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A Survey of Parasites from Anolis Lizards on Andros Island, Bahamas: Do Ecomorphs Host Similar Parasite Assemblages?

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Abstract:

The *Anolis* lizard ecomorphs of the Caribbean and Bahamian islands are a well-established example of both adaptive radiation and convergent evolution. However, due to a lack of parasite biodiversity surveys on these islands, it is unclear if the parasite fauna hosted by these lizards follow similar evolutionary pathways. This study attempts to determine if the parasites hosted by *Anolis* spp. display strict host specificity, which would indicate speciation events in-step with their hosts, or if the parasites have little specificity and are broadly distributed among the various lizard species. In 2015 and 2017, lizards were captured by hand and dissected as soon as possible after capture in three locations on Andros Island, Bahamas. First, an external exam was conducted to look for ticks and mites, then blood smears and fecal samples were taken to search for blood protozoans. Parasites and hosts were preserved and brought back to the Parasitology Lab at Florida Southern College. Preliminary results found the ground-trunk lizard, *Anolis sagrei,* to host nearly all species of parasites found in this study, whereas the treetop lizard, *Anolis smaragdinus*, hosted relatively few parasite species. We propose that this pattern is due to the parasites intermediate hosts being ground-dwelling insects which would be more likely to consumed by ground-trunk lizards. Overall, our findings suggest that the parasites of *Anolis* display moderate levels of host specificity, thus some species may have speciated with their hosts, while others are generalists.

Introduction:

Earth is comprised of a variety of ecosystems, species, and genes. This variety can be referred to as the biodiversity of earth and consists not only of the variety but the variability in which organisms occur together and consists of how these organisms interact with their environment (Ramesh, 2003). Studies of biodiversity on earth consist of an examination of these organisms as well as the methods by which they create and maintain their diversity. It has been stated that scientists have only discovered a portion of earths diversity, some estimates state fewer than ten percent (Mittermeier et al., 2011). While some groups, such as vertebrates, are quite well-known, variation with in these groups has been documented between distinct regions such as temperate regions versus the more abundantly diverse tropics (Rands, 2010). The diversity of the species already identified is a small fraction of the actual species diversity, especially in the order of organisms not readily observed such as invertebrates and microorganisms. It is important to note that a majority of the species on earth are relatively unknown, especially as pressures on biodiversity increase. Biodiversity is threatened due to overexploitation of species, habitat destruction, and climate change as well as pollution (Rands, 2010). The decline in biodiversity is alarming, especially as conservation efforts are increasing worldwide (Rands, 2010). A majority of wild species are on the verge of extinction due to human action and this loss is even more profound as people lose species due to the irreversibility of extinction and the loss of the chance for knowledge that dies with each species. It has been said by Russell Mittermeier that “the current loss of species has been compared to burning down the world’s libraries without knowing the content of 90% or more of the books” (Mittermeier et al., 2011). In order to combat this loss of knowledge biodiversity assessments need to be performed. Biodiversity assessments are used to not only examine the distribution and ecological niches of organisms but to also study an organism's composition and structure (Ramesh, 2003). These assessments help to explain phenomena such as adaptions that allow for organisms to fill multiple ecological niches, as is the case in the Bahamas. The Bahamas are oceanic islands and comprised of several island banks. These islands are part of the Greater Antilles, which has had numerous studies done on their biodiversity. Islands are unique in that species had to travel from the mainland and adapt to survival in a different habitat. Islands also allow for scientists to introduce controlled experiments to determine how the introduction of species could have occurred as well as to determine how said species evolved to fit a specific ecological niche that ensured its survival. In the Greater Antilles many studies have been completed on the diversification of the lizard species *Anolis*. The Bahamas are of particular interest due to Grand Bahama being one of the only islands in the Caribbean to be inhabited by more than two anole species (Losos, 2011).

