THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF BIOLOGY

SEED DISPERSAL BY *MIMUS POLYGLOTTOS* AND *TYRANNUS DOMINICENSIS* INTO ABANDONED FARMLANDS IN PUERTO RICO

CHRISTINE ALICE WANG
Spring 2011

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Biology
with honors in Biology

Reviewed and approved* by the following:

Tomás A. Carlo
Assistant Professor of Biology
Thesis Supervisor

Richard J. Cyr
Professor of Biology
Honors Adviser

* Signatures are on file in the Schreyer Honors College.

Abstract

Deforestation can have negative impacts on ecosystems, such as decreasing diversity, degrading soils, disruption of water cycles, and climate change. Seed dispersal by birds is one of the most important factors in the recovery of deforested and abandoned lands. By studying the effects birds have on seed dispersal into deforested areas, we hope to understand the mechanisms that shape forest recovery in tropical landscapes. In this study, bird activity was recorded using video cameras in cattle farms in Aguadilla, Puerto Rico. The two most abundant bird species recorded were *Tyrannus dominicensis and Mimus polyglottos.* Despite being primarily an insectivore, *T. dominicensis* was more responsible than the more frugivorous *M. polyglottos* for both seed dispersal and for seed species diversity arriving in the pastures. I conclude that *T. dominicensis* may play a major role in forest succession from abandoned pasture lands in Puerto Rico.

Table of contents

Acknowledgments

I would first like to thank Dr. Tomás A. Carlo for giving me the opportunity to work in his lab for the past two years. He has provided me with guidance and patience throughout this project and I would not have been able to complete my thesis without his ideas and support. Secondly, I would like to thank Melissa Simon, Benjamin Stafford, Dr. Mario L. Flores-Mangual, Danilo Cianzio, and Luis Anieses who were all responsible for the field work of this study in Puerto Rico. I would like to express my sincere gratitude to the rest of the Carlo lab, especially Jason Gleditsch who taught me how to use statistical programs, gave me ideas and direction, and always answered any questions I had. Lastly, I would also like to thank Dr. Richard Cyr for agreeing to be my second faculty reader.

Introduction

While only 11% of the world's forests are designated for conservation, forest destruction continues to occur at alarmingly high rates with an estimated 12 million hectares of forest lost annually (Johnson, 2005). Forests are often cleared in order to grow crops, create grazing land for cattle, or utilize timber for manufacturing purposes (Corlett & Hau, 2000). Agriculture in tropical lands where forests have been cleared is usually unproductive after a few years, and the majority of these lands are eventually abandoned after a few decades. Following abandonment, forest succession may take several decades and the process of forest recovery can be impeded by several biotic and abiotic factors (Ferreira & Prance, 1999).

The rate of succession is limited by different changes in the environment. For example, in pastures, soil structure and composition are altered by plowing soil and compaction, as well as by limited seed arrival, seed germination, and establishment (Holl, 1999). The combination of different factors such as soil compaction, decreased soil nutrients, high solar radiation, high temperatures, and increased evapotranspiration make it easier for competitive pasture grasses to grow, but harder for woody species to establish. Deforestation also decreases the diversity of organisms and animals, forcing them to relocate. Additionally, animals may leave because of decreased resource availability or because open areas make some animals vulnerable to predators (Howe & Smallwood, 1982).

One of the most important factors limiting succession is a lack of seed dispersal (Holl, 1999). Deforested areas have limited seed arrival and decreased seed banks compared to forested areas, which halts and/or slows down forest regeneration (Zahawi & Augspurger, 2006). Seeds are dispersed through wind, water, or most commonly animals. In fact, in Puerto Rico over 75% of all trees and shrubs are dispersed by vertebrates, especially birds (Carlo et al. 2003).

In open pastures, fruits from remnant trees and forest fragments will only fall within a few meters of its parent tree (Zimmerman et al., 2000). Seeds dispersed through water and wind are also limited by distance from sources. However, seed dispersal by animals is an effective means that can increase the influx of seeds into abandoned fields, potentially affecting forest regeneration and succession. Some common animal dispersers are birds, primates, rodents, bats, and other vertebrates (Pizo, 2002). Specifically, birds are keystone to the contribution to the diversity of communities and may have the ability to help forest regeneration because compared to other vertebrates, birds occur in higher abundance and have increased movement capacity (Corlett & Hau, 2000).

