THE NATIVE BEES (HYMENOPTERA: APOIDEA: ANTHOPHILA) OF COASTAL DUNE ENVIRONMENTS OF FLORIDA

By

ANTHONY P. ABBATE

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To my wife Katie and to my parents Val and John Abbate

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Anthony P. Abbate

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Bee communities are important in the pollination of >66% of the world's crop species and over 80% of all flowering plant species. Few studies have focused on urban habitats and the effects they have on native bee communities. In our study, we monitored bee abundance and diversity in Florida state parks, protected lands, and developed sites occurring throughout the coasts of Florida. Our aim was to assess the potential impacts that dune degradation and development could have on these economically and ecologically important insects. A total of 5,419 bees from 5 families and 56 taxa were captured during this study. Halictidae accounted for 70% of all bees collected, followed by Apidae (28%), Megachilidae (2%), Andrenidae (0.1%) and Colletidae (0.07%). Both species richness and Shannon-Wiener diversity indices were higher in protected lands when compared with developed sites (z=5.1, P<0.0001; z=4.2, P<0.0001, respectively). Most of the common bee species analyzed showed a preference for protected lands compared with developed sites. Protected lands also supported higher abundances of ground-and wood-nesting bees when compared with developed sites (z=4.3, P<0.0001; z=4.8, P<0.0001, respectively). Linear regressions

showed several significant relationships between species richness and land use types. As the level of development increased, species richness declined (r^2=0.12, P=0.02), and as the percentage of dunes increased species richness increased (r^2=0.14, P=0.02). Similar trends were observed for Shannon-Wiener indices. We suspect that bee abundance and diversities are driven not only by the amount of nesting resources, but by the diversity and abundance of floral resources that native bees utilize. State parks and protected lands are ecologically important bee sanctuaries and should be supported to help sustain native bee communities.

CHAPTER 1
INTRODUCTION

Bee communities are important in the pollination of >66% of the world's crop species (Roubik 1995) and over 80% of all flowering plant species (Moisset and Buchmann 2010). Before the introduction of *Apis mellifera* L. to the Americas from Europe in the early 1600s, native bees and other insect taxa pollinated the flowering plants of the Americas (Moissett and Buchmann 2010). Many native (and endemic) plants depend on the specialized pollination services of native bees and other pollinators (Moissett and Buchmann 2010). Furthermore, native bees are thought to be more efficient when it comes to pollinating native plants (Moisset and Buchmann 2010). It was estimated in 2006 that native bees are responsible for about $3.07 billion of pollination services on fruits and vegetables alone in the United States (Losey and Vaughan 2006). With the recent losses in *A. mellifera* populations due to CCD (colony collapse disorder) and other factors, populations of native bees have been thought to provide a buffer or "biological insurance" for pollination services previously provided by *A. mellifera* (Winfree *et al.* 2007). Kremen et al. (2002) observed organic farms that can rely solely on native bees for all their melon pollination; this may be extended to other crops that are currently being pollinated by *A. mellifera.*

Today there are about 4,000 documented native bee species in the United States, with 316 occurring in Florida (Pascarella and Hall 2016). These taxa belong to six families including Andrenidae, Colletidae, Apidae, Halictidae, Megachilidae and Melittidae. Many of the bee species from Florida have wide ranges and are not restricted to specific environments, while some have narrow ranges and are restricted to sandy environments (Pascarella and Hall 2016). Although the bee species of Florida are well documented in certain areas (Mitchell 1960, 1962; Pascarella *et al*. 1999; Deyrup *et al.* 2002; Hall and Ascher 2010, 2014), county level lists remain incomplete (Hall and Ascher 2014). Similarly, the status of native bee populations in the United States has been incomplete due to the challenges associated with assessing all habitat types nationwide. These challenges include the time and cost required to complete such assessments across large heterogeneous landscapes (Koh *et al*. 2016). Our understanding of native bee diversity and abundance has been viewed through the smaller lens of landscapes and local sites, for this reason there is a high level of uncertainty relative to assessing the status of native bee populations at a larger scale (Koh *et al*. 2016).

Along with *A. mellifera*, native bees are currently also facing threats of their own. Native bee diversity and abundance within coastal dune systems are threatened due to several factors. These potential losses in bee diversity and abundance within dune ecosystems are thought to be directly affected by land development (Hall and Ascher 2010), rises in sea level, erosion, seasonal storms (Florida Oceans and Coastal Council, 2010), pesticide use and disease (Goulson *et al*. 2015). Urban and suburban development of natural areas such as the building of homes, condominiums, hotels, parking lots, roads etc. alter the distribution of the flora and nesting resources that bees utilize (Tscharntke *et al.* 2005). The losses of such habitats within coastal dune systems may lead to a decrease in bee abundance and diversity at the community level (Steffan-Dewenter *et al.* 2002). Over geologic time, as sea levels rose or fell, new dune habitat was created at the new surf/land interface. Now, human development inland may limit natural processes as sea levels continue to rise. As the sea removes dune habitat, human residential development will interfere with this natural process by the use of sea walls and other engineering to stop the sea’s advance (Nordstrom 2000).

Some of the previously mentioned mechanisms that decrease bee habitat can be linked to the rise in global temperatures. The earth has experienced many fluctuations in global temperature throughout history, and since 1981, the earth has experienced 20 of the warmest years on record (Peterson and Baringer 2009). Over the last 100 years, global sea level has risen 17.0 cm, and the rate of sea level rise in the last decade has nearly doubled (NASA, 2016). The rise in global sea-levels can be attributed to ice melt from ice sheets and glaciers due to the warming temperatures of the ocean/earth (NOAA, 2016), and by the ice-albedo feedback effect (Karl and Trenberth 2003). This poses a real threat to dune-inhabiting bees because vegetation and nesting sites within the dunes are sensitive to rising sea levels, and can be easily destroyed or damaged. The majority of native bee species are ground nesters, and depend on periods of time when their nests are undisturbed. Thus, any disturbances to the coastal dunes affects their life cycles. Erosion also poses a serious threat to the dune systems of Florida and to the bees that utilize them. Erosion is constantly changing and reshaping Florida’s coasts. Over the last 100 years, 40% of the coasts have retreated due to sea level rise, storms, and human activities (Florida Oceans and Coastal Council, 2010). Seasonal storms, such as hurricanes and tropical storms, also exacerbate erosion and damage done to the dunes. In 2004, four hurricanes (Ivan, Charley, Frances, and Jeanne) made landfall and did considerable damage to Florida’s coasts, destroying and carrying away tons of sand, resulting in shoreline change. The average shoreline change of Florida’s coasts where the storms made landfall varied from 1 m of advancement to 20 m of retreat (Sallenger *et al.* 2006). Due to the dynamic nature of dune ecosystems and the numerous threats they face, important arthropod groups should be monitored for their conservation needs. In our study, we monitored bee abundance and diversity to assess potential impacts dune degradation could have on these economically and ecologically important insects. The goals of our study were to 1) survey and document which native bee species utilize deep sandy soils within the coastal dunes of Florida, 2) to investigate whether bee biodiversity and abundance is greater in natural undisturbed sites (state parks and protected lands) when compared with similar but developed sites within the coastal dunes of Florida, 3) to investigate site preferences (state parks vs. developed sites) among the common bee species captured, 4) to investigate various bee guilds (ground-,wood- nesting, and parasitic bees) and the preferences they may have between protected lands and developed sites, and to 5) investigate how land use may influence species abundance and richness. We hypothesize that protected lands may be able to support higher abundances and diversities of native bees when compared with developed sites. This study will also serve as a baseline for future studies to document how changes in Florida’s coasts influence the diversity and abundance of native bee communities.

CHAPTER 2
MATERIALS AND METHODS

Survey Sites

A total of 14 sites were chosen for this study and were distributed throughout Florida ranging from Brevard County to Pinellas (east to west) and from Pinellas County to Miami-Dade County (north to south) (Figure 2-1). A list of Florida's State Parks that contained beaches was provided to us by the Florida Parks Service, and only sites with well-developed dune systems dominated by sea oats (*Uniola paniculata L.)* were chosen for this study. Of the 14 sites chosen, 9 protected lands exemplified undisturbed dune habitats. Alternatively, 5 disturbed or "developed" sites were chosen for comparisons to investigate the effects of urbanization on bee abundance and diversity within the coastal dune ecosystem. The developed sites contained residential homes, condominiums, hotels, parking lots, roads, etc. built in close proximity to the coastal dune systems and was also primarily dominated by sea oats. All protected lands chosen for this study had less than 35% development averaged along each transect with a buffer of 200 m, and all developed sites had more than 35% development averaged along each transect with a buffer of 200 m (described in detail in GIS techniques).