Anole lizards are deceptively interesting and appealing for biodiversity surveys. Not only are anoles abundant in the field but they are fairly easy to observe and researchers often manipulate the lizards in order to answer questions on behavior and ecological behavior either in the field or in a lab setting (Losos, 2011). Anoles are one of the largest genera of vertebrates, comprised of nearly 300 species. Lizards of this genera are characteristically arboreal insectivores that are predominately small in size and more often than not share a habitat with multiple anole members. Due to competition between the multiple species of anoles, anoles have been forced to specialize in their environment. This specialization is described by adaptive radiation, or basically the rapid diversification of a group of organisms in order to fill ecological niches. Anoles have essentially become a model system for studying adaptive radiation. Adaptive radiation is important to study as it has been suggested that the result of adaptive radiation is much of the diversification seen in the life on earth (Losos, 2011). The anoles are important for this study as they have independently undergone adaptive radiations on each of the islands in the Greater Antilles, meaning that through phylogenetic analysis their evolutionary radiation can be tracked from a generalized species to a specialized species for a particular structural and climatic habitat (Losos et al., 1994). This phenomena has been so well studied that the anoles have their own term “ecomorph” to describe them. An ecomorph, according to Jonathan B. Losos, is a set of species that share similar independently derived morphology, behavior, and ecology (Losos, 2011). These ecomorphs, or habitat specialists, co-occur throughout the Greater Antilles, each island essentially has the same set of ecological types. Ecomorphs differ in three major areas, body size, structural habitat and microclimate. Ecomorph body size is directly related to prey consumption, the bigger the lizard the bigger the prey, which helps to cut down on food competition. Structural habitat on the other hand consists of the lizard’s perch height and diameter while microclimates refer to a lizard’s thermal habitat. In the Bahamas four out of the six ecomorphs occur and that is where the focus of this study is on. The Bahamas contain the trunk-crown, trunk-ground, trunk, and twig ecomorphs. The trunk-crown anoles are characteristically green and are a typically wide ranging arboreal species while the trunk-ground are typically found around a meter and a half up off the ground on broad surfaces such as tree trunks. The trunk anoles are predominantly discovered on broad tree trunks while the twig anoles, the extremists, are found on the very edge of twigs on branches about eye level.

While the lizard ecomorphs are generally well studied, a wide variety of internal and external parasites have been reported in many anole species, however they have not been well studied (Losos, 2011). Parasites, according to the Webster's Third International Dictionary, are essentially an organism that is living in or on another living organism that obtains its nutrients from the organism that the parasite lives on and typically exhibits to some degree adaptive structural modification and has the potential to cause real damage to its host (Price, 1980). Parasites are pervasive and contribute to a large proportion of diversity on earth; so much so that it is unlikely for someone to encounter a free-living organism that is not parasitized by at least a single type of parasite. More often than not an organism is parasitized by more than one species of parasite, as should be expected due to the fact that parasitism is more common than all the other feeding tactics of life combined (Price, 1980). Comprehensive studies of parasites are rare however and should be considered a top priority especially because so little is known about parasite colonization and extinction as well as the parasite-disease complex. It has been pointed out in literature that a parasite's host can essentially be considered an island that the parasite is free to colonize (Price, 1980). The probability of the colonization, of course, can vary due to the size of the host or how far away one host is from the next target. Just as some islands are idyllic for life, some hosts may be more suitable than other hosts, depending on availability as well as the severity of the host's defensive response to the colonizing intruders. It can be said that parasites are responsible for influencing nearly every aspect of population biology from altering the behavior of the host organism to allowing for the interaction and therefore co-occurrence between two species that otherwise could not exist together by reducing host density of the dominant species (Losos, 2011). In previous studies, susceptibility to parasitic infection was found to be lessened the more specialized the hosts were (Price, 1980).

An important question that needs to be answered is how the parasite manages to get inside its host in the first place. One explanation to this question is trophic transmission, or the movement of the parasite from host to host usually through predation. This form of transmission most likely evolved from the evolution of the parasite attempting to escape the death of its host by parasitizing the host’s predator (Lafferty, 1999). One significant way that the parasite ensures predation is through altering its host’s behavior or appearance. These behavior modifications inflicted by parasites cause the hosts to be more susceptible to predation through manipulation of normal behaviors, such as a decreased sense of alarm in dangerous situations. Parasite increased trophic transmission (PITT) is essentially used to increase the parasites fitness, allowing for increased transmission between the original intermediate host and the final host, or predator. It has been hypothesized that the host size is irrelevant in behavior modification and that modification does not differ between vertebrate and invertebrate hosts (Lafferty, 1999).

