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INVADERS ON THE ROAD: SYNANTHROPIC BIRD FORAGING ALONG HIGHWAYS

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ABSTRACT

Intercity roads potentially offer a high availability of easily accessible food and could therefore be expected to represent a preferential area for synanthropic bird foraging. As a consequence, a road-network could act as an invasion corridor for non-native urban birds. This study is a first approximation to verify such pattern of spread, by determining if foraging is actually the main activity carried out along intercity roads. With this aim, during the spring of 2011 we surveyed 200 points along the New Zealand intercity road-network, carrying out observations on four invasive synanthropic bird species (Eurasian house sparrow *Passer domesticus*, Eurasian blackbird *Turdus merula*, Eurasian starling *Sturnus vulgaris* and Indian myna *Acridotheres tristis*). For every species we also investigated: food preferences, the possibility that certain road features could affect the occurrence of feeding activity along roads, and foraging micro-habitat selection along roads. Predominant observed behaviors related to feeding activity, with differences concerning species-specific foraging strategies. Sparrows were mainly observed feeding on small-sized items (such as seeds and invertebrates), while both starlings and mynas showed more generalist feeding habits. These three species were mostly observed along the side of the lane, in contrast with blackbirds, mainly detected preying on invertebrates along the mown grassy verges of the road. Similarly to urban areas, intercity roads provide easily accessible food, available for all the study species. We propose a road-mediated invasion pattern for synanthropic birds, and encourage future studies to optimize management strategies, and targeting intercity roads as the most suitable control areas to prevent spread.
Keywords: Biological invasion; intercity roads; New Zealand; synanthropic birds; foraging.

RESUMO

INVASORES NAS ESTRADAS: AVES SINANTRÓPICAS FORRAGEANDO NAS RODOVIAS. Estradas intermunicipais potencialmente oferecem uma alta disponibilidade de alimentos de fácil acesso e pode-se esperar que representassem uma área preferencial para as aves sinantrópicas forragearem. Como consequência, uma rede de estradas poderia atuar como um corredor de invasão de aves urbanas não-nativas. Este estudo é uma primeira avaliação para verificar tal padrão de propagação, determinando se o forrageamento é realmente a principal atividade desenvolvida ao longo das estradas intermunicipais. Durante a primavera de 2011, amostramos 200 pontos ao longo da rede rodoviária intermunicipal de Nova Zelândia, realizando observações de quatro espécies de aves sinantrópicas invasoras (pardal *Passer domesticus*, melro *Turdus merula*, estorninho *Sturnus vulgaris*, myna indiano *Acridotheres tristis*). Para cada espécie também investigamos: preferências alimentares, características das rodovias que podem afetar a ocorrência de forrageamento ao longo das estradas, e seleção de microhabitats ao longo das estradas. Os comportamentos observados predominantes estiveram relacionados à atividade de alimentação, com diferenças referentes a estratégias espécie-específicas. Os pardais foram observados alimentando-se principalmente de itens de pequeno porte (sementes e invertebrados), enquanto os estorninhos e os mynas foram mais generalistas. Estas três espécies foram mais observadas ao longo do acostamento das rodovias, enquanto os melros foram detectados principalmente predando invertebrados ao longo das pradarias marginais às estradas. De forma similar às áreas urbanas, estradas intermunicipais fornecem alimentos de fácil acesso, disponíveis para todas as espécies de estudo. Propomos um padrão de invasão de

aves sinantrópicas mediado por estradas, e incentivamos futuros estudos para otimizar as estratégias de gestão, visando as estradas intermunicipais como as áreas de controle mais adequadas para evitar a propagação dessas espécies.
Palavras-chave: Invasão biológica; estradas intermunicipais; Nova Zelândia; aves sinantrópicas; forrageamento.

