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Parasitic Indicators of Foraging Strategies in Wading Birds

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By

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Abstract

Feeding ecology and trophic interactions of six species of wading birds were explored through a combined analysis of stable isotope profiles and endoparasite communities. Stable isotopes broadly characterize the feeding preferences and geographic information, while parasite communities reflect long-term trends in feeding ecology. Deceased birds were obtained from four South Florida wildlife rehabilitation organizations. Of the 81 birds dissected, 73 contained parasites. Parasites were predominately found within the gastrointestinal tract. Host and range extensions were noted for several parasite taxa. Bird host species had a significant effect on the parasite community (P=0.001) while wildlife center location and maturity status did not. Stable nitrogen ($\delta^{15}N$) values for pectoral muscle tissues, representing approximately 24 days, ranged from 6.44 to 13.48‰ while stable carbon ($\delta^{13}C$) values ranged from -33.39 to -11.66‰. $\delta^{13}C$ varied significantly among location (P=0.0002) and $\delta^{15}N$ varied significantly among species (P<0.0001). When $\delta^{15}N$ and $\delta^{13}C$ was analyzed in combination; bird species (P=0.001) and location (P=0.001) were significantly different. By using this combined approach of stable isotope analysis and parasite identification, it was possible to elucidate more components of bird feeding ecology. Stable isotope analysis provided knowledge on trophic interactions based on $\delta^{15}N$ values, while $\delta^{13}C$ was used to determine the differences in geographic foraging location. As endoparasites are acquired trophically via food-web interactions, identifying the parasite community allowed for trophic links to be drawn between organisms present within the same environment. Combining these two techniques allows for an abundance of information on feeding ecology and trophic interactions to be obtained.

Keywords: Ardeidae, Threskiornithidae, parasites, stable isotopes, $\delta^{15}N$, $\delta^{13}C$

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Introduction

The landscape of South Florida is a continually changing environment. Coastal zones are under increasing pressure due to urban developments, which in most cases are established on wading bird habitats. Wading birds are critical contributors to ecological function, driving energy flow within ecosystems via predator-prey interactions and mediating energy flow between terrestrial and aquatic habitats (Polis and Hurd 1996; Mallory *et al.* 2010). The feeding ecology, trophic interactions, and movements of these species are of significant interest in terms of understanding local ecology and in predicting the effects of coastal development and habitat alteration of these important species. Due to these inherent ecological linkages, wading birds can be thought of as sentinel species that indicate the ecological health of coastal habitats (Mallory *et al.* 2010). Particularly in South Florida, wading birds can be found in habitats ranging from the freshwater marshes in the Everglades to the saltwater mangals of the Florida Keys and can therefore provide valuable environmental information across a wide geographic scope.

Through a combined analysis of stable isotope profiles and endoparasite communities, the feeding ecologies and trophic interactions of six species of wading birds were investigated. Stable isotopes were used to broadly characterize the feeding preferences of individual birds. Parasite communities are reflective of long-term trends in diet, feeding ecology, movements, and environmental changes. It is difficult to track and measure the diets of wading birds using conventional approaches such as forced regurgitations, live observations, or *post mortem* stomach content analysis, which only provide a snapshot of an individual's diet (Marcogliese and Cone 1997; Inger and Bearhop 2008). By using stable isotope analysis in combination with characterization of the endoparasite community, it is possible to obtain dietary information over longer periods of time.

<u>Wading Birds</u>

The wading birds utilized in this study are from two families within the order Pelecaniformes: Family Ardeidae contains the herons, night herons, and egrets, while Family Threskiornithidae includes the ibisis. There is little to no sexual dimorphism with these species. Birds within these families are long-legged, often have long necks, and are adapted for wading in shallow-water habitats to capture animal prey. Wading birds feed on a variety of food including other birds (particularly chicks), small mammals, and a range of aquatic food items including fish, amphibians, and invertebrates (Table 1; Appendix 1). The majority of these birds are associated with aquatic habitats that range from frehswater marshes and meadows to the shores of marine environments, including mangrove mangals (Brooke and Birkhead 1991; Schreiber and Burger 2001; Lovette and Fitzpatrick 2016).

Study Species

Birds in Ardeidae have straight, harpoon-like bills and narrow heads. They also have a modification to their sixth cervical vertebrae, which allows their long necks to be held in an S-shape while in flight (Brooke and Birkhead 1991; Schreiber and Burger 2001). Most species feed in or along the water and use their dagger-like bills to probe and stab prey (Lovette and Fitzpatrick 2016). However, birds in this family exhibit a variety of feeding behaviors. Great blue herons (*Ardea herodias*) and green herons (*Butorides virescens*) primarily feed using stand or stalk techniques. Great egrets (*Ardea alba*) also use the stand technique in addition to hovering and swimming forage patterns. Black-crowned night herons (*Nycticorax nycticorax*) feed using a number of specialized techniques including hovering, plunging and even feeding while swimming (Kushlan 1976; Schreiber and Burger 2001).

Great egrets are migratory birds found throughout the Americas from southern Canada to southern Chile and Argentina (Sepúlveda *et al.* 1999a; Sepúlveda *et al.* 1999b). Great egrets are also present in Florida throughout the year (Cornell University, 2018). Wiese (1976) observed that great egrets typically feed away from their colony throughout the day and roost communally at night. The primary dietary item for great egrets is teleost fishes (Frederick *et al.* 1999).

The great blue heron is the largest heron found in North America (Forrester and Spalding 2003). In southeast Florida, they are relatively common and present throughout the entire year. Great blue herons typically feed on fishes in intertidal mud and sandflats, intertidal reedbeds, wetlands, and tidal flats. Foraging behavior ranges from solitary and territorial feeding to social feeding in large groups (Krebs 1974; Kushlan 1976; Kelsall and Simpson 1980; Gibbs and Kinkel 1997).

Green herons can be present throughout southeast Florida year-round, although some individuals may spend the summer in the northern and central states (Forrester and Spalding 2003; Cornell University 2018). Betts and Betts (1977) observed that green herons in Costa Rica mostly hunted from the small mud islands and from rocks along the shore, taking prey items such as frogs and tadpoles.

The yellow-crowned night heron (*Nyctanassa violacea*) is most often found inhabiting forested wetlands, swamps, and bayous. This night heron is found throughout all of the American continents from Peru northward to the New England region of the United States (Watts 1995). Adults have been observed foraging in tidal, saltwater marshes during daylight hours. Crustaceans are the main prey item for yellow-crowned night herons, although insects also comprise a small portion of their diet (Riegner 1982).

The black-crowned night heron is present in Florida year-round and some members of the species may spend their breeding summers in the northern United States (Kushlan 1976). This species of night heron is known to eat a wide variety of animals and will take advantage of temporary abundances in food items. Wolford and Boag (1971) identified food items collected from the regurgitations of nestlings and from the gullets and stomachs of fledged juveniles and mature birds. When teleost fishes are available, they are the primary component of the night heron's diet. Other food items include amphibians, invertebrates, voles, and the young of other bird species in nearby colonies (Wolford and Boag 1971).

Species in Threskiornithidae are typically shorter-legged than the Ardeidae and their bills are either down-curved, such as the ibises (Subfamily Threskiornithinae), or spatulate, as with the spoonbills (*Platalea* sp.). The grooved surfaces found on the bills of these birds are used for cleaning feathers (Schreiber and Burger 2001). The majority of species within Threskiornithidae lack face feathers (Brooke and Birkhead 1991).

White ibis (*Eudocimus albus*) is a resident to medium-distant migratory species (Cornell University 2018). It can be found from the coastal plain of southern North America to Central America and into Venezuela (Aguilera *et al.* 1993). In Southeast Florida, white ibis are present year-round (Cornell University 2018).

The white ibis is a tactile feeder that forages in a variety of habitats ranging from lakes and wetlands to forests, dry shrubs and grasslands (Cunningham *et al.* 2010). In shallow waters, ibis forage in waters usually 5-25 centimeters (cm) deep (Frederick *et al.* 2009). Food items for the white ibis include small fish and crustaceans (Kushlan and Kushlan 1975; Frederick *et al.* 2009). Kushlan and Kushlan (1975) examined the food and feeding habitat preferences for the white ibis in Florida based on regurgitation samples and stomach contents reporting that crayfish was the dominant food item followed by fish, with the sailfin molly (*Poecilia latipinna*) accounting for the greatest fish biomass.

Parasite Interactions

Atkinson *et al.* (2008) defines parasitism as "a long-term trophic association between individuals of two different species." In this relationship, one species – the parasite – obtains resources from a living organism – the host – of another species, causing it harm. Parasitism is ubiquitous in wild bird populations and individual birds are commonly hosts to a variety of parasites throughout their lifetime.

The study of animal parasites is crucial to understanding their population biology and ecology. However, knowledge of parasites that occur in wild wading birds is fragmentary. Most parasites have not been described taxonomically or are incorrectly reported in the literature. Some groups of parasites, such as those inhabiting blood, have been studied widely, while other parasite groups, such as intestinal parasites, are not as well studied (Atkinson *et al.* 2008).

Studying parasitism in wild birds can be challenging due to a number of constraints. These constraints include inadequate information on prior movements (migratory versus resident populations) or life history (age or gender) of the host species and difficulty in securing the necessary sample size. Additionally, the method of collection may not represent the actual random state of nature, as some studies have used carcasses obtained opportunistically from wildlife rescue centers (Atkinson *et al.* 2008).

Many parasites have complex life cycles that involve development in at least one intermediate host as well as development in a definitive (final) host where reproduction occurs. Typically, several different intermediate hosts and often paratenic hosts (hosts which participate in transmission but do not participate in parasite growth or development) are involved in the life cycle of the parasite. There are two ways in which parasites are transmitted between hosts. The infective stage of the parasite may be few living and will infect the next host passively (by being eaten by the host) or actively (by penetration into the host by the parasite). Otherwise, the infective stage may inhabit an intermediate host, which must be ingested by the next host in order for the parasite life cycle to develop further. Many parasites make these progressive steps in a food web through predator-prey interactions (Marcogliese and Cone 1997; Lafferty *et al.* 2008).

As endoparasites rely on trophic interactions for their transmission, parasites provide a useful means to track pathways within food webs and can be used to elucidate food web structures. The presence of a parasite within the host may be indicative of direct links within the food web. For example, the presence of a passively obtained parasite with a complex life cycle including three hosts indicates that a) all three hosts are present and b) the three hosts are linked trophically. The parasite assemblage within a host population can be reflective of many different trophic links within the food web. As parasites can reside within a host for months or years, they are reflective of long-term trends in host feeding (Marcogliese and Cone 1997).

This study examined four different endoparasite taxa. Digeneans are a class of trematodes and are common endoparasites of a variety of vertebrate hosts. Cestodes, better known as tapeworms, are segmented worms, which commonly infect the intestines. Acanthocephalans are known as the spiny-headed worms that absorb their nutrients directly through their integument (Atkinson *et al.* 2008). Nematodes, also called roundworms, consist of two groups; one, free-living forms, which occur in fresh water, seawater, and soil and two, species that parasitize animals and plants (Rysavy and Ryzhikov 1978).

Stable Isotope Analysis

Conventional approaches to diet assessment make it difficult to track and measure the diets of wading birds over extended periods of time. These approaches, such as forced regurgitations, live observations, or *post-mortem* stomach content analysis, provide a

Table 1. Foraging preferences of six species of wading birds. Specific dietary items are listed in Appendix 1.

Species	Study Location	Dietary Items	Reference
Great egret	Florida Everglades	Fishes	Frederick *et al.* 1999
	Puerto Rico	Fishes	Miranda and Collazo, 1997
		Fiddler crabs	
		Shrimp	
		Reptiles	
		Orthopteran insects	
Great blue heron	Florida	Fishes	Powell, 1983
	Southwestern British Columbia	Fishes	Kelsall and Simpson, 1980
	San Francisco, California	Fishes	Hom, 1983
	British Columbia	Fishes	Butler, 1993
Green heron	Florida	Crayfish	Baynard, 1912
		Orthopteran insects	
		Worms	
		Amphibians	
Black-crowned night heron	Alberta, Canada	Fishes	Wolford and Boag, 1971
		Amphibians	
		Birds (young)	
		Mammals	
		Coleopteran insects	
		Hemipteran insects	
		Orthopteran insects	
		Odonatean insects	
		Amphipods	
		Hirudinean leeches	
		Vegetation	
Yellow-crowned night heron	Eastern and Southern U.S.	Polychaetes	Riegner, 1982
		Gastropods	
		Bivalves	

		Crustaceans	
		Insects	
		Arachnids	
		Fishes	
		Reptiles	
		Mammals	
White ibis[1]	Southern Florida	Odonatean insects	Kushlan and Kushlan, 1975
		Crayfish	
		Fishes	
		Hemipteran insects	
		Coleopteran insects	
		Molluscs	
		Fishes	
		Amphibians	
		Vegetation	

[1] Includes dietary items with total percent frequency greater than 5%

limited window on feeding activity prior to examination and involve permitting and logistical challenges (DeNiro and Epstein 1978, 1981; Marcogliese and Cone 1997; Inger and Bearhop 2008; Lafferty *et al.* 2008). Wading birds also exploit several different habitats over relatively short time-scales (for example, individuals roosting nightly inland, but foraging daily in both inland and estuarine areas). It is challenging, therefore, to study their feeding patterns directly because the results may not be reflective of all habitats in which they feed. Stable isotope analysis is an advantageous tool for studying trophic ecology as it can provide dietary information over an extended period of time and reflects the assimilation of dietary items (Kelly 2000; Inger and Bearhop 2008). Stable isotopes provide a natural way to follow and trace details of element cycling directly to obtain insight into an animal's diet.