Lafferty (1999) described the relationship between the parasites and their hosts as “an evolutionary arms race between virulence and resistance”. Parasites are consistently looking for ways to infect and thrive in their host populations while the hosts are consistently trying to evolve defenses and better responses to infection. Another form of transmission, limb autonomy, is another way for parasites to transfer into a new host but not kill its current host. In Canary Island lizards, for example, the parasite *Sarcocystis* autotomizes in the tail of lizards and relays on cannibalistic tail predation to spread to new hosts (Lafferty, 1999). Lizards generally lose their tails as an escape response, so the parasite is passed on and the lizard is left living to possibly be parasitized again. Another non-lethal situation between hosts and parasites is a host's acquired immunity to a parasite. Acquired immunity allows for the parasites preferred host to feast on its infected prey without the host getting sick and avoiding that specific prey, or intermediate host. Co-occurring parasites can also affect the hosts they parasitize as more often than not more than one parasite will infect the same intermediate hosts. Some of the additional parasites can be seen as 'hitchhiking' as they don't alter their hosts behavior however they positively correlate with presence of an additional parasite that does alter the hosts behavior (Lafferty, 1999). However, should two parasites with competing interests come to occupy the same hosts there is also the potential for conflict, a phenomena that can be described as 'hijacking' (Lafferty, 1999). Hijacking parasites have evolved ways to compete within hosts for control of PITT however these competitive processes are relatively unstudied.

The main purpose of this study is to characterize the biodiversity of the parasites on Andros Island, Bahamas. The secondary goal of this research is to determine whether or not the parasites infecting the lizards on the island specialize with their hosts or remain generalists and parasitize multiple ecomorphs. Literature asserts that through host evolution, the parasites colonizing that host are more likely to rapidly evolve with specialized hosts while remaining generalists with less specialized hosts (Price, 1980).

Methods:

Site:

Lizards were collected from various locations around Andros Island, Bahamas. Andros is a 2300 square mile archipelago, the largest of the Bahamian Island chain. The island itself contains many small islets and cays that are connected by mangroves and tidal swamplands. The sites used for collection were broken down into south, central and north Andros for our purposes. Our south sites include the South Airport or Andros Town Airport, Androsia, and South Point; our central sites include Maiden Hair coppice, Captain Bill's Blue Hole, and Forfar field station while our northern sites include Conch Sound, Uncle Charlie's Blue Hole, and the North Airport or San Andros Airport. We also collected a small number of specimens from Jungle Pond, Dildo's Scrub as well as Saddleback Cay. The lizards were sampled from a variety of habitats, Maiden Hair being a hardwood coppice for example and Captain Bill's being a blue hole. Hardwood coppices contain trees or shrubs that at susceptible to fire and took root after a fire swept through and killed off their competition. The blue holes on Andros Island are essentially water filled cave systems and are important, as well as the other cave systems on the island, for stopping the spread of fire. The fire protection allows for hardwood trees such as pigeon plum to grow.

Table 1 Compilation of Locations Visited and Their GPS Coordinates

Site	Coordinates
South Airport/ Andros Town Airport	**24°41'55.6"N 77°47'42.7"W**
Androsia	**24°43'19.3"N 77°47'05.6"W**
Airport Coppice	**25°03'57.5"N 78°02'17.8"W**
Maiden Hair Coppice	**24°47'54.2"N 77°53'19.0"W**
Captain Bill's Blue Hole	**24°44'29.6"N 77°51'41.4"W**
Forfar Field Station	**24°53'54.0"N 77°55'53.5"W**
Conch Sound	**25°06'55.5"N 78°00'01.5"W**
Unlce Charlie's Blue Hole	**25°06'48.8"N 78°02'18.5"W**
North Airport/ San Andros Airport	**25°03'11.3"N 78°02'32.5"W**
Jungle Pond	**25°03'57.5"N 78°02'17.8"W**

Collection:

In order to obtain specimens lizards were collected by hand. The most effective method that yielded the highest results was just to reach out and grab the lizard as fast as possible. There was an attempt to use additional tools, such as rubber bands to stun the lizard off the tree. Cabella's pan fishing poles were also used, where a slipknot was tied on the end of fishing line and place over the lizard's neck. Once the loop was over the lizard's head and around its neck, a quick yank upwards allowed for the lizard to be stunned and grabbed. Once collected the lizards were placed in a lingerie bag for holding while additional specimens were collected. The lizards were then taken back to Forfar Field station where they were euthanized within forty-eight hours of capture. The lizards were euthanized by severing their spinal cord right behind their skull, cutting it with a pair of scissors. Once euthanasia was completed, measurements of the lizard's snout to vent length were taken and recorded. Blood smears were taken by coaxing blood from the lizard's severed spinal cord onto a glass slide, where a cover slip was used to drag the drop across the slide in an effort to create a thin, one cell layer of red blood cells. Once smeared, the blood slides were fixed in ethanol to deter bacteria growth and stained back in the lab at Florida Southern College using geimsa stain. Fecal samples were also collected from the lizards if they pooped. The poop was collected from the cloaca and stored in water with a small amount of ethanol and then brought back to Florida Southern's lab and stained so coccidians could be observed if present. A small portion of the lizards were dissected immediately in the Bahamas while the rest of the lizards were preserved in ethanol and taken back to Florida Southern College where they were dissected in the lab. The lizard dissections followed a regimen. First the lizards were observed for ecto-parasites, then the lizards were opened ventrally. After opening the lizard, the body cavity was observed and then the heart, lungs, liver, gall bladder, esophagus, stomach, small intestine, and large intestine were removed. Once the organs were removed they were thoroughly searched for parasites. The mouth was also searched for parasites. Parasites that were found were collected and placed into glass vials filled with 70% ethanol.

