TERRESTRIAL ISOPODS (ISOPODA: ONISCIDEA) OF THE ROBERT J. HUCKSHORN ARBORETUM IN JUPITER, FLORIDA

by

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This thesis was prepared under the direction of the candidate's thesis advisors, Dr. James Wetterer and Dr. Jon Moore, and has been approved by the members of her supervisory committee. It was submitted to the faculty of The Honors College and was accepted in partial fulfillment of the requirements for the degree of the Bachelor of Science in Liberal Arts and Sciences.

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ABSTRACT

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Many terrestrial isopod species (Isopoda) are very tolerant of human disturbance and are common in synanthropic habitats of urban and suburban areas. I surveyed terrestrial isopod species in the Robert J. Huckshorn Arboretum on the Jupiter campus of Florida Atlantic University. This small arboretum (4003 m^2) includes a variety of native trees and plants, potentially providing diverse resources for isopods. I found a surprisingly rich isopod fauna, totaling five species all in the suborder Oniscidea, which have been identified as: *Atlantoscia floridana* (Van Name, 1940), *Trichorhina tomentosa* (Budde-Lund, 1893), *Nagurus cristatus* (Dollfus, 1889), *Venezillo parvus* (Budde-Lund, 1885), and *Porcellionides pruinosus* (Brandt, 1833). Two (*A. floridana and V. parvus*) are considered native to Florida, while three (*T. tomentosa, N. cristatus* and *P. pruinosus*) are non-native.

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INTRODUCTION

Terrestrial isopods (Isopoda: Oniscidea), commonly called woodlice, pill bugs, sow bugs, roly-polies, slaters and countless other names, are important detritovores that recycle nutrients in an ecosystem (Zimmer et al. 2002). They are one of the few land-dwelling groups of the class Crustacea, and are more closely related to lobsters, crabs, and water fleas than other terrestrial arthropods like insects, spiders and centipedes. The order Isopoda has over 10,300 species (Wilson 2007), more than 3,600 of which are terrestrial species in the suborder Oniscidea (Schmalfuss 2003). It has been estimated that they successfully colonized land habitats in the second half of the Paleozoic era (Clousley-Thompson 1988) in marine littoral conditions without a freshwater stage (Schmalfuss 2005). To successfully live out of water and colonize terrestrial habitats, they have had to overcome ecological and physiological challenges such as reproduction, respiration, and protection against desiccation (Hornung 2011).

Without returning to the water to reproduce, certain adaptations had to take place for mothers to provide a moist environment for their young. Oniscidea provide substantial maternal care to their eggs and young (Kight 2009; Surbida and Wright 2001; Kight and Nevo 2004; Lardies et al. 2004b). The females carry their eggs and mancae (early-instar young) in a ventral marsupium, a fluid-filled pouch formed by oostegites on the ventral pereon. These females also supply their young with nutrients and an aqueous environment in the marsupium that provides protection from external threats and desiccation (Warburg 1968, 1987; Warburg and Rosenberg 1996).

In the order Isopoda, oxygen uptake and gas exchange happen mainly through the abdominal appendages. These appendages take the form of gills in the aquatic species, but terrestrial isopods (Oniscidea) have evolved for aerial respiration using pleopodal lungs (Hoese 1982a; Hornung 2011). The humidity requirements vary greatly between species and their corresponding pleopodal lung structures, but a common factor in the physiology of their respiration is moisture. The anatomy, structure, and functional principles show different evolutionary routes (Hoese 1981, 1982a, 1983, 1984; Ferrara et al. 1991, 1997; Paoli et al. 2002; Gruber and Taiti 2004). The most sophisticated pleopodal structures have formed in desert-dwelling species (Ferrara at al. 1997). These pleopodal lungs vary not only in structure among taxonomic families but also in the number present on the abdomen. The morphological development follows a close correlation to the ecological steps of colonization of terrestrial habitats, from littoral zones to the drier, inland habitats (Gruber and Taiti 2004). As noted by Elisabeth Hornung (2011), the "structural and correlating functional adaptations of respiratory organs might be the main factor in successful colonization of diverse types of land habitats. The developmental stages of lungs have evolved several times convergently during the evolution of isopod lineages."

Because varying degrees of humidity are required for respiration, it is a limiting factor in the distribution of terrestrial isopods. To prevent desiccation, Oniscidea have flagellar aesthetasks on the apical article of the first antennae and on the flagellar articles of the second antennae that monitor moisture, which is essential in finding suitable humidity conditions or short and long-term survival (Schmalfuss 1998). Another important aspect of their biology that helps prevent desiccation is the outer protective cover called the cuticle or exoskeleton. Cuticular lipids and hydrocarbons form a highly efficient barrier to help reduce transcuticular water loss (Hadley and Warburg 1986; Bursell 1955).