Stable isotopes are forms of the same element that differ in the number of neutrons in the nucleus. Differences in the relative abundance of the light (isotope with fewer neutrons) and heavy (isotope with more neutrons) isotope can be measured and expressed as a ratio which is standardized against international reference samples and reported as parts per thousand, or per mil (‰) (Fry 2006). Because different dietary items have distinctive isotopic signatures, the values in an animal's tissue can be used to investigate the trophic ecology of that animal (DeNiro and Epstein 1978, 1981; Kelly 2000; Bearhop *et al.* 2002). Different animal tissues are synthesized at different rates and the isotopic make-up of new tissues reflects the diet and habitat of animals at the time of tissue synthesis (Peterson and Fry 1987). The difference in animal tissue synthesis allows an animal's diet or habitat to be inferred over a range of different time scales.

Different dietary items may have different isotopic signatures, which are reflected in the tissues of the consumers (Peterson and Fry 1987). There is a predictable shift in isotopic ratios between prey and predator with the ingestion, digestion, and assimilation of diet. Fractionation is the magnitude of those shifts or the isotopic difference between sources and substrates in chemical reactions (Fry 2006). By analyzing carbon and nitrogen stable isotopes in muscle tissue, it is possible to obtain a variety of different dietary information over a discrete period of time. The ability to obtain a variety of dietary information allows stable isotope analysis to be a more relevant technique for foraging studies (DeNiro and Epstein 1981; Peterson and Fry 1987; Fry 2006; Hobson 2007; Inger and Bearhop 2008).

Elemental turnover rates vary among tissue types; therefore, different tissues offer varying insights into temporal dietary trends. Some keratinous tissues such as feathers are metabolically inert following synthesis and, therefore, reflect the isotopic record of the location where the tissue was synthesized. Other tissues are metabolically active and the dietary information that can be obtained will be temporal, ranging from a few days to several weeks depending on the turnover rates of the tissue (Mizutani *et al.* 1990; Hobson and Clark 1992; Hobson 1999). Hobson and Clark (1992) analyzed the isotopic turnover rates of ^{13}C in lab-reared Japanese quails (*Coturnix japonica*) to assess the different isotope turnover rates among tissues. They accomplished this by switching the diet from a wheat-based (C_3) diet to a corn-based diet (C_4) diet. Four different tissues were sampled periodically for 212 days to determine turnover rates. The half-life for the different tissues were determined to be: blood at 11.4 days, muscle at 12.4 days, liver at 2.6 days, and bone collagen at 173.3 days.

Carbon Isotope Ratios

In trophic studies stable carbon isotope ratios ($\delta^{13}C$) are used to determine the major sources of carbon within a food web. Carbon values can be used to discriminate between plants using different modes of photosynthesis. Carbon undergoes a small fractionation of less than 1‰ during assimilation so carbon signatures can be used to trace the importance of primary producers within food webs (France 1995; Gannes *et al.* 1998). Photosynthesis by C4 and crassulacean acid metabolism (CAM) pathways results in lower carbon isotope fractionation than C3 photosynthesis (Gannes *et al.* 1998). Additionally, the signatures of marine algae are higher than those of terrestrial plants (O'Leary 1981; Peterson and Fry 1987; Kelly 2000; Inger and Bearhop 2008). It is possible, therefore, to trace the importance of different carbon pools to a consumer or determine the source of carbon at the base of the food web (O'Leary 1981; Kelly 2000).

Nitrogen Isotope Ratios

The ratio of two naturally occurring stable nitrogen isotopes, ^{14}N and ^{15}N, are used in trophic studies. Stable nitrogen isotope ratios ($\delta^{15}N$) can provide information on potential food sources as well as trophic position. During assimilation of proteins, ^{14}N is preferentially used, which increases the ratio of ^{15}N to ^{14}N in the tissues of the consumer relative to its food source (Gannes *et al.* 1998). Nitrogen shows a step-wise enrichment as trophic level increases within a food web which allows for nitrogen to be used to estimate trophic position. There is approximately a 3-4 ‰ enrichment of ^{15}N as trophic level increases (DeNiro and Epstein 1981). Therefore, animals at higher trophic levels such as carnivores will have higher ^{15}N values than those at lower trophic levels (Gannes *et al.* 1998).

Stable Isotopes in Birds

Stable isotope studies have not been conducted for wading birds from southeast Florida. However, previous bird studies indicate that stable isotope analysis is predictive of the diet of birds. Hobson *et al.* (1994) used stable carbon and nitrogen isotope ratios to determine trophic relationships in 22 species of marine birds at three different study sites in the northeastern Pacific Ocean. The use of stable isotopes allowed the authors to determine trophic information over an extended period of time. This approach provides more accurate dietary analysis than analysis based on stomach contents or direct observation, which represent short-term diets and may be biased. Their study demonstrated that ^{15}N enrichment could be used to determine trophic positions for the organisms in their study. In the Barkley Sound region, mean $\delta^{15}N$ values were obtained for planktivorous fish, squid and euphausiids and a mean $\delta^{15}N$ trophic enrichment factor was calculated. Hobson *et al.* (1994) was then able to predict the relative contributions of fish and euphausiids to the diets of seabirds in this area. Cassin's auklets (*Ptychoramphus aleuticus*) had the lowest $\delta^{15}N$ values, which correspond to a dietary contribution of 60% euphausiids. Pigeon guillemots (*Cepphus columba*) had the most enriched $\delta^{15}N$ values, which indicated a diet exclusively of fish.

Hobson *et al.* (1994) also used ^{13}C to determine seabird foraging location via the links with the benthic food webs. As a result of this analysis, the authors were able to determine that the ^{13}C enrichment of the pigeon guillemonts off the west coast of Vancouver Island had a pattern consistent with inshore benthic feeding where the pigeon guillemonts likely consumed carbon of detrital origin. The lower $\delta^{13}C$ values for the Cassin's auklets and tufted puffins (*Fratercula cirrhata*) were consistent with feeding on pelagic prey items. Whether the seabird prey is from a benthic or pelagic environment is evident in the stable carbon isotope values for the prey organisms. Herring, squid, smelt, and sandlance show little ^{13}C enrichment compared to the benthic fishes such as surfperch and prickleback (Hobson *et al.* 1994). The present study illustrates how stable isotope analysis can be used to determine trophic position as well as inshore or offshore feeding preference for seabirds in the Pacific Ocean. The results of this study suggest that a similar type of analysis is appropriate for analyzing the food preferences and trophic position of wading birds in South Florida.

The present study focused on the foraging ecology of wading bird species in southeastern Florida. The feeding ecology, trophic interactions, and movements of these species are of significant interest, in terms of understanding local ecology. As wading birds are often at the top of the food chain within their environments, they can serve as sentinel species, indicating ecological health of coastal habitats. In South Florida wading birds can be found in habitats ranging from the Everglades to the Florida Keys and can therefore provide valuable environmental information across a wide geographic scope. Through a combined analysis of stable isotope profiles and endoparasite communities, the feeding ecology and trophic interactions of six species of wading birds was investigated. The intent of this study was to improve the understanding of foraging ecology and habitat preference for six species of wading birds.

Materials and Methods

<u>Permits</u>

Five different permits were necessary to conduct this study; three permits were needed for prey specimen collection and two permits were required to salvage bird carcasses. A Special Activities license (SAL) from Florida Fish and Wildlife Conservation Commission (FFWCC), permit number SAL-17-1865-SR, was necessary for prey specimens at all collection locations. For prey sampling locations within Florida

Bay, a National Oceanic and Atmospheric Association (NOAA) National Marine Sanctuaries Permit, number FKNMS-2016-133, was required. For collection at Card Sound Bridge (CSB) and Mosquito Creek (MQC), a special use permit from the National Wildlife Refuge (NWR) research and monitoring special use permit-Crocodile Lake NWR, permit number 41581-2017-01, was obtained. All bird specimens were collected in accordance with FWC permit LSSC-12-00075 and U.S. Fish and Wildlife Service (USFWS) permit MB8290-A-0. No permits were needed from the Institutional Animal Care and Use Committee (IACUC) because all bird samples were deceased when received by Nova Southeastern University (NSU) (D. Kerstetter, NSU IACUC, pers. commun.).

Field Collection

Fish, invertebrate, and insect samples were collected that represent prey items for wading bird species (Table 1). Collection of prey items occurred seasonally throughout 2017. At each study site samples were collected using either a seine net or a dip net. Collection sites were accessed by wading or snorkeling and Global Positioning System (GPS) was used to return to the same location each month. Eight different sampling locations across four different geographic regions were used: Paddleboard Station (PBS), Rickenbacker Causeway (RBC) and Virginia Key (VAK) were in Port of Miami; Card Sound Bridge (CSB), Mosquito Creek (MQC) and Gilberts (GBT) were located in Card Sound Aquatic Preserve; Islamorada Library Park (ILP) was in Florida Bay and Everglades (EVE) was in the Florida Everglades (Fig.1).

Bird specimen samples were collected from four wildlife rehabilitation centers in Florida: South Florida Wildlife Center (SFWC) in Fort Lauderdale, Pelican Harbor Seabird Station (PHSS) in Miami, Florida Keys Wild Bird Rehabilitation Center (FKWBC) in Tavernier, and Key West Wildlife Center (KWWC) in Key West (Fig. 1; Table 2). The birds died either while receiving treatment at the wildlife centers or were euthanized upon admittance. The wading bird species in this study include great egrets (GREG), great blue herons (GBHE), green herons (GRHE), yellow-crowned night herons (YCNH), black-crowned night herons (BCNH), and the white ibis (WHIB).

Laboratory Processing

Bird processing

When bird specimens were first collected from the wildlife centers, they were placed in standard freezers (*ca.* -20° C) for storage. To prepare birds for dissection, they were transferred a 20° C laboratory refrigerator for thawing and all birds were dissected immediately upon thawing. Information, such as wildlife center, date of collection, date of processing, maturity status (adult or juvenile), biological samples taken, and observable injuries was recorded on datasheets for each specimen. An ornithological standard four-letter code (AOS 2017) was assigned to identify each species and a numeric code was assigned for each individual. Before the dissection, morphometrics, such as weight, beak length, wingspan, and tarsus length, were recorded (McLaughlin 2001).

Parasite Analysis

The dissection process proceeded by cutting through the sternum and removing internal organs for endoparasite examination. The organs examined for parasites were the trachea, esophagus, stomach, liver, kidneys, and intestines. For the stomach and intestines, each organ was separated and cut open to remove any parasites or food particles using a stir-rinse-repeat cycle within glass jars filled with tap water until a majority of the food particles were removed. The remaining contents were examined for parasites. The trachea, esophagus, liver and kidneys were separated from the body cavity. All organs were pressed between two glass plates to allow for examination under a stereomicroscope for parasites. Parasites were quantified and the location in which they were found recorded (McLaughlin 2001). Non-nematode parasites were collected and fixed in 70% ethanol with an identification tag noting the specimen number and organ sample; they were then set aside for staining and identification. The collection process for nematode parasites was the same as other endoparasites except that these specimens were fixed and stored in a 70% ethanol/30% glycerol solution.

