brown et al. 2012; Jordano 2000; Gosper and Vivian-Smith 2010). Furthermore, there have been several studies showing the different macronutrient preferences of a range of bird species. Starlings *(Sturnidae)* prefer fructose or hexose, over sucrose (Lane, 1997; Avery et al., 1999), while sugarbirds *(Promeropidae)* and sunbirds (*Nectariniidae*) absorb sucrose as efficiently as glucose (Jackson et al., 1998). Bananaquits (*Coereba flaveola*) showed no preference when offered sucrose, glucose or fructose (Mata and Bosque, 2004). MacWilliams et al (2002) found that yellow-rumped warblers (*Setophaga coronate*) and red-eyed vireos (*Vireo olivaceus*) preferred diets with unsaturated fatty acids. Machovsky-Capuska et al., (2016) found that in a free ranging urban population, common mynas in Australia showed a preference for proteins compared with lipids and carbohydrates.

1.3 Alien invasive species used in this study (the common myna, *Sturnus tristis*)

The common myna (Fig. 1.1) (Order Passeriformes, Family Sturnidae), previously known as *Acridotheres tristis,* is one of four alien bird species that have successfully invaded southern Africa (Dean, 2000; Peacock et al., 2007). This alien species is native to southern Asia: it was initially released in Durban, South Africa, in the last century and has now established in various parts of southern Africa (Baker and Moeed, 1987; Sol et al., 2012b). Common mynas are considered amongst the 100 worst invasive species because of their ability to establish successfully in new environments (Holzapfel et al., 2006; Peacock et al., 2007; Van Rensburg et al., 2009). They are generally distributed in high rainfall areas and they have been seen in Cape Town but have not yet established there (Dean, 2000; SABAP 2). Common mynas generally live in close association with humans (Peacock et al., 2007; Griffin and Boyce, 2009; Lowe et al., 2011; Haythorpe et al., 2014). They thrive in anthropogenically transformed habitats, especially urban areas, and their population numbers generally increase with increased levels of habitat modification (Lowe et al., 2011; Haythorpe et al., 2014). Furthermore, common mynas are omnivorous, and readily eat anthropogenic foods. They have been observed feeding from rubbish bins and on human edible refuse (Haythorpe et al., 2014; Machovsky-Capuska et al., 2016). Common mynas mostly feed in pairs but roost in large numbers (Griffin and Boyce, 2009; Sol et al., 2012b). Common mynas are adaptable in nest selection and use cavities in a variety of natural and anthropogenic structures including steel structures, traffic lights, holes in trees and rooftops (Dean, 2000; Haythorpe et al., 2014). These alien invasive birds are believed to be posing a threat to native avian wildlife through competition for food and nesting resources (Peacock et al., 2007; Lowe et al., 2011; Haythorpe et al., 2014). Additionally, this could result in a decline in avian species richness in urban areas (Lowe et al., 2011). In other countries common mynas damage crops, and spread parasites and diseases (Peacock et al., 2007).

Figure 1.1: The alien invasive species used in this study, the common myna (*Sturnus tristis*).

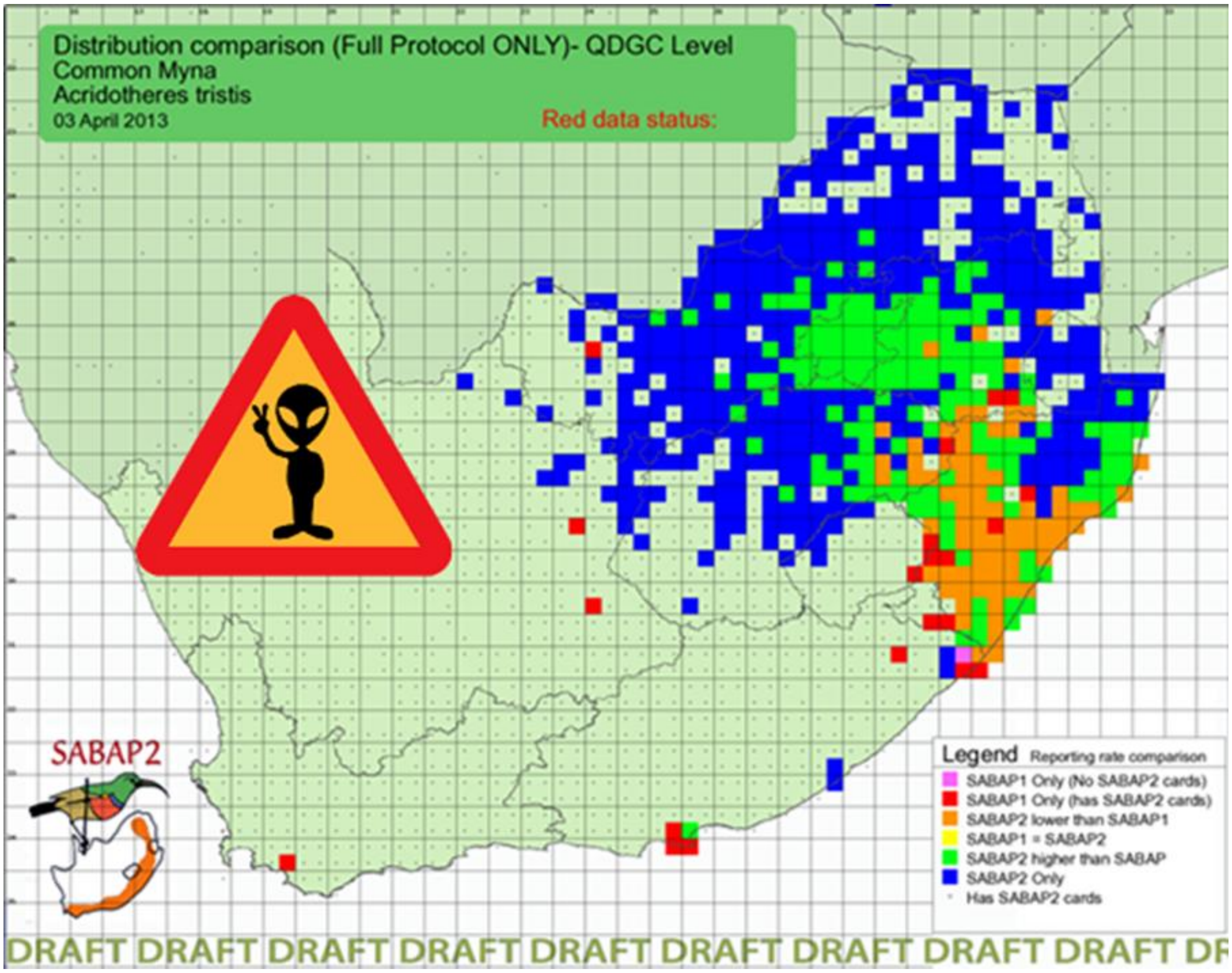

Figure 1.2: Distribution of common myna in southern Africa constructed from statistical smoothing of the records from the SA Bird Atlas Project, May 2016 (Image source: mybirdpatch.adu.org.za) (Brooks, 2013).

1.4 Motivation for the study

This study was motivated by the lack of information on the diet and food preferences of the common myna in their non-native habitats in South Africa. Anthropogenic activities such as agricultural practices, transportation and recreation often facilitate the unintentional spread of non-native species across new environments (Richardson et al., 2000; Kolar and Lodge, 2001). Some of these species that persist in new environments have negative impacts on human health and the economy, they threaten ecosystem functions, and negatively impact the native biodiversity (Kolar and Lodge, 2001; Pimentel et al., 2001). Environmental conditions, landscape type and resources are generally major factors influencing the success of these alien species (McDonald et al., 1995; Dean, 2000; Sol et al., 2002; Machovsky-Capuska et al., 2016). Although common mynas are considered one of the most successful invaders (Van Rensburg et al., 2009), there is relatively little information regarding their ecology, physiology and biology. They have invaded South Africa and their distribution is spreading towards the south and west (Fig. 1.2). The south western part of South Africa mainly produces wine which makes a major contribution to the economy (Bruwer, 2003). Common mynas are known to damage fruit in other countries, therefore, their distribution spreading towards western part of South Africa poses a potential threat to commercial orchards and vineyards with negative impacts on production and the economy. This study was also motivated by the strong association of common mynas with human-modified areas. This behaviour of common mynas raises questions about their nutrient requirements and diet preferences. Results from this study will provide important information that could explain aspects of the physiology, nutrient preferences and diet preferences of common mynas. Furthermore, understanding the factors that influence the persistence and dispersal of this species may assist in predicting and preventing future invasions.

The aim of this study was firstly to determine the effect of diet on common mynas food preference, food intake and digestion, and secondly to determine residents' perceptions of common mynas and what they had observed common mynas to feed on in the urban areas in Durban and Pietermaritzburg, South Africa. The first objective was to determine the dietary preference of common mynas when they were offered a pair-wise choice of either a diet high in lipids, high in carbohydrates or high in protein. Secondly, the sugar type and concentration preference of common mynas when given a choice of sugars were investigated. The third objective was to determine the main dietary items that common mynas feed on, and if the feed on anthropogenic supplementary food, and to document their occurrence in urban areas of Pietermaritzburg and Durban.

1.5 Study outline

This thesis consists of three experimental chapters, from Chapters 2 to 4 which can be read independently. These chapters were prepared for submission to international peer review journals and therefore some repetition was unavoidable.

Chapter 2. Dietary preference of the invasive alien bird, the common myna (*Sturnus tristis*) in South Africa.

Chapter 3. Sugar preference in invasive common mynas (*Sturnus tristis*).

Chapter 4. Diet preference and the occurrence of an alien invasive bird the common myna in urban areas of South Africa.

Chapter 5 is a general conclusion and summarizes all the results from the respective chapters in this study. It also includes some recommendations for managing common mynas in urban areas.

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Chapter 2

Dietary preference of an invasive alien bird, the common myna (Sturnus tristis), in South Africa

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Abstract

Common mynas *Sturnus tristis*, previously known as *Acridotheres tristis*, are considered among the world's worst alien invasive species. However, relatively little is known about the factors that affect their persistence and spread in new environments. They have been observed feeding on a wide range of foods, including anthropogenic foods in urban areas. Their diet preferences are relatively unknown. Therefore, we investigated the macronutrient preferences of common mynas in captivity. Common mynas (n = 10) were given a pairwise choice of three different diets (high in lipids, high in proteins, and high in carbohydrates (including sucrose)) in the laboratory to determine their preference. Common mynas showed a significant preference for the high lipid diet, followed by the high protein one, with the high carbohydrate diet least preferred. Consequently, common mynas preferred food high in lipids compared with proteins and carbohydrates. Potentially common mynas might not be a problem for South African agricultural since these enterprises generally provide relatively few dietary items high in fat so we expect the common

mynas will continue to be distributed mainly in urban areas of South Africa where anthropogenic foods relatively high in fat are more common.

Keywords*:* Dietary preference, macronutrients, alien invasive, urban exploiters, common myna

Introduction

Alien species invasions have been the part of human existence for a long time (Prins and Gordon, 2014). However, invasions only became an issue and part of the ecological agenda in the last century (Prins and Gordon, 2014). Alien species invasion is an important issue across the world as it threatens biodiversity and has major impacts on the environment (Richardson et al., 2000; Pimentel et al., 2001; Allendorf and Lundquist, 2003; Gurevitch and Padilla, 2004; Yap and Sodhi, 2004; Grarock et al., 2013). The general decline in native species with the increase in alien species has led many researchers to believe that there is a relationship between alien species invasions and extinctions (Gurevitch and Padilla, 2004). Successful invasive species have the ability to disperse, colonize and establish in new environments (Dean, 2000; Brousseau and McSweeney, 2016). Abiotic conditions of the new environment also influence the success of invasive species (Dean, 2000; Prins and Gordon, 2014). Generally, low competition and predation pressure allow invasive species to thrive in their new environments (Dudu, 2004; Prins and Gordon 2014).

Anthropogenic land use change, including urbanization, is generally causing biodiversity loss and fragmentation of habitats (McKinney, 2002; Ramírez-Restrepo and Halffter, 2016). However, species respond differently to changes in the environment (Lowe et al., 2011). Some species either persist, or colonize and establish in urban areas and are referred to as urban exploiters (Haythorpe et al., 2014). Urban exploiters have the ability to adapt to these environments created by urbanization by plasticity in their behaviour, ecology and/ or physiology (Duduś et al., 2014). Generally, species that successfully establish in urban areas are those that are able to live in a close association with humans (Lowe et al., 2011; Haythorpe et al., 2014). They have the ability to change habitat preference and their diet frequently (Sol et al., 2002). These characteristics are commonly found in alien invasive avian species (Sol et al., 2002).

During the process of invasion, species experience new types of foods and learn new foraging behaviours (Machovsky-Capuska et al., 2016). Generally, human-dominated areas provide rich food sources that are not available in wildlands (Merkle et al., 2013; Machovsky-Capuska et al., 2015). Therefore, they provide different amounts and ratios of macronutrients. Nutrient requirement and the ability to digest and absorb these macronutrients are the major influences in choosing the diet in species (McWilliams et al., 2002; Schaefer et al., 2003; Machovsky-Capuska et al., 2016). Nutrients are important for growth and provision of energy (Klasing, 1998; Machovsky-Capuska et al., 2016). Omnivorous birds feed on a wide range of foods with different macronutrients (Voigt et al., 2008).