RESUMEN

INVASORES EN RUTA: AVES SINANTRÓPICAS ALIMENTÁNDOSE EN LAS CARRETERAS. Las carreteras intermunicipales ofrecen potencialmente una alta disponibilidad de alimentos de fácil acceso y puede esperarse que representen un área preferente para la alimentación de las aves sinantrópicas. Como consecuencia, una red de carreteras podría actuar como un corredor de invasión de aves urbanas no nativas. Este estudio es una primera aproximación para verificar tal patrón de dispersión, determinando si la búsqueda de alimento es realmente la principal actividad desarrollada a lo largo de las carreteras intermunicipales. Con este objetivo, durante la primavera de 2011, muestreamos 200 puntos a lo largo de la red de vías intermunicipales de Nueva Zelanda, llevando a cabo observaciones sobre cuatro especies de aves sinantrópicas invasoras (el gorrión *Passer domesticus*, el mirlo *Turdus merula* y el estornino *Sturnus vulgaris,* todos de origen euroasiático; y el miná *Acridotheres tristis*, de origen indio). Para cada especie también investigamos: preferencias alimenticias, características de las carreteras que puedan afectar la búsqueda de alimento, y selección de microhábitats para alimentación a lo largo de las carreteras. Los comportamientos observados predominantemente estuvieron relacionados con la actividad de alimentación, con diferencias en las estrategias específicas de cada especie. Los gorriones fueron observados alimentándose principalmente de elementos de pequeño tamaño (como semillas e invertebrados), mientras los estorninos y los minás mostraron comportamientos alimenticios más generalistas. Estas tres especies fueron observadas principalmente a lo largo del borde de las carreteras, mientras que los mirlos fueron detectados principalmente depredando invertebrados a lo largo de los prados de las cunetas. De forma semejante a las áreas urbanas, las carreteras intermunicipales proveen alimentos de fácil acceso, disponibles para todas las especies de estudio. Proponemos la existencia de un patrón de invasión por aves sinantrópicas mediado por carreteras, e incentivamos futuros estudios para optimizar las estrategias de manejo, focalizado hacia las carreteras intermunicipales como las áreas de control más adecuadas para evitar la propagación de esas especies.
Palabras clave: Invasiones biológicas; carreteras intermunicipales; Nueva Zelanda; aves sinantrópicas; búsqueda de alimento.

INTRODUCTION

Human dominated landscapes are increasing worldwide, with associated potential threats to biodiversity and ecosystems (Vitousek *et al.* 1997, Hooper *et al.* 2012). Paradoxically, there are species taking advantage of global change, shifting their trophic and spatial preferences to the novel niches of recently degraded habitats (Rebele 1994, Marzluff 2001). In the case of urban and rural areas, these species are usually defined as synanthropic (di Castri *et al.* 1990), including human commensal birds (Luniak *et al.* 2004, Bonier *et al.* 2007). Urbanized environments are also selected by synanthropic birds because they have lower predator diversity and milder winter temperatures compared with natural habitats (Jokimäki *et al.* 1996, Gering & Blair 1999, McKinney 2006). Synanthropic bird species have been introduced worldwide for food, pest control and nostalgic purposes, and due to their adaptation to coexist with humans they have proliferated and also spread (Marzluff 2001, McKinney 2006).

Intercity roads usually cross rural and natural habitats, and probably show to a lesser extent the above mentioned characteristics of urbanized areas, including the availability of easily accessible feeding resources. Food availability is one of the main drivers of dispersal (Bowler & Benton, 2005), and for urban birds it should be easier to forage along intercity roads than in certain natural habitats. As a consequence, urban bird dispersal routes might not be randomly selected, and these species could preferentially move near this kind of linear infrastructure. In this case, road-networks might therefore act as invasion corridors for synanthropic birds. A first approximation to verify this spreading pattern would be an observational study describing the synanthropic bird behaviors along intercity roads,

trying to confirm the relative significance of feeding activities. A positive association between foraging and roads would encourage a simplification of current management strategies for these introduced species, by determining the suitable target control areas for carrying out actions focused on their containment.