Another evolutionary adaptation for life on land is the ability of some taxonomic families (such as Armadillidae, Eubelidae, Armadillidiidae, Sphaeroniscidae, and Tylidae) to conglobate (Hornung 2011) as a water conservation mechanism (Smigel and Gibbs 2008). Their common name, "pill bug" refers to their resemblance to pills when curled up (Post 2019). Even their excretory systems have adapted for life on land. Oniscidea are essentially ammonotelic (Dresel and Moyle 1950), which is advantageous because they do not need to perform the energy-expensive detoxification of nitrogenous end-products. Instead, they can get rid of ammonia directly. This may have facilitated their successful colonization of terrestrial habitats because they lack free water to wash away the ammonia produced during digestive processes (Hartenstein 1968) and instead, excrete it in its volatile gaseous form (Dresel and Moyle 1950).

In addition, surface-active Oniscidea are typically nocturnal (e.g. Tuf and Jeřábková 2008) which helps to prevent excessive water loss from the sun during the warmest part of the day. Oniscidea also use shelter, depending on species-specific tolerance, humidity and time of day (Hassal and Tuck 2007). All these physiological and behavioral adaptations have been crucial in their colonization of terrestrial habitats by preventing desiccation.

Many terrestrial isopod species are very tolerant of human disturbance and are common in synanthropic habitats of urban and suburban areas (Gregory 2014). They are frequently found in shaded leaf litter and decaying wood around the base of houses in developed areas (e.g. Schultz 1972). Florida is a suitable environment for many Oniscidea species because of its tropical to subtropical climate (Gregory 2014) of warm temperatures and moderate to high humidity. Many species have been widely spread throughout the world by human activity (Gregory 2014). In Florida alone, there has been documentation of more than 35 species, many of which are naturalized (WoRMS 2019; Jass and Klausmeier 2000).

METHODS

Study Area:

I surveyed the areas around the John D. MacArthur Campus at the Harriet L. Wilkes Honors College of Florida Atlantic University in Jupiter, Florida on October 28th, 2018. This campus is home to the Robert J. Huckshorn Arboretum that is an accredited Level 1 arboretum (Edwards 2016). The center of the arboretum is at 26.888764° N, 80.117706°W. The site has a butterfly garden and four separate habitat areas designed to reflect different biomes in Florida consisting of native plants characteristic of each habitat, which provide resources for terrestrial isopods. I surveyed multiple spots in each of the five habitat types, as well as a pergola nearby that is separate from the arboretum. Each habitat type, with its corresponding zone number, is following the numbers from the arboretum map posted on a large sign at the south side of the arboretum.

Figure 1. Digitized map of the Robert J. Huckshorn Arboretum (Edwards 2016)

Habitat Conditions:

I completed my field collections on October 28^{th}, 2018 at 9:30 in the morning on a dry day with clear skies and a light breeze. The temperatures were about 21-24 C (in the low 70s F) throughout the collection process. I surveyed five zones in the Huckshorn Arboretum, and a pergola about 15 m away, near the Honors College building. The zones are as follows:

Arboretum Zone 1: Pine Flatwoods

Pine flatwoods are the most widespread, prevalent type of terrestrial ecosystem in Florida. This habitat is characterized by a flat topography with a canopy of pine trees. These flatwoods are composed of South Florida slash pine (*Pinus elliottii* var. *densa*), short shrubs, such as saw palmetto (*Serenoa repens*), and a sparser herb-layer below, including wiregrass (*Aristida* spp.).

Arboretum Zone 2: Mixed Hardwood Swamp

A mixed hardwood swamp, also known as a seepage swamp, is a wetland habitat characterized by the predominance of hardwood trees on a low-lying flatland, or in scattered, isolated depressions. In Florida, these swamps are flooded most of the year due to the shallow water table and seasonally heavy rainfall. They contain flood-tolerant tree species, including both hardwoods and conifers, forming a dense, shaded canopy that reduces air circulation and traps humidity, further contributing to the damp conditions. Prevalent plant species include Magnolia trees (*Magnolia* spp.), Bay trees (*Persea* spp.), Cypress trees (*Taxodium* spp.), Sugarberry (*Celtis laevigata*), Walter's Vibernum (*Vibumum obovatum*), Fakahatchee grass (*Tripsacum dactyloides*), Sand Cordgrass

(*Spartina bakeri*), Cocoplum (*Chrysobalanus icaco*), Pond Apple (*Annona glabra*) and Red Maple (*Acer rubrum*).