Stain:

After collection, the parasites needed to be stained or cleared in order to observe and properly identify them under the microscope. Trematodes and nematodes separated under the dissection microscope and then procedures were followed depending on if the worms were nematodes or trematodes. Trematodes were placed in Semichon's stain for 24 hours to start the process. They were then de-stained with acid alcohol, the intention was that the inside of the worm was darkly stained while the outside of the worm was lightly stained in order to observe the internal structures of the worm. The worm was then dehydrated through an ethanol series of increasing concentration (70%, 85%, 90%) for at least an hour in each concentration to remove any remaining water in the worm. Once the dehydration was complete, the worm was washed with two to three changes of 100% ethanol, waiting several minutes between each wash. The worm was then placed in a 1:1 ratio of EtOH:xylene. Once completed the trematode was placed in straight xylene and allowed to clear. Once clear the trematode was mounted onto a slide with 5-6 drops of mounting medium. A paintbrush was used to pick up the trematodes and place them on the slide. Once on the slide the trematodes were placed onto a slide warmer to set them in the mounting medium. Nematodes on the other hand were placed directly on slides with 5-6 drops of glycerol. The nematodes were left for 24-48 hours, until their internal structures were clearly defined and then placed under a light microscope to identify.

Identification:

Once stained or cleared, the worms were placed under the microscope and pictures were taken as well as measurements to help in the identification process. Papers on various parasite species previously found in the Caribbean were downloaded and compared to the specimens collected from Andros Island. Identifications were completed based on the description of the holotype of the species.

Results:

Table 2 Prevalence and Mean Intensity of Helminths per Species Examined in this Study

Species	Helminth	Prevalence	Mean Intensity	Range	Site
Anolis distichus	*Allopharynx riopredensis*	1/21	16	16	Mouth
Anolis sagrei	*Allopharynx n. sp.*	1/60			
	Allopharynx riopedrensis	1/60	7	7	Mouth
	Urotrema shirleyae	8/60	1.75	1-3	Small Intestine
	Cyrtosomum penneri	23/60	93.1	4-229	Large Intestine
	Physaloptera sp.				
	Trichospirura teixeirai	1/60	1	1	Gall Bladder
	Spauligodon anolis	1/60	5	5	Large Intestine
	Oswaldocruzi sp.	1/60	1	1	Stomach
	Sarcocystis	2/60	.067	1-3	Muscle
	Centrorhynchidae sp.	1/60	1	1	Stomach
Anolis smaragdinus	*Rhabdias sp.*	1/15	1	1	Lung
	Allopharynx n. sp.	1/15	1	1	Large Intestine
Anolis angusticeps	N/A	0/8			

Table 3 Prevalence and Mean Intensity of Helminths per Species Examined in this Study Broken Down to Compare Seasonal Differences