Transects

A set of 2-3 fixed transects roughly 150 m in length were placed just behind the exposed primary dunes in dune vegetation at each site. Each transect paralleled the primary dune and was placed in the center of the dune habitat between the primary dune and the secondary dune. Flags marked the beginning and end of each transect with the use of GPS coordinates, this enabled us to survey each transect repeatedly during each surveying period. Transects for all sites were not necessarily placed in a straight line, allowing us to avoid dense vegetation patches to optimize bee capture. To view aerial images of each site's transects visit http://tinyurl.com/y72zaa2e**.**

Bee Collection and Preparation

All bees collected in the study were pan-trapped with the use of bee bowls. Bee bowls have been shown to be an effective way to sample the relative abundance and diversity of pollinators (Campbell 2007). Bee bowls used in this study were small 92.9 mL (3.14 oz) plastic Dart® deli cups painted with fluorescent blue, yellow or white paint (for paint formulations see (Droege 2015)). A set of 30 bee bowls containing 10 yellow, 10 blue, and 10 white ones were set out at each transect, at each site, every month for up to 12 months. Bee bowls were partly filled with slightly soapy water in a ratio of 5 mL of blue Dawn® dish soap to 3.79 L of water. Bee bowls of alternating colors were then placed on the ground (either on natural bare ground or on matted vegetation to increase discovery by bees) in transects, between the primary dune and the secondary dune for approximately 24 hours. Specimens were then strained out of the bee bowls using a paper paint strainer (all colored bee bowls were pooled) and placed into plastic vials (1 per transect) with 95% ETOH and placed in a freezer until processing could be completed. Processing included washing, drying, pinning, identifying, vouchering and databasing of each specimen. To maximize bee capture and to standardize sampling procedures, bee bowls were only placed in bee habitats when weather was appropriate for sampling flying bees. Appropriate sampling periods consisted of sunny days that had a ≤40% chance of precipitation. Sampling periods for each site were carried out during the same week of each month (weather permitting), and the time between each sampling period did not exceed 7 weeks.

GIS Techniques

Transect data was recorded using a geographical positioning system and uploaded into ArcGIS® 10.3 (ESRI 2015). To obtain land use types, a 200-meter buffer was placed around each transect and ArcGIS World Imagery online basemap (ESRI *et al*. 2017) was utilized to hand digitize the land use at a scale of 1:2000. Land use types consisted of the following five categories: water, beach, dunes, forested/hammock, and developed.

Statistics

A square root transformation (Shapiro-Wilk normality test) and log transformation was applied to data that lacked normality to assure homogeneity of variance, but was unsuccessful. A Wilcoxon signed-rank non-parametric test was used to assess species richness, diversity (Shannon-Weiner diversity index), bee guilds (ground, wood, or parasitic) and the common bee species' site preference differences between protected lands and developed sites. We averaged species abundances for all sampling events (months) and subsamples (transects) for each site (protected lands=86, developed sites=42). Bee species with less than a total of 50 specimens collected were not included in the statistical analysis for species site preference, but were included for species richness, diversity, and guild analysis.

Data acquired through GIS techniques were used to perform linear regressions for species richness vs. land use type, Shannon-Wiener diversity indices vs. land use type and for each of the common bee species vs. land use type. We averaged species richness, Shannon-Wiener diversity indices, and the abundance of the common bee species across all sampling events for each transect in the study (n=40), GIS land use data was then paired with each corresponding transect for the analysis. All statistical analyses was performed using Statistix9 (Analytical Software, Tallahassee, FL, USA).

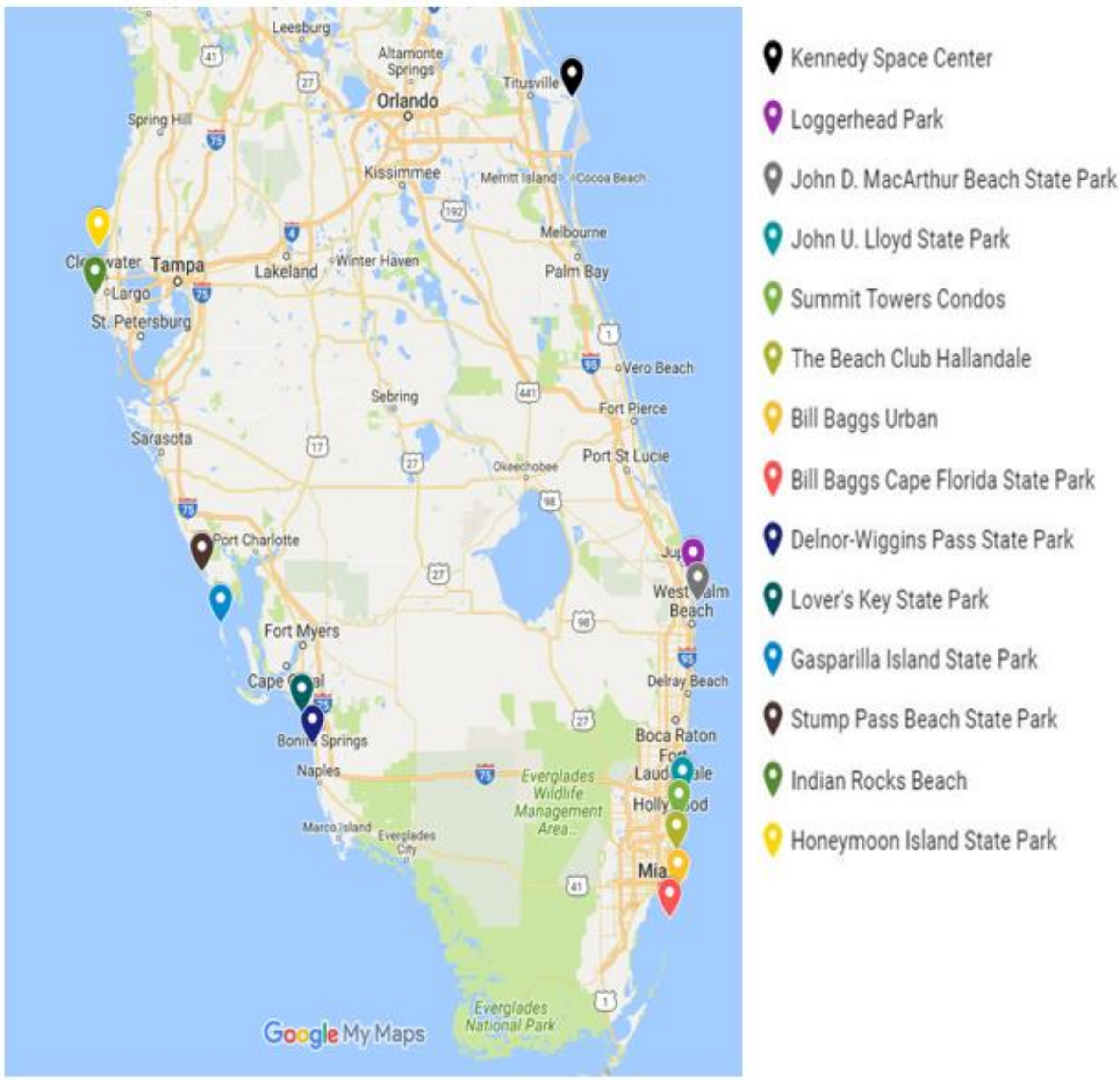

Figure 2-1. Study site locations where bee collecting occurred. Study sites are displayed in a clockwise direction on the map (left) with regards to the key (right).

