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The figs of winter: Seasonal importance of fruiting fig trees (*Ficus*: Moraceae) for urban birds

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ABSTRACT

Birds and figs are conspicuous members of the tropical and subtropical ecosystems. Because they are easily observed and very speciose, their relationships have been well studied in many areas, and the figs are considered a keystone resource for many bird species which are efficient fig seed dispersers. Taiwan has a relatively high endemism rate for many taxa (17% of bird species) but because of its high human population density, most lowland habitats are heavily developed, of which much of it covered by dense urban habitation. To establish the importance of urban figs for birds, we focused our surveys mostly on three common urban fig species (*Ficus caulocarpa*, *F. microcarpa* and *F. subpisocarpa*). We observed trees with ripening figs from July 2013 to December 2016 in order to determine the composition of the fig-consuming bird community. In addition, we added all the information available in the scientific literature and birdwatchers' observations which we could find. In total, we observed 42 bird species consuming 18 fig species. The bird diversity in urban areas was non-negligible even during winter. Therefore, there are two reasons why figs are important for Taiwan's bird avifauna: in cities, the tree diversity is generally low so that figs provide a stable food resource; and since figs are fruiting all year-round, they are one of the few reliable resources available during winter when many migrant birds overwinter in Taiwan. Already crucial for many species in tropical and subtropical forests, fig trees may also be essential for urban birds in tropical and subtropical regions.

1. Introduction

One of the best studied plant-bird interaction is the consumption of figs (*Ficus*) by birds (Janzen, 1979; Compton et al., 1996; Corlett, 1998; Shanahan et al., 2001; Harrison and Shanahan, 2005). One reason is the near ubiquitousness of the approximately 850 fig species within the tropical, subtropical and even some temperate regions of the world. Another reason is that most fig species provide large crops of nutritious fruits which are often available year-round to a bird community due to the asynchronous fruiting among individual trees observed in many fig species (Harrison, 2008; Kuaraksa et al., 2012). Therefore, the *Ficus* genus has been shown to be a keystone fruit resource in a number of bird communities (Terborgh, 1986; Lambert and Marshall, 1991; Shanahan et al., 2001; Harrison, 2005). Diversity and density of figs may even be a determinant for frugivore species richness and abundance at local as well as continental scales (Kissling et al., 2007).

Most of the *Ficus* species are zoochorous and may present two distinct types in the adaptation for animal consumption (Korine et al., 2000; Lomáscolo et al., 2008). In the first type, ripe figs are small, dark and soft, while in the second type the ripe figs are big, greenish, and hard. The former is hypothesized to be an adaptation for the consumption of figs by birds whereas the latter is mostly adapted for mammalian (and mostly fruit bat) consumption (Lomáscolo et al., 2010). These two frugivory syndromes are not linked to any phylogenetic pattern as *Ficus* species from the same group diverge in the ripe fig characteristics (Korine et al., 2000; Harrison et al., 2012). Consequently, figs are more adapted locally to their dispersers than phylogeny would predict (Lomáscolo et al., 2010). Many fig consumers are not restricted to one fig species but consume many species (Shanahan et al., 2001). Studies investigating the fig consumption in one single area allow us to understand the importance of figs in the regime of many species and their particular dependence on *Ficus* fruits (Lambert and Marshall, 1991; Daru et al., 2015).

Taiwan is an important hotspot of endemism for many different taxa, including plants (Hsieh, 2002) and birds (Severinghaus et al., 2010; Ding et al., 2014). At least 626 bird species have been recorded in all of Taiwan, including outlying islands (Ding et al., 2014). On the main island of Taiwan, 145 species have been reported as breeding

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birds (Fang, 2008) of which 25 species are recognized as endemic species (Ding et al., 2014). Thirty native or naturalized taxa of *Ficus* representing 27 species have been described from Taiwan (Bain et al., 2015). They are widely distributed on Taiwan from the coastline up to 1800 m altitude (Tzeng, 2004). Two species are endemic (*F. tannoensis* and *F. vaccinioides*), and two other taxa (*F. pedunculosa* var *mearnsii* and *F. tinctoria* subsp. *swinhoei*) are only found in the south of Taiwan and on some islands of The Philippines (Corner, 1965). However, all the other species have a wider distribution reaching all across Taiwan from Northern to Southern Taiwan, and some may even reach all the way to northern Australia (Berg and Corner, 2005). Thus, these fig species probably rely on efficient seed dispersers (Babweteera et al., 2007; García et al., 2009).

Figs are also common in urban environments where they are often visited by many frugivorous birds (Corlett, 2005, 2006; Caughlin et al., 2012; Lok et al., 2013). Some species from the subgenus *Urostigma* are particularly common in Asian urban areas such as Hong Kong and Singapore (Corlett et al., 1990; Corlett, 2006) but also in Taipei. We conducted this preliminary survey in order to establish (1) the current status of *Ficus*-bird interactions in Taiwan based on the literature and birdwatching information found on the internet, and (2) to supplement this knowledge by conducting surveys of frugivorous birds in fig trees, focusing mostly on urban fig trees (and mostly the aforementioned three common urban fig species: *Ficus caulocarpa*, *F. microcarpa*, and *F. subpisocarpa*) because most previous publications have focused on fig trees growing in natural and protected areas. The main aims of this study were (1) to provide a baseline for future research and (2) to establish if figs are important for urban birds and, if yes, for which bird species and during which seasons.