New Zealand is an insular country with a distinctive biota mainly characterized by its endemic bird communities (Cooper & Millener 1993, Daugherty *et al.* 1993). The principal threats to New Zealand biodiversity are biological invasions (Clout 2001, Norton 2009), including the introduction of synanthropic birds mostly carried out since 1860 by Acclimatization Societies (Druett 1983; McDowall 1994). Urban birds compete with native species and prey on endemic fauna (Meads *et al.* 1984; Greene & Jones 2003). Moreover, they contribute to the spread of infectious diseases and invasive plants (Williams & Karl 1996; Tompkins & Gleeson 2006), and they also impact several human activities such as orchard cultivation (Dawson & Bull 1970, Kross *et al.* 2012). Introduced synanthropic birds represent the most abundant and widespread avian species in New Zealand, particularly the Eurasian house sparrow *Passer domesticus*, the Eurasian blackbird *Turdus merula*, the Eurasian starling *Sturnus vulgaris* and the Indian myna *Acridotheres tristis* (Heather & Robertson 2005). They are regionally subjected to lethal control methods including shooting, trapping and baiting by avicides, principally alphachloralose and DRC-1339 (Nelson 1990, 1994). All these methods and especially the use of poison also entail mortality risk for non-target bird species (Nelson 1990, 1994), but the society generally supports control programs (Green & Rohan 2012). However, their planning nonetheless requires prudence.

The main purpose of the present study is to determine the principal activity carried out by these four synanthropic bird species along the intercity roads of New Zealand, where they are abundant. Our hypothesis advances that urban birds use such areas mostly to forage, with implications for their establishment and spread patterns and consequent management strategies. Moreover, with the aim of further improving the control and containment of these introduced birds, for every species we also investigated: food preferences, the possibility that certain road features could affect the occurrence of feeding activity along roads, and foraging micro-habitat selection along roads. All that considered, this species-specific observational study about the feeding habits of non-native synanthropic birds is of high interest to understand their activity along intercity roads, with several possible implications for the improved planning of their management.

MATERIALS AND METHODS

Our study was carried out along several New Zealand intercity roads, across both the North and the South Islands (Figure 1), during three weeks of the Austral spring 2011. We selected 200 sample points (50 for every surveyed species: sparrows, blackbirds, starlings and mynas) depending on features characterizing road and surrounding environment: traffic intensity (high or low), habitat (open or with shrubs/trees) and presence/absence of mown grassy verges. Each variable level was equally sampled for all the four species. Every sample point was at least five kilometers from another to avoid resurveying the same individual. At each sample point the observer waited inside a car for the arrival of an individual of our study species. The individual detection was the beginning of a binocular focal observation of five minutes, recording the main activity carried out. In the case of foraging behaviors, we also registered the most frequent feeding choice and the section of the road in which the action was mostly carried out.

To determine the principal activity carried out by introduced synanthropic birds along New Zealand intercity roads we carried out a first Pearson χ^2 test (goodness-of-fit; SAS Institute Inc. 2008) for each study species. In such test we analyzed if the observed frequency of every detected behavior significantly diverged from the distribution of behaviors if they were random. Furthermore, selecting only the observations of foraging activities, with a second Pearson χ^2 test (goodness-of-fit) we also determined the food resources most often consumed by every study species along roads. With the aim to analyze if certain roadway and surrounding environment features were affecting the appearance of feeding activity along intercity roads, we carried out a logistic generalized linear model (GLM: McCullagh & Nelder 1989) for each study species. The response variable was the presence/absence of foraging behaviors as the main detected activity of the observation, while the explanatory categorical variables were: traffic

volume (high or low), habitat (open or with shrubs/trees) and presence/absence of mown grassy verges. In all cases, we applied a binomial error distribution and logit link function. Finally, the fourth analyses also were Pearson χ^2 tests (goodness-of-fit), in this case with the aim to determine in which sections of the road (middle, shoulders and verges) the species carried out the main part of their foraging activities. Also for these analyses, we performed a test for each study species.