Common mynas (*Sturnus tristis* previously known as *Acridotheres tristis*) are omnivorous, invasive birds, native to southern Asia (Baker and Moeed, 1987; Peacock et al., 2007; Lowe et al., 2011; Haythorpe et al., 2014). These passerine birds are considered amongst the worst invasive species worldwide (Holzapfel et al., 2006; Peacock et al., 2007; Van Rensburg et al., 2009). They have invaded many countries including South Africa (Baker and Moeed, 1987; Peacock et al., 2007). Common mynas live in a close association with humans causing them to thrive in urban areas (Griffin and Boyce, 2009; Lowe et al., 2011; Haythorpe et al., 2014). They are also able to endure different environmental and climate conditions (Baker and Moeed, 1987; Peacock et al., 2007). In other countries flocks of common mynas are known to damage fruit (grapes and citrus fruits) crops (Baker and Moeed, 1987; Machovsky-Capuska et al., 2016). Furthermore, common mynas are known to compete with native species for resources such as nesting sites and food, posing a threat to native species (Peacock et al., 2007; Lowe et al., 2011; Haythorpe et al., 2014; Machovsky-Capuska et al., 2016). They have been observed feeding on a large range of foods and human refuse (Peacock et al., 2007; Machovsky-Capuska et al., 2016). As members of the Sturnidae, common mynas provide a good model system to study nutritional limitations (Machovsky-Capuska et al., 2016) and its role in this successful invader.

Birds' diet is influenced by many factors including their morphology and physiology (Nicolson and Fleming, 2014). Avian feeding guilds include nectarivores (feed on nectar predominately), frugivores (feed on fruits predominately), insectivores (feed on insects predominately), and omnivores (feed on a range of different foods) though many species switch diet depending on food availability (Levey and Rio, 2001; Voigt et al., 2008; Nicolson and Fleming, 2014). This variation in birds' diet preference results on them having different abilities in digesting and absorbing nutrients (Levey and Rio, 2001). Nutrients found in fruits and nectar are different from those found in insects, and require different digestive mechanisms (Levey and Rio, 2001). Urban birds, specifically common mynas, have been observed feeding on a range of anthropogenic foods (Machovsky-Capuska et al., 2016). In this study, we examined the macronutrient preference of common mynas in the laboratory when offered a pairwise choice of different diets varying in specific macronutrients (high protein, high lipid, and/ or high carbohydrate) but with similar energy yields. We predicted that common mynas would show a significant preference for the diet high in protein content as found in an Australian study of common mynas (Machovsky-Capuska et al., 2016).

Methods

Ten common mynas were captured in Pietermaritzburg, KwaZulu-Natal, South Africa (29° 35' 23.9994"S 30° 23' 59.9994" W) in April 2015 and in July 2016, using mists nets under permit from Ezemvelo KZN Wildlife. The common mynas were kept in outside aviaries at the University of KwaZulu-Natal animal house for four weeks before the diet trials. Birds were fed a maintenance diet that consisted of grated fruit and vegetable mix, slices of pawpaw, bananas and oranges supplemented with Aviplus Softbill Mynah Pellets (Aviproducts Durban, South Africa). After the outdoor acclimatization, birds were moved inside the animal house to a constant environmental room temperature and kept individually in cages (77 × 52 × 81 cm) and acclimated for a week before experiments. During this time, they were provided the maintenance diet daily as well as the three experimental diets.

Diets type preference trials

Pairwise choice tests were conducted using three experimental diets: high in protein vs high in lipids, high in protein vs high in carbohydrates, and high in lipids vs high in carbohydrates. These macronutrients were chosen as they are typical of urban anthropogenic food resources (Machovsky-Capuska et al., 2016; pers. obs.). The high protein diet was achieved by using two Aviplus products (Aviproducts, Durban, RSA). Aviplus high protein fat concentrate (Table 2.1, 40% protein, 14% fat and also vitamins, minerals and trace elements) was supplied in a ground form as it is usually added to birds' diet as a supplemental component. This was added to Aviplus parrot instant cooking mix dinner which contains rolled and roasted (cooked) grains and peas. We increased the protein content of the latter to 28% by adding the Aviplus high protein fat concentrate (Table 2.1). The mixture was ground together before being offered to common mynas.

Table 2.1 Nutritional composition of the three diets offered to common mynas.

Nutrient	Units	Actual		
		High fat mix	High carbohydrate parrot cooking mix	High protein fat
VOLUME	NONE	100	100	100
Metabolizable Energy	MJ/kg	16	0	15.9
ME Poultry	MJ/kg	0	15.45	0
Crude Protein	g/kg	165	124	396
Lysine	g/kg	7.3	5.72	21
ALysine	g/kg	6.4	0	0
Methionine	g/kg	4	1.88	9
TSAA	g/kg	6.7	4.06	15
Isoluecine	g/kg	6.5	4.43	18
Tryptophan	g/kg	1.8	1.07	4
Threonine	g/kg	5.6	4.3	15
Arginine	g/kg	12.3	8.11	0
Fat	g/kg	200	29.15	139
Fibre	g/kg	34	31.76	40
NDF	g/kg	65	0	108
Calcium	g/kg	6.2	0.42	10
Total Phosphorus	g/kg	5	3.27	6
Avl Phosphorus	g/kg	3.2	0	3
Sodium	g/kg	1.4	0.13	2
Chloride	g/kg	1.9	0	4
Potassium	g/kg	6.5	0	12
Sulphur	g/kg	2.6	0	0
Magnesium	g/kg	2.2	0	0
Ash	g/kg	43.35	18.02	58
Histidine	g/kg	0	1.96	0
Valine	g/kg	0	5.84	0
Linoleic Acid	g/kg	0	13.49	0
Carbohydrate	g/kg	0	580.8	0
Dry matter	g/kg	0	0	903
DE Swine	g/kg	0	0	16
NE Swine	g/kg	0	0	110
ASLysine	g/kg	0	0	18
ASMethionine	g/kg	0	0	8
ASTSAA	g/kg	0	0	13
ASIsoleucine	g/kg	0	0	13
ASTryptophan	g/kg	0	0	3

Ashreonine	g/kg	0	0	12
ASValine	g/kg	0	0	15

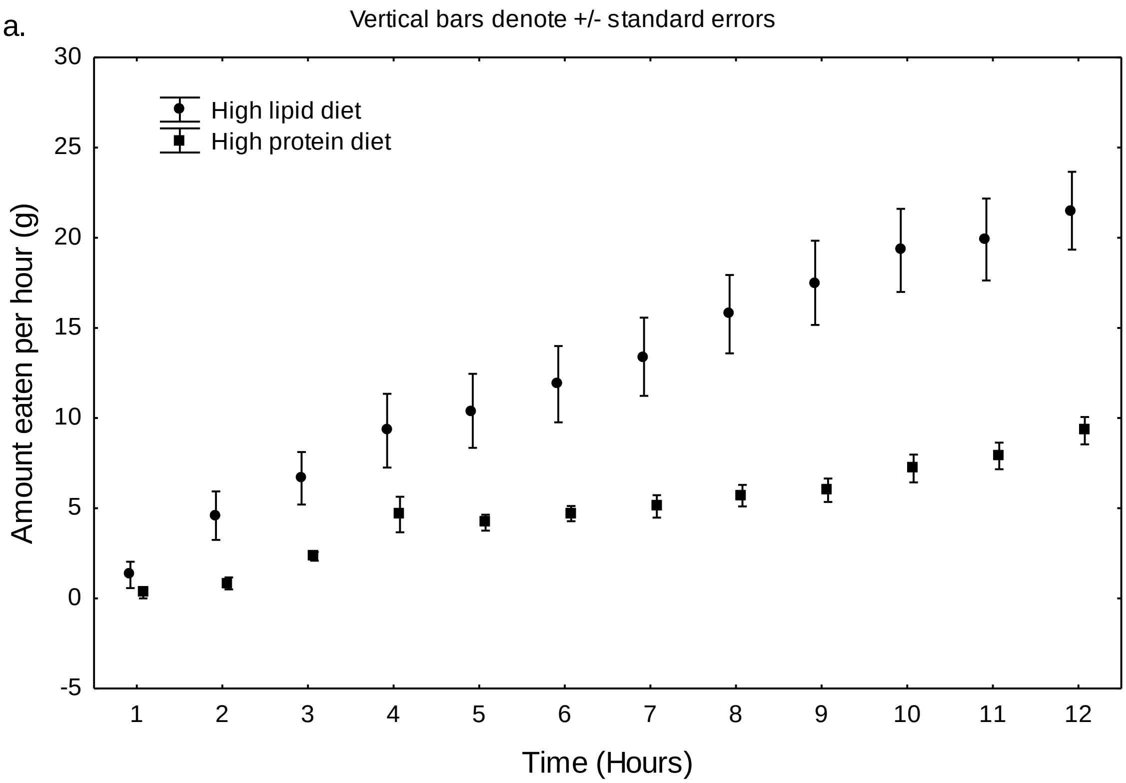
The Sutherland's high fat parrot mix (Aviproducts, Durban, RSA; lipids 20% of dry weight; contains peas, maize, wheat, palm oil, mixed nuts and sunflower seed mixed with parrot supplement; Table 2.1) was used as the high in lipids diet. Although it was pre- mixed by the manufacturer, we ground it before feeding it to common mynas. The high carbohydrate diet was prepared by adding brown sugar (sucrose) to the Aviplus parrot cooking mix dinner which increased carbohydrate to 20% dry weight (Table 2.1), and ground before feeding it to common mynas.

The respective choice experiments were conducted from 06:00 to 18:00h. Common mynas were weighed before and after each of the trials. The respective diets (50 g of each) were offered to common mynas in two separate bowls whose positions were changed at midday to avoid positional bias. Food consumption was measured each hour from 07:00 to 18:00h. All ten birds were given the same choice of food during trials. Trials were not run on consecutive days, one or two days were skipped before the next trial, and trials were randomized. Total food consumption was calculated for each trial by subtracting food (in grams) left from initial food offered to the birds and to determine preference, the T-Test in STATISTICA (Statsoft, Tulsa, USA) analysis was used. Body mass initially and finally were compared using Repeated Measures Analysis of Variance (RMANOVA) with STATISTICA.

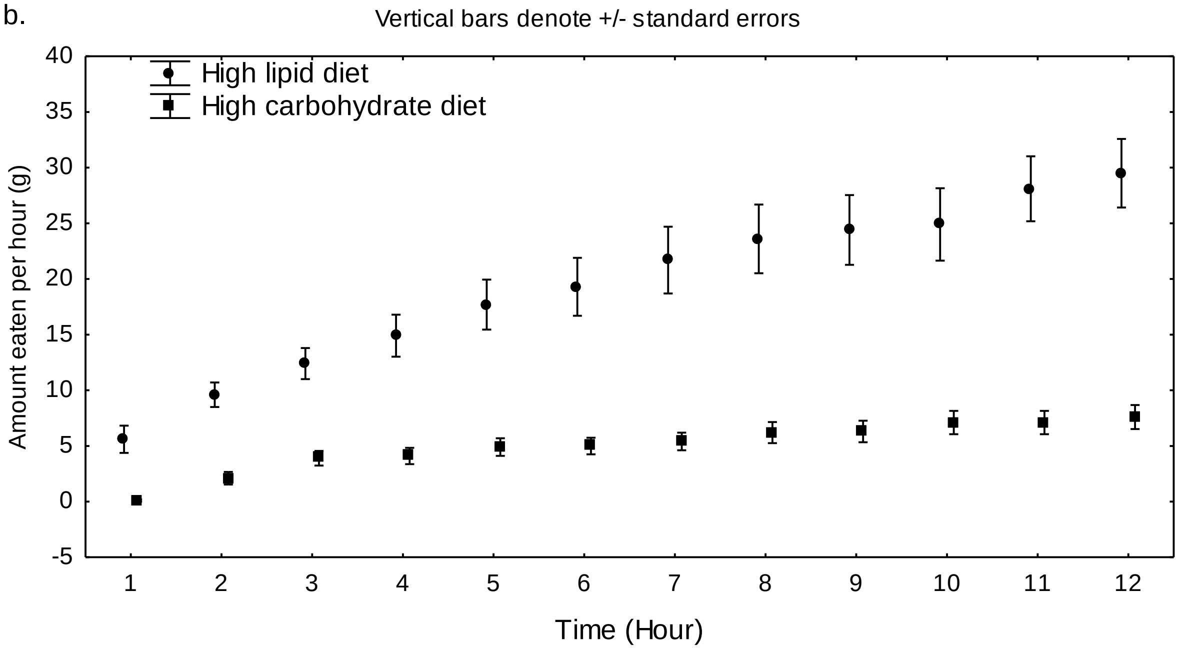
Results

Common myna initial body mass did not differ significantly between the three different diet trails (RMANOVA, $F_{(2, 18)} = 1.311$, $P = 0.294$), nor did their final body mass differ significantly between the respective trials (RMANOVA, $F_{(2, 18)} = 0.0$, $P = 1.0$). The mean initial body mass ranged from 96.6 – 99.6 g while mean final body mass was 101.0 g for the respective diet trials.

a.



b.



c.