Arboretum Zone 3: Butterfly Garden

A butterfly garden is generally characterized by flora that is attractive to butterflies for nectar or for caterpillars for food. While this area does not mimic any single ecosystem in South Florida, it is comprised of several species of flowering plants that are native or exotic in the area. Firebush (*Hamelia patens*), Wild leadwort (*Plumbago zeylandica*), Blue plumbago (*Plumbago auriculate*), Wild lime (*Zanthoxylum fagara*), Mistflower (*Conoclinium coelestinum*), and coontie (*Zamia integrifolia*) are abundant.

Arboretum Zone 4: Cabbage Palm/Oak Hammock

Also known as mesic temperate hammocks, the cabbage palm/oak hammocks are closed-canopy hammocks with temperate evergreen trees, predominantly cabbage palm (*Sabal palmetto*), laurel oak (*Quercus laurifolia*) and live oak (*Quercus virginiana*), with some tropical species in the shrub layer. The soil stays moist due to heavy ground litter and high humidity trapped underneath the closed canopy, but rarely floods (USFWS 1999a).

Arboretum Zone 5: Tropical Hardwood Hammock

Tropical hardwood hammocks are unique to southern Florida and are characterized by temperate and tropical hardwood trees, which form a canopy overhead, providing shade and shelter to the underlying plants and wildlife below. The warm, humid climate in south Florida is favorable for tropical hardwood hammocks. Some common plants species in this habitat are Gumbo Limbo (*Bursera simoruba*), Marlberry (*Ardisia escallonioides*), Wild leadwort (*Plumbago zeylandica*), Red Bay (*Persea borbonia*), Saw Palmetto (*Serenoa repens*), Seagrape (*Cocoluba uvifera*), and Wild Coffee (*Psychotria nervosa*) (USFWS 1999b).

Zone 6 Pergola:

The pergola is situated over a union of a concrete and brick walkway and is immediately adjacent to landscaped plants next to the walkway. The pergola is covered with dense vines of bougainvillea (*Bougainvillea* sp.) and the surrounding ground plantings are dominated by a number of exotic plants, including variegated umbrella plant (*Schefflera arboricola*), Lacy tree philodendron (*Philodendron bipinnatifidum)*, Dracaena Mahatma (*Cordyline fruticosa*), and a couple varieties of garden crotons (*Codiaeum variegatum*).

Collection Procedure:

I collected isopods from all the zones in the same matter. First, I would observe the undisturbed top layer of the ground. I collected any isopods that I observed moving around on the surface using an aspirator or hand collecting and placing in a small, ventilated vial. Next, I would disturb the leaf litter or anything directly on top of the soil by moving the leaves and branches aside, and then I collected isopods again using an aspirator or by hand removing them. Some species of isopods did not move when disturbed, but rather rolled into balls or completely froze. I took my time while observing, looking for movement, and also non-moving isopods. Many of the isopods I found were very quick moving once exposed from under the leaf litter, complicating the collection process. Because of this, I collected as many isopods as I could from one area before moving onto the next area. However, it is possible that I did not collect all the species that were living in the arboretum, due to human error while aspirating and also by only surveying 3-5 locations in each zone. I used a clean, empty vial for each zone observed, labeling according to the zone number. Isopods from each zone were collected and contained in the same vial, and were later sorted, studied and identified in the lab shortly after the field collections were finished.

RESULTS

I have collected and identified 5 different species of terrestrial isopods (Isopoda: Oniscidea) in the Robert J. Huckshorn Arboretum on the Jupiter campus of Florida Atlantic University: *Atlantoscia floridana* (Van Name, 1940), *Trichorhina tomentosa* (Budde-Lund, 1893), *Nagurus cristatus* (Dollfus, 1889), *Venezillo parvus* (Budde-Lund, 1885), and *Porcellionides pruinosus* (Brandt, 1833). I found *A. floridana* in all 6 zones, *T. tomentosa* in zone 6, *N. cristatus* in zone 6, *V. parvus* in zones 1 and 6, and *P. pruinosus* in zones 2 and 6, as shown in Table 1.

Table 1. Oniscidea species and corresponding location(s) where found

Zone	*A. floridana*	*T. tomentosa*	*N. cristatus*	*V. parvus*	*P. pruinosus*
1	X			X	
2	X				X
3	X				
4	X				
5	X				
6	X	X	X	X	X

In zones 1 through 5, *A. Floridana* was the most abundant species, with *V. parvus* and *P. pruinosus* being much less prevalent in zones 1 and 2, respectively. In zone 6, the prevalence of each species in order from most to least is as follows: *V. parvus, N. cristatus, T. tomentosa, A. floridana* and *P. pruinosus.* I collected about 5 individuals of each species from each location to ensure that I was correctly identifying them in the field as the same species. In total, I had 30 *A. floridana,* 5 *T. tomentosa*, 5 *N. cristatus,* 10 *V. parvus,* and only 4 *P. pruinosus*. Even though *P. pruinosus* were collected from two sites, I only found a total of 4 indivduals.