CHAPTER 3
RESULTS

A total of 5,419 bees were caught along the coasts of Florida representing 56 species in 22 genera and five families. Data for the bees are listed in Table 3-1, which lists the species names, authors and totals for the bees grouped by Family (see appendix for full table). The numbers and proportion of species and bees collected in each family were as follows: Andrenidae- 4 taxa (7%), 7 bees (0.1%); Apidae- 14 taxa (25%), 1507 bees (27.8%); Colletidae- 3 taxa (5.4%), 4 bees (0.07%); Halictidae- 21 taxa (37.5%), 3790 bees (70%); Megachilidae- 14 taxa (25%), 111 bees (2%).

Both species richness and Shannon-Weiner diversity indices were higher in protected lands compared with developed sites (z=5.1, P<0.0001; z=4.2, P<0.0001, respectively; Table 3-2). Most of the common bee species analyzed in this study showed a preference for protected lands compared with developed sites (P<0.05 and P<0.1; Table 3-3) except for *Apis mellifera* L., which showed a preference towards developed sites (z=3.2, P=0.002). Three of the most common bee species showed no preference (P>0.05) between protected lands and developed sites, they included *Ceratina cockerelli* Smith. (z=1.5, P=0.12), *Halictus poeyi* Lepeletier. (z=0.56, P=0.58), and *Megachile pseudobrevis* Mitchell. (z=1.1, P=0.29).

Bees grouped by guild, averaged across all survey sites and sampling periods, resulted in a significant difference between protected lands and developed sites. The abundance of ground- and wood-nesting bees was higher in protected lands when compared with developed sites (z=4.3, P<0.0001; z=4.8, P<0.0001, respectively; Table 3-4). Parasitic bees showed no preference between protected lands and developed sites (z=0.71, P=0.48). GIS data was used to compare land use categories between state park and developed site transects. On average, state park transects contained about eight percent development (man-made structures) within the 200 m transect buffer when compared with developed sites which contained an average of 46% development within the 200 m buffer (Table 3-5). Dune, forested /hammock and water percentages were on average 14.62%, 19.47%, 52.40% (respectively) in protected lands and were on average 6.18%, 0.00%, 41.05% (respectively) in developed sites. Beach percentages were on average 5.25% in protected lands and were on average 7.03% in developed sites.

Linear regressions performed for species richness *vs*. each land use type resulted in several significant relationships. As the percentage of development increased, species richness declined (r^2=0.12, P=0.02), and as the percentage of dunes increased species richness increased (r^2=0.14, P=0.02) (Table 3-6). Similarly, linear regressions performed for Shannon-Wiener diversity indices *vs*. each land use type resulted in several significant relationships. As the percentage of development increased, Shannon-Wiener diversity indices decreased (r^2=0.16, P=0.01), and as dune percentages increased, Shannon-Wiener diversity indices increased (r^2=0.12, P=0.04) No significant relationships were observed between both species richness and Shannon-Wiener diversity indices and the other land use types.

Linear regressions performed on the average abundances of each common bee species *vs*. each land use type resulted in several significant relationships (all r^2 and P-values are listed in Table 3-7). Significant relationships were observed between the common bee species and the land use types. Dunes contained more significant relationships (n=7) followed by developed (n=6), water (n=3), forest (n=2), and beach (n=1).

Table 3-1. Bee genera and species and total numbers captured in all traps throughout the state of Florida during April 2016-April 2017

Family	Genus/Species	Protected Lands	Developed	Total Captured
Andrenidae	*Andrena sp.*	1	0	1
	Perdita sp.- including *P. bequaerti Viereck, halictoides Smith*	6	0	6
Apidae	*Apis mellifera* L.	64	73	137
	Bombus impatiens Cresson	1	0	1
	Ceratina cockerelli Smith, *C. floridana* Mitchell	265	36	301
	Epeolus autumnalis Robertson	1	0	1
	Euglossa dilemma Bembé and Eltz	6	1	7
	Exomalopsis analis Spinola	1	0	1
	Melissodes spp.-including M. *bimaculatus*Lepeletier, *communis* Cresson, *comptoides* Robertson, *tinctus* LaBerge	858	197	1056
	*Svastra atripes*Cresson	1	1	2
	*Xylocopa micans*Lepeletier	1	0	1
Colletidae	*Colletes americanus* Cresson, *latitarsis* Robertson, *mandibularis* Smith	3	1	4
Halictidae	*Agapostemon splendens* Lepeletier	235	27	262
	Augochlorella aurata Smith, *A. gratiosa* Smith	167	0	167
	Augochloropsis anonyma Cockerell	123	0	123
	Halictus poeyi Lepeletier	70	58	128
	Lasioglossum spp.-including *L. apopkense* Robertson, *batya* Gibbs, *creberrimum* Smith, *eleutherense* Engel, *halophitum* Graenicher, *hitchensi* Gibbs, *lepidii* Graenicher/*puteulanum* Gibbs, *longifrons* Baker, *marinum* Crawford, *nymphale* Smith, *raleighense* Crawford, *tamiamense* Mitchell	2526	581	3107
	Nomia maneei Cockerell	1	0	1
	Sphecodes sp.	0	2	2

Table 3-1. Continued

Family	Genus/Species	Protected Lands	Developed	Total Captured
Megachilidae	*Anthidium maculifrons* Smith	1	0	1
	Coelioxys mexicana Cresson, *C. sayi* Robertson, *slossoni* Viereck	5	0	5
	*Megachile albitarsis*Cresson, *M. georgica* Cresson, *inimica* Cresson, *lanata* Fabricius, *mendica* Cresson, *pruina* Smith, *pseudobrevis* Mitchell, *concinna* Smith, *rubi* Mitchell, *townsendiana* Cockrell	91	14	105
	Totals:	4427	991	5419

Legend= Counts were consolidated within genera because of spacing limits.

Table 3-2. Mean species richness (S)(±SE), and mean Shannon-Wiener diversity indices (H') (±SE) from protected lands and developed sites. Diversity indices with an * indicate a significant difference between protected lands and developed sites at *P*=0.05.

Diversity Index	Protected Lands	Developed
(S)*	3.74(0.20)	1.95(0.22)
(H')*	0.8110(0.06)	0.38(0.07)

Table 3-3. Mean abundances (±SE) for the most common species of bees captured per site type, averaged across all sampling events (months) and subsamples (transects) within protected lands (n=86) and developed sites (n=42) from April 2016-April 2017. Species with a * indicate a significant difference between protected lands and developed sites at *P*≤0.05.

Species	Site Type	
	Protected Lands	Developed
*Agapostemon splendens**	0.95(0.17)	0.27(0.10)
*Apis mellifera**	0.27(0.04)	0.69(0.14)
Augochlorella gratiosa	0.65(0.30)	0.0(0.0)
*Augochloropsis anonyma**	0.48(.22)	0.0(0.0)
Ceratina cockerelli	0.20(0.04)	0.16(0.07)
*Ceratina floridana**	0.85(0.15)	0.13(0.06)
Halictus poeyi	0.28(0.06)	0.46(0.14)
*Lasioglossum halophitum**	0.29(0.14)	0.0(0.0)
Lasioglossum lepidii/putuelanum	5.39(0.86)	4.4(1.35)
*Lasioglossum marinum**	0.68(0.19)	0.10(0.07)
*Lasioglossum nymphale**	3.28(1.00)	0.03(0.02)
*Lasioglossum tamiamense**	0.23(0.09)	0.06(0.05)
Megachile pseudobrevis	0.18(0.04)	0.08(0.03)
*Melissodes communis**	2.26(0.42)	1.47(0.71)
*Melissodes comptoides**	1.15(0.56)	0.10(0.07)

Table 3-4. Mean numbers (±SE) of bees grouped by guild type captured per site type, averaged across all sampling events (months) and subsamples (transects) within protected lands (n=86) and developed sites (n=42) from April 2016-April 2017. Ground= ground-nesting bees, wood= wood-nesting bees, parasitic= bee that is parasitic on bees (nesting in substrate of host). Guild type with an * indicate a significant difference between protected lands and developed sites at *P*=0.05.

Guild	Site Type	
	Protected Lands	Developed
Ground*	16.0(1.7)	7.0(1.6)
Wood*	1.5(0.20)	0.42(0.09)
Parasitic	0.03(0.01)	2.0(0.22)

Table 3-5. Percent land-use type averaged for all protected land transects (n=27) and for all developed sites (n=13).