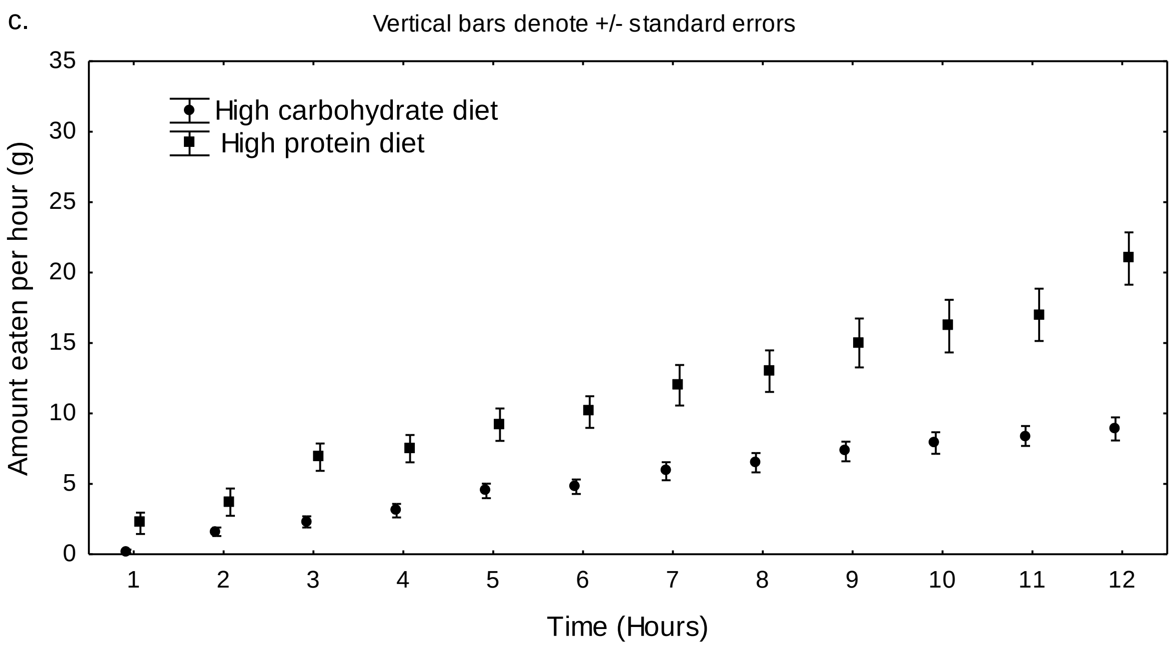


Figure 2.1: The rate of food consumption of common mynas (n = 10 for all tests) when offered the respective macronutrient diets offered in pairwise choice tests where **a**) was high in proteins versus high in lipids, **b**) high in lipids versus high in carbohydrates, and (**c**) high in proteins versus high in carbohydrates.

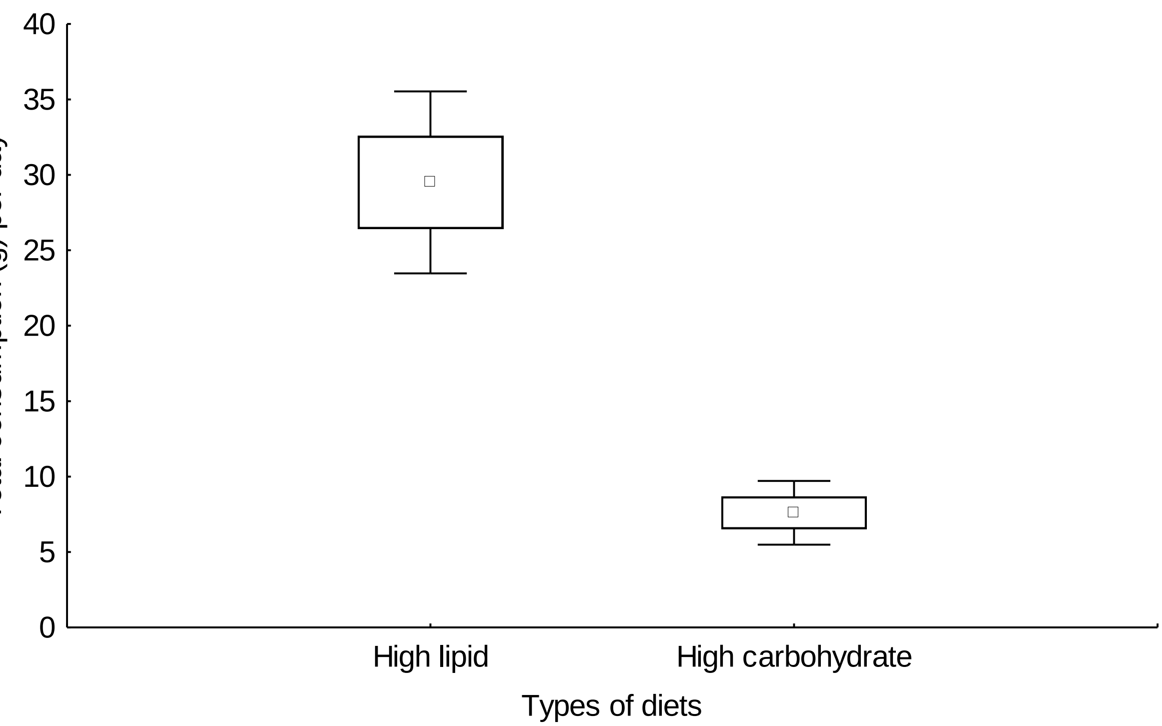
The rate of food consumption of the respective diets by common mynas differed significantly when offered the respective macronutrient diets offered in pairwise choice tests; high in proteins versus high in lipids (RMANOVA, $F_{(11, 99)} = 17.89$, $p < 0.05$; Fig. 2.1a); high in lipids versus high in carbohydrates (RMANOVA, $F_{(11, 99)} = 17.263$, $p < 0.05$; Fig. 2.1b), and high in proteins versus high in carbohydrates (RMANOVA, $F_{(11, 99)} = 15.424$, $p < 0.05$; Fig. 2.1c).

Common mynas showed a significant difference in preference between diets high in proteins and high in lipids in terms of total consumption (T-test: P = 0.003; t = 5.415; df = 18; Fig. 2.2a). The mean total consumption of the diet high in lipids was higher compared with that of the diet high in proteins (Fig.2.2a). There was also a significant difference between total consumption of the diet high in proteins compared with the diet high in carbohydrate (T-test: P = 0.012; t = 5.960; df = 18; Fig. 2.2b). Mean total consumption of the diet high in proteins was higher than the mean total consumption of the diet high in carbohydrates (Fig. 2.2b). Furthermore, there was a significant difference between the diet high in lipids and the diet high in carbohydrates (T-test: P = 0.003; t = 6.716; df = 18; Fig. 2.2c). Mean total consumption the diet high in lipids was higher than the mean total consumption of the diet high in carbohydrates (Fig. 2.2c). Overall, common mynas showed a preference for the diet high in lipids when offered in pairwise choices with other diets (high in protein or high in carbohydrates). The diet high in carbohydrates was least preferred when offered in pairwise choices with other diets (high in protein or high in lipids) (Fig. 2.2a, b and c).

a.


40
35
30
25
20
15
10
5
0
Total consumption (g) per day
High protein
High lipid
Types of diets

b.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Total consumption (g) per day
High lipid
High carbohydrate
Types of diets

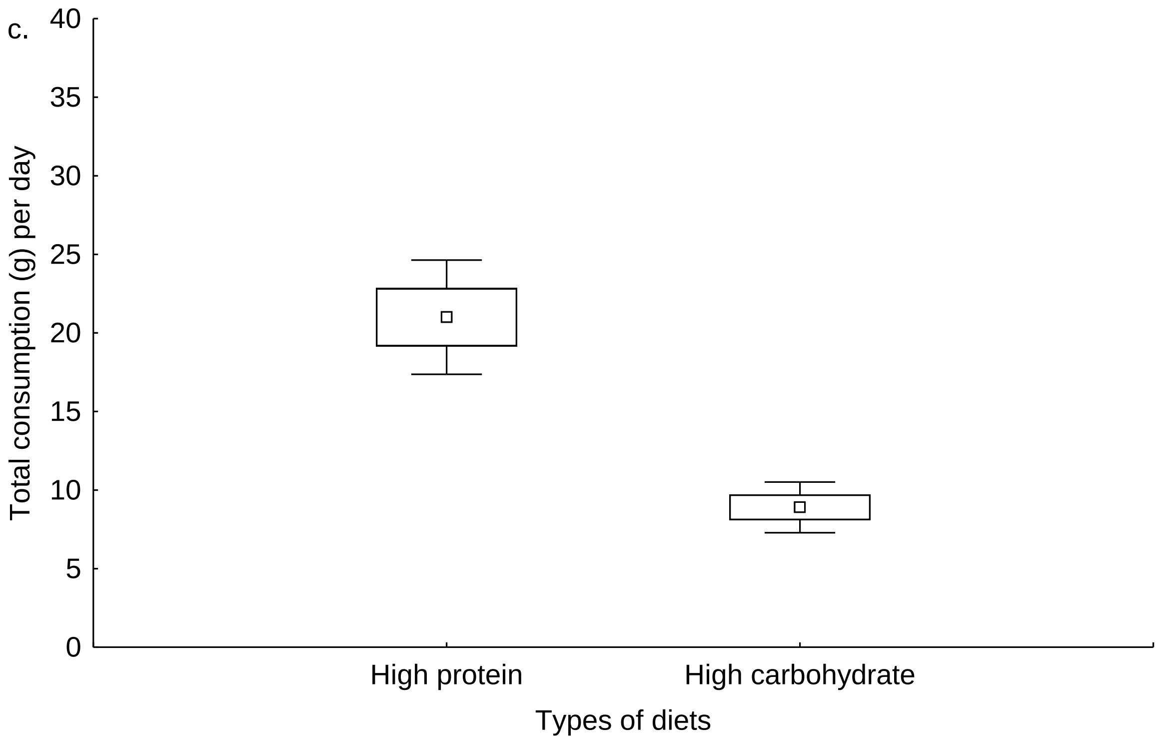

Figure 2.2: The total food consumption of the respective macronutrient diets offered in pairwise choice tests to common mynas (n = 10 for all tests), where **a**) was high in proteins versus high in lipids, **b**) high in lipids versus high in carbohydrates, and (**c**) high in proteins versus high in carbohydrates.

Discussion

Common mynas showed a significant preference for a diet high in lipids in this study when offered a pairwise choice of diet varying in macronutrients. They consumed a high in lipid diet at a relatively high rate compared with their consumption rate of high in protein and high in carbohydrate diets. Food selection in animal species is influenced by many factors such as physiological, morphology and behavioral qualities (Bozinovic and del Río, 1996; Klasing, 1998; Avery et al., 1999; McWilliams et al., 2002; Caron-Beaudoin et al., 2013; Zungu and Downs, 2016). In recent studies, Machovsky-Capuska et al., (2016) and Peneaux et al., (2017) found that common mynas in Australia showed a preference for proteins compared with lipids and carbohydrates. However, in our study the high lipid diet was the most preferred compared with the high protein or high carbohydrate diets offered. These birds are alien, invasive birds, and mostly urban and/or associated with human habitation (Peacock et al., 2007; Griffin and Boyce, 2009; Lowe et al., 2011; Haythorpe et al., 2014). Therefore, they are generally exposed to anthropogenic food sources (Caron-Beaudoin et al., 2013). Anthropogenic food sources are generally made up of a different range of macronutrients (Machovsky-Capuska et al., 2016). This might be an advantage to common mynas enabling them to digest and assimilate different types of macronutrients. Additionally, common mynas are omnivores and have a varied range of feeding habits (Klasing, 2005; Ríos et al., 2014). Furthermore, they are generalists which means there are likely to try new foods they find in human modified environments (Ducatez et al., 2015) and exhibit a degree of behavioural flexibility in feeding behaviour and choice.

In this study, common mynas showed a high preference for lipids compared with the other diets offered to them. Generally, fats are known to be digested and absorbed into the system with relatively high energy returns (McWilliams et al., 2002; Pierce et al., 2004; Kim et al., 2013; Roura et al., 2013). Specifically, unsaturated fatty acids may be absorbed more efficiently (Pierce et al., 2004). MacWilliams et al. (2002) found that yellow-rumped warblers (*Setophaga coronate*) and red-eyed vireos (*Vireo olivaceus*) preferred diets with unsaturated fatty acids. According to Roura et al., (2012), there is a direct relationship between nutrients and taste. The taste of fats is one of the types with high possible implications related to the poultry industry; the food intake increases with the increase of fats (Roura et al., 2013). However, ingestion of certain nutrients may be influenced by seasons or conditions (Ríos et al., 2014). During migrating season birds use lipids as their major source of energy (Pierce et al., 2004; Klasing, 2005) and in cold conditions they also store large amounts of fats in their bodies (McWilliams et al., 2002). In our study weather conditions were excluded since our study was done in the laboratory in a controlled environment, however, experiments were done in winter and birds body mass did not change significantly Furthermore, food availability influences the feeding behaviour of birds (Bozinovic and del Río, 1996; Klasing, 2005). In summer, most omnivorous birds feed on insects and switch to fruits in winter (Klasing, 2005; Podlesak and McWilliams, 2006). Insects are higher in proteins and fats but have less carbohydrate (Voigt et al., 2008). Therefore, it is not surprising that common mynas preferred lipids and proteins over carbohydrates in this study. It is clear that different avian species differ in their choice and ability to absorb nutrients from their respective diets.