Birds play an significant role in accelerating the process of forest recovery, and studies have shown the importance of remnant trees and perches as attractors of birds in open areas (Duncan & Chapman, 2001; Silva et al. 2002). Isolated trees and perching sites in pastures can disperse seeds and increase the seed bank through defecation and regurgitation. Another advantage of seed dispersal by birds is that they can bring seeds from different habitats and from far distances into deforested areas, thus increasing diversity and connectivity on the landscape (Pejchar et al., 2008).

Like many other tropical countries, Puerto Rico experienced a drastic shift from an agricultural to an industrial economy (Rivera & Aide, 1998). During the country's agricultural period, many lands were deforested in order to grow crops such as sugar cane and coffee. Additionally, forests were cleared to create grazing land for cattle. As industry became more prevalent, many of these lands and pastures were abandoned. In the last century, there have been many planting efforts in the tropics in order to assist recovery of deforested lands, however planting trees and vegetation only contributed to 0.8% of overall tropical forest cover (Corlett &

Hau, 2000). It seems that we must now rely on seed dispersers as the main mode of tropical forest regeneration (Pejchar, 2008).

In Puerto Rico, birds are the main dispersers and may assist in the recovery of abandoned lands (Carlo et al., 2003; Carlo, 2005). Most native fruit-eating birds live exclusively in forests, thus they are unlikely to contribute to the dispersal of seeds in deforested areas that are devoid of cover and fruit resources. However, the Northern Mockingbird (hereafter *Mimus)* and the Gray Kingbird (hereafter *Tyrannus),* are two recurring bird species in Puerto Rico that are common in forest edges and open grasslands (Raffaele et al., 1989). The diet of *Mimus* and *Tyrannus* consists largely of insects, but they also regularly eat fruits. The objective of the study was to determine the effects of birds on seed dispersal into abandoned pastures in Puerto Rico. Specifically, I compared the contribution of different bird species to seed dispersal in pastures, and determined the importance of species to the process by comparing their effectiveness.

Materials and Methods

Plot Design

The experiment took place in Aguadilla, Puerto Rico in grounds of the Finca Montaña, which is an agricultural experimental station administered by the University of Puerto Rico (Mayaguez). Aguadilla is located in the northwestern corner of Puerto Rico, which contains forest fragments and pasturelands for cattle. Ten sites were chosen, and each site contained one artificial perch placed at least 25 meters away from the forest edge. Each perch was made out of a 3-meter high metal pipe, and a wooden rod was attached to the top of the pipe to allow birds to perch on them. At the base of each artificial perch, there was a seed trap. At the end of each month, seeds that were deposited in the seed trap were collected, counted and identified to the species level using a reference collection.

Video Analysis

Video cameras were set up at each plot for five months from September 2010 to March 2011. Video footage was not available for December 2010 and therefore omitted from the analysis. In order to get a clear view of the perch and visiting birds, the cameras were positioned next to each perch and recorded bird activity for two hours each day on four separate days per month. Total sampling time encompassed 262 hours of footage. From the videos for each plot, we recorded the number of perch visitations, and total time each bird species spent on the perches.

Statistical Analysis

I used an Analysis of Covariance (ANCOVA) to examine the relationship between bird visitation times and diversity (response variables). I included bird species time (cumulative seconds spent on perches per month) continuous explanatory variables, and month and plot as categorical covariates in the JMP 7.0 Fit Model platform (SAS Institute 1998). The interaction between *Mimus and Tyrannus* visitation times was also added as a factor with no other interaction terms.

Results

Six different bird species were observed in video footage over the five sampling months: *Tyrannus dominicensis* (Gray Kingbird), *Mimus polyglottos* (Northern Mockingbird), *Tiaris bicolor* (Black Faced Grassquit), *Euplectes franciscanus (Red Bishop), Falco sparverius* (American Kestrel), and *Falco peregrines* (Peregrine Falcon). Of these six bird species, *Tyrannus* and *Mimus* predominated and were consistently spotted on each site's artificial perch. Cumulatively, *Tyrannus* spent more time at the artificial perches and had more visitations than *Mimus. Tyrannus* accounted for 53.4% of all visitation time, *Mimus* accounted for 26.9% of total bird visitation time, the remaining four bird species collectively accounted for 19.7% of the visitation time.