Site Type	Land Use Type				
	Developed	Dunes	Beach	Forested/ hammock	Water
Protected Lands	8.27%	14.62%	5.25%	19.47%	52.40%
Developed	45.73%	6.18%	7.03%	0.00%	41.05%

Table 3-6. Linear regressions for species richness *vs*. land-use type. Species richness and Shannon-Wiener diversity indices (respective dependent variables) were averaged for each site and transect across all months (April 2016-2017). GIS land use percentages (independent variable) were paired to the corresponding transects. Values with an * indicate a significant positive correlation at $P \leq 0.05$; values with a ** indicate a significant negative correlation at $P \leq 0.05$. Values within the table are $r^2(P)$.

	Land Use Type				
	Developed	Dunes	Beach	Forested/ hammock	Water
Diversity Index	$r^2(P)$	$r^2(P)$	$r^2(P)$	$r^2(P)$	$r^2(P)$
Species Richness (S)	0.14(0.02)**	0.14(0.02)*	0.01(0.55)	0.03(0.30)	0.02(0.34)
Shannon-Wiener (H')	0.16(0.01)**	0.12(0.04)*	0.00(0.79)	0.04(0.22)	0.04(0.22)

Table 3-7. Linear regressions for the most common species of bees *vs*. land use type. Species abundances (dependent variable) were averaged for each site and transects across all months (April 2016-April 2017). GIS land-use data (independent variable) was paired with the corresponding transect. Numerical values with an * indicate a significant positive correlation at $P \leq 0.05$, and numerical values with a ** indicate a significant negative correlation at $P \leq 0.05$.

	Land Use Type				
Species	Developed	Dunes	Beach	Forested/ hammock	Water
Agapostemon splendens	0.18(0.01)**	0.23(0.00)*	0.01(0.63)	0.00(0.91)	0.14(0.02)*
Apis mellifera	0.20(0.00)*	0.07(0.10)	0.08(0.08)	0.17(0.01)**	0.03(0.31)
Augochlorella gratiosa	0.00(0.82)	0.01(0.65)	0.01(0.47)	0.01(0.60)	0.01(0.66)
Augochloropsis anonyma	0.13(0.02)**	0.01(0.49)	0.03(0.33)	0.01(0.59)	0.25(0.00)*
Ceratina cockerelli	0.00(0.96)	0.13(0.02)*	0.01(0.66)	0.01(0.61)	0.05(0.16)
Ceratina floridana	0.05(0.15)	0.00(0.95)	0.01(0.63)	0.05(0.18)	0.03(0.30)
Halictus poeyi	0.08(0.09)	0.08(0.08)	0.01(0.54)	0.01(0.65)	0.01(0.46)
Lasioglossum halophitum	0.07(0.11)	0.64(0.00)*	0.00(0.84)	0.06(0.13)	0.00(0.83)
Lasioglossum lepidii/puteulanum	0.01(0.58)	0.12(0.03)*	0.04(0.23)	0.00(0.78)	0.02(0.35)
Lasioglossum marinum	0.06(0.14)	0.04(0.20)	0.05(0.15)	0.11(0.03)*	0.01(0.53)
Lasioglossum nymphale	0.00(0.93)	0.00(0.93)	0.00(0.78)	0.00(0.70)	0.00(0.77)
Lasioglossum tamiamense	0.11(0.03)**	0.09(0.07)	0.03(0.28)	0.04(0.20)	0.02(0.37)
Megachile pseudobrevis	0.05(0.18)	0.01(0.60)	0.01(0.47)	0.06(0.14)	0.05(0.16)
Melissodes communis	0.00(0.68)	0.06(0.14)	0.00(0.71)	0.04(0.21)	0.03(0.29)
Melissodes comptoides	0.08(0.08)	0.06(0.14)	0.02(0.44)	0.02(0.35)	0.27(0.00)*

CHAPTER 4
DISCUSSION AND CONCLUSION

Specimens collected in this study represented five of the six bee families (Andrenidae, Colletidae, Apidae, Halictidae, and Megachilidae). We did not catch any bees belonging to the family Melittidae, which are small to medium-sized ground-nesting bees (Ascher and Pickering 2014). There are about 32 species of Melittids found in the United States, with two species occurring in Florida (*Hesperapsis oraria* Snelling and Stage, and *Melitta americana* Smith). These two species have been recorded in northern counties of Florida where we did not conduct surveys.

Andrenid bees are small (10-20 mm) solitary ground-nesters with over 1,200 species in the United States (Ascher and Pickering 2014), and 63 in Florida (Pascarella *et al*. 1999). Andrenid bees are also known as mining bees because females dig long branching tunnels in sandy soils (Cane 1991) where they fill cells with pollen balls and nectar before laying an egg on the provisions (Milne and Milne 1980). We caught four distinct taxa in low numbers in our surveys. This may be attributed to their southern range limit. Their southernmost range limit is thought to be near the northern edge of Lake Okeechobee (Pascarella *et al*. 1999). This aligns with our findings; as all Andrenid bees caught in our study were in localities north of Lake Okeechobee. Additionally, bees in the genus *Perdita* are known to be oligolectic and have been documented to visit *Helianthus divarictus* L., *Physalis lanceolata* Michaux., and *P*. *virginiana* Miller, which occur only in several northern Florida counties, and may be why we did not capture bees in this particular genus in south Florida (Wunderlin and Hansen 2017). Deyrup *et al*. (2002) documented *P. bequaerti* visiting two other flowering plants *Balduina angustifolia* (occurs throughout Florida) and *Palafoxia feayi* (occurring in central and south Florida). Also, *Perdita* species have been reported as far south as NW Miami, Hollywood, and Coral Gables in several older surveys (Graenicher 1930, Mitchell 1960, 1962). In the case of the two *Perdita* species we caught, range restrictions might be attributed to factors such as changes in climate, soils, peninsular effects, and/or habitat loss (Pascarella *et al.* 1999).

Apidae is a diverse group with about 1,000 species in 50 genera and 3 subfamilies in the United States (Ascher and Pickering 2014). This group is made up of cuckoo, carpenter, digger, bumble, and honey bees. Eighty-seven species within Apidae can be found in Florida. We caught 14 distinct species in 9 genera varying in abundances. Bees in the genus *Ceratina* and most of the bee species in *Melissodes* were common throughout the state of Florida and were caught in high abundances. *Ceratina cockerelli* Smith, and *C. floridana* Mitchell are small carpenter bees and can be found throughout Florida (Daly, 1973). Bees in the genus *Ceratina* are small-bodied bees that might be utilizing small twigs and stems as suitable nesting sites within the dunes of Florida. Several *Ceratina* species have not shown a preference between smaller and larger diameter twigs as nesting sites, and will readily utilize them (McIntosh 1996). The primary vegetation within the forested/hammocks within our survey sites are dominated by mangroves, sea grape, and pine trees, which produce smaller diameter twigs. Additionally, *Ceratina* bees might be nesting and foraging within the dune systems of Florida, their foraging ranges are thought to be smaller than larger bodied bees (Greenleaf *et al.* 2007). This might be why we caught them in high abundances in protected lands when compared with developed sites because protected lands contain less developed areas. Two species of bees in the genus *Melissodes* were caught in high abundances and are common throughout Florida, they included *M. communis* Cresson, and *M. comptoides* Robertson. Both *M. communis* and *M. comptoides* are ground nesters and were trapped in higher abundances in protected lands compared with developed sites (see supplemental table in appendix). It might be that there are more nesting resources available in and around protected lands compared with developed sites. Because they are larger-bodied, and therefore capable of longer foraging ranges, they might be attracted to the floral resources in protected lands yielding higher abundances. There were species of bees within the genera *Bombus, Epeolus, Euglossa, Exomalopsis, Svastra, and Xylocopa* that were caught in low abundances during this study and were either uncommon in Florida, or have been introduced from the Caribbean and South America (Ascher and Pickering 2014). Although *Bombus impatiens* Cresson occurs throughout Florida, we were only able to capture one individual in Brevard County, it is possible that the deep sandy soils that occur within the dunes are not suitable for their nesting requirements. *Epeolus autumnalis* Robertson is common throughout the northeastern United States and Canada, and only has been reported in Florida once prior to this study (Ascher and Pickering 2014). It might be that *E. autumnalisi* is uncommon in Florida or has not established yet. *Euglossa dilemma* Bembé and Eltz is a species that has been introduced and detected in south Florida. In 2003 *E. dilemma* was trapped in Broward County during fruit fly monitoring surveys (Skov and Wiley 2005), and since has spread to Miami-Date County, Palm Beach County (Pemberton and Wheeler 2006), Collier County, and Lee County (Pascarella 2017). Additionally, Pemberton and Wheeler (2006) has shown that *E. dilemma's* bee-perfume orchid mutualism may be facultative and *E. dilemma* will readily utilize other plants such as basil leaves to obtain chemical fragrances that they use in courtship rituals. *Exomalopsis analis* Spinola is another introduced species from the Caribbean and has only been caught once in the state of Florida since 2005 prior to this study (Sam Droege, personal communication, June 15, 2017). Another bee caught in low abundances (*Svastra atripes* Cresson), were caught in low abundances and seemed to be restricted to central and northern parts of Florida. There are currently two subspecies of *Svastra atripes* reported in Florida (*S. atripes georgica* and *S. atripes atrimitra*) that are thought to hybridize in North Florida (Pascarella and Hall 2016). Only one *Xylocopa micans* Lepeletier specimen was trapped during our study and was caught in Lee County. *Xylocopa micans* are large carpenter bees that chew nesting galleries in dead branches of trees, logs, solid wood, or in stumps. Since suitable nesting resources might be sparse within coastal dune systems, this might be a reflection of their low abundances within the dunes. When comparing both large and small carpenter bees caught in this study, *Ceratina* might be able to utilize smaller branches and twigs for their nesting sites, while *Xylocopa micans* require a minimum branch diameter of 2.5 cm (Hurd 1958) that might be a factor that is excluding *Xylocopa micans* populations from the coastal dune systems.