Season	Species	Helminth	Prevalence	Mean Intensity	Range	Site
Spring	*Anolis distichus*	*Allopharynx riopredensis*	1/20	16	0-16	Mouth
Summer			0/1			
Spring	*Anolis sagrei*	*Allopharynx n. sp.*	0/30			
Summer			0/30			
Spring		*Allopharynx riopedrensis*	0/30			Mouth
Summer			1/30	7	0-7	
Spring		*Urotrema shirleyae*	3/30	2	1-3	Small Intestine
Summer			5/30	1.6	1-3	
Spring		*Cyrtosomum penneri*	3/30	15.23	81-229	Large Intestine
Summer			19/30	88.74	4-206	
Spring		*Physaloptera sp.*	/30			
Summer			/30			
Spring		*Trichospirura teixeirai*	1/30	1	0-1	Gall Bladder
Summer			0/30			
Spring		*Spauligodon anolis*	0/30			Large Intestine
Summer			5/30	5	0-5	
Spring		*Oswaldocruzi sp.*	0/30			Stomach
Summer			1/30	1	0-1	
Spring		*Sarcocystis*	2/30	2	1-3	Muscle
Summer		*Sarcocystis*	0/30			
Spring		*Centrorhynchidae sp.*	1/30	1	1	Stomach
Summer			0/30			
Spring	*Anolis smaragdinus*	*Rhabdias sp.*	1/13	1	0-1	Lung
Summer			0/2			
Spring		*Allopharynx n. sp.*	1/13	1	0-1	Large Intestine
Summer			0/2			

Spring	*Anolis angusticeps*	N/A	0/8			
Summer		N/A	0/0			

Table 4 Prevalence and Mean Intensity of Helminths Examined in this Study Broken Down by Location Collected From, Acanthocephalan omitted for clarity of data

Location	Helminth	Prevalence	Mean Intensity	Range
Airport	Mites	0/6		
	Trematodes	3/6	1.7	
	Nematodes	1/6	81	0-81
	Cysts	1/6	1	0-1
Airport Coppice	Mites	1/2	1	0-1
	Trematodes	0/2		
	Nematodes	0/2		
	Cysts	0/2		
Androsia	Mites	0/18		
	Trematodes	1/18	16	0-16
	Nematodes	4/18	384	1-383
	Cysts	2/18	2	0-2
Captain Bill's	Mites	4/19	3.8	0-9
	Trematodes	4/19	1.5	6
	Nematodes	6/19	37.7	226
	Cysts	4/19	1	4
Conch Sound	Mites	0/4		
	Trematodes	0/4		
	Nematodes	1/4	157	157
	Cysts	1/4	1	1
Forfar	Mites	2/37	2.3	1-6
	Trematodes	2/37	4.5	9
	Nematodes	10/37	98.5	1-984
	Cysts	4/37	7	1-4
Jungle Pond	Mites	1/5	21	21
	Trematodes	0/5		
	Nematodes	0/5		
	Cysts	0/5		
Maiden Hair	Mites	3/8	5.7	9
	Trematodes	1/8	3	3
	Nematodes	2/8	41.5	83
	Cysts	1/8	1	1
South Airport	Mites	0/4		
	Trematodes	1/4	1	1

	Nematodes	1/4	5	5
	Cysts	1/4	1	1
Uncle Charlie's	Mites	1/6	1	1
	Trematodes	0/6		
	Nematodes	4/6	260	2-258
	Cysts	0/6		

Table 5 Prevalence and Mean Intensity of Helminths Examined in this Study Broken Down by Location Collected from and Season Obtained in, Acanthocephalan omitted for clarity of data

Location	**Helminth**	**Prevalence**	**Mean Intensity**	**Range**
Airport				
Spring	Mites	0/6		
Summer				
Spring	Trematodes	3/6	1.7	1-3
Summer				
Spring	Nematodes	1/6	81	81
Summer				
Spring	Cysts	1/6	1	1
Summer				
Airport Coppice				
Spring	Mites	1/2	1	1
Summer				
Spring	Trematodes	0/2		
Summer				
Spring	Nematodes	0/2		
Summer				
Spring	Cysts	0/2		
Summer				
Androsia				
Spring	Mites	0/18		
Summer				
Spring	Trematodes	1/13	16	16
Summer		0/5		
Spring	Nematodes	2/13	115	1-383
Summer		2/5	77	30-124
Spring	Cysts	2/13	2	0-2
Summer		0/5		
Captain Bill's				
Spring	Mites	4/13	3.8	0-9
Summer				
Spring	Trematodes	1/13	1	6
Summer		3/6	1.7	