Nectarivores and frugivores consume mainly simple carbohydrates which are sucrose, glucose and fructose (Brown et al., 2010a; Bizaaré et al., 2012). Generally, granivorous and omnivorous birds react negatively to sugars (Roura et al., 2013). In this study, carbohydrates were the least preferred nutrient to common mynas. As members of the Sturnidae, common mynas were expected not to prefer carbohydrates (Gatica et al., 2006; Brown et al., 2012). Sturnidae members are unable to digest sucrose because they lack the enzyme sucrase responsible for digestion of sucrose and this result into sucrose intolerance (Gatica et al., 2006; Bizaaré et al., 2012; Brown et al., 2012). Preference of simple sugars are related to the efficiency and degree at which these simple sugars are assimilated (Bozinovic and del Río, 1996). This behaviour has been observed in several other avian species such as the common starling (*Sturnus vulgaris*) (del Rio et al., 1988), the American robin (*Turdus migratorius*) (Karasov and Levey, 1990), the red-winged starling (*Onychognathus morio*) (Bizaaré et al., 2012), the austral thrush (*Turdus falcklandii*), and the Chilean mockingbird (*Mimus thenca*) (Gatica et al., 2006). In our study, common mynas showed dietary flexibility but showed the least preference for the carbohydrate high diet, which was relatively high in sucrose.

Managing invasive avian species, like common mynas, that exhibit dietary flexibility is a challenging task. In South Africa, common mynas have invaded the eastern part of the country and the distribution is extending towards south western part of the country. The south western part of South Africa produces wine and deciduous fruit agriculture is extensive (Kaplan and Kaplinsky, 1999; Bruwer, 2003). Common mynas in other countries are known to damage fruit crops (grapes and citrus fruit) (Baker and Moeed, 1987). However, in South Africa there has been no evidence reported of common mynas damaging fruit crops. Therefore, their potential negative impact on agriculture in South Africa cannot be confirmed at this point. In terms of the results in this study, common mynas are likely less of a problem for commercial fruits (e.g. nectarines, mangoes, peaches and bananas) relatively high in sucrose. Furthermore, common mynas have been mostly invading urban areas rather than natural or rural habitats in South Africa (SABAP 2, 2007). For invasive species to successfully invade new environments, they have to be able to exploit novel food resources which are made up of different macronutrients. In this study common mynas showed dietary flexibility which may enhance their foraging behaviours in new environments. However, further studies on common mynas are required to understand their interactions with these environments.

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Appendix 2.1

a) **b)** **c)**

Appendix 2.1: The three commercial diets used in the myna dietary choice experiment where **a)** is the Aviplus high protein fat concentrate, **b)**, the Aviplus Sutherland's high fat parrot mix, and **c)** the Aviplus parrot cooking mix dinner products.

Chapter 3

Sugar preference in invasive common mynas (*Sturnus tristis*)

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Abstract

Nectarivorous and frugivorous birds have been found to select their diet according to sugar type. Consequently, many studies of sugar preference have been conducted on various avian species. Common mynas, *Sturnus tristis* previously known as *Acridotheres tristis,* are considered amongst the 100 worst invasive species worldwide and damage fruit crops in some countries. However, their sugar preferences have never been studied. Therefore, we investigated the effect of sugar type and concentration on sugar preference and assimilation efficiency in common mynas (n = 7). These birds were given pairwise choice tests of sugars (fructose, sucrose and glucose) of 5g/ml (5%) to test sugar preference. Common mynas showed preference for glucose over sucrose and fructose. To determine at which concentrations they prefer glucose, they were offered three different concentrations of glucose (5%, 10% and 25%). They showed distinct preference for the 10% concentration of glucose in comparison with 5% and 25% glucose nectars. The birds maintained body mass in the respective experimental trials showing sufficient energy intake. Common mynas failed to digest and absorb sucrose, but fructose and glucose were digested and assimilated efficiently for all concentrations. Results of this study showed that common mynas prefer glucose, especially at ~10% concentration. Species distribution is determined by food resources, and these

results on sugar type and preference of common mynas might contribute to preventing or managing their spread in South Africa

Keywords: Invasive birds, sugar preference, sugar concentration, assimilation, common mynas.

Introduction

Food selection in nectarivorous and frugivorous birds is influenced by several factors including gut physiology and sugar preference (Avery et al., 1999; Gartrell, 2000). According to Ayala-Berdon et al. (2013), food selection in nectar and fruit feeding animals is influenced by two main mechanisms, the ability to digest sucrose and the ability to taste the sweetness of sugar. Sugar preferences have been studied in many birds' species (Downs and Perrin, 1996; Downs, 1997; Schaefer et al., 2003; Wellmann and Downs, 2009; Brown et al., 2010; Odendaal et al., 2010; Brown et al., 2010b) and these studies have shown different sugar preferences and abilities to digest and assimilate sugars in birds. Sugar preference of avian species may be affected by the presence or absence of the enzyme sucrase that is responsible for digestion of sucrose (Downs, 1997; Witteveen and Brown, 2014). The enzyme sucrase has been found present in passerine and non-passerine bird families (Lotz and Schondube, 2006). However, some avian species like the Sturnidae generally have an inability to digest and absorb sucrose efficiently because they lack the enzyme sucrase responsible for the digestion of sucrose (Gatica et al., 2006; Bizaaré et al., 2012; Brown et al., 2012). Generally, species lacking enzyme sucrase or having a relatively low sucrase activity, are unable to digest and assimilate sucrose efficiently (Lane, 1997; Nicolson and Fleming, 2014). These species usually show no preference for or avoid sucrose nectar, but show significant preference for fructose and hexose nectars (Lane, 1997).

Sugar concentration and type plays an important role in influencing the diet selection of nectarivorous and frugivorous birds (Martínez del Rio et al., 2001; Brown et al., 2010a,b,c, 2012; Downs et al., 2012; Witteveen and Brown, 2014). Generalist nectarivores pollinate plants producing large volumes of diluted hexose-dominant nectar and generalist frugivores are able to subsist in the absence of a particular fruit crop (Larson, 1996; Witteveen and Brown, 2014). Whereas specialist nectarivores pollinate plants producing less volumes of high concentrated, sucrose-dominant nectar (Witteveen and Brown, 2014) while specialists frugivores rely on particular fruit crops for their dietary needs (Larson, 1996). Sugar concentration may be fundamental in managing the daily intake energy in nectar and fruit feeding birds (López-Calleja et al., 1997). Some birds prefer higher concentrations in order to capitalize on their level of energy but they reduce the intake as the concentration increases (Downs 1997; Brown et al., 2010a). Sugar and concentration preferences appear to be the outcome of the close relationship between the pollinators and the plants they pollinate (López-Calleja et al., 1997; Jackson et al., 1998; Mata and Bosque, 2004) and seed dispersal in fruit feeding birds.

Invasive species are organisms that have been accidentally or intentionally introduced outside their normal distribution ranges (Gurevitch and Padilla, 2004) which then reproduce, establish a breeding population, and spread rapidly in their new environment (Richardson et al., 2000). These species are generally a major threat to biodiversity conservation and ecosystem service provision worldwide (Richardson et al., 2000; Pimentel et al., 2001). Common mynas, *Sturnus tristis* previously known as *Acridotheres tristis,* are native to Southeast Asia and widespread from Afghanistan, the Indian subcontinent, Burma to Indochina (Baker and Moeed, 1987). Common mynas are considered among the 100 worst invading species worldwide (Holzapfel et al., 2006). They have successfully invaded many countries including South Africa

(Baker and Moeed, 1987; Peacock et al., 2007). In South Africa, common mynas are widely distributed in areas with an annual rainfall greater than 600 mm in southern Africa (Dean, 2000). Common mynas are occasional nectarivores (Brown et al 2012b), they have a wide-ranging diet (from fruit, occasionally nectar to anthropogenic foods), and are omnivorous (Peacock et al., 2007). This alien invasive species is mostly associated with human habitation and urban areas (Peacock et al., 2007; Griffin and Boyce, 2009; Lowe et al., 2011; Haythorpe et al., 2014). Common myna flocks are known to damage fruit crops such as, pears, strawberries, figs, gooseberries, apricots and apples in some other countries (Baker and Moeed, 1987). These birds appear to have behavioural and physiological flexibility and so cope with different environmental conditions, and these characteristics make them successful invaders (Baker and Moeed, 1987; Peacock et al., 2007).

According to our knowledge, no study of sugar preference has been conducted on common mynas. However, early research on sugar-type preferences in passerine, occasional nectarivores has shown regular preferences for hexose sugars at low concentrations, and either hexose preference or no preference at high concentrations (Brown et al., 2010; Odendaal et al., 2010; Brown et al., 2010a). In this study, we examined the effect of sugar type and concentration on sugar preference in common mynas when given a choice of sugars commonly found in nectar and fruit (i.e. sucrose, glucose and fructose). We also examined their ability to digest these sugars. Red-winged starlings, *Onychognathus morio* preferred hexose over sucrose and were unable to digest sucrose due to the absence of enzyme sucrase (Bizaaré et al., 2012; Brown et al., 2012). Since common mynas are members of Sturnidae, we predicted that common mynas would prefer hexose over fructose and sucrose regardless of the concentration. We also predicted that they will prefer low concentrations of hexose when given different concentration choices.

Methods

We captured seven adult common mynas using the mists net in Pietermaritzburg, KwaZulu-Natal (29° 35' 23.9994"S 30° 23' 59.9994" W) in April 2015. Birds were acclimated for two weeks in outside aviaries at the University of KwaZulu-Natal animal house. They were fed grated fruit and vegetable mix (apples, pears, carrots and beetroot) and slices of pawpaw and banana as the maintenance diet, supplemented with Aviplus Softbill Mynah Pellets (Aviproducts, Durban, RSA). Birds were then moved into a constant environmental room (12h: 12D) after the outdoor acclimatization where there were kept separately in cages (77 × 52 × 81 cm). The birds were then acclimated for another week on the maintenance diet. Before experimental trials started, birds were familiarized with modified burettes by offering them water in burettes daily. All seven birds were used in all trials.

Sugar type preference trials

We conducted pairwise choice tests using the following pairs of solution: 5% sucrose and 5% fructose, 5% sucrose and 5% glucose, 5% fructose and 5% glucose which were offered to the common mynas. To prepare each of these concentrations, 5 g of each sugar was placed into the container and distilled water was added to the 100 mL mark. Birds were offered 100mL of each pairwise choice in modified burettes. The concentration of 5% (a dilute concentration) was used because it is a typical concentration that opportunistic nectarivores prefer (Brown et al., 2012). Birds were not offered the maintenance diet nor additional water during the trials. No food was available overnight as common mynas are diurnal and feed only in the day. Birds were weighed before and after trials. Trials were conducted from 06:00 to 18:00h. During the experimental trials the consumption of sugar solution was measured each hour from 07:00 to 18:00 h. At midday, positions of the burettes were changed to avoid positional bias. Trials were not run on consecutive days, with a period of separating consecutive trials. All birds were offered the same choice of solutions per experiment. The total volume consumed for each sugar type was calculated using the formula: the amount of the solution of each sugar type drank divided by the total volume of solution drank (Brown et al., 2012). To determine the sugar type preference in birds and changes in their initial and final body mass for each experiment, we used the dependent T-Test in STATISTICA (Statsoft, Tulsa, USA).

Glucose concentration preference trials

To determine if common mynas have a concentration preference for glucose, we offered each bird a choice of three glucose solutions of different concentrations (5, 10 and 25%) simultaneously. We tested the concentration preference for glucose because it was the sugar type most preferred in sugar type preference trials. These solutions were randomly placed in each bird cage. The trials were conducted in the same manner as the sugar preference trials (above). The consumption of each glucose concentration was measured each hour from 07:00 to 18:00 h and the total consumption calculated for each concentration. The maintenance diet was not offered to birds during the trials. The volume of each solution consumed was converted into energy consumed per gram of body mass per day. Energy intake and volumetric intake were compared from each of the three concentrations offered to birds concurrently and analysed using Repeated Measures Analysis of Variance (RMANOVA) with STATISTICA.

Apparent assimilation efficiency

In a separate experiment, we determined the apparent assimilation efficiency (AE) of glucose, sucrose and fructose at 25% concentrations. A tray of liquid paraffin was placed under the wire mesh cage where birds were kept to prevent the evaporation of liquid excrete. Birds were deprived food the night before the trials to make sure they are hungry. During the trial no other foods or water was offered to birds. Birds were fed a single sugar solution (100 ml) for a period of 6h and deprived food for the next 2 h to make sure that food was digested and processed during the trial. Amount of sugar solution consumed was recorded every hour for the duration of the trial. Excreta were collected from the liquid paraffin using a syringe (excreta and paraffin do not mix which made it easy to collect excreta) and weighed at the end of the trial. Samples were then centrifuged at 1,300 rpm and sugar content was analyzed using the Shimadzu (LC-20AT) high-performance liquid chromatograph (HPLC) manufactured in North America.