Colletid bees, also known a plasterer, cellophane, or masked bees comprise about 160 species in the United States. They get their name from the method with which they construct the walls of their nest cells with cellophane-like secretions (Michener 2000), and by the distinct markings on their faces. There are about twenty-six species of colletid bees in Florida; we caught three of them during our surveys. Colletid bees do not make up a large proportion of the total bee species of Florida, and the numbers we caught might be a reflection of that.

Halictid or sweat bees make up about 520 species in the United States (Ascher and Pickering 2014). They are small to medium-sized bees that are usually black or brown, while some are metallic blue or green (Arnett 2000). Halictid bees tend to be ground nesters and most species are polylectic (Eickwort and Eickwort 1973). Sixty-six species of halictid bees have been reported from Florida, whereas we trapped twenty-one distinct taxa in 7 genera. Some of the halictids we caught in this study occurred in high abundances (*Lasioglossum*), and some occurred in low abundances such as the parasitic bees (*Nomia* and *Sphecodes*). Although several *Lasioglossum* species were caught in high abundances (*Lasioglossum lepidii* Graenicher/ *puteulanum* Gibbs, and *L. nymphale* Smith) there were 12 species that were uncommon in our surveys, including *Lasioglossum eleutherense* Engel, *L. apopkense* Robertson, *L. batya* Curtis, *L. hitchensi* Gibbs, *L. raleighense* Crawford, and two unidentified species. *Lasioglossum eleutherense* is known from the Bahamas and Cuba, and has only been recorded from Miami-Dade County and Polk County prior to this study (Ascher and Pickering 2014). The status of *L. eleutherense* in Florida is unknown; we caught one *L.eleutherense* in Broward County which might be a range extension. *Lasioglossum apopkense* is another species we caught in low abundances, county records include Alachua, Liberty, Santa Rosa, and Volusia County (Ascher and Pickering 2014); whereas we caught one specimen from Lee County which might represent a range extension for this species. *Lasioglossum batya*'s range is from South Carolina south to Florida (Ascher and Pickering 2014), and only has been documented in Alachua County (Hall and Ascher

2014); we caught two specimens in Brevard County which is also a range extension. *Lasioglossum hitchensi* is common in the Eastern United States and has only been documented in Central Florida once prior to this study (Ascher and Pickering 2014); we caught one specimen in Miami-Dade County which might be a range extension. *Lasioglossum raleighense's* range is known from North Carolina to Florida and has been documented in Alachua and Volusia County (Ascher and Pickering 2014); we caught one specimen in Brevard County which might also be a range extension. We also caught a parasitic halictid *Sphecodes sp.* which is parasitic on other Halictinae (Michener 2007). *Nomia maneei* Cockerell is another species that we caught in very low abundances, they are known to occur in Alacuha, Highlands, Levy, Marion, Suwanee, and Wakulla Counties (Ascher and Pickering 2014). We caught one specimen in Collier County which is the southernmost record for this species in Florida. One halictid, *Augochlora pura* Say that is common in Florida was not recovered in our surveys. Ulyshen *et al.* (2010) conducted a survey in a bottomland hardwood forest in the southeastern United States and captured *A. pura* in high abundances, accounting for 91% of their total captured bees. Ulyshen *et al.* (2010) utilized flight-intercept traps suspended within the canopy and near the ground; *A. pura* was 40 times more abundant in the canopy when compared with the ground. *Augochlora pura* have also been captured in previous Florida surveys (Pascarella *et al.* 1999, Deyrup *et al.* 2002, Hall and Ascher 2010, 2011, 2014). Although Pascarella *et al.* (1999) does not list total specimens captured, *A. pura* was recovered between 12% and 53% of the time while surveying within the Everglades National Park. Pascarella *et al.* (1999) caught *A. pura* while hand-netting as *A. pura* were visiting flowers and while *A. pura* was in flight. All sampling sites they collected from contained a degree of hardwood hammocks. Deyrup *et al.* (2002) collected *A. pura* within the Archbold Biological Station (ABS) in Lake Placid, FL with the use of malaise traps and hand netting. Archbold Biological Station's soil is made up entirely of sand except for organic matter in the form of leaf litter, and has an over-story of pines in most areas (Deyrup *et al.* 2002). Hall and Ascher collected *A. pura* in their surveys (2010, 2011, and 2014), and in 2010 they collected bees from natural areas within Alachua County with the use of colored bowl traps and netting. They caught 10 *A. pura* with the use of bowl traps and 14 with the use of hand-netting over a three-year period. All survey sites in Hall and Ascher's 2010 study contained a degree of forested canopy. In another study, Hall and Ascher (2011) collected one *A. pura* on an organic farm with the use of hand-netting during a one year period. Similarly, Hall and Ascher (2014) caught a single *A. pura* specimen with the use of colored bowl traps within the Ordway-Swisher Biological Station. *Augochlora pura* might be utilizing the canopies during periods when nectar and pollen are low (Ulyshen *et al.* 2010). If *A. pura* depends on the presence of a canopy, this explain why we did not catch a single *A. pura* specimen within the coastal dunes of Florida. Alternatively, Florida surveys have not been successful in capturing high abundances of *A. pura* with the use of colored bowl traps. Colored bowl traps may not work as efficiently with *A. pura* when compared with other sampling techniques. It might be valuable to set up both malaise and flight-interceptor traps to monitor for *A. pura* within the coastal dunes of Florida.