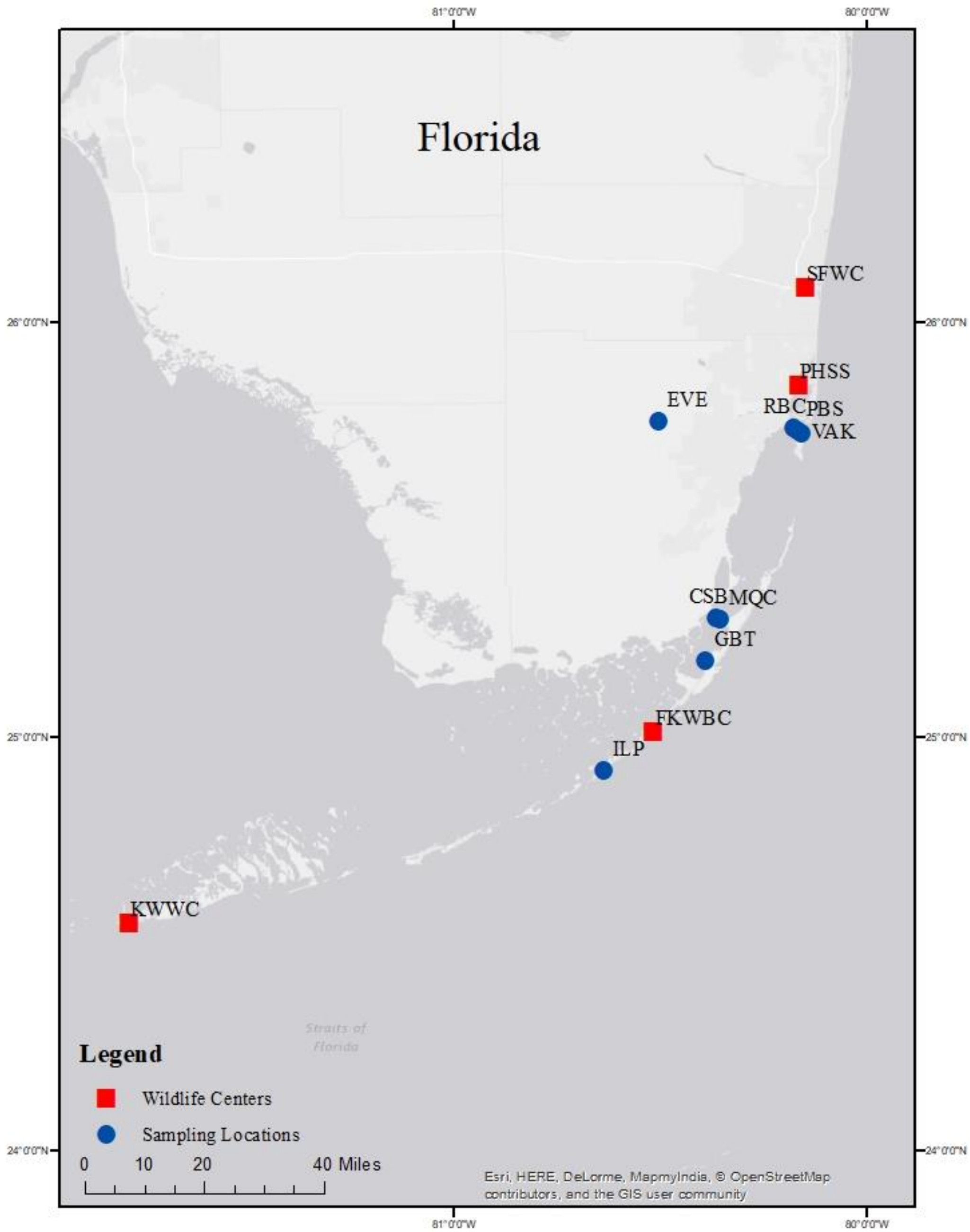

Figure 1: Map of wildlife centers and sampling locations for prey items. Wildlife centers are: South Florida Wildlife Center = SFWC, Pelican Harbor Seabird Station = PHSS, Florida Keys Wild Bird Center = FKWBC, and Key West Wildlife Center = KWWC. Prey sampling locations are Paddleboard Station (PBS), Rickenbacker Causeway (RBC) and Virginia Key (VAK), Card Sound Bridge (CSB), Mosquito Creek (MQC), Gilberts (GBT), Islamorada Library Park (ILP) and the Everglades (EVE).

Table 2: Total number of each wading bird species dissected for this study, including the size (via tarsus length) and the number of specimens obtained from each wildlife center. As this study is lacking foraging behavior observations, the tarsus length measurement is provided as a proxy for wading depth. *Analyzed for parasites only.

Species	**n**	**Tarsus Length ($\bar{x}$ ± SD; mm)**	**South Florida Wildlife Center**	**Pelican Harbor Seabird Station**	**Florida Keys Wild Bird Center**	**Key West Wildlife Center**
Great egret	18	138.55 ± 9.05	6	1	11	[none]
Great blue heron	27	176.46 ± 19.31	6	2	17	2
Green heron	9	44.4 ± 2.11	[none]	1	8	[none]
Yellow-crowned night heron	4	80.75 ± 10.21	4	[none]	[none]	[none]
Black-crowned night heron	3	80.0 ± 7.81	[none]	[none]	3	[none]
White ibis	21	82.71 ± 11.45	7	3	10	1*

All parasites except nematodes were transferred from their storage vial to an acetocarmine/70% ethanol solution for 20-30 minutes for staining, and then dehydrated through a 70%-95%-100%-100% ethanol series. After completing the dehydration process, parasites were cleared in clove oil for two to three minutes. After the parasites were removed from the oil, they were placed on a slide and any residual clove oil was removed using kimwipes (KimTech, Kimberly-Clark). Two to four drops of Eukitt or Permount mounting medium was placed over the parasites followed by a cover slip. Parasitic nematodes remained in the ethanol/glycerol solution for a minimum of two weeks to allow the ethanol to slowly evaporate. They were then removed from the solution and placed on glass slides. To form a semi-permanent slide mount, glycerine was placed over the nematodes. After parasites were mounted on the slides, they were identified to the lowest possible taxonomic level (Pritchard and Kruse 1982; McLaughlin 2001).

Stable Isotope Analysis

During the dissection process, a sample of pectoral muscle tissue was collected for stable isotope analysis. Samples were taken from the left pectoral region of the bird if no injuries were present at that location. A portion of the muscle sample was placed in a labeled tin and placed in the drying oven at 60° C for a minimum of 72 hours. A duplicate sample was labeled and stored in the laboratory freezers.

Specimens collected in the field representing wading bird potential prey items were placed in a standard freezer after fieldwork was completed. Potential prey samples were thawed, identified and recorded in laboratory notebooks. Prey items, including fish and invertebrates, were rinsed using deionized water. If it was possible, for fish samples only white muscle tissue was collected. Invertebrates had muscle removed when possible and concentrated hydrochloric acid fumed samples to remove carbonates when potentially present.

Bird muscle samples and prey items were placed in a drying oven set at 60° C for a minimum of 72 hours. Samples were ground and homogenized using a dental amalgamator (Wig-L-Bug, Crescent). Samples were homogenized prior to weighing. Muscle samples were weighed to approximately 0.6-0.8 milligrams (mg) and packaged in small tin capsules for stable carbon and nitrogen isotope analysis. Additional prey samples collected by Dr. Kerstetter were processed following the same procedure.

Stable isotope samples were sent to the Smithsonian Institution's Museum Conservation Institute in Suitland, MD for combustion and analysis of $\delta^{13}C$ and $\delta^{15}N$ isotopic values using a Thermo Delta V Advantage mass spectrometer in continuous flow mode coupled to a Costech 4010 Elemental Analyzer (EA) via a Thermo Conflo IV (CF-IRMS). A set of standards was run for every 10-12 samples. The standards included USGS40 and USGS41 (L-glutamic acid) as well as Costech acetanilide. All samples and standards were run with the same parameters; this included an expected reproducibility of the standards $\leq$ 0.2‰ (1σ) for both $\delta^{13}C$ and $\delta^{15}N$.

Stable isotope values were expressed in terms of δ and were reported in comparison to the standard reference material, Pee Dee Belemnite (PDB) for carbon and atmospheric air (N_2) for nitrogen. The isotopic values were reported with the standard parts per thousand notation (‰):

$$\delta X = [(Rsample/Rstandard)-1]*1000$$

where X is the isotope being analyzed and R is the ratio of the heavy to light isotope.

Statistical Analysis

The software package PRIMER (v. 7.0.13; PRIMER-e, Quest Research Limited) was used to analyze host morphometrics, parasite communities and stable isotope ratios. Resemblance matrices were created to show the relationship between every pair of samples based on whether the suite of recorded variables have similar or dissimilar values. A Bray-Curtis similarity matrix with a dummy variable, as some individual bird hosts had no parasites, was created for the parasite community. Euclidian distance was established for host morphometrics and stable isotope data.

Analysis of similarity (ANOSIM) was used to test for statistically significant differences among sampling units. A three-way, fully crossed design with replication was used to test for significant differences between host morphometrics and three factors: species, collection location, and maturity status. The test statistic, R, ranges from 0 to 1 and is used to measure the separation between groups of samples. Values that are closer to 0 are similar while values that are closer to 1 indicate that samples are more dissimilar. Statistical significance was evaluated at p=0.05.

Non-metric multidimensional scaling (nMDS) figures were created to show the relationship between parasite communities, analyzed at the family level, and species of wading birds. Non-metric MDS ordinations show the rank order of dissimilarities among pairs of samples; the closer the data points are to each other the more similar the parasite community. Analysis of similarity (ANOSIM) was used to test for statistically significant differences among sampling units. A three-way, fully crossed design with replication was used to test for significant differences between parasite community structure and the three factors: species, collection location and maturity status. The RELATE procedure was used to determine how closely related two sets of resemblance matrices are and was conducted for host morphometrics, parasite community, and host stable isotope values.

Prevalence and parasite component community species richness was calculated for each species within the wading bird complex. Parasite data was fourth-root transformed to downweight the contributions of quantitatively dominant species and analyzed at the genera level. A shade plot, which provides a simple visualization of parasite abundance, was used to illustrate the variation among parasite communities and wading bird species. A cluster analysis was run on both the wading bird host resemblance matrix and the parasite community matrix. Similarity profile (SIMPROF) analysis was used to identify statistically significant clusters within the dataset.

Descriptive statistics were conducted in Microsoft Excel (v. 14.7.2; Microsoft Corporation) to calculate the range, mean, and standard deviation for stable isotope ratios for wading bird data. In PRIMER principal component analysis (PCA) was used to identify patterns among bird species. Principal component analysis is an ordination method where the samples are projected onto a best-fitting plane and the new axes are defined by the principal components (PC). PCA was used to identify patterns within stable isotope ratios and species of wading birds. Cluster analysis with SIMPROF was used to identify statistically significant clusters. Analysis of similarity tested for the effect of host species, collection location, and maturity status on stable isotope values in combination. In JMP (v. 12.1.0; SAS Institute Inc.) a one-way analysis of variance (ANOVA) was used to test for the effect of stable carbon and nitrogen isotope values separately on wildlife center location and wading bird species. Tukey's HSD test was used to determine which specific groups differed. Analysis of similarity was used to test for the effect of prey type (freshwater, marine, or terrestrial) on stable isotope ratios in combination and ANOVA was used to determine the effect of prey type on stable carbon and nitrogen signatures analyzed separately (Clarke and Gorley, 2015).

Results

Specimen Collection

A total of 82 individual bird specimens belonging to two taxonomic families were sampled. The endoparasite community was examined and stable isotope samples were collected for 81 individuals. Great blue herons had the highest number of collected individuals (n=27), followed by white ibis (n=21), great egrets (n=18), green herons (n=8), yellow-crowned night herons (n=4), and black-crowned night herons (n=3) (Table 2). The distribution of bird specimens varied among the four wildlife center locations. A total of 54 specimens were collected from the island wildlife centers and 31 individual birds were collected from mainland wildlife center locations. Florida Keys Wild Bird Center contributed the most specimens (n=51), followed by South Florida Wildlife Center (n=24), Pelican Harbor Seabird Station (n=7), and Key West Wildlife Center (n=3).

Analysis of similarity for host morphometrics showed a significant difference for wading bird species (R=0.786, P=0.001) and maturity status (R=0.211, P=0.048) but no significant difference for wildlife center location (R=0, P=0.588). Host morphometrics are summarized in Appendix 2.

Potential bird prey items included amphipods, freshwater fish, marine fish, shrimp, polychaetes, insects, centipedes, reptiles, amphibians, mammals, and gastropods, and crabs. Prey was sampled from four different locations: Everglades, Florida Bay, Miami-Dade County, and Broward County.

Parasite Data

Parasites were found in 73 of the 81 specimens examined. The prevalence – the number of hosts infected with parasites divided by the number of hosts examined – was determined for each species (Table 3). Both species of night herons had the highest infection rate (100%) while the great blue herons had the lowest infection rate (85.18%). Meanwhile, great blue heron had the highest species diversity – number of distinct parasite species – (n=26), followed by great egrets (n=25); yellow-crowned night herons had the lowest species diversity (n=4).

The majority of parasites discovered were found in the intestines, followed by the stomach, esophagus and trachea. No endoparasites were observed in the liver and kidneys. Endoparasites representing four different taxa – Acanthocephala, Nematoda, Cestoda and Trematoda – were observed, collected and identified to the lowest possible taxonomic level (Appendix 3). *Ascocotyle* (34.57% infection in birds examined) and *Contracaecum* (27.16% infection in birds examined) were the two genera of parasites most abundantly found in the six wading bird species examined. *Cathaemasia nycticoracis*, *Diplostomum spathaceum*, and *Ribeiroia* sp. were the least abundant with one individual parasite for each species present within the six wading bird species examined (1.23% of birds infected). A total of 29 new host-parasite records and four geographic range extensions were noted for several parasite taxa (Appendix 4). Unfortunately, several individual cestodes could not be further identified due to the degraded condition of the specimens.

A non-metric multidimensional scaling (nMDS) of the parasite community analyzed at the family level was used to determine the relationship between parasite community structure and wading bird species (Fig. 2). Proximity of the data points indicates similarity; data points that are closer together represent individual wading birds with more similar parasite communities. Pearson Correlation vectors for parasite families are displayed. The white ibis are clustered based on the presence of Echinostomatidae, Capillariidae, and Cyclocoelidae. Great egrets and great blue herons have no distinct clustering based on their parasite community. Green herons cluster together as a host species, but have a diverse parasite community assemblage that precludes the determination of a dominant taxa.