Seeds from 16 plant species were identified and collected across the ten sites (Figure 1). The most abundant seed was *Cestrum diurnum* (Day Jasmine) and *Citharexylon fruticosum* (Fiddlewood). *Cestrum diurnum* accounted for 45.9% of the seeds collected and *C. fruticosum* accounted for 16.4% of seeds. The other four most abundant seed species were *Bourreria virgata, Bursera simaburba, Bourreria succulenta,* and *Dendropemon caribaeus*, which when combined accounted for 23.3% of all seeds. Fewer seeds were deposited during the months from September to October, than in January and February (Figure 2a). Seed species richness ranged from 6 to 15 species per month, with the lowest number of seed species found in February (Figure 2b).

The relationship between *Tyrannus* visitation time and mean seed number averaged across all months per plot was statistically significant and almost linear for *Tyrannus*, but not for *Mimus* (Figure 3a, 3b). The number of seed species per plot was also significantly correlated with the activity of the perches by *Tyrannus*, but not to the activity of *Mimus* (Figure 3c, 3d).

Comparison of *Mimus* and *Tyrannus* on seed dispersal using ANCOVA analysis shows *Tyrannus* had a significant effect on the total seed number but *Mimus* did not (Table 1a). However, there was a significant interaction between *Tyrannus* and *Mimus* on total seed number and seed species diversity (Table 1a). Neither *Mimus* nor *Tyrannus* showed a significant effect on the total number of seed species brought to each site (Table 1b). For this variable, the most important sources of variation were the plots and the months (Table 1b).

The effect of *Tyrannus* on the cumulative seed species richness in the ANCOVA analysis was marginally significant while *Mimus* showed no significance (Table 1b). When analyzing the effect of *Tyrannus* and *Mimus* visitation time on only the 6 most abundant seed species, *Tyrannus* has a significant or marginal effect on the dispersal of four out of six seed species (*Cestrum diurnum, Citharexylon fruticosum, Dendropemon caribaeus, and Bourreria succulenta)*, but *Mimus* was not significant or marginal for the dispersal for any of the seed species (Figure 4).

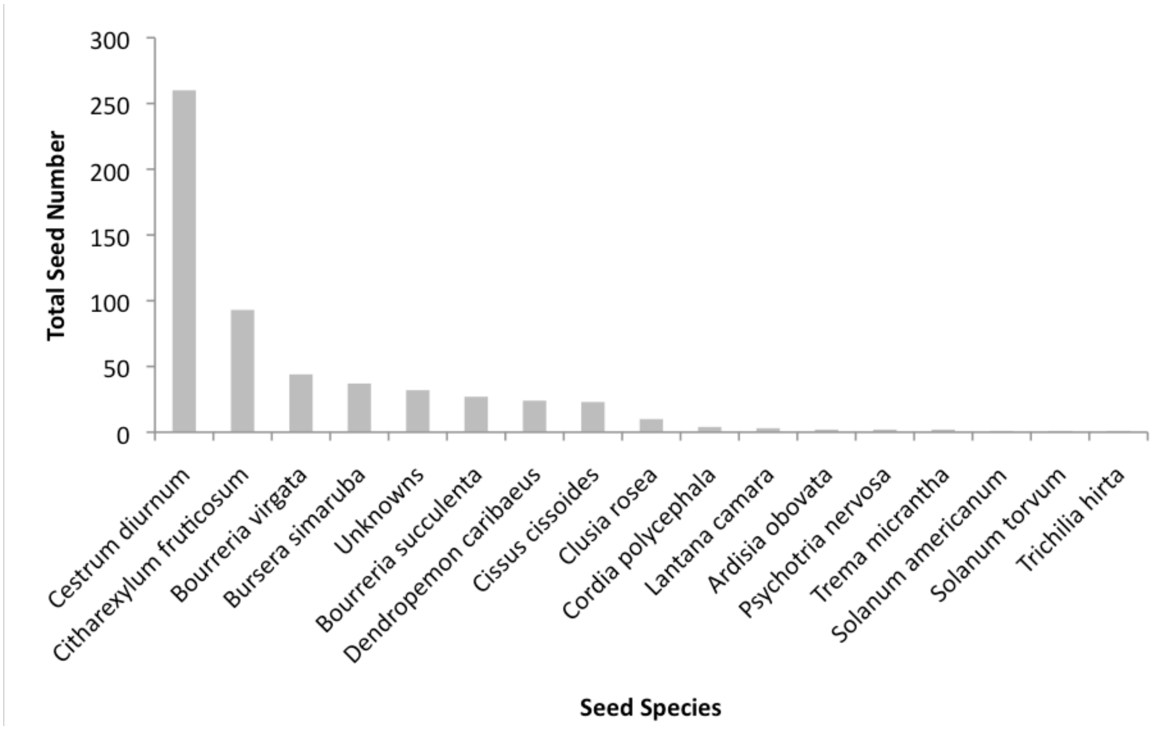

Figure 1. Frequency of seeds from plant species collected over a five month period at ten plot sites located in abandoned pastures in Puerto Rico.