2. Methods

2.1. Bird survey and study areas

Our systematic surveys were conducted from July 2013 to February 2014. Twenty-five individual trees of five *Ficus* species, namely, *F. caulocarpa* (n = 2), *F. microcarpa* (n = 5), *F. septica* (n = 1), *F. subpisocarpa* (n = 16), and *F. virgata* (n = 1), were observed in three main locations: Taipei city (National Taiwan University campus and Da'an forest park); New Taipei city (Wulai and Gongliao districts); and the Hengchun and Manzhou townships (Pingtung county) in the south of Taiwan Island (Fig. 1, Table 1).

For each surveyed tree, an estimation of fruit abundance was made (Sanitjan and Chen, 2009) whereby the volume of the tree was multiplied with a measure of fruit density (estimated from eight 1-m branches). Furthermore, the size (namely, diameter and height) of ten randomly chosen figs was measured. Observations were spread across all daylight hours (6:30–17:30) and divided into 10-min intervals for a total of 1050 intervals (or 175 h of observation). During each interval, the species and number of birds within the tree were recorded, and if the birds consumed the figs or not. The method of consumption was divided into: (1) swallowing, i.e, the whole fruit was swallowed; (2) pecking, i.e., the bird either pecked pieces of the whole fruit by either tearing the pieces from the hanging fruit or by holding the fruit in its feet.

For each bird species, the mean body mass of each bird species was taken from Dunning (2008) and the species status (endemic species or subspecies, resident or introduced breeding species) from Ding et al. (2014).

2.2. Literature review

In addition to the classical literature review of scientific peer-reviewed publications, an internet search was performed using the keywords “Taiwan” combined with mainly “*Ficus*”, “fig” or “bird” in both Chinese and English on the Google Taiwan search website (www.google.com.tw). We also contacted all Taiwanese ornithologists and birders that the first author personally knew in the summer of 2013, and we received about 15 replies. The date and location of each observation was noted if available. To this database, we added our own opportunistic observations from July 2013 until December 2016. During this search, we also opportunistically noted down any mammal consumption of figs which we summarized in Table A1 but did not analyze further.

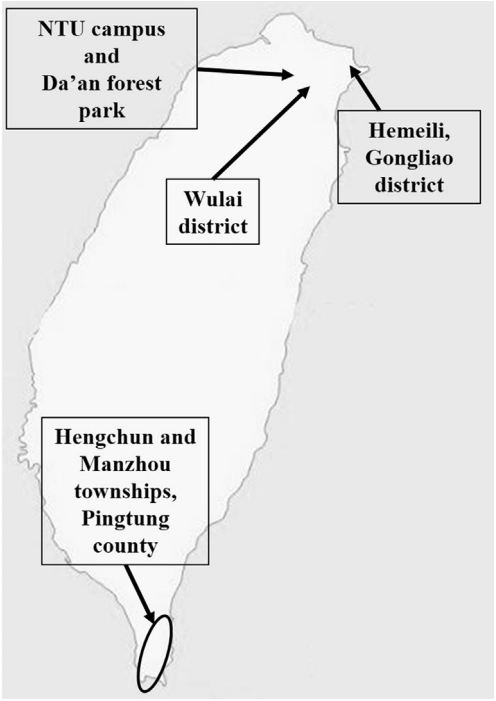

Fig. 1. Survey locations.

Table 1
The locations of the 25 individual fig trees which were observed during our systematic surveys (see Methods for details).

Ficus species	Tree ID	Location	observations	Date
F. caulocarpa	1	NTU campus	116	September 2013
F. caulocarpa	2	Wulai	18	August 2013
F. microcarpa	1	Hengchun (S)	47	October 2013
F. microcarpa	2	Da'an forest park	28	August 2013
F. microcarpa	3	Da'an forest park	13	September 2013
F. microcarpa	4	Da'an forest park	13	September 2013
F. microcarpa	5	Da'an forest park	59	September 2013
F. septica	1	Da'an forest park	47	August 2013
F. subpisocarpa	1	Da'an forest park	62	August 2013
F. subpisocarpa	2	Da'an forest park	12	August 2013
F. subpisocarpa	3	Da'an forest park	84	September 2013
F. subpisocarpa	4	Da'an forest park	34	September 2013
F. subpisocarpa	5	Da'an forest park	99	September 2013
F. subpisocarpa	6	Da'an forest park	22	September 2013
F. subpisocarpa	7	Da'an forest park	73	September 2013
F. subpisocarpa	8	Da'an forest park	13	August 2013
F. subpisocarpa	9	NTU campus	41	July 2013
F. subpisocarpa	10	NTU campus	38	October 2013
F. subpisocarpa	11	Taipei city	6	February 2014
F. subpisocarpa	12	Taipei city	6	February 2014
F. subpisocarpa	13	Wulai	57	August 2013
F. subpisocarpa	14	Gongliao	68	September 2013
F. subpisocarpa	15	Hengchun (S)	54	October 2013
F. subpisocarpa	16	Manzhou (S)	23	October 2013
F. virgata	1	NTU campus	18	September 2013