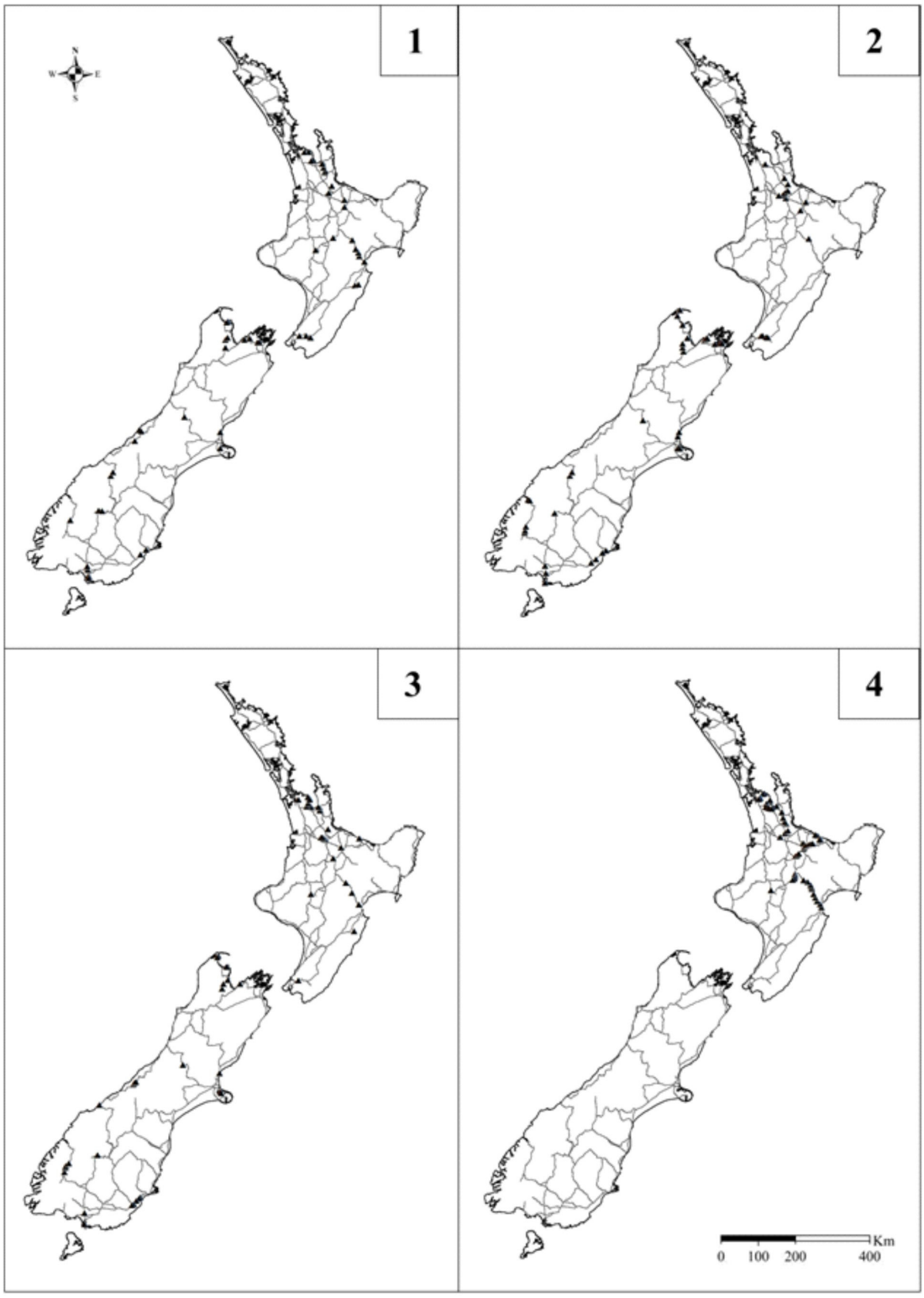

Figure 1. Sample point distribution for each study species. 1) sparrows, 2) blackbirds, 3) starlings and 4) mynas.