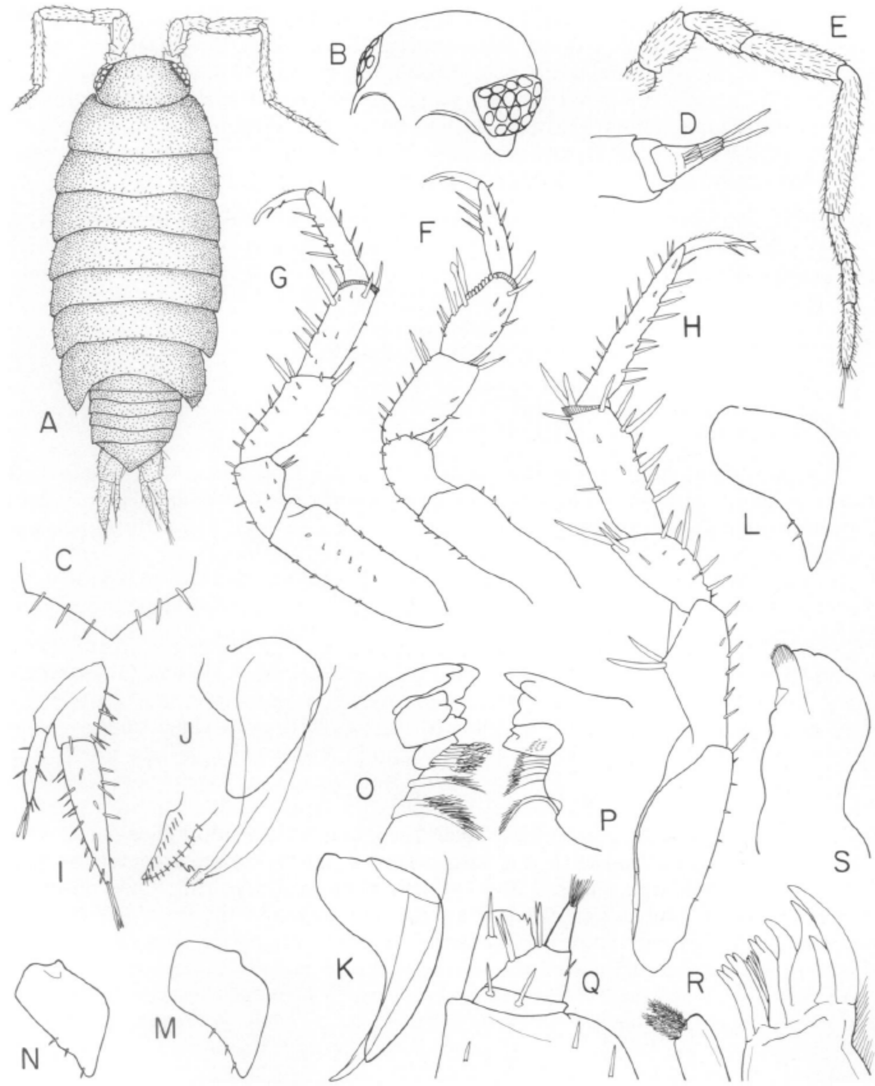

Figure 2. ***Atlantoscia floridana*** **(Van Name, 1940) sketch**, male 4.7 mm long: A) dorsal view; B) frontal oblique view of cephalon; C) pleotelson; D) antenna 1; E) antenna 2; F-H) pereiopods I, II and VII; I) uropod; J-M) pleopods 1-5; O) right mandible; P) left mandible; Q) apex maxilliped; R) maxilla 2 (endopod and exopod); S) maxilla 1 (Source: Schultz and Johnson 1984).

Figure 3. ***Atlantoscia floridana*** **(Van Name, 1940) photograph** (Source: Amato et al. 2003).