Analysis of similarity, using a three-way, fully crossed design, was conducted to determine the effects of host species, collection location and maturity status on parasite community analyzed at the family level. Only host species showed a statistically significant effect on the parasite community (R=0.186, P=0.001). The relationship between collection location (R=0.104, P=0.097) and maturity status (R=0, P=0.601) was not significantly different. Pairwise tests showed relationships between great egrets and great blue herons (R=0.14, P=0.023), great egret and white ibis (R=0.155, P=0.049), great blue heron and white ibis (R=0.216, P=0.027), green heron and white ibis (R=0.436, P=0.04), and black-crowned night heron and white ibis (R=0.463, P=0.029) were statistically significant.

Cluster analysis combined with similarity profile analysis was used to distinguish co-occurring groups of parasites (Fig. 3). Six statistically significant clusters were identified among the six bird species. The first cluster contained parasite genera *Polycyclorchis* sp., *Capillaria* sp., *Diplostomum* sp., and *Ribeiroia* sp., which were exclusively found in the white ibis. A shade plot was used to visually demonstrate the distribution of parasite communities for the six species of wading birds. Parasites were clustered into co-occurring groups (Fig. 4). Bird host species were clustered on similarity of parasite communities; yellow-crowned night herons and black-crowned night herons have more closely related parasite communities than the other wading bird host species. Additionally, great egrets and great blue herons have more similar parasite communities than other wading bird host species.

Stable Isotope Data

A total of 81 muscle samples were analyzed for $\delta^{13}C$ and $\delta^{15}N$. The percent weight of carbon and nitrogen were analyzed for all muscle samples to determine if sample contamination or lipid content biased the results. For proteinaceous material, the hypothetical C:N is 3.0; in this study C:N was 3.80. The values of $\delta^{15}N$ for all bird tissues ranged from 6.44 to 13.48‰. The white ibis (7.49 ± 1.0‰) was the species least enriched in $\delta^{15}N$ followed by the green heron (8.27 ± 1.21‰), yellow-crowned night herons (8.71 ± 1.01‰), great egret (9.56 ± 0.84‰), black-crowned night heron (10.39 ± 2.98‰), and the great blue heron (12.11 ± 1.23‰) (Table 4; Fig. 5). The range of $\delta^{13}C$ was -33.39 to -11.66‰. The species most depleted in $\delta^{13}C$ was the green heron (-23.03 ± 6.21‰) followed by the great egret (-20.87 ± 3.85‰), white ibis (-20.76 ± 2.21‰), yellow-crowned night heron (-19.34 ± 3.44‰), great blue heron (-19.20 ± 5.54‰), and the black-crowned night heron (-18.77 ± 1.54‰) (Table 4; Fig. 5).

Stable carbon signatures and nitrogen signatures were analyzed separately for wildlife center collection location and wading bird species. Stable carbon values varied significantly among wildlife center location (R^2=0.223, P=0.0002). Post-hoc comparisons show the association between Fort Lauderdale and Tavernier (P=0.0045), Key West and Miami (P=0.0276) and Miami and Tavernier (P=0.0129) are significant. Stable nitrogen values did not have a significant effect on wildlife center location (R=0.0150, P=0.7591). With respect to bird species, $\delta^{13}C$ did not vary significantly across species while $\delta^{15}N$ did (R^2=0.604, P<0.0001). Tukey's HSD tests showed significant relationships between black-crowned night heron and white ibis (P=0.0020), great blue heron and great egret (P=0.0009), great blue heron and green heron (P<0.0001), great blue heron and white ibis (P<0.0001), great blue heron and yellow-crowned night heron (P=0.0066), and great egret and white ibis (P<0.0001).

Principal component analysis of combined $\delta^{13}C$ and $\delta^{15}N$ values revealed the variation among stable isotope profiles for the six wading bird species. The two PCA axes account for 100% of the variation. PC1 ($\delta^{13}C$) corresponds to 86.2% of the sample variation for the stable carbon isotope ratios entirely, while PC2 ($\delta^{15}N$) accounts for 13.8% of the variation and represents stable nitrogen isotope ratios entirely. Cluster analysis in combination with similarity profile analysis identified five isotopic groups of wading birds and one isolated individual (great blue heron) (Fig. 6). The great egrets fell into three of the clusters and were primarily separated based on their stable carbon signatures. The great blue herons were present within three of the clusters and one lone individual; the basis of this separation were the different stable carbon signatures and to a lesser extent the nitrogen signatures. The lone great blue heron exhibited the most depleted $\delta^{15}N$ values and the most enriched $\delta^{13}C$ values of individuals from this species. White ibis specimens were found within two of the clusters; however, the majority of this species was present in one cluster.

Analysis of similarity was used to test for the effect of wading bird species, collection location, and maturity status on the combined $\delta^{13}C$ and $\delta^{15}N$. Maturity status was not statistically significant (R=0, P=0.491), likely a result of the paucity of juvenile birds collected. Both bird species (R=0.331, P=0.001) and location (R=0.359, P=0.001) were statistically significant. As combined locations had a higher R-value than all species, it had more of an effect on the combine isotope values (Fig. 7). Pairwise tests on bird species and collection location were conducted, and the following had significant interactions: great egret and great blue heron (R=0.217, P=0.013), great egret and white ibis (R=0.189, P=0.045), great blue heron and green heron (R=0.445, P=0.003), yellow-crowned night heron and white ibis (R=0.629, P=0.033), Fort Lauderdale and Tavernier (R=0.46, P=0.001), and Fort Lauderdale and Key West (R=1, P=0.036).

To test for a correlation between the host morphometric data and the stable isotope profiles, the RELATE procedure in PRIMER was used. Stable isotope profiles were nested within species because previous morphometric analysis found a significant difference driven by wading bird species. Host morphometrics and stable isotope profiles were significantly correlated among the six species of wading birds (Rho=0.286, P=0.002).

The RELATE procedure was used to test for correlation of the parasite community structure matrix and host morphometrics and between parasite community structure and host stable isotope profile. Parasite community structure and host morphometrics were not closely related (Rho=0.164, P=0.169). However, the resemblance matrices for parasite community structure and host stable isotope profiles were closely related (Rho=0.326, P=0.01).

Potential prey items for these species of wading birds included amphibians, freshwater fishes, polychaetes, amphipods, crabs, shrimp, marine fishes, gastropods, earthworms, centipedes, terrestrial insects, reptiles, and mammals (Table 5; Fig. 8). Prey items were grouped according to prey type (freshwater, marine, or terrestrial) and ANOSIM revealed a significant effect of prey type on $\delta^{13}C$ and $\delta^{15}N$ (R=0.519, P=0.001). Both marine and freshwater (R=0.763, P=0.001) and marine and terrestrial (R=0.473, P=0.001) interactions were statistically significant, while the interaction between freshwater and terrestrial prey was not (R=0.046, P=0.282). Analysis of variance showed a significant effect for both stable carbon isotopes (R^2=0.3895, P<0.0001) and nitrogen (R^2=0.2314, P<0.0001).

Discussion

The feeding ecology, trophic interactions, and movements of wading birds are of significant interest because of their ecologically important role in coastal ecosystems. They redistribute nutrients within their environments by importing energy and biomass into marine and land ecosystems through food scraps, carcasses, feathers and guano (Powell *et al.* 1991, Polis and Hurd 1996, Frederick *et al.* 2009). As wading birds typically occupy the top of the food web, predating on invertebrates and small fishes, they can serve as sentinel species indicating the ecological health of their environment (Schreiber and Burger 2001).

Opportunisty collection of wading bird specimens did not allow for the desired sample size. For all species, with the exception of the yellow-crowned and black crowned night herons, species accumulation curves showed a sufficient number of individuals had been examined to allow for the majority of parasite richness in the system to be captured. Analysis of species richness, within the parasite community indicated the community was linked to sample size and was under sampled for some species within this study. With respect to mean species richness, sample size was adequate for robust analysis. When comparing individual samples on a bird-by-bird basis, the results of the RELATE procedure showed stable isotope profiles and parasite community structure were directly linked.

Parasites

Endoparasites were predominantly found in the gastrointestinal tract within the wading birds examined. Class Cestoda could not be taxonomically further identified as they tend to lose rostellar hooks, fragment easily when thawed, and both scolex and mature proglottids were rarely observed within the bird's intestines (McLaughlin 2001). The parasite community structure was analyzed against three different factors (wading bird species, wildlife center location, and maturity status), but only the relationship between wading bird species and parasite community was significant.

Table 3: Wading birds examined for endoparasites. Prevalence (number of hosts infected with parasite species divided by the number of hosts examined), parasite component community species richness (number of species of parasites; S) and mean species richness (MSR) is given.

Species	**n**	**Prevalence (%)**	**Community species richness (S)**	**Mean species richness (MSR; $\bar{x} \pm$ SD)**
Great egret	18	94.44	25	3.17 ± 1.98
Great blue heron	27	85.18	26	3.00 ± 2.60
Green heron	9	88.9	15	3.67 ± 2.45
Yellow crowned night heron	4	100	4	1.75 ± 0.50
Black crowned night heron	3	100	8	3.00 ± 1.00
White ibis	21	90.48	16	1.76 ± 1.09

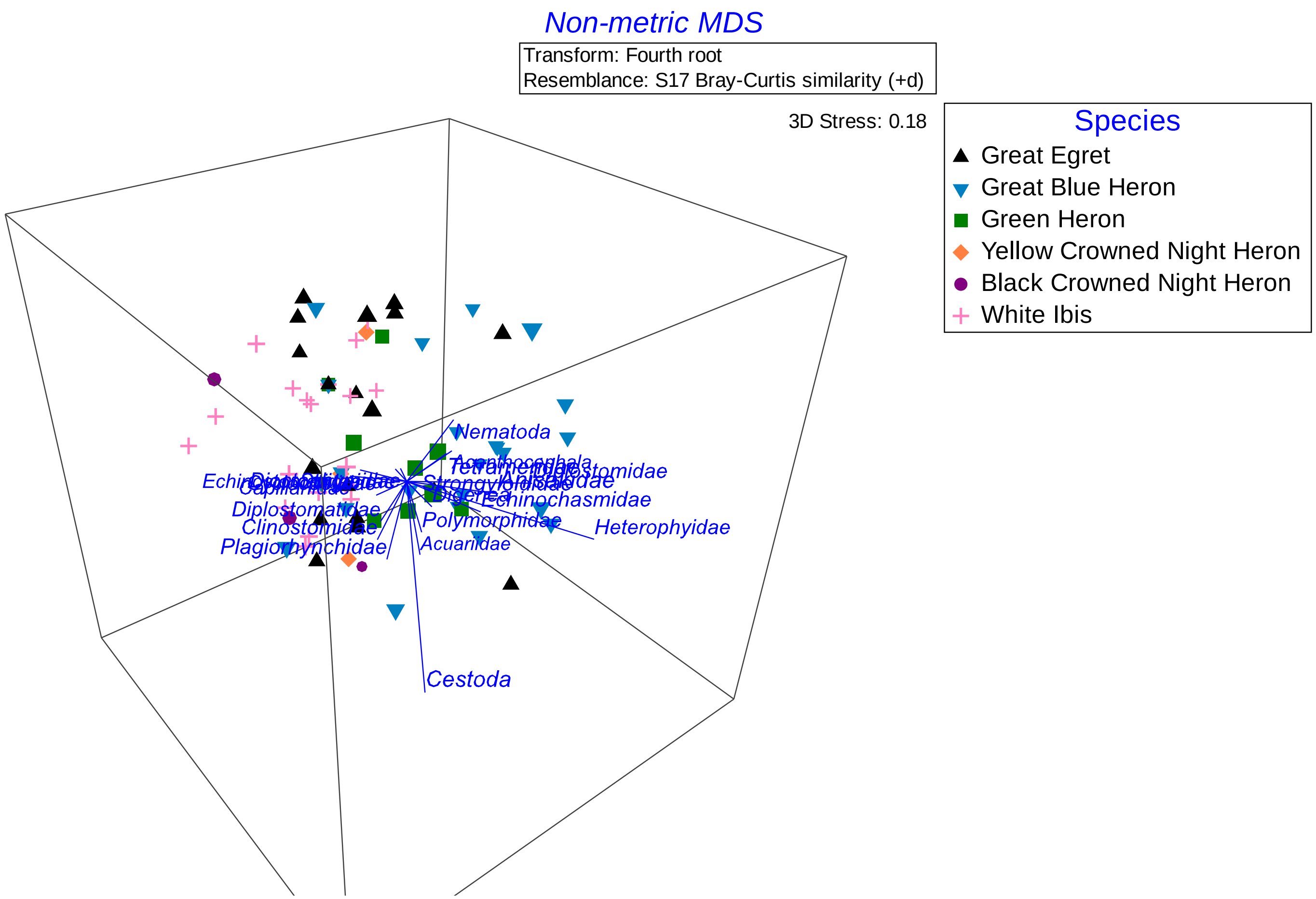

Figure 2. Non-metric multidimensional scaling (nMDS) ordination of the parasite community analyzed at the family level. Individual data points correspond to individual host birds. Proximity of data points indicates similarity. Pearson Correlation vectors for parasite taxa are displayed.