Spring	Nematodes	0/13		
Summer		6/6	37.7	2-98
Spring	Cysts	1/13	1	1
Summer		3/6	1	1
Conch Sound				
Spring	Mites	0/4		
Summer				
Spring	Trematodes	0/4		
Summer				
Spring	Nematodes	1/4	157	157
Summer				
Spring	Cysts	1/4	1	1
Summer				
Forfar				
Spring	Mites	2/24	2.3	1-6
Summer				
Spring	Trematodes	0/24		
Summer		2/13	4.5	
Spring	Nematodes	1/24	1	
Summer		9/13	109.3	73-206
Spring	Cysts	4/24	1.5	1-2
Summer		2/13	2	2
Jungle Pond				
Spring	Mites	1/5	21	21
Summer				
Spring	Trematodes	0/5		
Summer				
Spring	Nematodes	0/5		
Summer				
Spring	Cysts	0/5		
Summer				
Maiden Hair				
Spring	Mites	3/6	2.8	9
Summer				
Spring	Trematodes	1/6	3	3
Summer		0/2		
Spring	Nematodes	1/6	10	10
Summer		1/2	73	73
Spring	Cysts	1/6	1	1
Summer		0/2		
South Airport				
Spring	Mites			
Summer		0/4		

Spring	Trematodes			
Summer		1/4	1	1
Spring	Nematodes			
Summer		1/4	5	5
Spring	Cysts			
Summer		1/4	1	1
Uncle Charlie's				
Spring	Mites	1/3	1	1
Summer				
Spring	Trematodes	0/3		
Summer		0/3		
Spring	Nematodes	1/3	2	2
Summer		3/3	86	39-126
Spring	Cysts	0/3		
Summer		0/3		

Table 6 Prevalence and mean intensity of blood helminths examined in this study

Species	Helminth	# Infected	Prevalence
Anolis distichus	*Plasmodium*	3	3/21
	Hemogregarine	0	0/21
Anolis sagrei	*Plasmodium*	19	19/60
	Hemogregarine	12	12/60
Anolis smaragdinus	*Plasmodium*	7	7/15
	Hemogregarine	1	1/15
Anolis angusticeps	*Plasmodium*	2	2/8
	Hemogregarine	1	1/8

Table 7 Prevalence and mean intensity of blood helminths examined in this study differentiated by season

Species	Helminth	# Infected	Prevalence
Anolis distichus			
Spring	*Plasmodium*	3	3/20
Summer		0	0/1
Spring	*Hemogregarine*	0	0/20
Summer		0	0/1
Anolis sagrei			
Spring	*Plasmodium*	14	14/30
Summer		5	5/30
Spring	*Hemogregarine*	7	7/30
Summer		5	5/30

Anolis smaragdinus			
Spring	*Plasmodium*	7	7/13
Summer		0	0/2
Spring	*Hemogregarine*	1	1/13
Anolis angusticeps			
Spring	*Plasmodium*	2	2/8
Summer			
Spring	*Hemogregarine*	1	1/8
Summer			

Figure 1: Pictures of Trematodes and Nematodes Identified. (A) Allopharynx riopedrensis. (B) Urotrema shirleyae. (C) Oswaldocruzi sp. (D) Cyrtosomum penneri. (E) Centrorhynchidae sp. (F) Posterior view of Spauligodon anolis. (G) Anterior view of Spauligodon anolis.