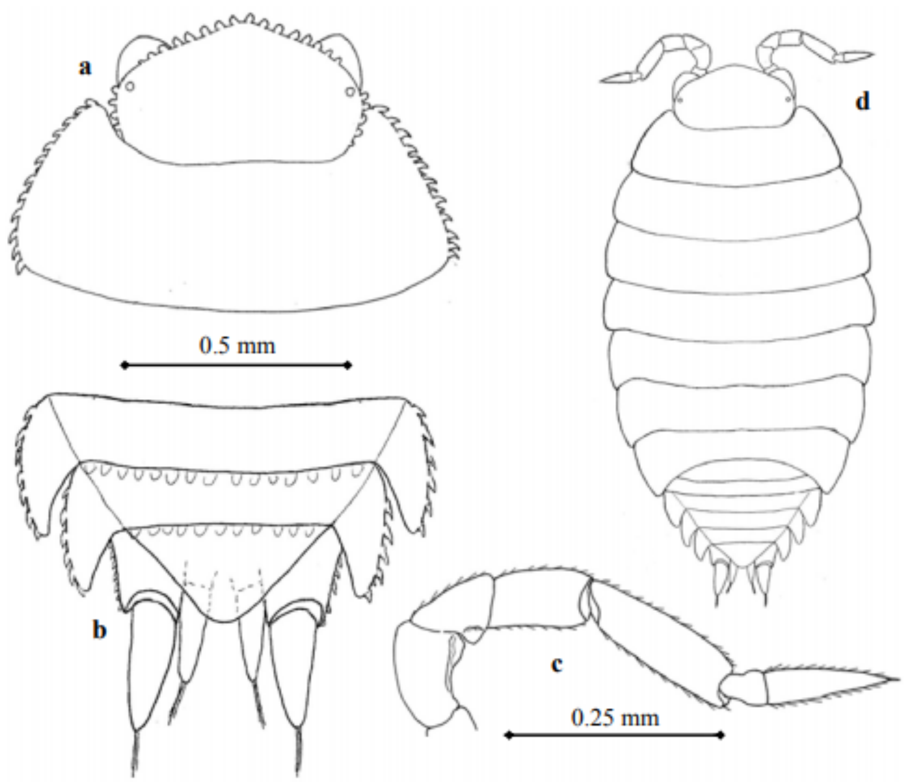

Figure 4. ***Trichorhina tomentosa*** **(Budde-Lund, 1893) sketch**, female; A) head and first pereionite, dorsal view; B) fourth and fifth pleonites, telson and uropods, dorsal view; C) antenna; D) entire animal, dorsal view (Source: Gregory 2014).

Figure 5. ***Trichorhina tomentosa*** **(Budde-Lund, 1893) photograph** (Source: Keith Lugg in BMIG 2019).

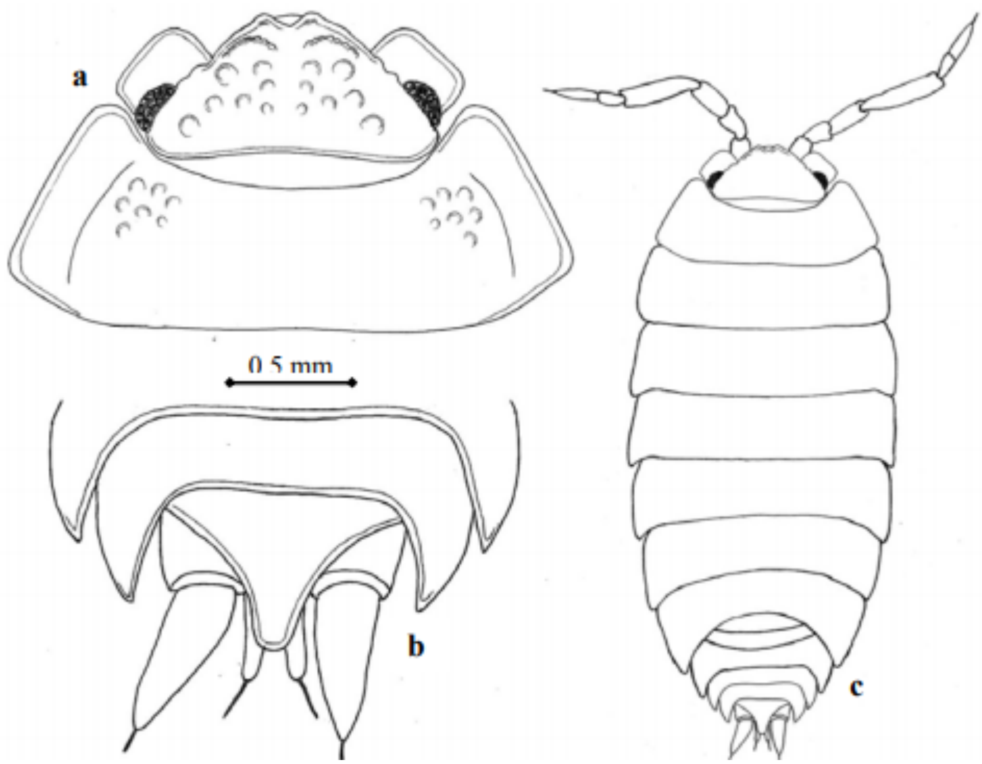

Figure 6. ***Nagurus cristatus*** **(Dollfus, 1889) sketch**, female; A) head and first pereionite, dorsal view; B) last pleonite, telson and uropods, dorsal view; C) entire animal, dorsal view (Source: Gregory 2014).