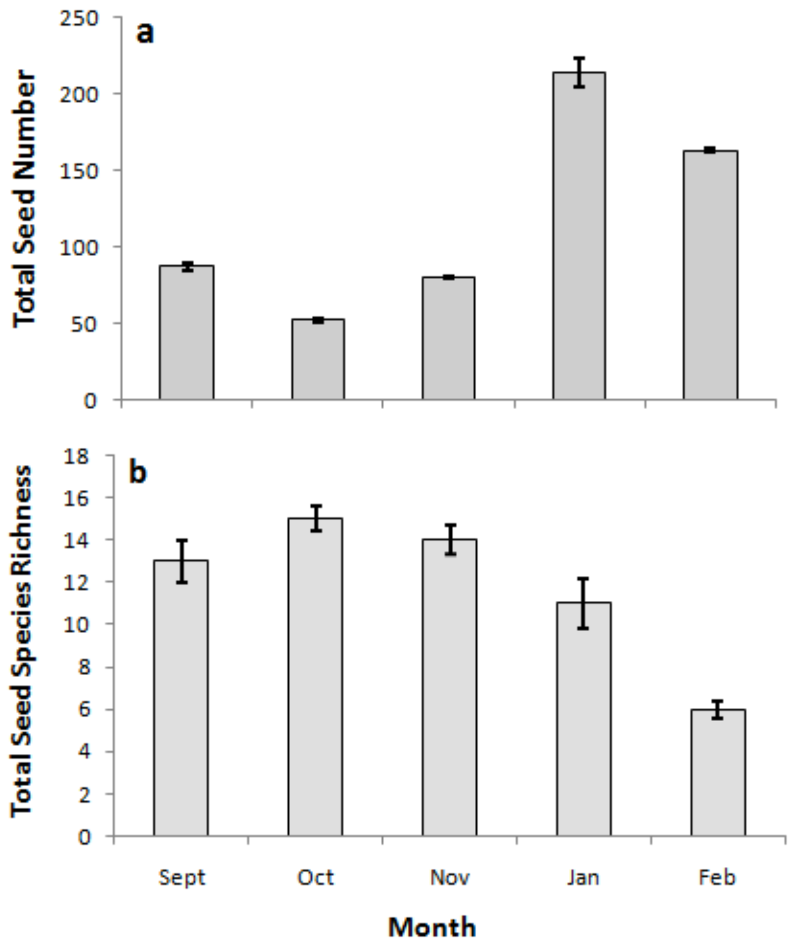

Figure 2. (a) Average seed number and (b) Average number of seed species found in ten plots over a five month period, with standard error bars.