RESULTS

We mostly detected four types of activities along the New Zealand intercity roads: foraging, searching, perching and interacting. The latter included attacks and fighting, courtship, copulations, and also parental care of fledglings. Other activities were also detected (passing, alert, escaping, preening, defecating), but none of them reached the status of predominant behavior during an observation. Sparrows were observed carrying out all the four main activities, especially foraging (76% of the observations: Figure 2). The first Pearson χ^2 test indicated that such behavior was more frequent ($p < 0.0001$) than searching, perching and interacting (respectively 8%, 10% and 6% of the observations). We did not detect interactions among blackbirds, and also in their case foraging was more frequent (74% of the observations; $p < 0.0001$) than both searching and perching (16% and 10%). Starlings carried out all the four main activities, with feeding being more frequent (80% of the observations; $p < 0.0001$) than the other behaviors (searching 8%, perching 4% and interacting 8%). The first Pearson χ^2 test for mynas also revealed the same pattern (foraging 74%, searching 4%, perching 12% and interacting 10%; $p < 0.0001$; Figure 2).

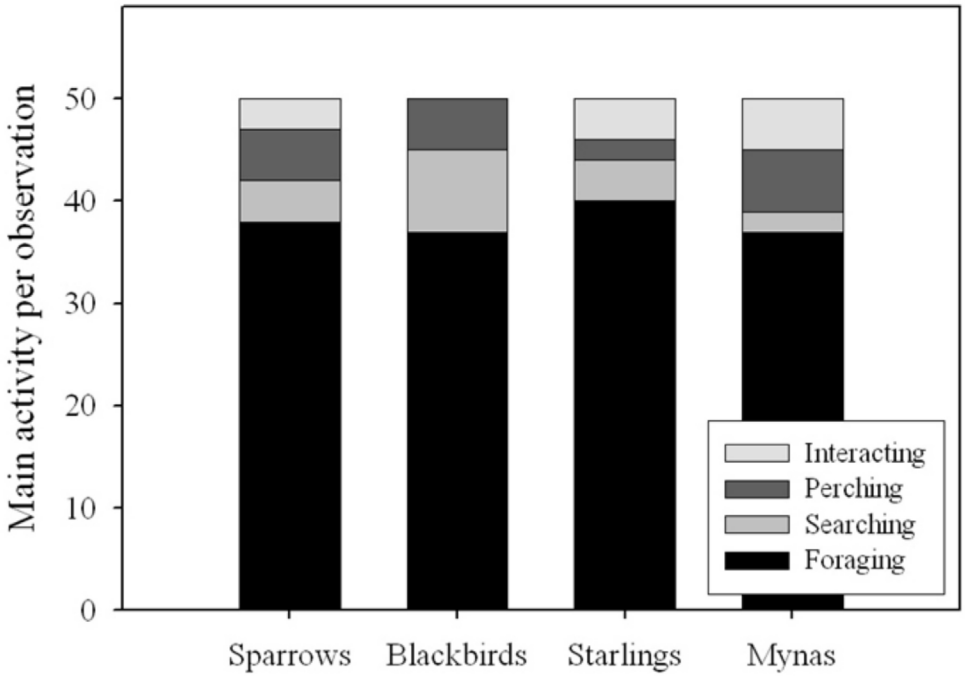

Figure 2. Non-native urban bird main activity for each of 50 observations. For all the four foraging activity significantly represents the main observed behavior.

Concerning the main food resources consumed along intercity roads, we detected six categories: garbage, identifiable carrions (mostly introduced mammals; hedgehogs *Erinaceus europaeus*, possums *Trichosurus vulpecula* and rabbits *Oryctolagus cuniculus*), flattened organic matter, invertebrates, seeds/fruits and unrecognizable items. We could not identify the most part of the items selected by sparrows (55% of foraging observations; Table 1). The second Pearson χ^2 test showed that foraging activity on unrecognizable resources was more frequent ($p=0.0003$) than on garbage, flattened organic matter and seeds (respectively the 11%, 18% and 16%). For sparrows, we did not detect scavenging behavior and identifiable predation on invertebrates. Conversely, blackbirds mainly fed on invertebrates, and also on unrecognizable items (respectively 35% and 46% of foraging observations). Flattened organic matter and seeds/fruits were consumed less (8% and 11%; $p = 0.0016$), and foraging on garbage and carrions was not detected. We could not categorize the most part of items selected by starlings (50% of the feeding observations). Foraging activity on flattened organic matter and invertebrates was less