Figure 7. ***Nagurus cristatus*** **(Dollfus, 1889) photograph** (Source: Keith Lugg in BMIG 2019).

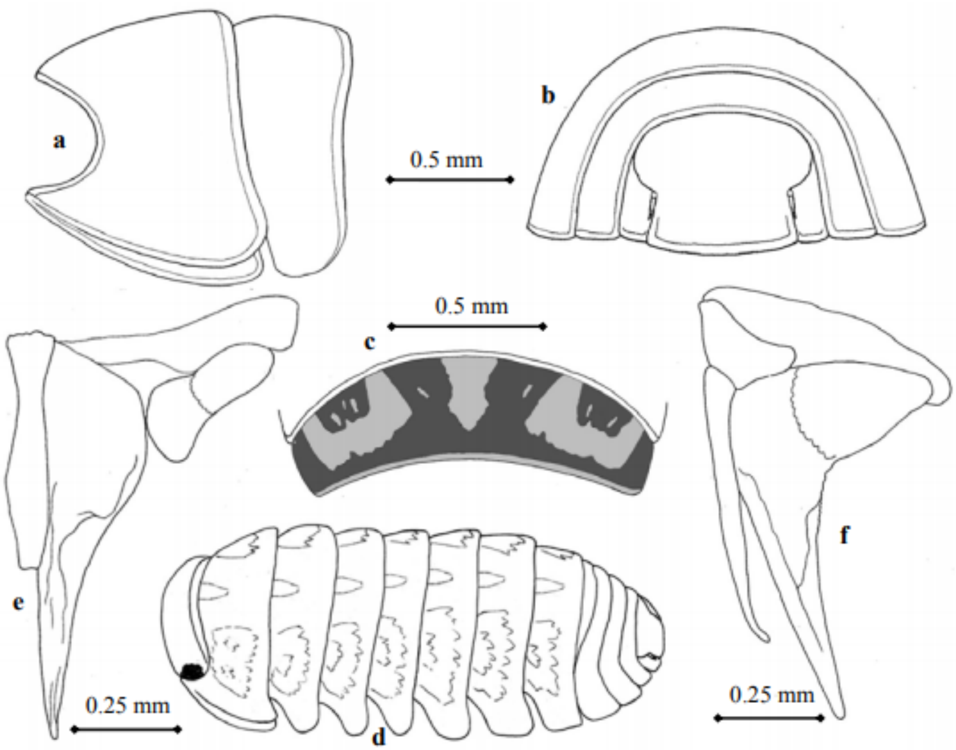

Figure 8. ***Venezillo parvus*** **(Budde-Lund, 1885) sketch**, male; A) first and second pereionite, lateral view; B) telson, uropods and last two pleonites, rear view; C) first pereionite indicating typical pigmentation pattern, dorsal view; D) entire animal, dorso-lateral view; E) first pleopod; F) second pleopod (Source: Gregory 2014).

Figures 9 and 10. ***Venezillo parvus*** **(Budde-Lund, 1885) photographs A and B**, (Sources: A – Andy Murray in BMIG 2019, B – Keith Lugg in BMIG 2019).