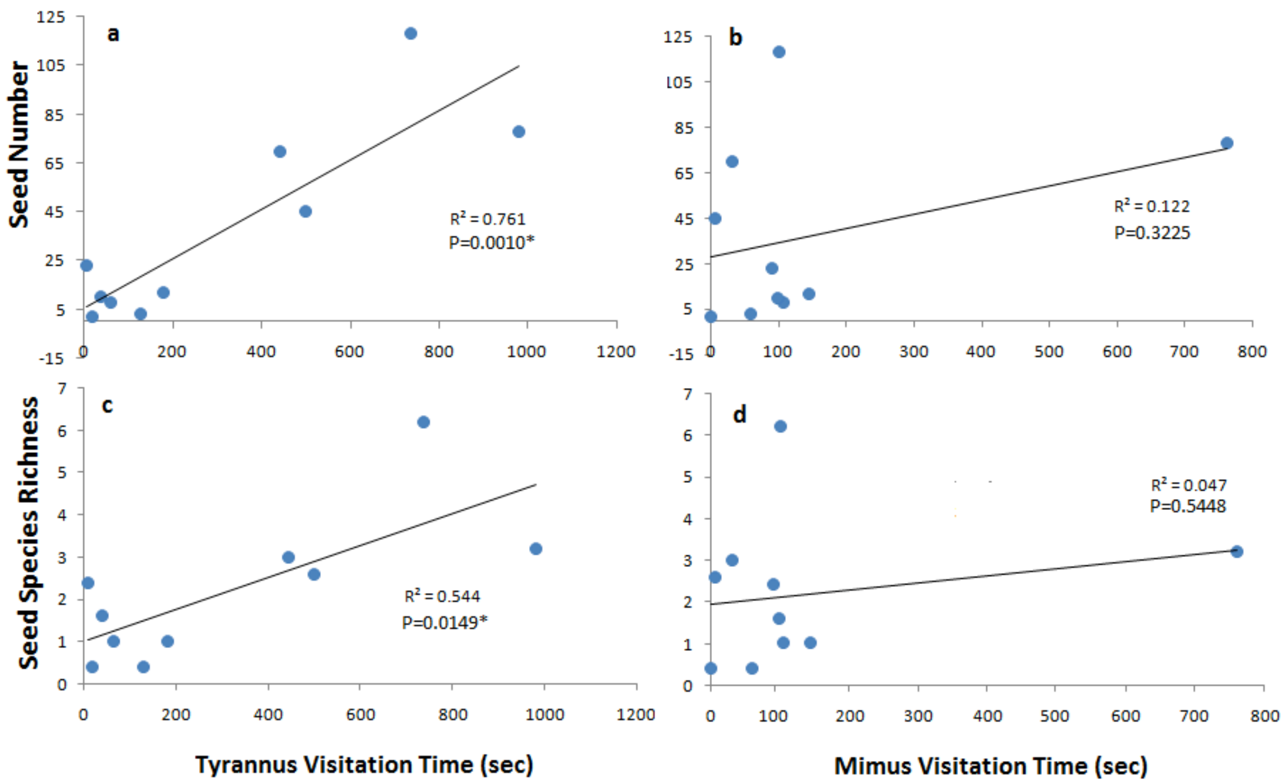

Figure 3. The relationship between (a) *Tyrannus dominicensis* visitation time and seed number, (b) *Mimus polyglottos* visitation time and seed number, (c) *Tyrannus dominicensis* visitation time and seed species richness, (d) *Mimus polyglottos* visitation time and seed species richness.

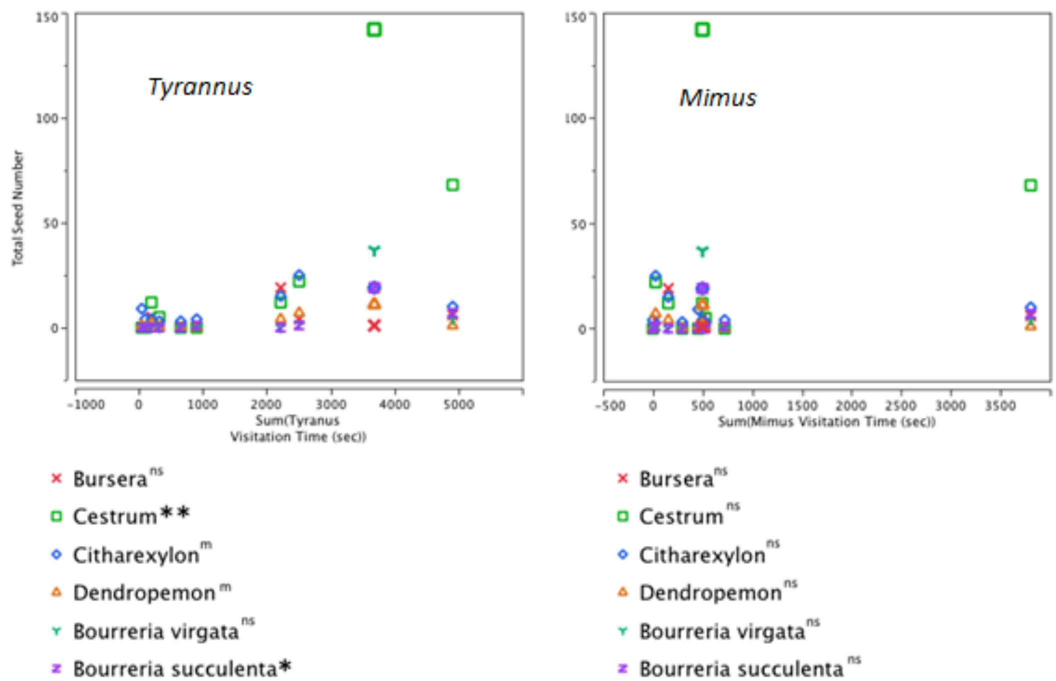

Figure 4. The Effect of *Tyrannus dominicensis* and *Mimus polyglottos* visitation time on six different seed species from September to March in ten plots, ^{ns}not significant, ^{m}marginally significant: $0.05<p<0.07$, *significant: $0.01<p< 0.05$, **most significant: $0.001<p< 0.01$.