Megachilid or leaf-cutter and mason bees make up over 630 species in the United States (Ascher and Pickering 2014). Bees of the family Megachilidae nest in the ground and cavities in wood. They get their names from the leaf material they cut and clay material that they use to seal their cells once an egg is laid (Arnett 2000). Seventy-two species of bees from the family Megachilidae occur in Florida; we caught 14 species in our surveys. The 14 species belonged to three genera, one of which is parasitic (*Coelioxys*) and lays their eggs in the nests of other bees in the same family. The two most common Megachilid species caught in our surveys were *Megachile pruina* Smith, and *Megachile pseudobrevis* Mitchell. *Megachile pruina* has been documented to occur in Monroe and Miami-Dade County (Pascarella *et al.* 1999), and has also been reported from Highlands County (Deyrup *et al.* 2002). *Megachile pruina* has also been reported in many other central and southern Florida counties; the same is true for *Megachile pseudobrevis.* All other species of Megachilids caught during our surveys occurred in low abundances including *M. albitarsis* Cresson, *M. concinna* Smith, *M. georgica* Cresson, *M. inimica* Cresson, *M. lanata* Fabricius, *M. mendica* Cresson, *M. rubi* Mitchell and *M. townsendiana* Cockrell. *Megachile albitarsis* has been reported throughout Florida including Miami-Dade, Duval, Palm Beach, Highlands, Alachua, Volusia, Lee, and Okeechobee Counties (Mitchell 1960, 1962) and Baker, Columbia, Wakulla, and Leon Counties (Pascarella and Hall 2016); we caught 9 specimens throughout Collier, Charlotte, and Lee County. *Megachile concinna* is thought to have been introduced from Africa and had been reported after World War II and can now be found from Florida and Alabama to Pennsylvania and Ohio (Ascher and Pickering 2014). *Megachile georgica* and *M. inimica* are common in southern Florida despite being trapped in low abundances in our surveys. It might be that the floral resources that they utilize do not occur within the coastal dunes of Florida or occur in low densities. *Megachile lanata* Fabricius is an interesting exotic bee in that it might have been one of the first bees to reach the New World via global trading routes from West Africa in slave ships during the slave trade (Ascher and Pickering 2014). *Megachile rubi* and *M. townsendiana* nest in sandy soils and can be found in xeric areas such as sandhills, scrub, and coastal dunes (Mitchell 1960, 1962). Both species were trapped in low abundances and few records exist for them in Florida, it might be that they are not well established yet in Florida.

Our study corroborates the hypothesis that protected lands support higher abundances and diversities of native bees when compared with developed sites. Species richness and Shannon-Wiener diversity indices showed that there were significant differences between protected lands and developed sites along the coasts of Florida (Table 3-2). Only a few studies have focused on urban habitats (Hostetler and McIntyre 2001, Cane *et al*. 2006, Hernandez *et al.* 2009), and studies have shown that natural areas support higher abundances and diversities of bees when compared with urban sites (Dalmazzo 2010). We analyzed the 15 most abundant bee species in our study and found that 9 species occurred in higher average abundances in protected lands relative to developed sites (Table 3-3). The one exception was *A. mellifera,* which were found in higher abundances in developed sites. *Apis mellifera* populations have been shown to be associated with man-made structures (Hostetler and McIntyre 2001) and may be better adapted to surviving in urban areas because they are generalist foragers and able to utilize exotic ornamental plants used in landscaping, or have been managed in urban areas by humans. Eighty-nine percent (n=8) of the bee species that were found in higher abundances in protected lands were ground nesters. Perhaps there are not enough suitable ground-nesting sites in developed areas when compared to protected lands. The building of parking lots, condominiums, hotels, roads, and other man-made structures leave the ground surfaces impermeable and unusable to ground-nesting bees, thus limiting their populations. Heavy mulching of landscaping might also make the soil inaccessible for ground nesting bees. Similarly, wood-nesting bees may also be limited by the amount of suitable nesting materials available in the forested/hammocks that occur near the dunes. This might be especially true for the developed sites in this study where the amount of forested/hammocks occurred in low percentages. The results from our guild-level analysis support this hypothesis. Ground- and wood-nesting bees were trapped in significantly higher abundances in protected lands compared with developed sites because there might be more nesting resources available in protected lands when compared with developed sites. There were no significant differences in the parasitic guild between protected lands and developed sites (z=0.71, P=0.48), which might be due to sampling biases with our trapping method (Rubene *et al.* 2015).

Our GIS data also support the hypothesis that protected lands might be able to support higher abundances and diversities of bees when compared with developed sites. Averaging the percent development, dunes, beach, forested/hammocks, and water for all state park transects (n=27) and for all developed transects (n=13) established an interesting perspective on the factors that might be influencing bee site preference (Table 3-5). Protected lands were about 8% developed, meaning that only about 8% of the land that falls within a 200 m buffer of each transect contained man-made structures. Developed sites on average, contained about 46% development. These percentages might be directly related to the amount of nesting resources that were available for the ground-nesting bees within the genera *Agapostemon, Augochloropsis, Augochlorella, Lasioglossum, Melissodes,* and others which tunnel and nest in the ground to provision their larvae with pollen. Protected lands also contained higher percentages of forested/hammocks (coastal strand, coastal hardwood hammock, and tropical hammocks) (19%) when compared with developed sites (0%). This might be why we saw more wood-nesting bees in protected lands and lower abundances in developed sites. There were also higher percentages of dunes in protected lands (15%) when compared with developed sites (6%), which might translate into more floral resources that native bee communities are attracted to and utilize for metabolism, reproduction and nesting.

To determine if there were significant relationships between each land use type and species richness and diversity, we ran linear regressions pairing average species richness and average Shannon-Wiener diversity indices to each transects' specific land use percentages in our study (n=40). Overall, percentages of development and dunes appeared to be driving species richness and Shannon-Wiener diversity indices. As the percentages of development increased both species richness and Shannon-Wiener diversities decreased and as the percentages of dunes increased both species richness and Shannon-Wiener diversities increased (Table 3-6). No significant relationships were observed between the average species richness and average Shannon-Wiener diversity indices and the percentages of beach, forested/hammocks, and water. This supports the hypothesis that man-made structures might be one of the factors limiting native bee abundances and diversities, and that native bees require larger areas of undisturbed dune habitats.

To elucidate the factors that might be driving the abundances of the 15 most common bee species captured in this study, linear regressions were used to show relationships between the average abundances of each bee species and land use type percentages (Table 3-7). There were four significant relationships in the developed land use category, with three species having significant negative correlations (*Agapostemon splendens, Augochloropsis anonyma,* and *Lasioglossum tamiamense*). We expected to see more significant negative correlations between species abundance and the developed percentages since many of the top 15 species are ground-nesting bees and require undisturbed ground-nesting sites. *Apis mellifera* abundance showed a positive correlation with development, and this is what we expected since we manage honeybee colonies in both urban and rural settings, and because they are generalist foragers. There were four significant correlations between species abundance and the percentage of dunes; they included *Agapostemon splendens, Ceratina cockerelli, Lasioglossum halophitum, and L. lepidii/puteulanum.* As the percentage of dunes increases, there might be more suitable nesting and floral resources available for ground-nesting bees. We expected to see more significantly positive correlations between each species' abundance and the percentage of dunes. Thus, there might be other factors that influence species abundance and richness within the coastal dune systems. It is interesting that *Lasioglossum marinum* Crawford is a sand dune specialist (Gibbs 2010), and did not have any significant correlations between their abundances and dune percentages, yet it did have a significantly positive correlation with forested/hammock percentages. It might be that *L. marinum* is attracted to or is utilizing something within the forested/hammocks more than the dunes, future studies should look into what *L. marinum* is utilizing within the forested/hammocks. Because most of the r-squared values were low throughout Table 3-7, and several common bee species showed no significant correlations in their average abundance *vs.* each land use type, there might be other factors that are driving their abundances. Floral resources are an important factor to examine and might be a major driver for species richness and abundance. One study has shown that the diversity and abundance of bees is more affected by floral resource abundance and distribution than the impact urbanization has on bee abundance (Wojcik 2011). Although documenting the abundance and diversity of floral resources within the dunes at each site was not a stated objective of this project, we have gathered data for future analysis to investigate potential correlations between specific bee species' abundances and the density and richness of flowering plants within the coastal dunes of Florida. When collecting bees each month at each site, we noticed that one of the developed sites (Indian Rocks Beach) appeared to have a high density and diversity of flowering plants each month. I contacted the mayor of Indian Rocks Beach and discovered that he had been planting and supplementing the dune systems with native flowing plants adjacent to my transects (Estrada 2016). When comparing the Shannon-Wiener diversity index averaged across all sampling events (months) and sub-samples (transects) for both protected lands and developed sites, we observed that Indian Rocks Beach had the highest Shannon-Wiener diversity index of all developed sites, and had a similar Shannon-Wiener diversity index when compared with protected lands (Table 4-1). Future studies should look into how supplementing developed sites might increase native bee diversity and abundance, and how it might create native bee sanctuaries within developed sites. Another factor that might be worth examining would be the foraging ranges of the common bee species captured in this study. Gathmann and Tscharntke (2002) concluded that solitary bees have small foraging ranges and that the local habitat plays a larger role than large-scale landscape structure. Similarly, Greenleaf *et al*. (2007) reported that bee foraging ranges increased non-linearly with body size. Some of the larger-bodied bees captured in our study area might have only been foraging within the dune systems and utilizing them as nesting sites, while the smaller-bodied bees might have been nesting and foraging within the dune systems and could have been more greatly affected by human development and other natural disturbances. One last factor that might be worthwhile elucidating in future studies would be timing when certain bee species are active throughout the year in Florida. In this study, we decided to look at the 5 most common bee species captured, and to document their monthly abundances throughout the year (Figure 4-1). This information might be valuable for entomologists who are interested in trapping specific species throughout the year. In Florida, *Agapostemon splendens*' abundances peak around the month of November (Figure 4-1) and remain relatively low throughout the rest of the year. *Lasioglossum nymphale* and L. lepidii/puteulanum show inverse abundances of one another, suggesting that their populations might be temporally or ecologically isolated from one another. *Melissodes comptoides'* abundance appears to peak in July and *M. communis*' abundance appears to decline during that same month. It might be that there is competition between the two species between May and September. Future studies should not only survey which native bee species are present in certain areas, but also when they are present throughout the year.