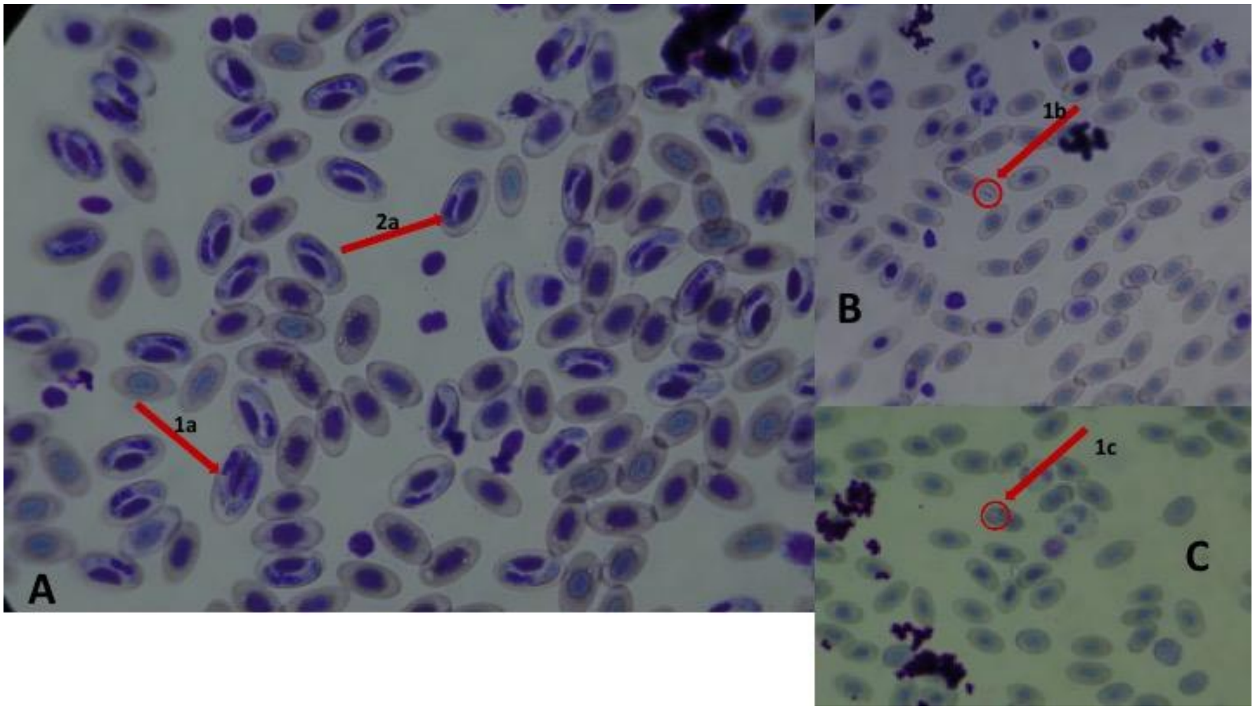

Figure 2: (A) Anolis host infected with hemogregarines. (1a) Infection of a red blood cell with two hemogregarine parasites. (1b) Infection of a red blood cell with one hemogregarine parasite. (B) Anolis host infected with Plasmodium. (1b) Plasmodium gametocyte present in the red blood cell. (C) Anolis host infected with Plasmodium. (1c) Plasmodium schizont present in the red blood cell.

Discussion:

In the anoles dissected and reported in table 2 it was discovered that there were 2 species of known trematodes, *Allopharynx riopredensis* (Fig. 1, A) and *Urotrema shirleyae* (Fig. 1 B); 1 species of unknown trematode, *Allopharynx n. sp.*; 5 species of nematodes, *Cyrtosomum penneri* (Fig 1, D), *Physaloptera sp.*, *Trichospirura teixeirai*, *Spauligodon anolis* (Fig. 1, F and G), *Oswaldocruzi sp* (Fig. 1, C), *Rhabdias sp.*; 1 protozoan, *Sarcocystis* ; and 1 acanthocephalan, *Centrorhynchidae sp.* (Fig. 1, E)*;* in table 6 it is reported that *Plasmodium* (Fig. 2, B and C) and hemogregarines (Fig. 2, A).were also discovered. Based on previous research done by Stephen Goldberg et al. (1997) these parasites have been reported in other reptilian and amphibian species, meaning that the parasites are not hosting in the lizards by accident.

Trematodes typically have a complex life cycles where they require more than one host. There is currently not much work done on the life cycle of *Allopharynx riopredensis*. *Urotrema shirleyae* on the other hand has also been observed to infect insectivore bats, which is strange that it infects both reptiles and mammals. Both of the observed trematodes come from the order Plagiorchiida. The Plagiorchids have a complex life cycle and typically infect insectivore hosts, with aquatic insects being their most common intermediate host. It is possible that the infected lizards consumed an aquatic insect, as two of the sites sampled contained small pools of standing water. Another possibility is that the parasite found its way into a terrestrial mollusk, however this is the less likely of the two possibilities. The typical life cycle of a Plagiorchid contains some kind of aquatic mollusk, then the parasite moves into an aquatic insect or crustacean and finally ends up in a vertebrate insectivore (Roberts et al., 1996).

Nematodes can be separated into two categories based on whether or not they are heteroxenous or monoxenous. Heteroxenous nematodes have more complex life cycles that require the use of an intermediate host, while monoxenous nematodes only require a single host and typically penetrate hosts through the skin or through autoinfective routes. The heteroxenous nematodes will most likely move on to parasitize additional vertebrae such as birds (Goldberg et al., 1997). The nematodes listed, such as *Physaloptera sp.*, typically utilize insects and lower vertebrates as intermediate hosts; which would explain the encysted larvae in the anoles, however it has yet to be determined whether or not the anoles are paratenic or accidental hosts (Goldberg et al., 1997). The monoxenous nematodes, according to Goldberg et al.(1997), have been reported to have a wide distribution and contain nematodes such as *Oswaldo cruzi sp*.