frequent (both of them respectively 20%; $p < 0.0001$), followed by consumption of garbage and seeds/fruits (both of them respectively 5%). Scavenging behavior was not detected for starlings. Finally, there were no significant differences in the food resources consumed by mynas along intercity roads. The most exploited item was flattened organic matter (30% of foraging observations), followed by invertebrates (17%), garbage, carrions, seeds/fruits and unrecognizable items (each of them respectively 14%; Table 1).

Table 1. Number of foraging observations for every main consumed food item. The meaning of the acronym FOM is flattened organic matter, and for NII is not identified items. Total represents the overall number of foraging observation per species. The only species without significant differences among consumed items is the myna.

	Garbage	Carrions	FOM	Invertebrates	Seeds/Fruits	NII	Total
Sparrows	4	0	7	0	6	21	38
Blackbirds	0	0	3	13	4	17	37
Starlings	2	0	8	8	2	20	40
Mynas	5	5	11	6	5	5	32

Regarding the GLMs carried out, the only candidate variable affecting the appearance of synanthropic birds foraging along intercity roads was the presence of mown grassy verges, increasing the occurrence of blackbirds ($p = 0.007$; Figure 3).

Finally, about the road sections preferably used for feeding activities by introduced synanthropic birds, the third Pearson χ^2 test for sparrows revealed they significantly selected the shoulders of the lanes (76% of foraging observations; $p < 0.0001$; Figure 4), compared with the middle of the roadway and its verges (respectively 11% and 13%). Conversely, blackbirds are the only species actively selecting the verges (76%; $p < 0.0001$), followed by the sides (21%) and the middle of the road (3%). On the other hand, similarly to sparrows, the starlings also preferred the shoulders (60%; $p=0.0005$), and used the middle of the road and the verges less (10% and 30%). The mynas mostly selected the external sides of the lanes (81%; $p < 0.0001$), compared with the middle of the roadway or its verges (respectively 16% and 3% of foraging observations).

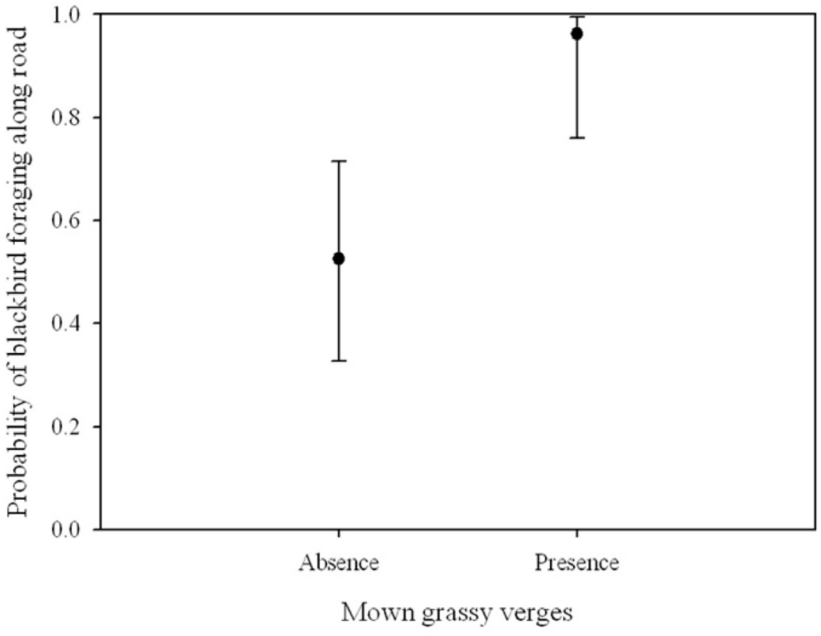

Figure 3. Probability to observe a blackbird foraging along the highway during an observation, in relation to the presence/absence of mown grassy verges.