Table 1. ANCOVA analysis of the bird visitation time (log-transformed seconds) with (a) total seed number month (b) seed species diversity per plot per month

a. Total Seed Number

Source	DF	F Value	P Value
Log *Mimus* Visitation Time	1	3.4959	0.0704
Log *Tyrannus* Visitation Time	1	7.3120	0.0107*
Log *Mimus* Visitation$^{\times}$log *Tyrannus* Visitation Time[1]	1	5.7876	0.0219*
Month	4	4.1453	0.0079*
Plot	9	2.8223	0.0141*

Whole Model R^2=0.72 RMSE=0.8149
*Probability > F is <0.0001.
Note: The response variables were month, plot, and logarithrm of Mimus and Visitation Times
[1]The interaction of *Mimus* visitation and *Tyrannus* visitation times

b. Seed Species Richness

Source	DF	F Value	P Value
Log *Mimus* Visitation Time	1	2.2218	0.1456
Log *Tyrannus* Visitation Time	1	3.1305	0.073
Log *Mimus* Visitation$^{\times}$log *Tyrannus* Visitation Time[1]	1	11.4343	0.0019*
Month	4	3.7452	0.0128*
Plot	9	4.1076	0.0013*

Whole Model R^2=0.68 RMSE=0.5349
*Probability > F is 0.0001.
Note: The response variables were month, plot, and logarithrm of Mimus and Visitation Times
[1]The interaction of *Mimus* visitation and *Tyrannus* visitation times

Discussion

The results of this study indicate that *Tyrannus* played a major role as a seed disperser in the ten abandoned pasture sites in Puerto Rico. *Tyrannus* had a greater presence in open pastures than any other bird species. In a previous study, Carlo and Yang (*submitted*) reported that out of 592 observations in Puerto Rican pastures, *Tyrannus* accounted for 68.8%, *Mimus* accounted for 30.1% and other species accounted for 1.1% of the perching time, frugivore movements, and crossovers between forest and pastures. They also argued that *Tyrannus* contributes to seed diversity in open pastures, while *Mimus* does not. These results agree with this study's bird observations. *Tyrannus'* diet consists of both fruit and insects, therefore *Tyrannus* may have also utilized perches in open pastures to feed on insects. Many insectivorous birds use both fruiting and non fruiting trees as feeding roosts, and contribute to seed rain by dropping seeds in less forested areas (Cortlett & Hau, 2000). Though *Mimus*' diet is more frugivorous than *Tyrannus'* diet, *Mimus* was not as significant in seed dispersal and seed diversity (Carlo & Yang, *submitted*).

Tyrannus was most significant for *C. diurnum* in the seed rain, while Mimus was not. This preference was also seen in fruit removal field observations, in which *Tyrannus* consumed more *Cestrum* fruits than *Mimus* (Carlo, 2005). The contents of the collected seed rain may be attributed to specific feeding preferences of *Tyrannus*, or *Tyrannus* may have eaten berries that were most available during the time of year the study was conducted. *Cestrum diurnum and C. fruticosum* were two most abundant species found in the seed rain and were also at their peak during the months of observation. *Cestrum diurnum* is at its fruiting peak during the months October to November and *C. fruticosum* is most abundant from December to February (Cubiña & Aide, 2001). Also in Puerto Rico, the driest time of the year occurs from February through

April. This might account for the low species richness found in February for this experiment (Figure 2b).

In addition to seed dispersal, another factor that limits forest regeneration is seed predation (Zimmerman et al., 2000; Myster, 2003). Even though *Tyrannus* contributed to increased seed rain in abandoned pastures, it is unsure how much of the seed rain will result in germination due to seed predation by ants, rodents, or other animals. The seed traps were covered in our study, so predation was most likely reduced. However, in another study in Puerto Rico, almost half of seed species from seed traps showed some level of predation (Carlo et al., *in press*). Also in an experiment in Puerto Rico, seeds were placed in Petri dishes in pastures and forests, and more seeds were removed from pastures than forests, so this may indicate that pastures are more vulnerable to predation (Zimmerman et al., 2000).