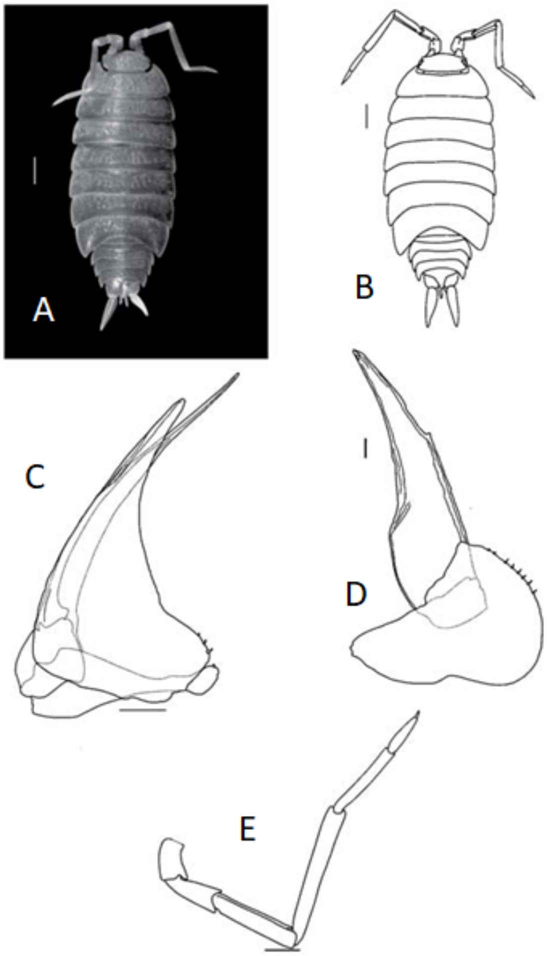

Figure 11. ***Porcellionides pruinosus*** **(Brandt, 1833) sketch**, A) entire animal, dorsal view; B) entire animal, dorsal view; C-D) exopod and endopod of the pleopod; E) antenna (Source: Carpio-Díaz et al., 2016).

Figures 12 and 13. ***Porcellionides pruinosus*** **(Brandt, 1833) photographs A and B** (Sources: A – Warren Maguire in BMIG 2019, B – J. P. Richards in BMIG 2019).

DISCUSSION

I found a surprisingly rich isopod fauna in the small arboretum, totaling five species, all in the suborder Oniscidea. Two (*A. floridana and V. parvus*) are considered native to Florida, while three (*T. tomentosa, N. cristatus* and *P. pruinosus*) are non-native.

Species Accounts:

Atlantoscia floridana is a native isopod called the 'Florida fast isopod' because it scurries quickly and erratically when disturbed. It has a smooth, oblong-oval body about 9 mm in length and 3 mm in width. The head is moderately large with an eye compound comprising of 16 or 17 ocelli taking up half or more of the head's lateral surface. The exopod of the second male pleopod is distinctly concave on the lateral margin. The uropods are very prominent with large basal segments, with slight dorsal concavity between the bases of the endopod and the exopod. The endopod is about as long as the protopod branching from it at about two-thirds the length of the protopod. The endopod is laterally compressed and three times as long as the endopod or protopod. Both endopods have prominent apical setae. The telson is triangular with a round apex. The color pattern is also distinctive, especially the nonpigmented inverted U-shaped band on the cephalothorax and the concentration of dark pigment along the lateral sides of the pereonites forming a dark stripe on each side (Schultz 1964; Schultz and Johnson 1984; Campos-Filho et al. 2013; Johnson 1986).

There has been a complicated taxonomic history for this species. It was originally described and named *Philoscia floridana* (Van Name, 1940) and has had many synonymized names since then (WoRMS 2019). This species is the most widely distributed species of its genus, being recorded in neotropical regions from coastal regions of Florida, Brazil, Argentina, and Ascension and St. Helena islands (Souza-Kury 1998; Schmalfuss 2003). It is known to be parthenogenetic in northern Florida, but male species have been found in the central and southern Florida populations (Johnson 1986). It has more of an inland distribution than other species of this taxonomic family and is synanthropic, often being found in leaf litter of open spaces of residences and vacant lots.

Venezillo parvus is thought to be native to Florida (Schultz 1963, 1972). Females can reach up to 6 mm in length and 3.5 mm in width, with males being slightly smaller. The dorsal surface of the body is smooth. The background color is dark brown with a characteristic pattern of pale yellow on each pereionite, comprising of a pale central wedge and a pair of large pale patches with irregular margins (each with a dark center) on either side. A diffuse orange band is usually present along the posterior margin of each pereionite. The pattern is less clear and less pigmented in juveniles. The cephalon has a frontal margin forming a low ridge between the ocelli, which are composed of a cluster of numerous ommatidia. The antennal flagella have two segments. The first pereionite bears a distinctive double flange along its ventral edge, which facilitates conglobation. The telson has a distinctive hourglass shape with a broad rectangular tip. Adjacent uropod protopodites are roughly rectangular and bear small exopodites on their inner margin.

Both males and females have been documented for this species. It has a pan-tropical distribution, being widespread across tropical and sub-tropical regions of America and Africa (Schmalfuss 2003). In Europe, it has been introduced into heated glasshouses in the Netherlands (Soesbergen 2003).