The acanthocephalan, *Centrorhynchidae sp.*, is thought to be a bird parasite and occurs sporadically throughout the Caribbean (Goldberg et al. 1997).

Plasmodium are malarial parasites that infect the blood of their hosts. In the anoles of the Caribbean the parasite is transferred from host to host through its vector, the sand fly (Schall, 1996). While we have not yet identified the *Plasmodium* species in our sample there is the possibility that more than one species of *Plasmodium* exists within the lizard hosts. Literature states that this is the case in some infections of *Plasmodium* however the exact interaction between the multiple species is unknown (Schall, 1996). The parasite typically infects the blood with a pre-eythrocytic stage, which then leads into the eruption of the parasite into the peripheral blood which causes an exponential increase in parasitemia (Schall, 1996). The exponential increase of parasites can cause either the death of the host or the crash of the parasite population, which can either be eliminated or remain in the blood in very low densities (Schall, 1996). Malaria levels have been shown in studies to vary with the seasons, typically increasing in exponential levels around late spring and early summer while maintaining relatively low levels in early spring (Schall, 1996). While our data (Table 7) does not appear to support this trend outright, that could be due to our low number of confirmed infected specimens. In order to make a more accurate assumption to the malarial levels of anoles on Andros Island more data would need to be collected in order for analysis. Another point of data that should be collected for continuation of this study is the temperature of the area. *Plasmodium* can fluctuate depending on temperature as lower temperatures don’t allow for it to come to maturation in its sand fly host.

Hemoogregarines, like malaria, are reported to undergo sporogonic cycles (Telford, 2016). The parasites can utilize several vectors, of which contain the mosquito as well as some species of ticks and mites (Telford, 2016). Several species of these parasites, with some exceptions, are transferred from host to host through predation, for example the mite would have to be eaten by the lizard. The life cycles of this parasite are relatively unknown beyond these basic interactions as they have not been studied extensively. It has been suggested however that the sporozoites, once in their vertebrate host, penetrate through the intestinal wall and enter the circulatory system (Telford, 2016).

While the main purpose of this study was to complete a biodiversity survey on the parasites of Andros Island, Bahamas, the secondary goal of this study was to determine whether or not the parasites infecting the lizards on the island were specialists or generalists. In previous studies, susceptibility to parasitic infection was found to be lessened the more specialized the hosts were (Price, 1980). The findings of these previous studies so far seem to be supported by our results. In *Anolis sagrei* (Brown Anole) we have found the most species of parasites, while in *Anolis angusticeps* (Twig Anole) we have found no species of parasites and in *Anolis distichus* (Bark Anole) and *Anolis smaragdinus* (Green Anole) we have found a small number of species (see Table 2). The brown anoles are the most generalized of the four species present on Andros with the twig anole being the most extreme in its habitat niche. We believe that the brown anole may come into contact with more parasites through its diet and therefore host most than the other species of *Anolis* listed. As we are trying to determine if parasites are coevolving with their hosts it may be beneficial in future studies to observe the diets of these lizards and see if they are contracting the parasite through what they eat. Due to the fact that ecomorphs occupy various habitat niches it may be important to determine what kind of food they come into contact with on various parts of the tree that they live. A twig anole, for instance, may never come into contact with the same insects that a brown anole might, thereby excluding the twig anole from the chance to contract those insects parasites. Another key point that could be playing a factor however is our sample sizes. It can be seen in the tables 2 and 3 that brown anoles outnumber all the other species we were able to capture. This could suggest that we have just not collected a large enough sample size of the other lizards to detect the presence of parasites. Not only may diets be important but it is also worth identifying the trophic interactions between the lizards and their environment. The parasites in the lizards may be hitching rides on specific species of lizards in order to end up in their preferred predator host.

Future work:

The new species of trematode still remains to be identified. The lab is hoping to accomplish this by sending a sample of the parasite out to be genetically sequenced to determine whether or not the species is unique or part of an existing group.

There also remains several worms and cysts that were obtained from the lizards that need to be identified as well and hopefully added to the list of parasites discovered in *Anolis*.

This study is currently ongoing as biodiversity surveys are meant to collect a large amount of data in order to determine the information needed about the populations. As more data is collected, hopefully there will be better chance to analyze the trends in the data. Another point that can be added in the future is a seasonality component. It is stated in literature that parasite infections fluctuate with the seasons and it would be interesting to determine if the populations on Andros Island follow this trend (Schall, 1996).

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