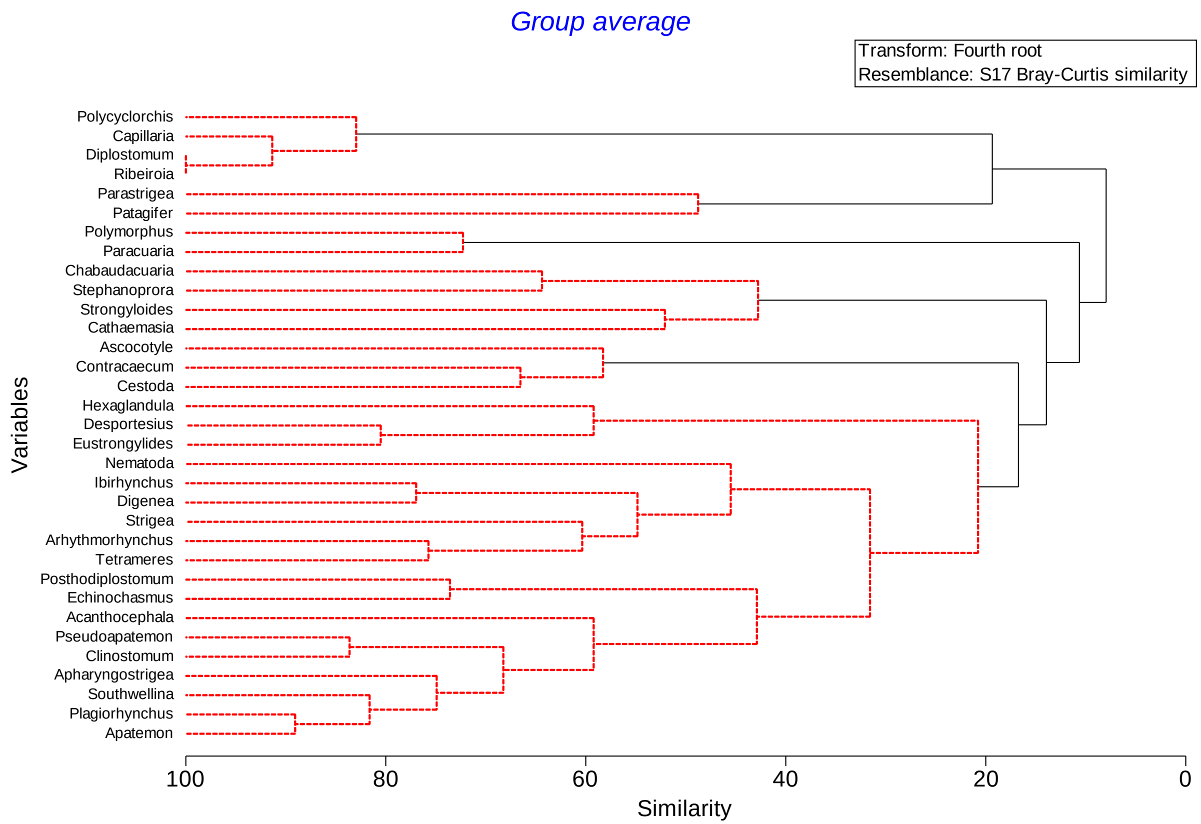

Figure 3. Cluster analysis with similarity profile analysis to identify co-occurring groups of parasites. Parasite groups are clustered together based on the likelihood genera were likely found together within the six species of wading birds. Parasite community was analyzed at the genus level and was fourth root transformed. Samples connected by red lines are not significantly different, while the black lines represent statistically significant groups based on hierarchical cluster analysis ($p < 0.05$). Six statistically significant clusters of parasites were identified. The first cluster contained parasite genera *Polycyclorchis* sp., *Capillaria* sp., *Diplostomum* sp., and *Ribeiroia* sp., which were exclusively found in the white ibis.

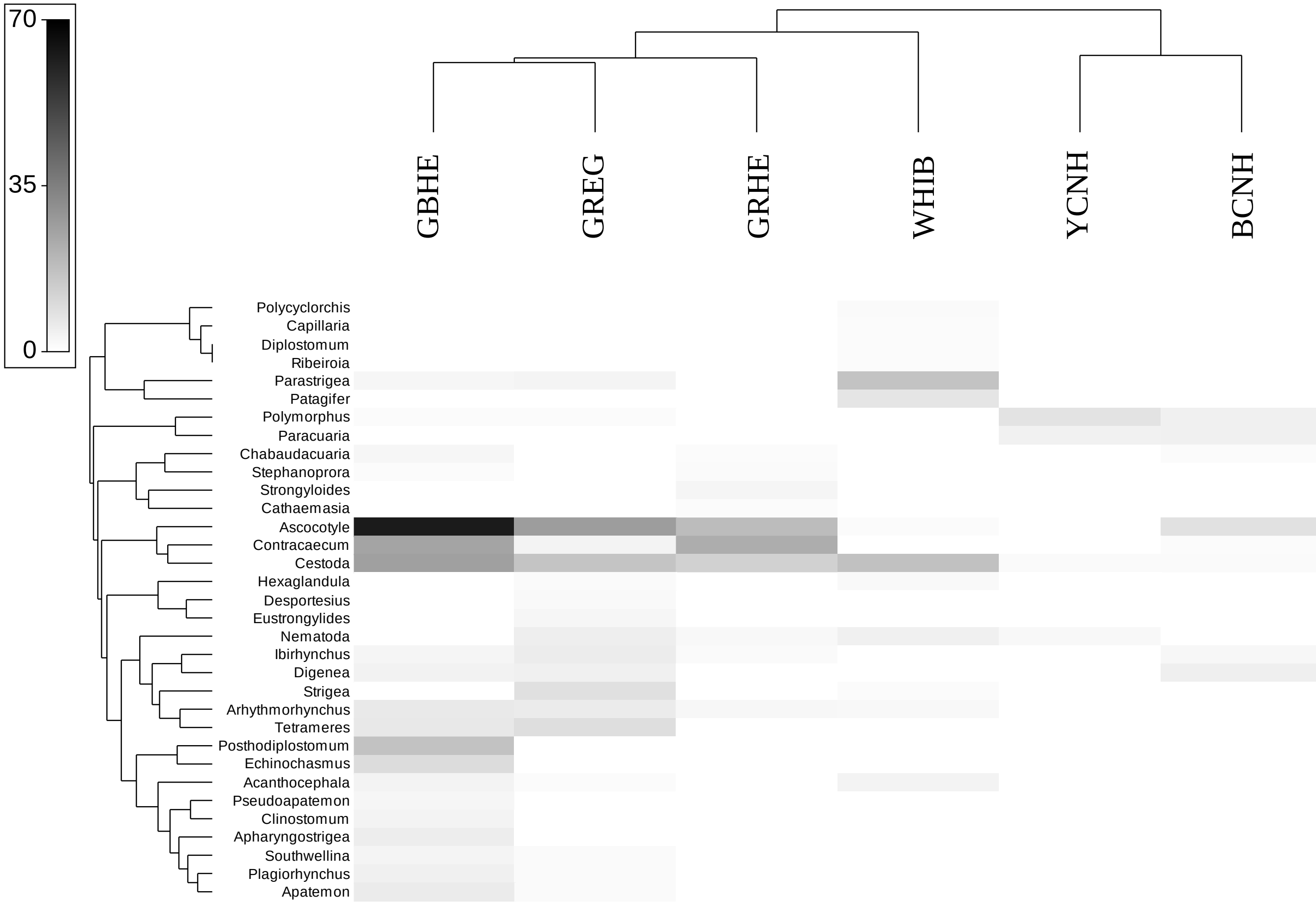

Figure 4. Shade plot illustrates the distribution of the parasite community structure, fourth root transformed, and analyzed at the genus level across six species of wading birds. Bird host species are clustered by the similarity of their parasite communities. Parasites are clustered into co-occurring groups based on likelihood parasites were found together (see Fig. 3). GBHE = great blue heron, GREG = great egret, GRHE = green heron, WHIB = white ibis, YCNH = yellow-crowned night heron, and BCNH = black-crowned night heron.

Table 4: Species, total number (n), mean ($\bar{x}$), standard deviation (SD) and range of $\delta^{15}N$ and $\delta^{13}C$ for pectoral muscle.

Species	**n**	**$\delta^{15}N$**		**$\delta^{13}C$**	
		$\bar{x}$ ± SD (‰)	**Range (‰)**	**$\bar{x}$ ± SD (‰)**	**Range (‰)**
Great Egret	18	9.56 ± 0.84	8.17 to 11.24	-20.87 ± 3.85	-26.64 to -14.33
Great Blue Heron	27	12.11 ± 1.23	8.54 to 13.48	-19.20 ± 5.54	-28.15 to -11.66
Green Heron	9	8.27 ± 1.21	6.62 to 9.97	-23.03 ± 6.21	-33.39 to -14.79
Yellow-Crowned Night Heron	4	8.71 ± 1.01	7.50 to 9.96	-19.34 ± 3.44	-23.48 to -15.07
Black-Crowned Night Heron	3	10.39 ± 2.98	6.96 to 12.31	-18.77 ± 1.54	-20.52 to -17.67
White Ibis	20	7.49 ± 1.00	6.44 to 10.62	-20.76 ± 2.21	-24.54 to -17.14

Table 5: Prey type, total number (n), mean (x̄), standard deviation (SD) and range of $\delta^{15}N$ and $\delta^{13}C$ for prey samples are given for muscle or whole organism. *Moquitofish (*Gambusia holbrooki*) were captured in both freshwater and saltwater sampling locations.

Prey Type	**n**	**$\delta^{15}N$** x̄ ± SD (‰)	**Range (‰)**	**$\delta^{13}C$** x̄ ± SD (‰)	**Range (‰)**
FRESHWATER PREY					
Amphibian	3	5.38 ± 1.32	4.06 to 6.71	-21.77 ± 0.21	-21.97 to -21.55
Greenhouse Frog (*Eleutherodactylus planirostris*)					
Freshwater Fishes	6	7.24 ± 1.25	5.54 to 8.51	-27.09 ± 1.70	-29.04 to -24.06
*Mosquitofish (*Gambusia holbrooki*)	1	6.39		-26.96	
Mayan cichlid (*Cichlasoma urophthalmus*)	1	8.43		-28.20	
Oscar (*Astronotus ocellatus*)	1	5.54		-29.04	
Pumpkinseed (*Lepomis gibbosus*)	1	8.40		-26.85	
Smallmouth bass (*Micropterus dolomieu*)	2	7.89 ± 0.74	7.46 to 8.51	-25.74 ± 2.38	-27.42 to -24.06
MARINE PREY					
Polychaetes	4	8.27 ± 0.52	7.73 to 8.88	-17.57 ± 1.86	-19.54 to -14.03
Amphipods	3	6.54 ± 2.53	3.67 to 8.44	-19.14 ± 4.44	-23.05 to -14.32
Crabs	9	7.76 ± 2.52	3.82 to 10.50	-16.49 ± 1.77	-19.54 to -14.03
Mangrove crab (*Aratus pisonii*)	3	9.08 ± 0.63	8.59 to 9.80	-15.73 ± 1.08	-16.98 to -15.09
Sargassum crab (*Portunis sayi*)	3	4.64 ± 0.72	3.82 to 5.18	-18.44 ± 1.21	-19.54 to -17.15

Spider crab (*Libinia emarginata*)	3	9.56 ± 1.55	7.78 to 10.50	-15.29 ± 1.10	-16.08 to -14.03
Shrimp	12	6.55 ± 2.00	3.30 to 8.99	-17.42 ± 1.79	-19.31 to -13.84
Unidentified shrimp	2	7.60 ±0.70	7.10 to 8.09	-19.19 ± 0.16	-19.31 to -19.08
Farfantepenaeus sp.	1	8.64		-17.51	
Sargassum shrimp (*Laterutes fucorum*)	3	3.61 ± 0.54	3.30 to 4.24	-18.64 ± 0.24	-18.82 to -18.37
Brown grass shrimp (*Leander tenuicornis*)	3	6.37 ± 0.30	6.11 to 6.70	-17.72 ± 0.57	-18.06 ± -17.06
Penaeus sp.	3	8.26 ± 0.92	7.23 to 8.99	-14.70 ± 0.75	-15.24 to -13.84
Marine Fishes	74	9.18 ± 1.67	5.90 to 12.56	-15.64 ± 3.19	-25.28 to -10.03
*Mosquitofish (*Gambusia* sp.)	11	8.26 ± 0.74	7.38 to 9.37	-19.23 ± 4.62	-25.28 to -12.67
Sailfin molly (*Poecilia latipinna*)	3	9.44 ± 1.53	7.54 to 11.97	-14.96 ± 1.98	-14.50 to -12.81
Unidentified grunt (Family Haemulidae)	10	10.11 ± 1.53	7.54 to 11.97	-14.96 ± 1.98	-17.86 to -12.41
Sheepshead (*Archosargus probatocephalus*)	10	10.45 ± 1.79	7.17 to 12.56	-13.69 ± 1.44	-16.24 to -11.50
Mojarra (Family Gerreidae)	20	9.20 ± 1.59	6.46 to 11.99	-15.27 ± 2.86	-24.20 to -10.03
Bay anchovy (*Anchoa mitchilii*)	9	7.73 ± 1.32	5.90 to 10.20	-13.75 ± 1.93	-17.80 to -11.39
Rainwater killifish (*Lucania parva*)	1	7.57		-13.01	
White mullet (*Mugil curema*)	3	8.50 ± 0.82	7.64 to 9.28	-15.63 ± 0.19	-15.84 to -15.48
Atlantic silverside (*Menidia mendia*)	3	11.71 ± 0.45	11.26 to 12.16	-19.02 ± 0.29	-19.19 to -18.69
Scaled sardine (*Harengula jaguana*)	3	7.98 ± 0.79	7.29 to 8.69	-17.89 ± 0.48	-18.38 to -17.41