Results

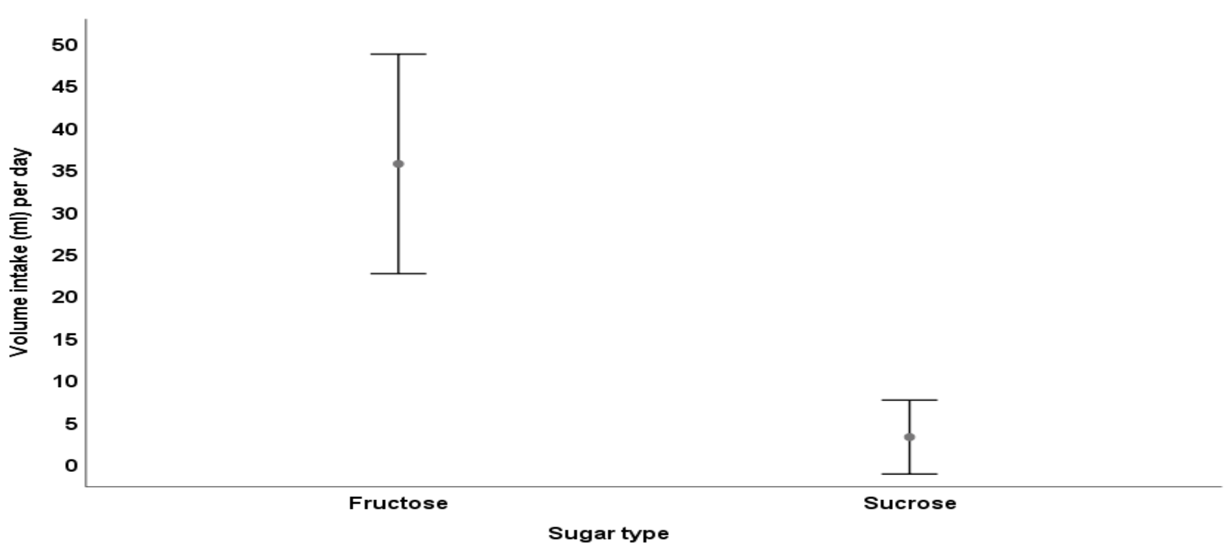
Body mass

In the fructose versus sucrose experiment, common myna initial body mass differed significantly to final body mass (T-Test, $t_{(6)} = -6.908$, P = 0.0005; mean (± SD) initial body mass = 93.93 ± 10.30; mean (± SD) final body mass = 95.56 ± 10.49). Similarly in the glucose versus fructose experiment, their initial body mass differed significantly to final body mass (T-Test, $t_{(6)} = 11.94$, P = 0.00002; mean (± SD) initial body mass = 97.31 ± 5.88; mean (± SD) final body mass = 94.96 ± 6.06). However, in the glucose versus sucrose experiment, their initial body mass was not significantly different to final body mass (T-Test, $t_{(6)} = 1.71$, P = 0.139; mean (+ SD) initial body mass = 97.37 ± 7.28; mean (+ SD) final body mass = 96.92 ± 6.84). In the experiment where different concentrations of glucose were offered, their initial body mass was not significantly different to final body mass (T-Test, $t_{(6)}$ = 1.76, P = 0.129; mean (+ SD) initial body mass = 99.61 $\pm$ 2.71; mean (+ SD) final body mass = 99.17 $\pm$ 2.86).

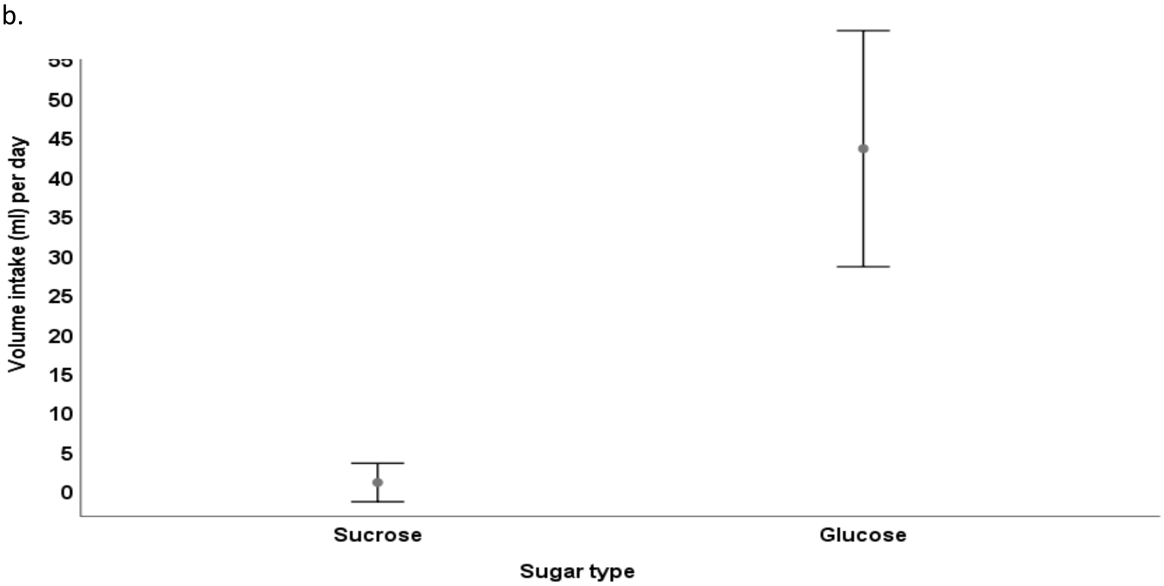
Sugar type preference trials

During the sugar preference test there was a significant difference in volume intake between fructose and sucrose (T-Test: $t_{(12)}$ = 8.062, P = 0.003, Fig. 3.1a). Mean volume intake of fructose was higher than mean volume intake of sucrose (Fig. 3.1a). There was also a significant difference between the choice of glucose and sucrose volume intake (T-Test: $t_{(12)}$ = 6.828, P = 0.008, Fig. 3.1b). Mean volume intake of glucose was higher than mean volume intake of sucrose (Fig. 3.1b). There was a significant difference between glucose and fructose in terms of volume intake (T-Test; $t_{(12)}$ = 6.334, P = 0.033, Fig. 3.1c). The mean volume intake of glucose was higher compared with mean volume intake of fructose (Fig. 3.1c).

a.



b.



c.

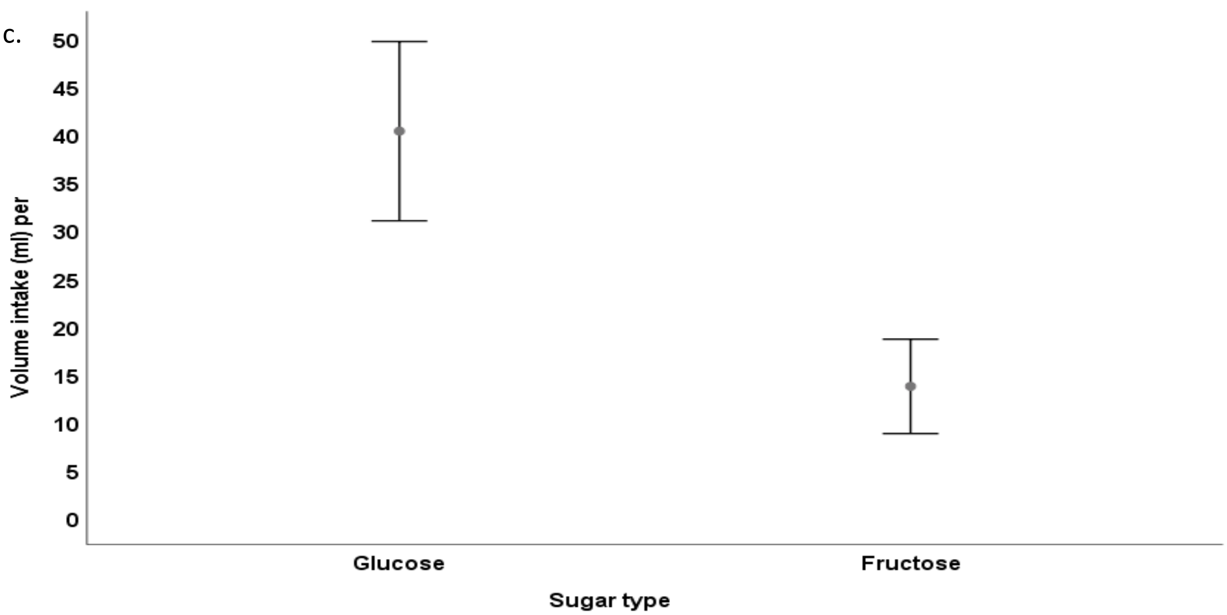
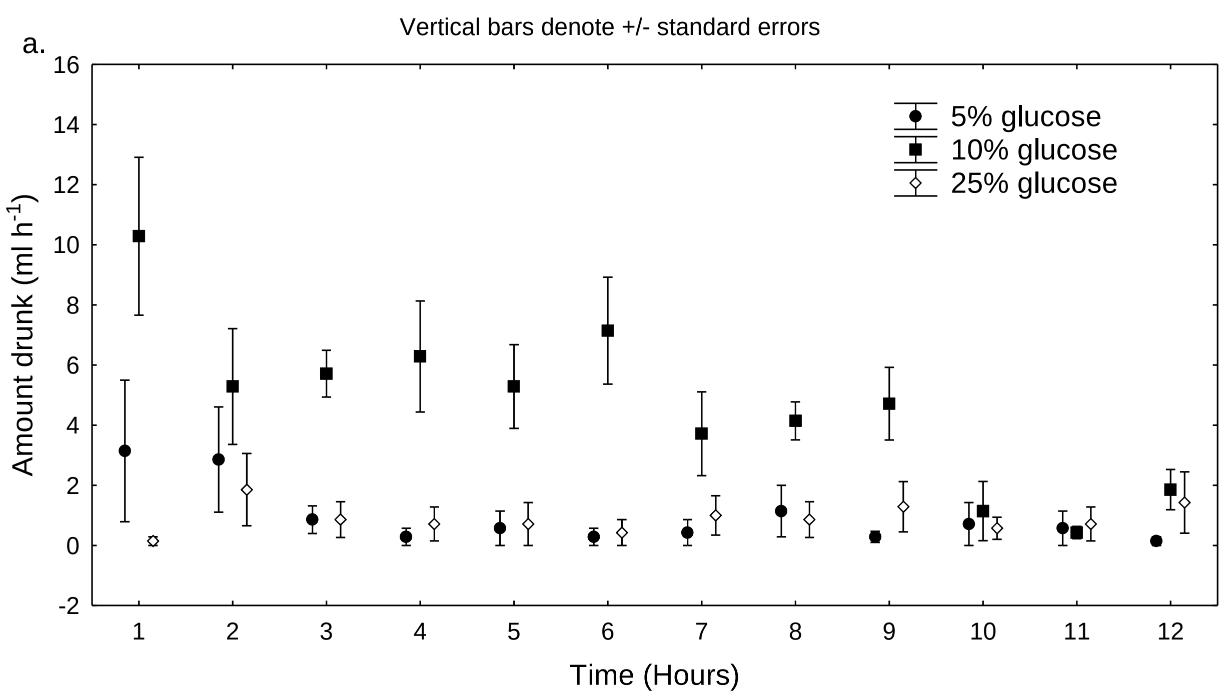
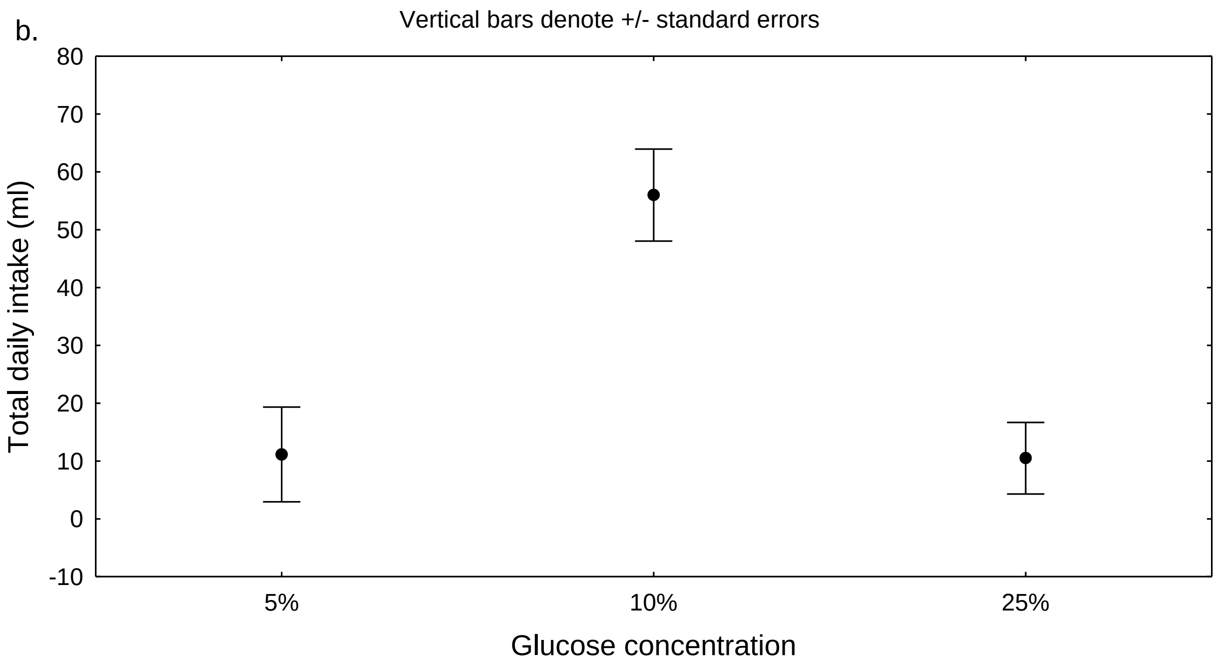


Figure 3.1: The total volume intake of common mynas (n = 7) in pairwise tests of sugar types, a.) fructose versus sucrose, b), glucose versus sucrose and c) fructose versus glucose.