In conclusion, protected lands support higher abundances and diversities of native bees compared with developed sites. State parks and protected lands should be protected and supported because they could be serving as native bee sanctuaries. Future research should evaluate methods of dune restoration and how incorporating more native flowering plants into developed sites might positively influence native bee abundance and diversity. Future work should also look into the effects of fire in coastal strand habitats on bee abundance and species richness. Future studies should also assess the effect of mulching and other landscape practices on native soil-nesting bee populations. Future surveys should also focus on longer multi-year studies to track changes in urban development, sea-level rise, erosion, and other factors that might be influencing native bee communities that utilize coastal dune systems.

Figure 4-1. Monthly abundances for the 5 most abundant species including A) *Agapostemon splendens,* B) *Lasioglossum nymphale,* C) *Lasioglossum lepidii/puteulanum,* D) *Melissodes comptoides,* E) *Melissodes communis.*

Table 4-1. Survey sites with Shannon-Wiener diversity indices averaged across all sampling events (months) and subsamples (transects) within protected lands (n=86) and developed sites (n=42) from April 2016-April 2017

Protected Lands	H'	Developed Sites	H'
Lover's Key	1.16	Indian Rocks Beach	0.85
Gasparilla Island	1.07	Summit Towers	0.47
Stump Pass	0.94	Bill Baggs Urban	0.45
Kennedy Space Center	0.9	Loggerhead Park	0.38
Honeymoon Island	0.87	Beach Club Hallendale	0.08
John U. Lloyd	0.83		
Bill Baggs Cape	0.67		
Delnor-Wiggins	0.67		
John D. MacArthur	0.53		

APPENDIX
SUPPLEMENTAL TABLES AND FIGURES

Supplemental Table S1. List of species and numbers captured in all traps throughout the state of Florida during April 2016-April 2017.

Family	Genus/Species	Protected Lands	Developed	Total Captured
Andrenidae	*Andrena sp.*	1	0	1
	Perdita sp.	3	0	3
	Perdita bequaerti Viereck	1	0	1
	Perdita halictoides Smith	2	0	2
Apidae	*Apis mellifera* L.	64	73	137
	Bombus impatiens Cresson	1	0	1
	Ceratina cockerelli Smith	49	20	69
	Ceratina floridana Mitchell	216	16	232
	Epeolus autumnalis Robertson	1	0	1
	Euglossa dilemma Bembé and Eltz	6	1	7
	Exomalopsis analis Spinola	1	0	1
	Melissodes sp.	3	1	4
	Melissodes bimaculatus Lepeletier	4	0	4
	Melissodes communis Cresson	558	183	741
	Melissodes comptoides Robertson	293	13	306
	Melissodes tinctus LaBerge	1	0	1
	Svastra atripes Cresson	1	1	2
	Xylocopa micans Lepeletier	1	0	1
Colletidae	*Colletes americanus* Cresson	0	1	1
	Colletes latitarsis Robertson	1	0	1
	Colletes mandibularis Smith	2	0	2
Halictidae	*Agapostemon splendens* Lepeletier	235	27	262
	Augochlorella aurata Smith	3	0	3
	Augochlorella gratiosa Smith	164	0	164
	Augochloropsis anonyma Cockerell	123	0	123
	Halictus poeyi Lepeletier	70	58	128
	Lasioglossum sp. 1	2	0	2
	Lasioglossum sp. 2	16	0	16
	Lasioglossum apopkense Robertson	1	0	1
	Lasioglossum batya Gibbs	2	0	2
	Lasioglossum creberrimum Smith	7	1	8
	Lasioglossum eleutherense Engel	0	1	1
	Lasioglossum halophitum Graenicher	74	0	74
	Lasioglossum hitchensi Gibbs	0	1	1
	Lasioglossum lepidii	1345	555	1900
	Lasioglossum longifrons Baker	13	1	14
	Lasioglossum marinum Crawford	165	12	177
	Lasioglossum nymphale Smith	842	3	845
	Lasioglossum raleighense Crawford	1	0	1
	Lasioglossum tamiamense Mitchell	58	7	65
	Nomia maneei Cockerell	1	0	1
	Sphecodes sp.	0	2	2
Megachilidae	*Anthidium maculifrons* Smith	1	0	1
	Coelioxys mexicana Cresson	1	0	1
	Coelioxys sayi Robertson	1	0	1
	Coelioxys slossoni slossoni Viereck	3	0	3
	Megachile albitarsis Cresson	9	0	9
	Megachile georgica Cresson	2	0	2
	Megachile inimica Cresson	1	1	2
	Megachile lanata Fabricius	3	0	3
	Megachile mendica Cresson	1	0	1
	Megachile pruina Smith	32	3	35
	Megachile pseudobrevis Mitchell	41	9	50
	Megachile concinna Smith	0	1	1
	Megachile rubi Mitchell	1	0	1
	Megachile townsendiana Cockrell	1	0	1
	Totals:	**4428**	**991**	**5419**

REFERENCES

Arnett, R. H. 2000. American insects: a handbook of the insects of America north of Mexico. 2nd ed. Crc Press, Boca Raton, FL.

Ascher, J., and J. Pickering. 2014. Discover Life bee species guide and world checklist (Hymenoptera: Apoidea: Anthophila). http://www.discoverlife.org/mp/20q?search=hymenoptera

Campbell, J. W., and J. Hanula. 2007. Efficiency of Malaise traps and colored pan traps for collecting flower visiting insects from three forested ecosystems. J. Insect Conserv. 11:399-408.

Cane, J. H. 1991. Soils of ground-nesting bees (Hymenoptera: Apoidea): texture, moisture, cell depth and climate. J. Kans. Entomol. Soc. 64: 406-413.

Cane, J. H., R. Minckley, L. Kervin, and N. M. Williams. 2006. Complex responses within a desert bee guild (Hymenoptera: Apiformes) to urban habitat fragmentation. Ecol. Appl. 16:632-644.

Dalmazzo, M. 2010. Diversity and biological aspects of wild bees in an urban and a natural environment in the central region of Santa Fe, Argentina. Rev. Soc. Entomol. Argent. 69: 33-44.

Daly, H. V. 1973. Bees of the genus *Ceratina* in America north of Mexico (Hymenoptera: Apoidea). Publ. Entomol. Univ. Calif. 74: 1-114.

Deyrup, M., J. Edirisinghe, and B. Norden. 2002. The diversity and floral hosts of bees at the Archbold Biological Station, Florida (Hymenoptera: Apoidea). Insecta Mundi 16: 87-120.

Droege, S. 2015. The very handy bee manual: how to catch and identify bees and manage a collection. https://www.pwrc.usgs.gov/nativebees/Handy%20Bee%20Manual/The%20Very%20Handy%20Manual%20-%202015.pdf

Eickwort, G. C., and K. Eickwort. 1973. Notes on the nests of three wood-dwelling species of *Augochlora* from Costa Rica (Hymenoptera: Halictidae). J. Kans. Entomol. Soc. 46: 17-22.

ESRI. 2015. ArcGIS Desktop: Release 10.3. Environmental Systems Research Institute, Redlands, CA.

ESRI, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community. 2017.