Spanish sardine (*Sardinella aurita*)	1	9.14		-17.50	
TERRESTRIAL PREY					
Gastropod	5	6.56 ± 3.05	3.22 to 9.23	-18.17 ± 6.61	-26.83 to -13.15
Cuban brown snail (*Zachrysia provisoria*)	1	3.26		-23.81	
Florida flat coil snail (*Polygyra septemvolva*)	1	3.22		-26.83	
Striped false limpet (*Siphonaria pectinata*)	3	8.78 ± 0.41	8.34 to 9.23	-12.41 ± 0.25	-13.64 to -13.15
Earthworm	1	0.76		-23.27	
Centipede	2	5.19 ± 0.50	4.84 to 5.55	-19.91 ± 0.29	-20.11 to -19.70
Florida blue centipede (*Hemiscolopendra marginata*)					
Terrestrial insect	11	4.90 ± 3.78	1.90 to 12.38	-19.18 ± 4.95	-26.76 to -12.98
Florida wood roach (*Eurycotis floridana*)	2	3.09 ± 0.23	2.93 to 3.26	-24.47 ± 0.12	-24.55 to -24.40
European chafer beetle (*Rhizotrogus majalis*)	2	3.86 ± 0.60	3.44 to 4.29	-13.66 ±0.96	-14.33 to -12.98
Rice beetle (*Dyscinetus morator*)	4	2.50 ± 0.66	1.90 to 3.28	-16.67 ± 3.67	-21.74 to -13.20
Flesh fly (*Sarcophaga crassipalpis*)	2	12.28 ± 0.14	12.19 to 12.38	-20.62 ± 0.01	-20.63 to -20.62
Housefly (*Musca domestica*)	1	5.45		-26.76	
Reptile	4	7.08 ± 1.01	5.95 to 8.10	-22.68 ± 1.53	-23.72 to -20.40
Brown anole (*Anolis sagrei*)	2	7.02 ± 1.52	5.95 to 8.10	-21.86 ± 2.07	-23.33 to -20.40
Indo-Pacific gecko	2	7.14 ± 0.86			

(*Hemidactylus garnotii*)					
Mammal	9	6.65 ± 1.68	3.90 to 9.09	-21.57 ± 2.62	-23.85 to -16.28
Gray squirrel (*Sciurus carolinensis*)	5	6.05 ± 1.89	3.90 to 8.32	-21.41 ± 0.49	-23.85 to -22.75
Eastern wood rat (*Neotoma floridana*)	4	7.39 ± 1.91	6.38 to 9.09	-19.27 ± 2.29	-21.52 to -16.28

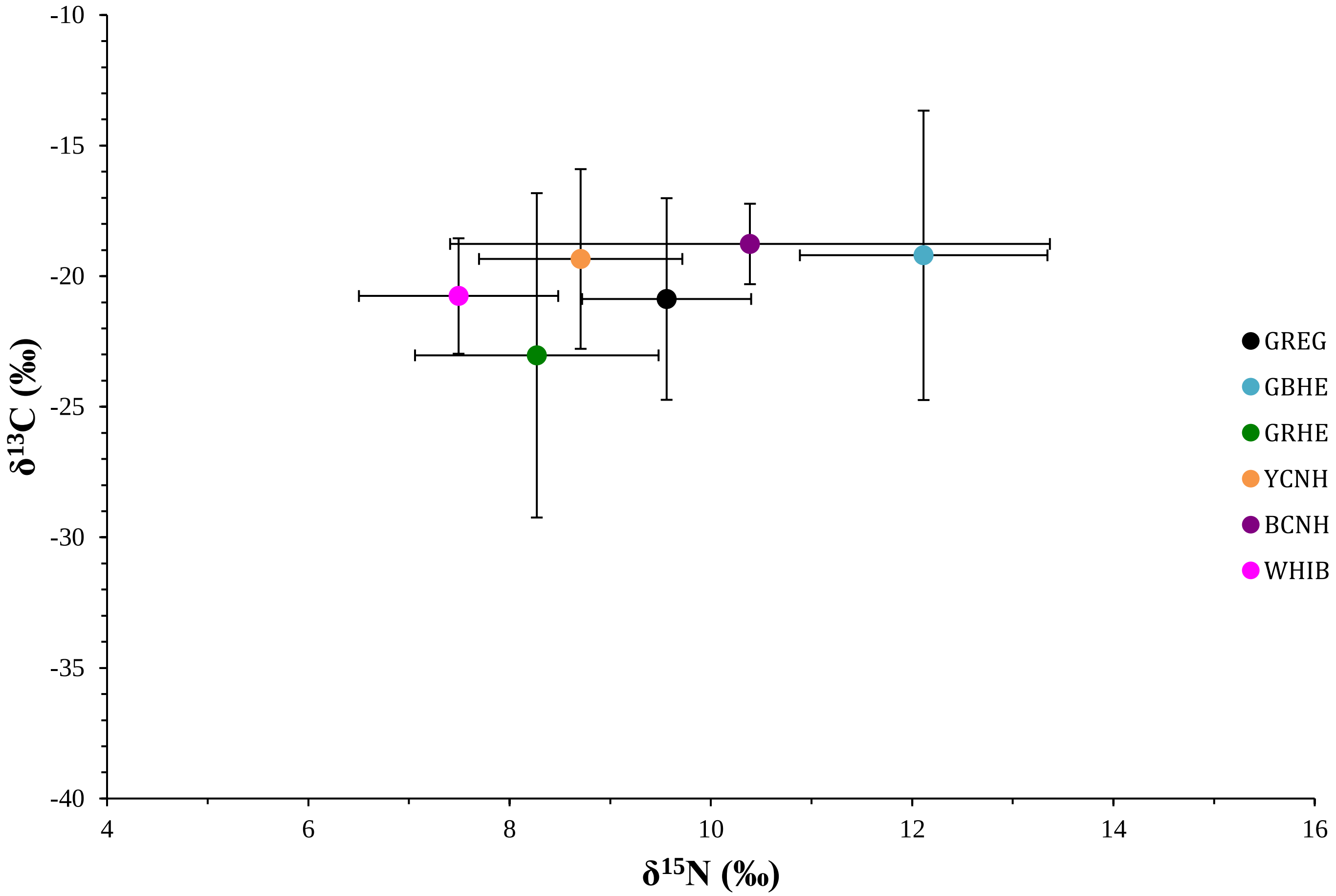

Figure 5. Mean and standard deviation of muscle stable carbon and nitrogen isotope ratios for six species of wading birds; GREG = great egret, GBHE = great blue heron, GRHE = green heron, YCNH = yellow-crowned night heron, BCNH = black-crowned night heron, and WHIB = white ibis.

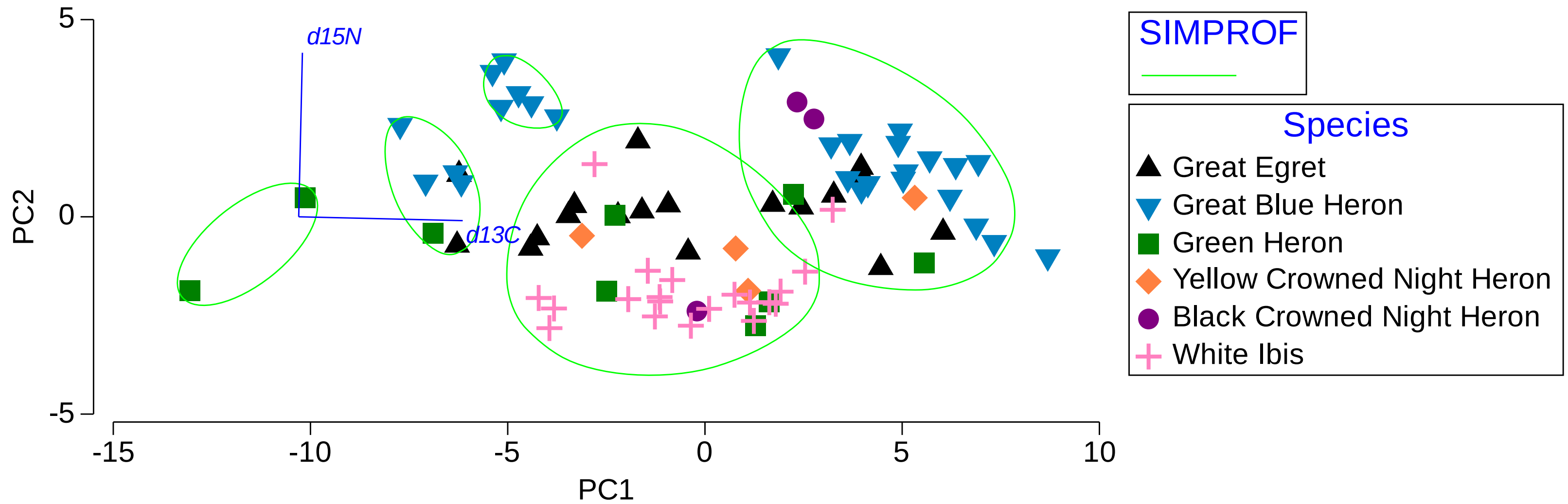

Figure 6. Principal component analysis of muscle stable carbon and nitrogen isotope ratios. Data points represent individuals for each wading bird species. Cluster analysis combined with similarity profile analysis (SIMPROF) identified significant clusters within the stable isotope dataset represented by the green circles.

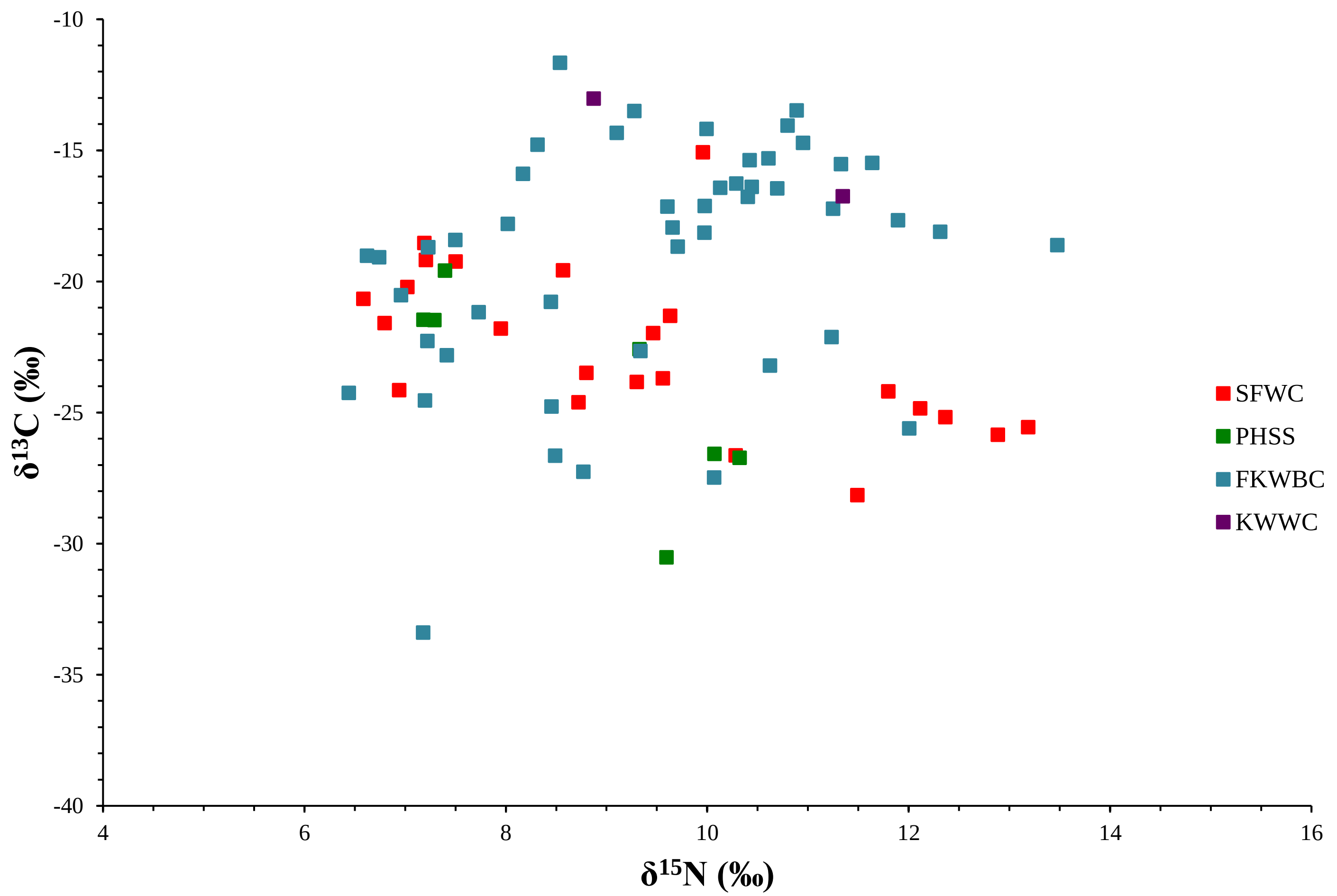

Figure 7. Muscle stable carbon and nitrogen isotope ratios for individual wading birds by wildlife center collection location; SFWC = South Florida Wildlife Center in Fort Lauderdale, PHSS = Pelican Harbor Seabird Station in Miami, FKWBC = Florida Keys Wild Bird Center in Tavernier, and KWWC = Key West Wildlife Center in Key West.