Glucose concentration preference trials

Common mynas showed a significant difference in hourly volume intake of the three different glucose concentrations (5%, 10%, 25%) offered concurrently (RMANOVA, $F_{(22, 132)} = 2.766$, $P = 0.0002$, Fig. 3.2a). There was a significant difference in total daily mean volume intake between the three glucose concentrations offered concurrently (RMANOVA, $F_{(2, 12)} = 8.560$, $P = 0.0049$; Fig. 3.2b), with the 10% glucose significantly higher compared with the 5 and 25% concentrations (Post-hoc Tukey, $P < 0.05$). The concentration of glucose had no significant effect on total energy intake obtained per glucose concentration offered concurrently to common mynas (RMANOVA, $F_{(2, 12)} = 2.138$, $P = 0.161$, Fig. 3.2c).





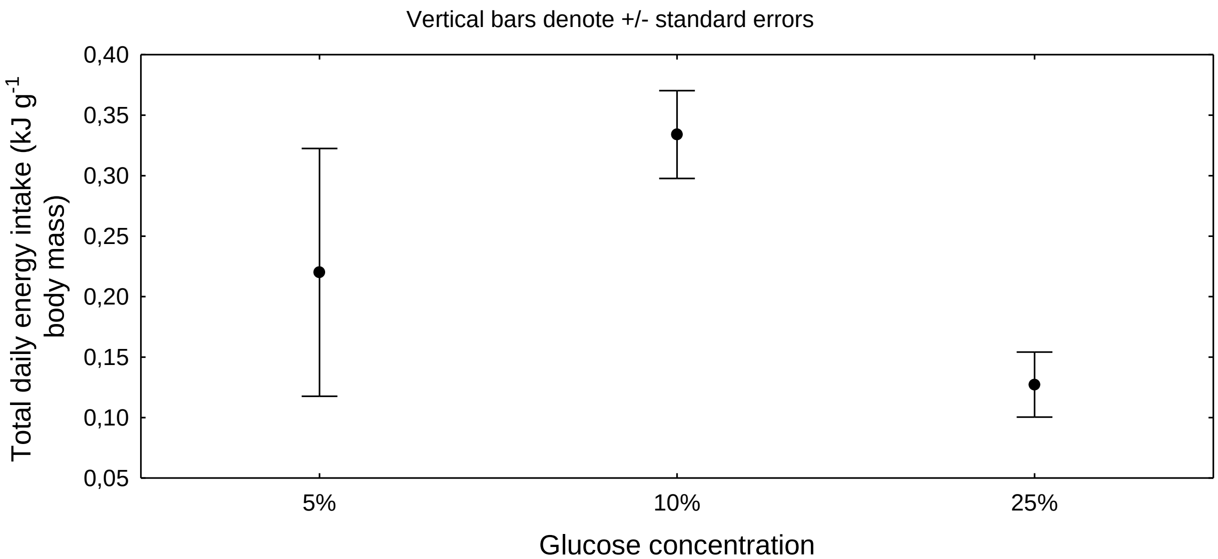


Figure 3.2: Comparison of common myna (n = 7) glucose nectar intake when offered 5, 10 and 25% concentrations concurrently where a.) is mean hourly rate, b.) total daily mean volume intake, and c) total daily mean energy intake.

Table 3.1: Assimilation efficiencies of different sugars in common mynas (n = 7) offered 100ml of each sugar type over a period of six hours from 06h00-12h00 midday.

		Concentration(g/ml)		
Sugar type	**Product**	**Initial offered**	**Left (in excrete)**	**Assimilated%**
Sucrose	Glucose	25	2.71	90
	Sucrose	25	19.47	22.1
	Fructose	25	2.82	89
Fructose	Fructose	25	0.2	99
Glucose	Glucose	25	0.21	99

Apparent assimilation efficiency

Common mynas had a high assimilation efficiency when feeding on glucose and fructose, absorbing 90% of both these sugars with only 10% of glucose and fructose found in their excreta (Table 3.1). In contrast, common mynas showed low assimilation efficiency for sucrose, with 80% of sucrose found in the excreta and only 20% absorbed (Table 3.1).

Discussion

As much as common mynas are known to have a broad diet and are omnivorous (Peacock et al., 2007), in our study they showed a distinct preference for fructose over sucrose nectar when presented with fructose and sucrose of the same concentration (5%). As mentioned, common mynas, as members of the Sturnidae, were expected to avoid sucrose solutions (Brown et al., 2012). The Sturnidae generally have an inability to digest and absorb sucrose efficiently because they lack the enzyme sucrase responsible for the digestion of sucrose (Gatica et al., 2006; Brown et al., 2012). Common mynas also showed a preference for glucose over sucrose, or fructose, of the same concentration (5%). Generally, birds prefer sugars that they have the ability to digest and absorb efficiently. Therefore, our findings support that common mynas generally avoid sucrose solutions when offered glucose or fructose concurrently. This in contrast to some other nectar studies on specialist nectarivores (Mata and Bosque, 2004, Brown et al., 2010a). However, our results were similar to some studies on generalist nectarivores, especially members of the Sturnidae (Brown et al., 2010c, 2012). Thrushes (Turdidae**)** decreased their volume of food consumed when they were offered sucrose and they also lack sucrase activity (Gatica et al., 2006). Common mynas similarly had little volumetric intake of sucrose when offered glucose, fructose and sucrose solutions concurrently in the sugar preference experiment. The assimilation experiment confirmed that common mynas are unable to digest sucrose efficiently (Ayala-Berdon et al., 2013). Birds lacking sucrase enzyme experience osmotic diarrhoea when ingesting sucrose therefore they generally avoid this sugar solution (Schondube and Del Rio, 2003; Lotz and Schondube, 2006). During our experiments birds were not offered water as the nectars were relatively dilute so providing sufficient water. Birds maintained body mass during the feeding trials showing they obtained sufficient energy.

Our results showed a distinct difference when common mynas were presented with three nectar concentrations of glucose (5, 10 and 25%). Common mynas showed a preference for 10% concentration of glucose with decreased intake of the low (5%) and high (25%) glucose concentrations. This suggests that common mynas prefer glucose not too sweet nor too dilute. Similarly, red-winged starlings reduce intake of glucose solutions with high concentrations (Brown et al., 2012). Another generalist nectarivore, the village weaver (*Ploceus cucullatus*) also did not prefer high concentrations (20% and 25%) of glucose (Odendaal et al., 2010). Ingestion of hexose in high concentrations sometimes causes dehydration (Odendaal et al., 2010).

Specialist nectar feeding birds increase their nectar consumption with decreased sugar concentration to compensate and regulate energy intake (Downs, 1997; Mata and Bosque, 2004; Brown et al., 2010a). The common myna had sufficient volume intake to maintain body mass and obtain their daily energy requirements in the various sugar experiments we conducted.

Common mynas had the ability to efficiently absorb glucose and fructose sugars (~ 90%), compared with sucrose (~ 22%), which was similar to red-wing starlings (Brown et al., 2012), and this is attributed to their lack of the enzyme sucrase (Bizaaré et al., 2012). Common mynas avoided the sucrose solution with a low total consumption compared with other sugars. In contrast, common mynas preferred hexose sugar and were able to digest and absorb it efficiently.

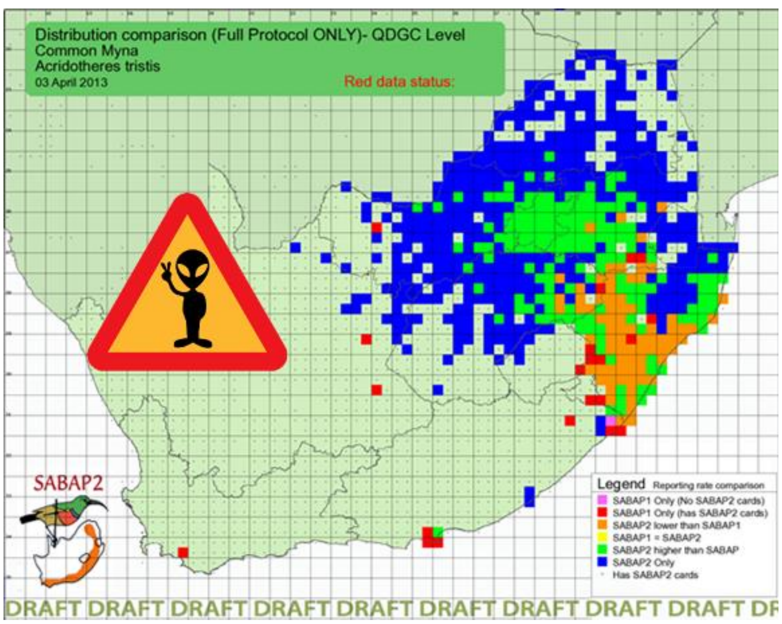


Figure 3.3: Distribution of common myna in southern Africa constructed from statistical smoothing of the records from SA Bird Atlas Project, May 2016 (Image source: mybirdpatch.adu.org.za, Chapter 1) (Brooks, 2013).

Food is vital for species to survive, reproduce and spread successfully. Common mynas are invasive and highly associated with humans (Hythorpe et al., 2014). Understanding the sugar and concentration preference of common mynas may contribute to finding management strategies to control or eradicate common mynas. Currently common mynas are extending their range in South Africa but have not established extensively in the Western Cape Province (Fig. 3.3). The south-western part of South Africa is known for its wine and deciduous fruit industries (Kaplan and Kaplinsky, 1999; Bruwer, 2003) which contribute to the regional development, economy, employment and tourism (Kaplan and Kaplinsky, 1999; Bruwer, 2003). As mentioned, common mynas have been reported damaging fruit crops (Baker and Moeed, 1987). Therefore, preventing or managing common myna spread towards south-western part of South Africa is of high importance. To prevent the spreading of alien species, it is desirable to be able to predict individual invasions (Heger and Trepl, 2003). One possibility is to look for characteristics that lead to invasiveness in species, or to search for features in ecosystems that make them susceptible to invasions (Heger and Trepl, 2003). Therefore, understanding the sugar preference of common mynas gives insight of what areas are susceptible to invasions, such as areas with fruit crops high in glucose and fructose. However, further studies on this species is required to get more information on factors allowing it to be successful invaders.

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Chapter 4

Diet preference and the occurrence of an alien invasive bird, the common myna, in urban areas of South Africa.

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Abstract

Species distribution and abundance is determined by various factors including availability of food and preferred habitats. Urbanization has provided these factors to many urban exploiters, many of which are alien invasive species. These are successful in urban areas as a result of factors including the ease of access to anthropogenic foods and supplementary feeding. Common mynas *Sturnus tristis* are considered one of the worst alien invasive avian species. They are particularly successful in urban environments. They are omnivorous and opportunistic. Common mynas display a variety of feeding innovations in the wild. Therefore, in this study we conducted surveys to determine the occurrence, dietary habits and preferences of non-captive common mynas in urban areas and human perceptions of them. We distributed questionnaires in the urban areas of Pietermaritzburg and Durban, South Africa. Common mynas were reported feeding on anthropogenic foods compared with natural foods (insects, fruits and nectar). They were also found to be abundant in the urban areas and cities where there was high access to the anthropogenic foods or supplementary feeding compared with gardens. Most of the respondents made no comment on how they perceived common mynas. However, others perceived common mynas as aggressive and chasing away

indigenous species. Therefore, control of available anthropogenic edible waste is necessary to manage common mynas population in and around towns and cities in South Africa.

Keywords: Common myna, *Acridotheres tristis*, invasive species, urban areas, supplementary feeding and diet preference.

Introduction

Determining the contribution of different foods to the diet, and understanding how consumers switch between resources, is essential in improving the understanding of the impact of predators and maintaining bird species interactions in ecological communities (De Barba et al., 2014). This is particularly relevant due to the beginning of the increase in human modified habitats resulting in changes in range and availability of food resources (Berger et al., 2001; Soulé et al., 2003). It is essential to understand how these bird species survive in the urban areas (McGiffin et al., 2013). Urbanized environments are generally associated with low species diversity (Croci et al., 2008; Haythorpe et al., 2014) as compared with their natural counterparts. Bird species surviving in urban environments are those able to take advantage of unique conditions experienced in an urban landscape (Haythorpe et al., 2014). These bird species are called urban exploiters because of their ability to tolerate urban conditions and succeed (Kark et al., 2007; Croci et al., 2008; Stracey, 2011; Haythorpe et al., 2014). Often, urban exploiters are alien invasive species (Haythorpe et al., 2014). Alien invasive species present major threats to the biodiversity across the globe (Grarock et al., 2014). However, the threats posed by them differ: some alien invasive species may have adverse impacts while others are comparatively not threatening (Grarock et al., 2014). Urbanization has induced disturbances due to human activities and created favorable conditions for urban exploiters (Croci et al., 2008).