World Imagery.
https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer/4

Estrada, S. 2016. Custodian of dunes and caretaker of beach vegetation. http://www.tampabay.com/news/environment/custodian-of-dunes-and-caretaker-of-beach-vegetation/2284507.

Florida Oceans and Coastal Council. 2010. Climate change and sea level rise in Florida: An update of a 2009 Report, “The effects of climate change on Florida’s ocean and coastal resources”. Tallahassee, FL. http://www.dep.state.fl.us/OceansCouncil/meetings/files/2010/12-13/SLR_1214.pdf

Gathmann, A., and T. Tscharntke. 2002. Foraging ranges of solitary bees. J. Anim. Ecol. 71:757-764.

Gibbs, J. 2010. Revision of the metallic species of *Lasioglossum* (*Dialictus*) in Canada (Hymenoptera, Halictidae, Halictini). Zootaxa 2591:1-382.

Goulson, D., E. Nicholls, C. Botias, and E. L. Rotheray. 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. Science 347:1255957.

Graenicher, S. 1930. Bee-fauna and vegetation of the Miami region of Florida. Ann. Entomol. Soc. Am. 23: 153-174.

Greenleaf, S. S., N. Williams, R. Winfree, and C. Kremen. 2007. Bee foraging ranges and their relationship to body size. Oecologia. 153: 589-596.

Hall, H. G., and J. Ascher. 2010. Surveys of bees (Hymenoptera: Apoidea: Anthophila) in natural areas of Alachua County in north-central Florida. Fla. Entomol. 93: 609-629.

Hall, H. G., and J. Ascher. 2014. The distinctive bee fauna (Hymenoptera: Apoidea: Anthophila) of sandhill habitat at the Ordway-Swisher Biological Station in north-central Florida. J. Kans. Entomol. Soc. 87: 1-21.

Hernandez, J. L., G. Frankie, and R. W. Thorp. 2009. Ecology of urban bees: a review of current knowledge and directions for future study. Cities and the Environment (CATE). 2: 1-15.

Hostetler, N. E., and M. E. McIntyre. 2001. Effects of urban land use on pollinator (Hymenoptera: Apoidea) communities in a desert metropolis. Basic Appl. Ecol. 2: 209-218.

Hurd Jr, P. D. 1958. Observations on the nesting habits of some new world carpenter bees with remarks on their importance in the problem of species formation (Hymenoptera: Apoidea). Ann. Entomol. Soc. Am. 51: 365-375.

Karl, T. R., and K. E. Trenberth. 2003. Modern global climate change. Science. 302: 1719-1723.

Koh, I., E. Lonsdorf, N. Williams, C. Brittain, R. Isaacs, J. Gibbs, and T. H. Ricketts. 2016. Modeling the status, trends, and impacts of wild bee abundance in the United States. Proc. Natl. Acad. Sci. U. S. A. 113: 140-145.

Kremen, C., N. Williams, and R. W. Thorp. 2002. Crop pollination from native bees at risk from agricultural intensification. Proc. Natl. Acad. Sci. U. S. A. 99: 16812-16816.

Losey, J. E., and M. Vaughan. 2006. The economic value of ecological services provided by insects. Bioscience. 56: 311-323.

McIntosh, M. 1996. Nest-substrate preferences of the twig-nesters *Ceratina acantha*, *Ceratina nanula* (Apidae) and *Pemphredon lethifer* (Sphecidae). J. Kans. Entomol. Soc. 69: 216-231.

Michener, C. D. 2000. The Bees of the World. John Hopkins University Press, Baltimore. MD.

Michener, C. D. 2007. The Bees of the World. 2nd. Ed. Johns Hopkins University Press, Baltimore, MD.

Milne, L. J., and M. Milne. 1980. The Audubon Society field guide to North American insects and spiders. Knopf, NY.

Mitchell, T. B. 1960. Bees of the eastern United States. Vol 1. North Carolina Agri. Exp. Station. Raleigh, NC.

Mitchell, T. B. 1962. Bees of the eastern United States. vol. 2. North Carolina Agri. Exp. Station. Raleigh, NC.

Moissett, B., and S. Buchanan. 2010. Bee basics: an introduction to our native bees. USDA, Forest Service and Pollinator Partnership, Washington, DC.

National Aeronautics and Space Administration (NASA). 2016. Global climate change: Vital signs of the planet. http://climate.nasa.gov/evidence/.

National Oceanic and Atmospheric Administration (NOAA). 2016. Ocean facts: Is sea level rising? http://oceanservice.noaa.gov/facts/sealevel.html.

Nordstrom, K. F. 2000. Beaches and dunes of developed coasts. Cambridge University Press, Cambridge, UK.

Pascarella, J. B., K. Waddington, and P. R. Neal. 1999. The bee fauna (Hymenoptera: Apoidea) of Everglades National Park, Florida and adjacent areas: distribution, phenology, and biogeography. J. Kans. Entomol. Soc. 72: 32-45.

Pascarella, J., and H. G. Hall. 2016. The bees of Florida. http://entnemdept.ufl.edu/HallG/Melitto/Intro.htm

Pascarella, J. 2017. Range extension of the introduced bee species *Euglossa dilemma* (Hymenoptera: Apidae) in Monroe County, Florida, with notes of additional range extensions in southern Florida. Fla. Entomol. 100: 209-210.

Pemberton, R. W., and G. S. Wheeler. 2006. Orchid bees don't need orchids: evidence from the naturalization of an orchid bee in Florida. Ecology 87: 1995-2001.

Peterson, T. C., and M. Baringer. 2009. State of the climate in 2008. Bull. Am. Meteorol. Soc. 90: S1-S196.

Roubik, D. W. 1995. Pollination of cultivated plants in the tropics. Food and agriculture organization of the United Nations. Rome, Italy. Bull. 118.

Rubene, D., M. Schroeder, and T. Ranius. 2015. Estimating bee and wasp (Hymenoptera: Aculeata) diversity on clear-cuts in forest landscapes–an evaluation of sampling methods. Insect Conserv. Divers. 8: 261-271.

Sallenger, A. H., H. Stockdon, L. Fauver, M. Hansen, D. Thompson, C. Wright, and J. Lillycrop. 2006. Hurricanes 2004: An overview of their characteristics and coastal change. Estuar. Coast. 29: 880-888.

Skov, C., and J. Wiley. 2005. Establishment of the neotropical orchid bee *Euglossa viridissima* (Hymenoptera: Apidae) in Florida. Fla. Entomol. 88: 225-227.

Statistix. 2008. *Statistix for Windows user's manual version 9.* Analytical Software, Tallahassee, FL.

Steffan-Dewenter, I., U. Münzenberg, C. Bürger, C. Thies, and T. Tscharntke. 2002. Scale-dependent effects of landscape context on three pollinator guilds. Ecology. 83: 1421-1432.

Tscharntke, T., A. Klein, A. Kruess, I. Steffan-Dewenter, and C. Thies. 2005. Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. Ecol. Lett. 8: 857-874.

Ulyshen, M. D., V. Soon, and J. L. Hanula. 2010. On the vertical distribution of bees in a temperate deciduous forest. Insect. Conserv. Divers. 3: 222-228.

Winfree, R., N. Williams, J. Dushoff, and C. Kremen. 2007. Native bees provide insurance against ongoing honey bee losses. Ecol. Lett. 10: 1105-1113.

Wojcik, V. A. 2011. Resource abundance and distribution drive bee visitation within developing tropical urban landscapes. J. Pollinat. Ecol. 4: 48-56.

Wunderlin, R.P., and B. Hansen. 2017. Atlas of Florida plants. http://florida.plantatlas.usf.edu/

BIOGRAPHICAL SKETCH

Born in Southampton, New York, Anthony Abbate was always intrigued and excited by nature’s beauty. Since a young age, he has spent most of his time outside in the wilderness camping, hiking, fishing, or just exploring. As he spent more time in nature, he wanted to know more about the fungi, plants, and animals he encountered while hiking or camping. To gain more knowledge about nature and the sciences as a whole, Anthony earned his bachelor’s degree from High Point University in biological sciences and enrolled in graduate school studying entomology and nematology at the University of Florida. He currently resides in Davie, FL with his wife Katie. He plans to devote his life to studying the ecologically and economically important native bees of the United States and abroad.