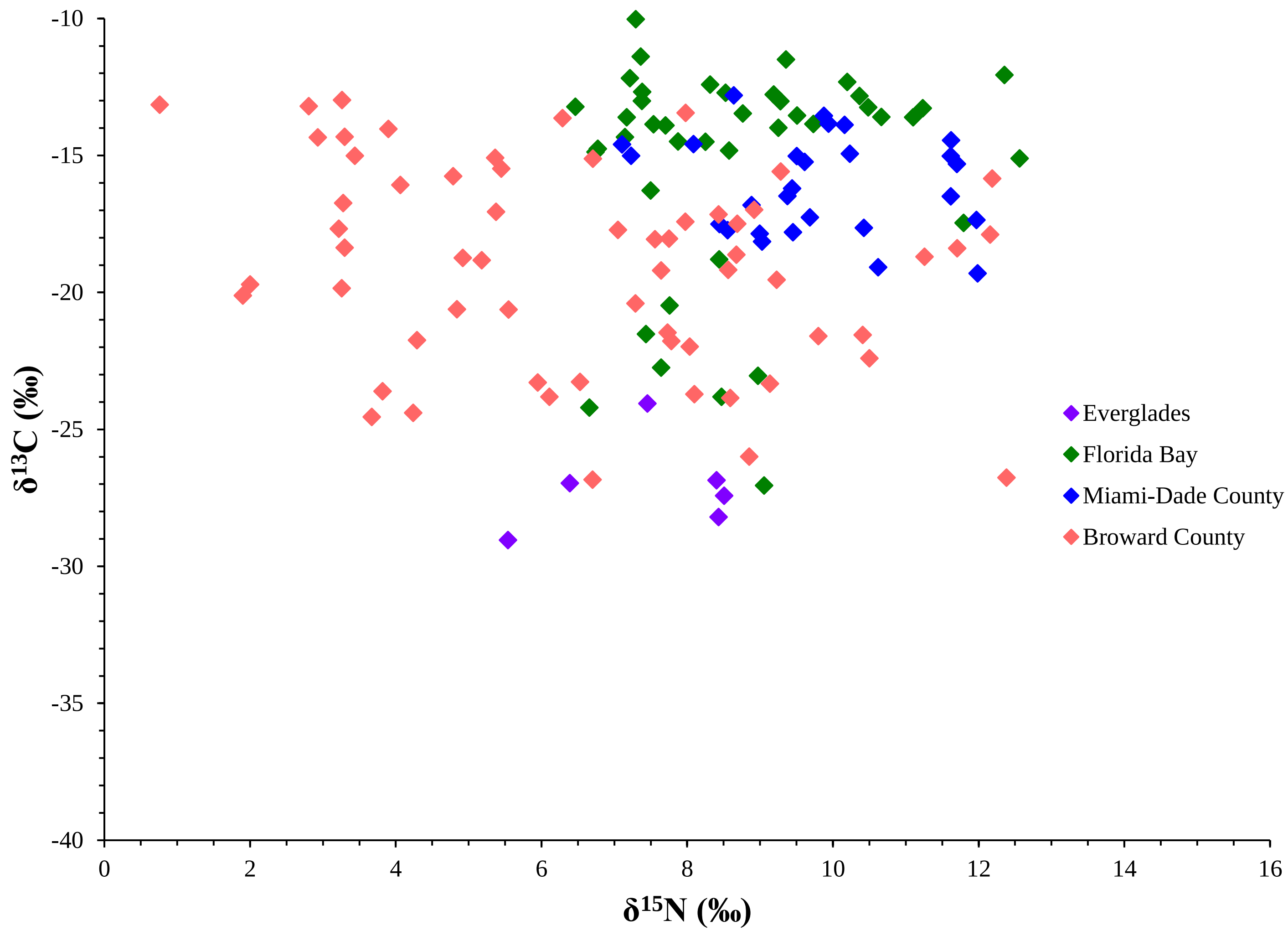

Figure 8. Stable carbon and nitrogen isotope ratios for potential prey items (muscle or whole organism) by collection location.

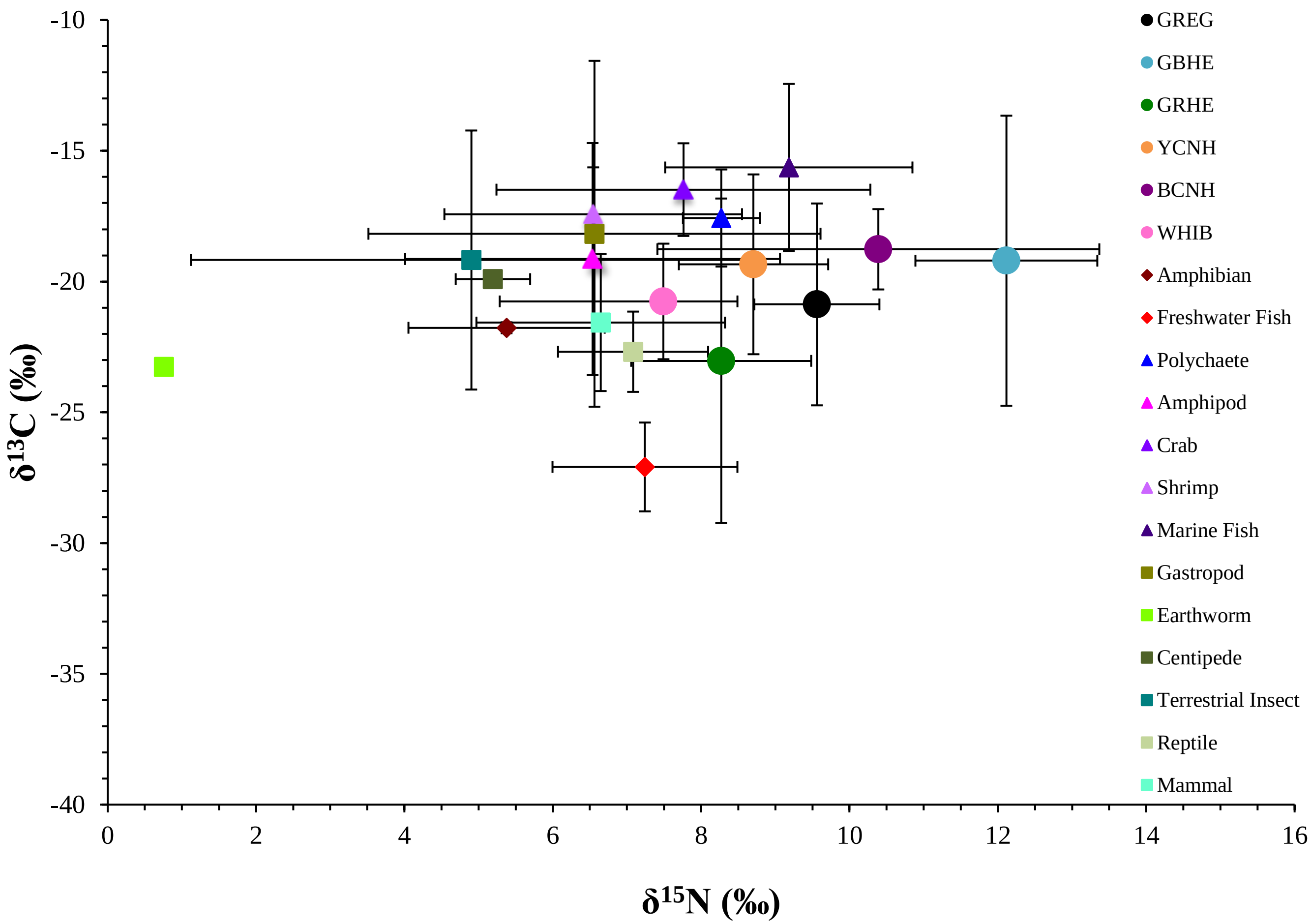

Figure 9. Mean and standard deviation (muscle or whole organism) of wading bird and potential prey stable carbon and nitrogen isotope ratios. Wading bird species (represented by circles); GREG = great egret, GBHE = great blue heron, GRHE = green heron, YCNH = yellow-crowned night heron, BCNH = black-crowned night heron, and WHIB = white ibis. Diamonds represents freshwater prey; triangles represent marine prey; and squares represent terrestrial prey.

Maturity status and parasite community, as well as $\delta^{13}C$ and $\delta^{15}N$ combined, were not significantly related. This was likely due to maturity status sample size; not all of the six species of wading birds were represented at the juvenile level. Dietary preferences may also have been similar for both adults and juveniles. McLaughlin (2001) noted young birds typically acquired the same parasite species as adults.

No significant relationship between parasite community and collection location was found. As the transmission of endoparasites is predominately associated with food web interactions, it is likely that individuals within each species of the wading bird complex have a similar diet throughout the South Florida region.

Ascocotyle and *Contracaecum* were the two genera of parasites most abundantly found in the six wading bird species examined. These parasite taxa are generalists and are commonly found in fish-eating birds due to many fish species serving as intermediate hosts (Scholz *et al.* 1997; Anderson *et al.* 2009; Shamsi *et al.* 2009; Drago and Lunaschi 2011; Scholz *et al.* 2011). The presence of these two parasite taxa lends support that fishes are an important component of the wading bird diet, especially for the great egret, great blue heron, and the green heron. *Ascocotyle* and *Contracaecum* were found in high abundances in these host species. Parasite species within the Strigeidae family were found in lower abundances in all bird species except the white ibis. The life cycle for members of the Strigeidae family, particularly *Parastrigea* sp., typically involves a reptile or an amphibian as intermediate host. Due to the high abundance of this family represented within ibis specimens, reptiles and amphibians are potentially an important component of the ibis diet. The low abundance of this family within the remaining wading bird species suggests less dietary importance for these prey items in South Florida. While parasite complexes within individual birds offer insight into diet, the number and mass of the different parasite taxa were insufficient for stable isotope analysis, a mechanism to study trophic interaction.

<u>Diet</u>

The location of the four wildlife centers, two in the Florida Keys and two on the Florida peninsula, showed regional differences based on combined analysis of $\delta^{13}C$ and $\delta^{15}N$. The bird muscle $\delta^{13}C$ ranged from -33.39 to -11.66‰, indicating that these six species of wading birds likely feed across a variety of environments as variation in $\delta^{13}C$ signatures varied among geographic locations. Each of the bird species could likely access a diversity of environments.

In freshwater ecosystems, $\delta^{13}C$ varies widely depending on the source of dissolved CO_2 in the water; $\delta^{13}C$ signatures can be influenced by carbonate rock weathering, mineral springs, input from the atmosphere, or from respired organic matter. The $\delta^{13}C$ for dissolved inorganic carbon may approach -20‰ when respired organic matter inputs are strong (Peterson and Fry 1987). Proximity of the Everglades and adjacent wetlands could provide a rich source of depleted carbon.

Differences in $\delta^{13}C$ signatures also result from the photosynthetic pathways of the plants (Smith and Epstein 1971, O'Leary 1981, Peterson and Fry 1987). The $\delta^{13}C$ of C_3 plants average -28‰ while C_4 plants, mainly tropical plants and salt grasses, are approximately -13‰ (Peterson and Fry 1987). Great blue herons were the only species, with individuals from the Florida Keys, to exhibit enriched $\delta^{13}C$ that could be found in a C_4 based food web (Figs. 5 and 7).