In this study, the usage of video cameras maximized sampling time and detail, which allowed our observations to be more complete than all previous studies (i.e., those by Carlo & Yang, *submitted*). Other similar studies in open pastures which have reported low bird activity may have been limited due to lack of observation time. In one such study, an open pasture site, with 20 seed traps it was found that only one seed was animal dispersed (Zimmerman et al., 2000). In another experiment, in a 36 hour observation, no birds fed in Puerto Rican pastures, despite fruit abundance nearby (Zimmerman et al., 2000). This clearly shows the importance of bird perching sites for the process of seed dispersal.

There were 16 known fruiting species and 12 unidentified species in this study, and the distances between the perch and forest edge ranged from 25 to 310 meters. In another experiment in Puerto Rican pastures, seed bank and seed species were also analyzed. However only 5 out of 35 fruit producing species in a forest were detected at distances greater than 4 meters from the forest edge, showing seed dispersal is a major factor in limiting forest recovery (Cubiña & Aide, 2001). By placing perches in deforested areas, this might increase succession rates. However, most often in open pastures, there are remnant trees, power lines, and fence posts that birds can perch on, which can also increase seed rain in the area.

Pastures may seem less attractive to frugivorous birds because they lack rewards such as fruits, and have harsher environmental conditions (Wunderle, 1997). Unlike other bird species, *Tyrannus* can tolerate degraded landscapes and open pastures, making it an important species for the initial stages of forest succession (Corlett, 1998). *Tyrannus*' presence can increase seed dispersal into open pastures, and with successful germination, this may dictate which plants and species get established in the area. Fruiting plants that are established due to *Tyrannus* may attract other bird species which might be more tolerant to fragmented lands, such as *Mimus,* and thus would further contribute to forest regeneration.

In conclusion, *Tyrannus* spends more time in pastures than other bird species, and the results indicate that *Tyrannus* is significant in contributing to both seed rain and seed diversity. In future experiments, it would be important to observe recruitment and predation rates of seed rain in order to see if *Tyrannus'* preference in fruits influences vegetation that gets established in open pastures.

References

Carlo, T.A. (2005). Interspecific neighbors change seed dispersal pattern of an avian-dispersed plant. *Ecology* (86): 2440–2449.

Carlo, T.A., M.L. Flores-Mangual ML, and M. Caraballo (*in press*). Post-dispersal seed predation rates in a Puerto Rican pasture. *Caribbean Journal of Science.*

Carlo T.A., J.A. Collazo, M.J. Groom. (2003). Avian fruit preferences across a Puerto Rican forested landscape: pattern consistency and implications for seed removal. *Oecologia* (134):119-131.

Carlo, T.A. and S. Yang. (*submitted*). From frugivory to seed dispersal networks: challenges and opportunities of a new paradigm.

Corlett, R.T. (2000). Environmental heterogeneity and species survival in degraded tropical landscapes. *Ecological Consequences of Environmental Heterogeneity.* Blackwell Science, Oxford: 333-355.

Corlett, R.T. and B.C. Hau . (2000). Seed dispersal and forest restoration. In Elliott, S., J. Kerby, D. Blakesley, K. Hardwick, K. Woods and V. Anusarnsunthorn (Eds), in Forest Restoration for Wildlife Conservation. Forest Restoration for Wildlife Conservation*:* 317-325

Corlett, R. T. (1998). Frugivory and seed dispersal by vertebrates in the oriental (Indomalayan) region. *Biological Review* (73): 413-448.

Cubiña, A. and T. M. Aide. (2001). The Effect of Distance from Forest Edge on Seed Rain and Soil Seed Bank in a Tropical Pasture (33): 260-267.

Duncan, R.S. and C.A. Chapman. (2001). Limitations of animal seed dispersal for enhancing forest succession on degraded lands. in D.J. Levey, M. Galetti and W.R. Silva (eds). Seed Dispersal and Frugivory: Ecology, Evolution and Conservation. CAB International, Wallingford, U.K.

Ferreira, L. V. and G. T. Prance. (1999). Ecosystem recovery in terra firma forests after cutting and burning: a comparison on species richness, floristic composition and forest structure in the Jau National Park, Amazonia. *Botanical Journal of the Linnean Society* (130): 97-110.

Global Forest Resource Assessment 2005: Progress toward sustainable forest management. Food and Agriculture Organization of the United Nations (147): 3-8.