Generally, the distribution and abundance of species is primarily determined by resources that are essential for their survival (Kark et al., 2007; Grarock et al., 2014). Diet plays a critical role in determining where specific bird species may be found (Kark et al., 2007). A popular activity carried out by millions of households i.e. bird feeding occurs in gardens and backyards of urban areas (Goddard et al., 2013; Galbraith et al., 2015; Wilcoxen et al., 2015). Supplementary foods are provided to wildlife intentionally by having bird feeding stations or unintentionally such as anthropogenic food waste (Steyaert et al., 2014; Galbraith et al., 2015). Supplementary feeding has both positive and negative effects on good biodiversity. It can provide food for species during the dry or cold seasons when food availability is reduced therefore, improving the survival of the population. However, anthropogenic supplementary feeding can also enhance the biological invasion (Goddard et al., 2013). Food availability is considered the primary driver of avian population regulation, consequently supplementary feeding has been found also influencing the distribution of some birds (Plummer et al., 2015). Human presence can affect many aspects of birds such as the foraging behaviour, therefore, for them to survive and colonize the urban environment, they require the ability to tolerate human presence (McGiffin et al., 2013).

In this study, we focused on how common myna's (*Sturnus tristis)* occurrence and diet is influenced by supplementary feeding or anthropogenic foods in urban areas. Common mynas are considered amongst the 100 worst invasive species worldwide (Peacock et al., 2007; Grarock et al., 2014; Sarangi et al., 2014). This omnivorous invasive species is native to South Asia (Peacock et al., 2007; McGiffin et al., 2013; Taylor et al., 2013; Hubbard et al., 2015) and has invaded many countries including South Africa. Common mynas live in close association with humans and are not distracted by the anthropogenic noises (McGiffin et al., 2013; Munoz et al., 2014; Hubbard et al., 2015). As a result, common mynas are generally abundant in modified urban landscapes (Grarock et al., 2014).

The purpose of our study was firstly to document the occurrence of non-captive common mynas in the urban areas. Secondly, we determined how anthropogenic foods and supplementary feeding influenced their diet preference. Thirdly, we determined the perceptions of urban dwellers towards common mynas and determined their level of understanding of invasive alien birds in urban areas of Pietermaritzburg and Durban, South Africa. As mentioned, common mynas are urban exploiters, it is essential to establish how supplementary feeding affects their population persistence and increase (McGiffin et al., 2013; Grarock et al., 2014). Findings from our study will provide with important insights regarding the distribution and management of common mynas populations in urban areas.

Methods and Materials

Study site

This study was conducted in Pietermaritzburg and Durban urban areas (Fig. 4.1) in a period of five months from October 2016 – February 2017. Pietermaritzburg is situated at 29.6006° S, 30.3794° E altitude in KwaZulu-Natal, South Africa (Msunduzi Municipality IDP report draft, 2016). This is the capital and the second-largest city in the province of KwaZulu-Natal, founded in year 1838, and it is currently governed by the Msunduzi Local Municipality (Msunduzi Municipality IDP report draft, 2016). Currently the human population of Pietermaritzburg is estimated to be 618 536 (Msunduzi Municipality IDP report draft, 2016). Durban is the largest coastal city in the South African Province of KwaZulu-Natal (eThekwini Municipality IDP report, 2016/2017). It is located 29.8587° S, 31.0218° E altitude in South Africa with a population of approximately 3 442

398 and it is known for its African, Indian and colonial influences (eThekwini Municipality IDP report, 2016/2017). All the interviews using questionnaires were conducted within the formal urban areas by handing out questionnaires to communities and sending out emails.

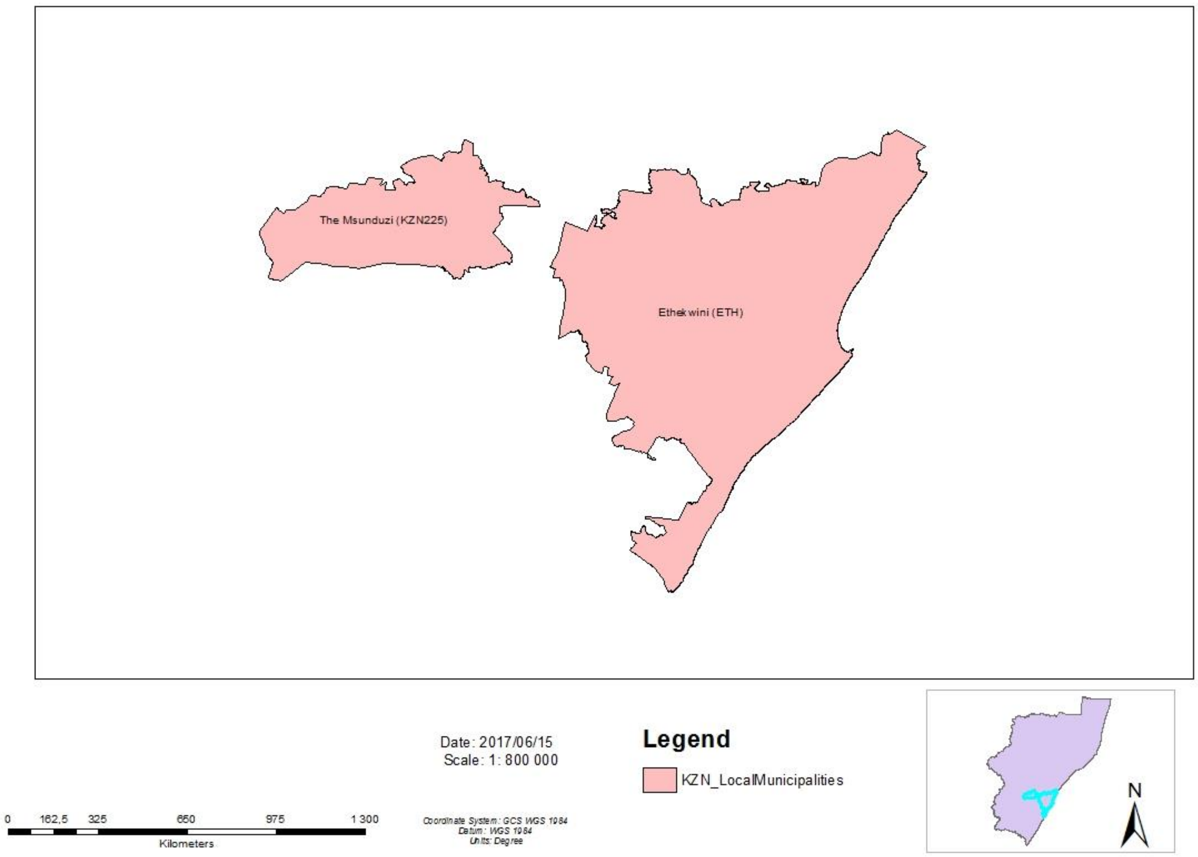

Figure 4.1: Durban and Pietermaritzburg municipalities, KwaZulu-Natal, South Africa.

Questionnaire survey

A questionnaire covering where and when common mynas are seen by communities, what activities they are observed doing, their feeding ecology, and perceptions of common mynas was drafted. All interviews were carried out with the participation of the respondents. The survey had University of KwaZulu-Natal (UKZN) ethical clearance (HSS/145/016M), which complied with the ethical standards of the relevant national and institutional committees on human experimentation. Interviews were conducted in different years. From March to September 2013 and October 2016 to February 2017 a self-administered electronic questionnaire was made available for residents in Durban and Pietermaritzburg to complete online through Survey Monkey (www.surveymonkey.com). The questionnaire's online link was distributed widely via email, door to door circulations and social media (Facebook), to reach as many people as possible around Pietermaritzburg and Durban. University of KwaZulu-Natal (UKZN) postgraduate students and staff assessed the survey before the online link was distributed to the public.

The supplementary feeding in the community was categorized as the presence or the absence of the bird feeding stations at respondents' homes. The survey respondents were asked to provide data on the supplementary type of food they provided at their bird feeding stations, and what birds they were aiming to feed. They were asked whether they saw common mynas visiting feeding stations or gardens. The responses were categorized as yes or no. In terms of what activities common mynas were observed doing respondents were given options of nesting, feeding or other where they were specifying the activity. If common mynas were observed feeding, respondents were asked what were they were observed feeding on given the option of nectar, fruits or other types of foods. Respondents were asked to comment on their perceptions of common mynas. Quantities of how many responses from each variable received were recorded.

Statistical analyses

Chi-square (χ^2) tests were used to analyze the responses from the respondents in relation to supplementary feeding, the influence of anthropogenic foods and community perceptions of common mynas in urban areas of Pietermaritzburg and Durban. All statistics were performed in SPSS version 22.

Results

A total of 733 responses were received from community members within Durban and Pietermaritzburg urban areas. Communities did not respond to all questions asked, however, all responses received were analyzed. Respondents were residing in different urban areas, some were residing close to central business district and others away from it. Respondents varied with age, ranging from 22 to 69 years of age. Fifty five percent of respondents were retired from work, 40% were working and 5% were studying.

How often common mynas are seen in the cities

A total of 130 people responded to the question asking if they had seen common mynas in their cities/urban areas, with a significantly higher proportion of people who had seen them than not (Chi-square = 103.508 df = 1, $P < 0.001$). Seventy percent (n = 91) of these respondents had seen common mynas year around, 28% (n = 36) percent had seen common mynas in summer while 2% (n = 3) saw them in winter only.

Common mynas feeding in gardens

There were 602 responses from the question of common mynas feeding in gardens. Thirty two percent (n =192) respondents had seen common mynas feeding in their gardens whereas 68% (n = 410) respondents had not. A significant number of common mynas were found feeding in resident’s gardens (Chi-square = 78,944, df = 1 P = 0.00). Of 192 respondents with common mynas feeding in their gardens, 49% (n = 94) of them often see common mynas feeding there while 51% (n = 98) rarely see common mynas feeding in their gardens. There was no significant difference between common myna presence and how they were often seen feeding in resident’s garden (Chi-square = 0.083, df = 1, P = 0.773). The occurrence of common mynas in resident’s garden did not necessarily mean they were feeding there. A large number of common mynas were reported in the city centres compared with residents’ gardens (Fig. 4.1).

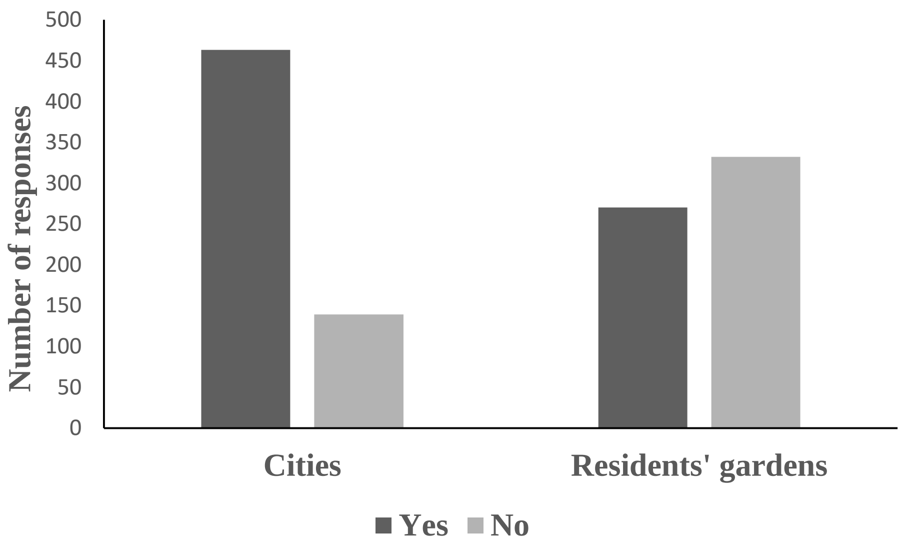

Figure 4.2: Common mynas sightings in Durban and Pietermaritzburg areas (n = 602) showing that most respondents observed them in the city centres (cities) rather than in residential gardens.

Bird feeders

When respondents were asked if they have bird feeding stations on their properties, 602 people responded to this question. There was no significant difference between having a bird feeding station and not having it on myna presence on people’s properties (Chi-square = 0.007, df = 1, P

= 0.935). Almost half, 50.1% (n = 302) of respondents had bird feeding stations at their homes while 49.9% (n = 300) of them did not have bird feeding stations.

Behavioural and feeding ecology of common mynas

When asked 'What activities common mynas do when you see them' 59 % (n = 77) have seen common mynas feeding while 16% (n = 21) and 25% (n = 32) had seen common mynas nesting and walking around the city and their urban areas respectively. There were significant differences in the number of mynas seen exhibiting different behaviours (feeding, nesting or walking around) around urban areas and cities (Chi-square = 40.631, df = 2, P = 0.00). Common mynas were observed feeding on significant amounts of anthropogenic foods (human edible food waste, bread and dog food) compared with natural foods. Only 33%, 10% and 2% of mynas were observed feeding on insects, fruits and nectar, respectively and 55% were reported feeding on anthropogenic foods.