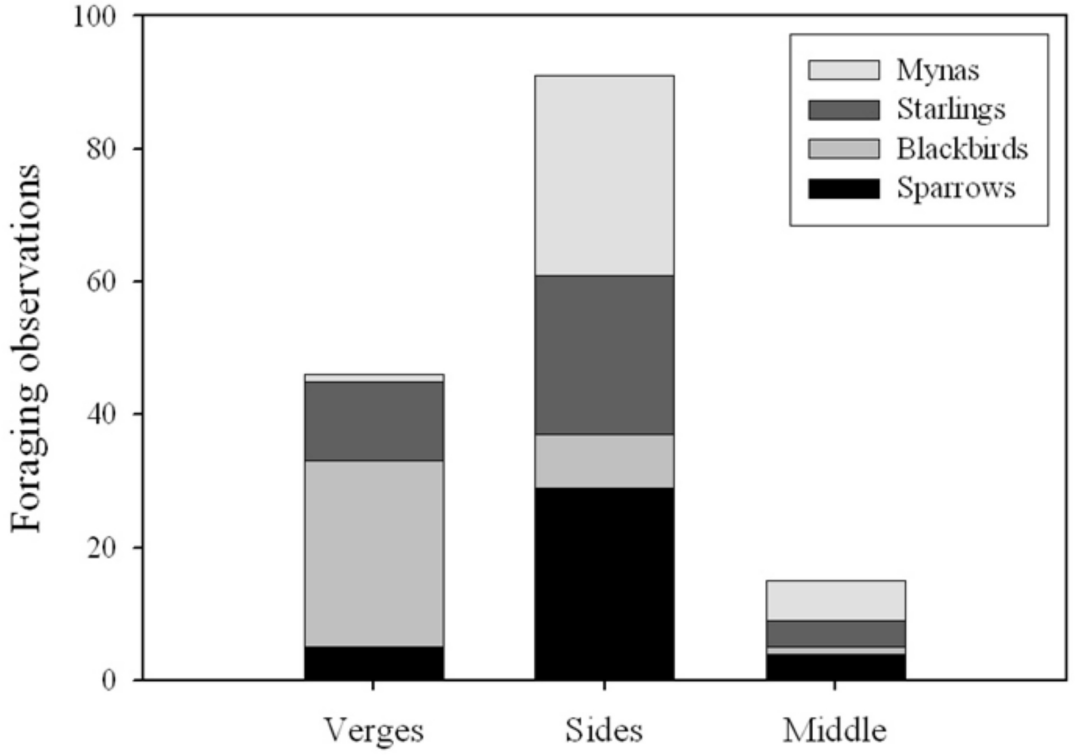

Figure 4. Number of foraging observations for each species and area of the road (verges, shoulders and the middle of the roadway). For each species, foraging activity is significantly higher in correspondence to the main plot.

DISCUSSION

The present study represents a simple approximation to the use of behavioral observations with the aim to understand habitat use and diet, and optimize control strategies of invasive species. With a moderate effort we recorded that introduced synanthropic birds are generally using intercity roads mainly for foraging purposes, affirming the plausibility of a road-mediated invasion pattern for synanthropic birds. This could have consequences on the current management strategies for these species.