Trichorhina tomentosa is believed to have originated from Central and South America. This species is commercially sold in pet stores as the ‘dwarf white isopod’, primarily as food or as a cleaner organism in a bioactive terrarium. It has an elongated, oval body shape. Adults are approximately 3 to 5 mm in length and 1.5 to 2 mm wide. It is white or off-white in color. Its entire body is covered in blunt-tipped scale-spines. Lateral lobes of cephalon are weakly developed and the medial lobes are very feeble. The ocelli are composed of a single black ommatidium. The antennae are stout and entirely covered in setae. The flagellum consists of two distinct parts with the proximal segment being shorter than the distal segment. The posterior margins of the anterior perionites are rounded without backward projections. The posterior perionites and pleon have well developed backward projections. The telson is triangular and translucent with a rounded tip. The uropods are conical and terminate in conspicuous bristles (Gregory 2014).

This species reproduces parthenogenetically and no males have been documented. It is frequently found burrowing in the top layers of soil or hiding underneath damp leaf litter and rotting wood. It has been introduced throughout the pantropics (Schmalfuss 2003) and into heated glasshouses across most of Europe (Cochard et al. 2010) as a synanthropic, cosmopolitan species.

Nagurus cristatus is not believed to be a native Florida species. It is approximately 4.5 to 5.5 mm long and 1.8 mm wide. The body has a yellowish background with four irregular brown longitudinal stripes of varying widths running the length of the pereion. The cephalon and pleon are darker brown but the basal two antennal segments and uropods (except the tips) are contrastingly pale. The cephalon has broad raised bumps which are more prominent towards the lateral margins. The lateral lobes are well developed and have a rectangular shape. The medial lobe is poorly developed and bears a prominent central cleft. Laterally, the medial lobe extends backwards along the front of the cephalon in the form of a low ridge. Ocelli are composed of many ommatidia and the antennae have two flagellum segments. The pereion and pleon are smooth, bearing a few minute tubercles. The posterior margins of the anterior pereionites are rounded and their epimera lack backward projections, giving a characteristic rectangular shape to the epimera of the first pereionite. The pereion and pleon outline is continuous and the posterior pleonites bear prominent backward projections. The telson is triangular with concave lateral margins and a rounded tip (Gregory 2014).

This species reproduces parthenogenetically and no males have been documented. It has a pantropical distribution, having been widely dispersed by human activity (Gregory 2014). It can occur in more temperate climates in greenhouses (Schmalfuss 2003).

Porcellionides pruinosus is native to the Mediterranean region (Dollfus 1897; Vandel 1960, 1962). It measures from 6 mm to 11 mm in length. It has a rather slender body. It is light gray or blue in color with whitish legs. Its body has a “bloom,” the appearance of being covered in a white powdery film which is why this species is commonly named ‘powder blue isopod’. The antennae are long and have distinctive white joints that help distinguish between its sister species, *Porcellionides floria.* The first two pairs of pleopods have pleopodal lungs. Both males and females were found in the population sample. They are commonly found in leaf litter or decaying organic matter in developed areas alongside residences and businesses.

This species has spread throughout the world with reports from every continent except the polar regions (Garthwaite and Sassaman 1985). It is for this reason that *P. pruinosus* is considered a synanthropic cosmopolitan species. In fact, it shows extensive geographical variations in morphology and some have suggested that it may consist of several distinct and localized species rather than one cosmopolitan species (Garthwaite and Sassaman 1985).

CONCLUSION

After reading many relevant papers on Oniscidea species and diversity in Florida, I have seen no mention of five or more species living in the same inland area or microhabitat. I am surprised to find five species in my small area of research at the Robert J. Huckshorn arboretum and the pergola just adjacent to it. The area with the most diversity, zone 6, is the smallest and most man-made environment of the zones I surveyed. All five species were present in zone 6. This provides evidence for the claim that Oniscidea can be synanthropic, living near and benefitting from an association with humans and the somewhat artificial habitats that humans create around them, such as tropical species living in a more temperate region inside heated glasshouses. They can only survive year-round in these situations in association with humans. Some species also seem to be anthropophilic, as seen in this research study that the most diversity was found to be nearest a building and walkway rather than in a more natural environment. The higher species diversity in zone 6 may be due to the introduction of exotic plants from an exotic nursery, whereas the plants from zones 1-5 are from a Florida native plant nursery. When given the proper conditions, most species thrive, further providing evidence that many Oniscidea are synanthropic. In fact, many Oniscidea species are kept as pets inside vivaria, either as a lone colony or as cleaner organisms for a “bioactive” style vivarium for another animal.

More current and complete documentation of Oniscidea species in Florida, and each of its counties will facilitate the publication of a field identification guide for Florida Oniscideans and lead to a more complete knowledge of the Oniscidea species diversity, functional diversity and ecosystem diversity in Florida. In Florida, no major terrestrial community if without Oniscidea. They are generally very beneficial to man since they aid in reducing organic litter to fine particles improving the soil fertility. Terrestrial isopods play a very important role in any ecosystem throughout the state.

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