Community perceptions of common mynas

Most of people either disliked common mynas or had neutral feelings about them. Out of 602 respondents, 11% had no problem with common mynas and actually said they like them, and 48% were neutral, while 41% disliked common mynas. Many respondents, 40% (n = 249) had no comments on their perception on common mynas or they chose not to comment on this section. Relatively few, 21% (n = 128) of respondents perceived common mynas as aggressive and had observed them chasing away indigenous species and 6% (n = 38) people do not like common mynas due to the fact that they are alien invasive birds. Furthermore, when asked 'How do you feel about common mynas?' 19% of respondents liked common mynas as other birds, they are not bothered by them, and 2% perceived common mynas as pests, and 3% said they are noisy. Finally, 9% of participants believe that population of common mynas is decreasing in urban areas of Durban and Pietermaritzburg.

Fifty percent of respondents (n = 130) knew that common mynas were alien invasive birds. Respondents showed no significant difference between understanding that common mynas are alien invasive birds and not (Chi-square = 0.00 df = 1 P = 1.00). However, most of respondents (74%) understood what alien invasive species are and 26% did not understand. Half of respondents (50%) believed that eradication of nests would be the most effective strategy to get rid of common mynas. Out of 130 respondents, 10% had no comment on which strategy could work effectively to remove common mynas, 11% chose shooting as the effective strategy and 18% preferred spraying roosts as the better strategy for removal of common mynas. Furthermore, the rest of 9% of respondents were not sure which strategy could work effectively or preferred not to do anything to common mynas. Starving common mynas and using natural enemies was also mentioned as potential effective strategies to remove common mynas.

Discussion

Our results showed that common mynas were abundant year-round in the urban areas of the study. These observations confirmed that common mynas are successful urban exploiters that persist successfully in the cities and are abundant in highly urbanized landscapes and their occurrence seems not to be influenced by seasonal changes (Yap et al., 2002; Peacock et al., 2007; Lowe et al., 2011; Taylor et al., 2013; Grarock et al., 2014). However, in our study there were relatively few respondents who observed common mynas in their gardens which raised the question: Do common mynas prefer gardens less or it depends on where the urban area is located? This behaviour of common mynas been relatively less abundant in gardens was also observed in the study of house sparrows (*Passer domesticus*) (Magudu and Downs, 2015). Common mynas have been found roosting in trees that are close to food sources, the closer the food source to the roost the shorter the distance travelled and longer feeding time (Yap et al., 2002). House sparrows showed a similar trend where they were found to be abundant in shopping malls and relatively rare in suburban gardens (Magudu and Downs, 2015). Additionally, species distribution and abundance is mainly determined by resources that are important for their survival (Grarock et al., 2013).

Our study showed that common mynas were observed mostly feeding on anthropogenic scraps, human edible refuse, and other waste compared with natural foods (insects, nectar and fruits). Common mynas are omnivorous, opportunistic and live commensally with humans (Peacock et al., 2007; Griffin and Boyce, 2009; Lowe et al., 2011; McGiffin et al., 2013; Sarangi et al., 2014; Hubbard et al., 2015). When animals are exposed to new environments they are confronted with many challenges such as trying new habits (Kark et al., 2007; Sol et al., 2011). Møller, (2009) reported that common mynas might have learnt to feed on human edible refuse because it is the most abundant and available food source in urban areas. Additionally, common mynas are passerines which is the avian family known for high numbers of foraging innovations in the wild (Webster and Lefebvre, 2001; Griffin and Guez, 2014). Generally, urban areas are characterized by relatively high food abundance and availability because of anthropogenic supplementary feeding (feeding of birds and waste) (Møller, 2009; Plummer et al., 2015). This supplementary feeding results in an enhanced survival (Chamberlain et al., 2009; Avizanda et al., 2016). Therefore, this might result in the continued increase of common mynas population in areas with anthropogenic supplemental feeding such as residential areas, towns and cities (Oro et al., 2013). Anthropogenic food has been reported to be the cause of the increase of non-native house crow (*Corvus splendens*) in Singapore (Lim et al., 2003). Supply of food by humans was found to determine the distribution of blackcap *Sylvia atricapilla* during winter in Britain and they were also found adapting their feeding habits to exploit human-provision foods (Plummer et al., 2015). Almost 50% of respondents in our study had bird feeders in their households which showed that supplemental feeding was relatively high in these urban areas. The accessibility of anthropogenic food is likely to have a significant effect on avian demography in urban areas (Chamberlain et al., 2009). Eating behaviours have an influence on where to find certain birds (Baharuddin et al., 2014).

Twenty one percent of respondents perceived common mynas as aggressive alien invasive species chasing away indigenous avian species in our study. This response is similar to other studies (Lim et al., 2003; Haythorpe et al., 2014; Munoz et al., 2014). However, there has been no scientific evidence of common mynas showing aggressive behaviours towards native species (Parkes and Avarua, 2006; Lowe et al., 2011). Nevertheless, common mynas are considered potential drivers of species decline (Grarock et al., 2014). This is supported by the study done by Pell and Tidemann (1997) where common mynas showed the potential to reduce the breeding success of native parrots in Australia. In South Africa there has been no scientific evidence of common mynas as pests. However, in other countries common mynas are known to predate cultivated fruits and young crops, predating on other birds and spreading weeds (Lim et al., 2003; Parkes and Avarua, 2006; Lowe et al., 2011).

Our study showed that communities in urban areas of Pietermaritzburg and Durban have a knowledge of alien invasive species. In terms of effective strategies to remove common mynas, respondents supported a nest eradication strategy. However, eradication of nests of common mynas has been unsuccessful in Australia (Yap et al., 2002). Generally, birds are sensitive to changes in vegetation cover, structure and composition (Lowe et al., 2011). In Singapore, common mynas population declined because of the steady loss of its preferred habitats (agricultural land) (Lim et al., 2003). In South Africa common mynas are rarely encountered away from human settlements (Peacock et al., 2007). Therefore, controlling anthropogenic food waste in the cities, avoiding supplementary feeding and thinning of trees canopies may reduce roosting sites available to common mynas (Yap et al., 2002). Habitat alteration has long been adopted as the correct way to manage wildlife species (Yap et al., 2002; Yap and Sodhi, 2004). Our study showed that numbers of common mynas were higher in urban areas near cities and shopping malls where anthropogenic food is relatively abundant year round: therefore, control of edible refuse should be implemented to manage common mynas in these urban areas as suggested in other studies (Yap et al., 2002; Yap and Sodhi, 2004).

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Appendix 4.1 Questionnaire used in the current study.

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Myna MSc Project 2016: Questionnaire

Common mynas diet in the wild

We are currently investigating the diet of an alien invasive, the common myna *Acridotheres tristis* in the wild. The main aim of this survey is to determine the diet of non-captive common mynas, particularly in urban areas.

We would be most grateful for your input about your observations of the common myna. Your responses will be collated and summarized with others to determine the trends and be reported as part of a manuscript. If you have any queries about the questionnaire or common mynas, please call Thobeka Gumede at 033-2605127 or 0630069299; or email thobekagumede123@gmail.com or downs@ukzn.ac.za.

NB: *You are not obliged to complete this questionnaire but your input will be appreciated.*

Section A: YOUR BIRD FEEDING STATION/S

Yes No

1. Do you have a bird feeding station/s that you feed birds at regularly?

   (If No, move to sections b and c.)

2. What food do you generally provide birds at your feeding station/s?

____

3. What kind of feeding station do you have and how many? ____________________________

4. Are there any specific birds you are aiming to feed? [Yes] [No]

5. If yes, name them. ____

6. How often do you feed birds? daily [Yes] ; weekly [Yes] ; monthly [Yes]; irregularly [Yes]

7. Have you seen any common mynas at your feeding station/s? [Yes] [No]

8. If yes, how often do you see mynas at your feeding station/s:

   Daily [Yes] ; weekly [Yes] ; monthly [Yes] ; irregularly [Yes]

9. What time of the day they generally come to your feeding station/s? ____________

10. Do they come throughout the year? [Yes] [No]

11. What time of the year do they mostly come to your feeding station/s? ____________

    ____

12. Do they come in groups or in pairs? ________________________________

13. How many common myna generally visit your garden? ____________

14. How many common myna generally visit your feeding station/s? ____________

15. Do they show any aggressive behaviour towards other birds in your garden? [Yes] [No]

16. Do they show any aggressive behaviour towards other birds at your feeding station/s? [Yes] [No]

17. Which type of food is mostly preferred by common mynas at your feeding station/s if they feed? ______________________________________

<u>Section B: ADDITIONAL INFORMATION</u>

1. In which suburb do you live? ______________________________

2. Do you see common mynas around your city? Yes No

3. Do they come to your home/ garden? Yes No

4. What activities they do when you see them?

feeding	nesting	Other (specify)

5. If feeding, what mostly do you see them feeding on?

Insects	Fruits	Nectar	Other (specify)

<u>Section C: Management of common myna</u>

1. Did you know that common mynas are alien invasive birds? Yes No

2. Do you understand what an alien invasive bird is? Yes No

3. Do you think common mynas should be fed? Yes No

4. Do you think common mynas fill an urban niche? Yes No

5. Do you think common mynas compete with indigenous birds for food and nest sites? Yes No

6. Do you think common mynas should be removed from South Africa? Yes No

7. If yes, which strategy do you think can work better for removing common mynas?

Spraying roosts	Eradicating nests	Shooting	Other (specify)

8. What is your perception of common mynas? ____

Thank you for your time answering this questionnaire. We would be grateful for any further information you may have on common mynas.

CHAPTER 5

Conclusions

There have been no studies of diet preference of common mynas (*Sturnus tristis*) done in South Africa, however there have been population distribution studies done previously (Baker and Moeed 1987; Peacock et al., 2007; Van Rensburg et al., 2009). Common mynas are found to be urban exploiters (Giffin and Boyce 2009; Lowe et al., 2011; Haythorpe et al., 2014) and live in close association with humans, which might have an influence on their diet preference. Consequently, the aim of this thesis was to provide insight into sugar type and diet preferences of common mynas, the influence of anthropogenic supplementary feeding on these birds and document the occurrence of non-captive common mynas in the urban areas of Pietermaritzburg and Durban in the hope of understanding more about the success of these birds in urban areas.

Common mynas preferred high lipid and high protein diets respectively compared with carbohydrates (Chapter 2) in this study. Anthropogenic food sources were found to be a major influence on common mynas preferring lipids and proteins diets (Machovsky-Capuska et al., 2015). Common mynas are generalist, therefore they are likely to try new foods they find in environments impacted by humans (Ducatez et al., 2015).

Numerous studies on sugar preference have been done on many birds (Downs and Perrin, 1996; Downs, 1997; Schaefer et al., 2003; Wellmann and Downs, 2009; Brown et al., 2010a, b, c; Odendaal et al., 2010; Brown et al., 2012) showing different preferences. Common mynas preferred diluted glucose over sucrose and fructose nectars (Chapter 3). Furthermore, common mynas were unable to digest and absorb sucrose efficiently (Chapter 3). Therefore, common mynas may be lacking the enzyme sucrase responsible for digestion and absorption of sucrose. This behaviour showed that common mynas may possibly avoid certain nectars or fruits high in sucrose in the wild and may be damaging fruit high in glucose and fructose. Results of this study give an insight on which agricultural fruit are susceptible to be damaged by common mynas. Therefore, future potential invasion may be predicted.

Common mynas are successful urban exploiters and persist well in cities (Chapter 4). There have been studies confirming this behaviour of common mynas previously (Yap et al., 2002; Peacock et al., 2007; Lowe et al., 2011; Taylor et al., 2013; Grarock et al., 2014). A preliminary study on field observation of diet preference of common mynas was conducted to see what type of diet common mynas prefer in the field (Chapter 4). We believe that diet preference of common mynas is influenced by their close association with humans which allows them (common mynas) to take advantage of anthropogenic foods available in urban areas year round. Factors such as anthropogenic supplementary feeding and inappropriate placement of edible waste were significant in influencing the diet preference and the occurrence of common mynas in the cities we studied (Chapter 4).

Although there has been no scientific evidence of common mynas aggression behaviour, in this study respondents have witnessed this behaviour in common mynas (Chapter 4). There have been few studies in South Africa reporting a negative impact of common mynas on native species. Communities also mentioned a decrease of common mynas numbers in some areas of Pietermaritzburg and Durban (Chapter 4), especially in gardens, while higher numbers were observed by respondents near high density parts of the cities studied. However, there have been no other scientific studies confirming this.

In preparing our diet high in carbohydrates in Chapter 2, we added sucrose to the diet. This may be flawed, as starlings cannot digest sucrose readily. However, some starling species still eat foods with sucrose. In addition, common mynas were commonly observed feeding on anthropogenic foods (dog food, bread, etc.) (Chapter 4) which are all relatively high in sucrose so they appear to tolerate some sucrose in the diet. Whereas in our nectar preference study in Chapter 3, when common mynas were given a choice they showed preference for glucose and fructose compared with sucrose.

There is comparatively little research on monitoring or management of common mynas in South Africa, considering common mynas are the worst avian invaders. Birds are generally sensitive to changes in their habitat (Lowe et al., 2011), studying their roosting sites may be of assistance in monitoring the population numbers. Avoiding supplementary feeding, controlling anthropogenic food waste may reduce the preferred habitats and food availability to common mynas which may results in the decrease to their population in South Africa. However, more research need to be done in all environments including agricultural areas, to understand the persistence of common mynas in new environments.

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