Our results show that the four study species were detected carrying out feeding activities during approximately 75% of the observations. This proportion might also increase considering that two of the three other detected behaviors (both searching and perching) are probably related to foraging in several cases. We did not categorize such behaviors as feeding activities because searching can also concern grit and nest materials, and perching may just correspond to a resting activity. Such prevalence of foraging activities along intercity roads can be related to the easily accessible food availability that we also detected during the fieldwork of the present study. This availability represents a pronounced feature of urban areas as well, and probably one of the main causes of synanthropization of several bird species (Marzluff 2001, Davies *et al.* 2009, Evans *et al.* 2009). Therefore, considering the importance of feeding resources for dispersal (Bowler & Benton, 2005), intercity roads might represent a preferential first step of invasion spread for urban birds, prior to the colonization of natural habitats. The confirmation of the road-mediated invasion pattern that we suggest could enable the optimization of introduced synanthropic bird containment strategies, which might be mainly focused on urban areas and the surrounding intercity roads. This management choice would have less probability to accidentally target native New Zealand birds, which tend to avoid human dominated environments (van Heezik *et al.* 2008). All that considered, we strongly recommend further research regarding our suggestion of road-mediated invasion by non-native synanthropic bird species.

Concerning the main food items consumed along intercity roads, we can differentiate them in two categories, directly and indirectly related with

human activity. The first category includes garbage and carrions resulting from road-kills and the flattened organic matter consequent to the repeated transit of vehicles. The second category consists of invertebrates, seeds/fruits and unrecognizable items. We could not identify the latter items due to their small size, and therefore we suspect they should also correspond with invertebrates and seeds. We consider that invertebrates and seeds/fruits availability along verges were indirectly related with human activity because these might respectively depend on roadway/roadside building materials and verge vegetation management. Indeed, temperatures are usually higher along paved roads than in natural surrounding environments, attracting arthropods and their predators (Hannay 2001, Jackson 2003). Moreover, roadside vegetation management can affect invertebrate availability for insectivorous birds, facilitating their foraging activities in the presence of mown grassy verges (Romanowski & Zmihorski 2008, Devereux *et al.* 2006). Roadside hedgerows and plantations also determine seed and fruit availability along the verges. All of our four study species fed along intercity roads according to their previously known diet preferences (Moeed 1976, 1980, MacMillan 1981, Williams & Karl 1996), but we also detected the consumption of food items directly related with human activity. Mynas were observed feeding on road-killed carrions, and all the species consumed garbage (excluding blackbirds) and flattened organic matter. This exploitation of human-related food items suggests a plausible lack of neophobia among urban birds, which could be capitalized by wildlife managers selecting live-trapping as the main strategy to control such invasive species, also eliminating mortality risk for autochthonous species. The previously mentioned baiting with avicides (Nelson 1990, 1994) could then be limited to particular situations, such as intercity roads crossing degraded environments with consequent low densities of native avifauna (van Heezik *et al.* 2008).

Regarding the influence of certain features of roadway and surrounding environment on the presence of urban bird foraging along intercity roads, the only significant variable was the presence of mown grassy verges increasing the occurrence of blackbirds. As previously suggested, this kind of roadside management could facilitate the feeding activities of insectivorous birds (Romanowski & Zmihorski 2008, Devereux *et al.* 2006), and we largely detected blackbirds preying on invertebrates (especially earthworms) during our observations. The mowing of grassy verges could therefore be an effective strategy to attract blackbird individuals in order to expose their populations to management, should it be required.

We also observed blackbird preference for verges through the analysis of foraging micro-habitat selection, as a further confirmation of their relative dependence on roadside food resources. Conversely, the other three study species significantly used road shoulders to carry out their feeding activities, probably because there they can access both the roadway and roadside food resources. Moreover, comparing mynas with sparrows and starlings, we can appreciate how they additionally used the middle of the roads too, confirming their preference for human-related food items. All that considered, the use of the roadway shows us that road-kill mortality seems to be a tolerable risk for these three species, denoting a boldness that can indicate again the pertinence of trapping as a main control method.

The results of the present study imply relevant suggestions for the management of these introduced species. We also reaffirmed the plausibility of a road-mediated invasion pattern for synanthropic birds and we strongly suggest its confirmation through future studies, due to its potential power of optimization for the containment of these species, especially determining if urban areas and intercity roads are the most suitable control target areas. We also encourage further and more exhaustive studies regarding environmental variables affecting the presence of introduced synanthropic birds, with the aim to improve management protocols and consequently to limit associated risks for New Zealand native avifauna.

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