Holl, K.D. (1999). Factors limiting tropical rain forest regeneration in abandoned pasture: seed rain, seed germination, microclimate, and soil. *Biotropica*: 31(2): 229-242.

Howe, H.F. and J. Smallwood (1982). Ecology of seed dispersal. *Annual Review of Ecology, Evolution and Systematics* (13): 201–228.

Myster, R.W. (2003). Effects of species, density, patch-type, and season on post-dispersal seed predation in a Puerto Rican pasture. *Biotropica* (35): 542-546.

Pejchar, L., R. Pringle, J. Ranganathan, J. Zook, G. Duran, and G.C. Daily. (2008). Birds as agents of seed dispersal in a human-dominated landscape in southern Costa Rica. *Biological Conservation* (141): 536-544.

Pizo, M. A. (2002). The seed dispersers and fruit syndromes of Myrtaceae in the Brazilian Atlantic forest. In: Levey, D. J., W. R. Silva e M. Galetti (eds), Seed dispersal and frugivory: ecology, evolution and conservation. CABI Publishing, Wallingford, Oxfordshire, Inglaterra: 129-143.

Raffaele, H., J. Wiley, O. Garrido, A. Keith, and J. Raffaele. (1989). *A guide to the Birds of Puerto Rico and the Virgin Islands*. Princeton, New Jersey: Princeton University Press.

Rivera, L.W., and T. M. Aide. (1998) Forest recovery in the karst region of Puerto Rico. *Forest*

*Ecology and Management (*108): 63-75.

Silva W.R., P. De Marco, E. Hasui, V.S. Gomes. (2002). Patterns of fruit-frugivore interactions in two Atlantic forest bird communities of South-eastern Brazil: implications for conservation. In: Levey DJ, Silva WR, Galetti M, editors. *Seed dispersal and frugivory: ecology, evolution and conservation*. Wallingford, UK: CAB International: 423–435.

Wunderle, J.M. (1997). The role of animal seed dispersal in acceleration native forest regeneration on degraded tropical lands. *Forest Ecology and Management* (99): 223-235.

Zahawi, R.A., and C.K. Augspurger. (2006). Tropical Forest Restoration: Tree Island as recruitment foci in degraded lands of Honduras. *Ecological Applications*, 16(2): 464-478.

Zimmerman, J. K., J. Pascarella, and T. M. Aide (2000). Barriers to forest regeneration in an abandoned pasture in Puerto Rico. *Restoration Ecology* (8): 350-360.

Christine Alice Wang
Academic Vita

Education

Pennsylvania State University, University Park, PA

Schreyer Honors College

Anticipated Graduation: May 2011

Majoring in Biology (vertebrate physiology option)

Leeds University, Leeds, England

Spring 2010 Study Abroad Program

Awards

- Edward Hammond Scholarship in Sciences, $600 (*Fall 2010 and Spring 2011)*

- Louis A. Martarano Endowment *, $350 (Spring 2010)*

- Roebling Knoch Memorial Scholarship in Sciences, $1000 (*Fall 2009 and Spring 2010)*

- Travel Grant to University of Leeds, $850 (*Spring 2010)*

- Schreyer Research Grant, $750 (*Summer 2010)*

Research Experience

Undergraduate Research Assistant in Tomas A. Carlo Lab, January 2009 to Present

- Assisted with grinding samples and measuring for mass spectrometry analysis

- Worked with nitrogen isotope solution to experiment with flower and petal nutrient absorption rates

- Experimented with mistletoe and lignin agar plates to detect lignin breakdown

Work Experience

Undergraduate Biology Office Secretary May 2008 to October 2009

- Helped to coordinate student and advisor meetings
- Answered phone calls, greeted students, assisted with FTCAP in Summer 2008

Biology 110 Peer Tutor, Fall 2008

- Tutored freshman in Introductory Biology course

Volunteer Experience

Mount Nittany Medical *Center Patient Floor Volunteer*, May 2008 to December 2009

- Assisted nurses, doctors, and patients
- Handled equipment for pharmacy, sterile processing, and maternity departments
- Penn State Fresh Start *Team Leader*, Fall 2009
- Organized day of service for incoming freshman and new students
- Helped clean and organize Faith Center Goodwill Store in Bellefonte, PA

Other Activities

- Penn State Marathon Club, 2009- Present
- AASIA Peer Mentor, 2008-2009
- Penn State Welcome Week Leader, Fall 2008