More enriched $\delta^{13}C$ signatures were observed in wading birds obtained from the Florida Keys wildlife centers as opposed to specimens obtained from mainland centers; this is likely due to the presence of seagrass beds and their associated $\delta^{13}C$ signatures found within the Florida Keys National Marine Sanctuary (FKNMS) (Fig. 7). Previous studies have shown more enriched $\delta^{13}C$ values in seagrasses compared to other types of marine producers. Fourqurean *et al.* (2005) assessed the $\delta^{13}C$ of *Thalassia testudinum* collected throughout the FKNMS and obtained values ranging from -13.5‰ to -5.2‰. In additional examination of stable carbon signatures of three species of seagrasses in South Florida, Campbell and Fourqurean (2009) noted average $\delta^{13}C$ of -6.2‰ for *Syringodium filiforme*, 8.6‰ for *Thalassia testudinum*, and -10.6‰ for *Halodule wrightii*. Furthermore, their study showed that seagrasses within the FKNMS sites that were in close proximity to terrestrial dissolved inorganic carbon sources displayed the most enriched $\delta^{13}C$.

Bird $\delta^{13}C$ indicates a latitudinal trend of more enriched $\delta^{13}C$ in the Florida Keys to more depleted values moving northward to Fort Lauderdale (Fig. 7). The island wildlife centers are dominated by a marine-based food web while the more northern locations have greater access to freshwater and terrestrial sources for food. The eastern half of both Miami-Dade (Miami) and Broward (Fort Lauderdale) counties are cross-hatched with freshwater rivers and canals that are readily occupied by all six of these bird species.

The large range in $\delta^{13}C$ signatures is likely due to variations in production. In their trophic structure study of Florida Bay, Chasar *et al*. (2005) noted a gradient in stable carbon signatures across the bay, which was indicative of a shift from a strong benthic signal (enriched in $\delta^{13}C$) in lower Biscayne Bay and interior Florida Bay to a phytoplankton-based food web (depleted $\delta^{13}C$) along the western edge of the bay. This shift in $\delta^{13}C$ in estuaries along a gradient from seagrass beds towards more open marine environments results primarily from a shift in the dependence of consumers from a benthic to planktonic production (Chanton and Lewis 2002, Chaser *et al.* 2005). The $\delta^{13}C$ from wading birds collected from wildlife centers in the Florida Keys are more enriched than birds from mainland centers and are similar to $\delta^{13}C$ of consumers collected by Chaser *et al.* (2005) from lower Biscayne Bay and interior Florida Bay (Fig. 7).

Stern *et al.* (2007) examined the source and turnover rates of carbon in the Florida Everglades using stable and radiocarbon isotopic contents of dissolved organic carbon, particulate organic carbon and dissolved inorganic carbon. The $\delta^{13}C$ from dissolved organic carbon displayed increasingly depleted values with increasing distance from the Everglades Agricultural Area. The depletion of $\delta^{13}C$ is reflective of a diminished contribution of sugarcane agriculture and an increase in the contribution of wetland vegetation to the dissolved organic carbon pool. The $\delta^{13}C$ of birds collected from the South Florida Wildlife Center in Fort Lauderdale have similar values to those of dissolved organic carbon collected in the Everglades National Park.

The white ibis, and potentially other species within this study, are known to opportunistically forage on garbage (Dorn *et al.* 2011). It is possible the variation in stable carbon signatures observed within this wading bird complex may be due to consumption of garbage. It is difficult to determine the impact of garbage on wading bird diet as stable isotope values are difficult to predict and are expected to be diverse. Hobson (1987) used $\delta^{13}C$ to examine the contribution of marine and terrestrial protein to the diet of gulls (*Larus* spp.). Determining terrestrial contributions to the North American gull diet was difficult to establish because garbage contains a broad spectrum of food types.

However, it is doubtful that sewage outfalls had little impact on the variation in $\delta^{13}C$. If anthropogenic inputs had an impact on stable isotope signatures, enrichment in $\delta^{15}N$ due to increases in ammonium and nitrate concentrations within the environment would be noted (McClelland *et al.* 1997, Fry 2006). While the variations in $\delta^{13}C$ are likely explained by differences in primary production, the lack of significant differences among bird species may also be due to the imbalanced demise and collection of the six bird species.

Since there was less variation in $\delta^{15}N$, this suggests that the six species of wading birds were feeding at the same or similar trophic levels. The $\delta^{15}N$ values spanned from 6.44 to 13.48‰, a 7.04‰ spread across all wading bird species. Assuming a 3-4‰ increase in $\delta^{15}N$ per trophic level, the individual wading birds were likely feeding across one to two trophic levels (DeNiro and Epstein 1981). The $\delta^{15}N$ was significantly different among bird species but not wildlife centers. Great blue herons were significantly enriched compared to all other species of birds except the black-crowned night herons. This suggests trophic overlap between these two species and the great blue herons were foraging at a trophic level higher than the remaining bird species (Fig. 5).

White ibis was significantly different from great egrets, black-crowned night herons, and great blue herons. Mean $\delta^{15}N$ differences between the white ibis and great egret (Δ = 2.07‰), black-crowned night heron (Δ = 2.9‰), and great blue heron (Δ = 4.62‰) indicate a trophic separation between the white ibis and these three bird species (DeNiro and Epstein 1981). White ibis are tactile feeders that forage on small fish and crustaceans in shallow waters (Frederick *et al.* 2009). The ibis foraging tactics include probing into the water or soil with their bill held 1-2 cm open at the bill tip (Kushlan 1975, Kushlan 1979). Since the size and shape of the bird's beak are a major factor in prey selection, the narrow opening of the ibis bill allows for small, lower trophic level prey items to be consumed (Proctor and Lynch 1993). As the size and shape of the ibis bill differs from that of the great egret, black-crowned night heron, and great blue herons, this is likely a contributing factor to the trophic separation between the ibis and these three species. Pairwise tests of $\delta^{13}C$ and $\delta^{15}N$ showed a large difference between the most enriched bird species, the great blue heron, and the most depleted species, the white ibis.

Few studies have evaluated the impact of euthanasia methods on stable isotope ratios. Atwood (2013) compared the impacts of five, well-known euthanasia methods on stable isotope ratios in larval wood frogs; no significant difference was detected in $\delta^{13}C$ or $\delta^{15}N$ based on the method of euthanasia.

Wading Birds

Wading birds can be found across a variety of habitats in southeast Florida, ranging from inland to coastal waters and wetlands to dry biomes. The great blue herons in this study separate into two distinct groups on the basis of their carbon isotope signatures, suggesting that the great blue herons are feeding in two distinct geographic locations. One group of herons, collected exclusively from the island wildlife centers, had $\delta^{13}C$ values similar to that of marine fishes, while the other great blue heron group had $\delta^{13}C$ values similar to those of freshwater fishes collected from the Everglades. These great blue heron specimens were exclusively from mainland wildlife center locations minus two individuals from Tavernier. As great blue herons typically forage in tidal flats, this implies that great blue herons in this study use both freshwater and marine environments for foraging.

The great blue herons had the most enriched $\delta^{15}N$ values of the birds in this study and they ranged approximately 5‰, indicating their diet spans nearly two trophic levels (Table 4, Fig 5). Great blue herons are the largest species of heron within North America, and the largest species within this study, with a body mass more than twice the size of any other species of heron (Butler 1999). Since the overall size and shape of the bill reflects the physical demands of the bird's diet and the great blue heron is the largest heron species, this allows the great blue herons to eat larger prey items located at higher trophic levels (Proctor and Lynch 1993). The high abundance of *Ascocotyle* sp. and *Contracaecum* sp. also confirm that both freshwater and marine fishes are a major component of the great blue heron diet as these parasites are commonly found in fish-eating birds (Scholz *et al.* 1997; Anderson *et al.* 2009; Shamsi *et al.* 2009; Drago and Lunaschi 2011; Scholz *et al.* 2011).

Great egrets, green herons and white ibis had $\delta^{15}N$ values spanning 3-4‰, indicative of foraging predominately in one trophic level. White ibis were the most depleted of the six species. As no *Ascocotyle* sp., *Contracaecum* sp., or *Paracuaria aduncta*, which are all common parasites of fish-eating birds, were found within ibis specimens, this lends support to ibis feeding on lower trophic level organisms within their food web.

Stable carbon isotope values for great egrets and green herons spanned a large range and did not cluster into groups, suggesting these birds feed in a variety of environments. The white ibis $\delta^{13}C$ had little variability, suggesting these birds fed in a similar geographic location. Though their stable carbon signatures were not similar to either marine or freshwater fishes, other potential terrestrial prey items, such as apple snails, crayfish, and water beetles are possibilities (Kushlan and Kushlan 1975).

The two species of night herons had the highest percent infection of parasites (100%). Species of Acanthocephala were found in high abundances within the night herons. As their intermediate hosts are commonly crustaceans, this suggests crustaceans are a component of the night heron diet (McDonald 1988). Cluster analysis shows how dissimilar parasite communities of both the black-crowned night heron and yellow-crowned night heron were from the other wading bird host species (Fig. 4). *Paracuaria aduncta* was a commonly occurring parasite in both night heron species and was not present in any other species of wading bird. The intermediate host for *Paracuaria aduncta* is unknown, although this species is a common parasite among fish-eating birds (Wong and Anderson 1982). The presence of *Paracuaria aduncta* indicates that certain species of fish are an important component of the night heron diet, and likely not in the diet of the remaining bird species. The narrow range in $\delta^{13}C$ of black-crowned night herons indicated foraging in a similar habitat while the narrow range of yellow-crowned night heron $\delta^{15}N$ signifies feeding within one trophic level. As the black-crowned night heron carbon values ewre between those of C3 (-28‰) and C4 (-13‰) plants, it is likely the herons foraged in a variety of environments (Peterson and Fry 1987).

Conclusion

Foraging, parasitology, and stable isotope studies on wading birds have not been thoroughly conducted and, with the exception of Frederick *et al.* (1999) and Kushlan and Kushlan (1975), these types of studies are nearly non-existent for wading bird species in southeast Florida. As wading birds are an ecologically important component of coastal ecosystems, it is necessary to gain a better understanding of their feeding ecology, trophic interactions, and movements both in terms of understanding local ecology and predicting the effects of coastal development and habitat alteration. Through a combined approach of endoparasite community analysis and stable isotope analysis, this study gained insight into the feeding ecology and trophic web interactions for six species of wading birds in southeast Florida.

Parasite communities differed significantly among species of wading birds. As endoparasites are acquired trophically via food web interactions, this indicates these species of wading birds have differing dietary preferences in South Florida. Stable isotope data support separation in foraging strategies, as stable isotope values varied significantly among species of wading birds.

Since great egret, green heron, and white ibis had $\delta^{13}C$ values ranging between marine and freshwater habitats, future foraging studies should focus on expanding the stable isotope facet of this project as a proxy for understanding the foraging ecology of these wading bird species. To assist with habitat segregation, stable sulfur isotope ($\delta^{34}S$) analysis can be used to differentiate between marine and freshwater environments as sulfur differs isotopically between these environments with little or no trophic fraction and temperature effect (Peterson and Fry 1987; Fry 2006; Barnes and Jennings 2007). Sulfate in the ocean is 21‰ heavier than primordial sulfur. Continental vegetation averages 2-6‰ while marine plankton and seaweeds have $\delta^{34}S$ values ranging from 17-21‰ (Peterson and Fry 1987, Fry 2006). The relative contribution of the marine or freshwater prey would presumably be reflected in the sulfur isotopic analysis of the bird's tissue. The combination of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ could be used to differentiate foraging locations, such as estuarine versus strictly freshwater or marine environments.

By using the combined approach of stable isotope analysis and parasite identification, it is possible to elucidate wading bird feeding ecology. Stable isotope analysis was used to provide knowledge on trophic interactions based on $\delta^{15}N$ values, while $\delta^{13}C$ is useful in determining the differences in geographic foraging location. As endoparasites are acquired trophically via food-web interactions, identifying the parasite community allows for trophic links to be drawn between organisms present within the same environment. Much as the sole use of stable isotopes cannot identify species-specific prey in the diet, parasite identification does not provide in-depth information on foraging location, as many parasite speicies are generalists. Combining these two techniques allows for an abundance of information on feeding ecology and trophic interactions to be obtained.

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Appendix 1: Dietary items of six wading bird species.

Species	**Study Location**	**Dietary Items**	**Reference**
Great egret	Florida Everglades	Fishes: *Belonesox belizanus, Cichlasoma bimaculatum, C. urophthalmus, Lepomis gulosus, L. marginatus, L. punctatus, Micropterus salmoides, Poecilia latipinna*	Frederick *et al.* 1999
	Puerto Rico	Fishes including: Centropomidae, Elopidae, Gobidae, Gerridae, Mugilidae, Poecilidae, Cichlidae *Uca* spp. *Xiphocaris* spp. *Anolis* spp. Orthoptera	Miranda and Collazo, 1997
Great blue heron	Florida	Fishes	Powell, 1983
	Southwestern British Columbia	Fishes including: *Gasterosteus aculeatus*, blenny species including *Apodichthys flavidus*, sculpins including *Leptocottus armatus*, gobys including *Clevelandia ios*, *Cymatogaster aggregate*, *Platichthys stellatus*	Kelsall and Simpson, 1980
	San Francisco, California	Fishes including: *Leptocottus armatus, Roccus saxatilis, Cymastogaster aggregate, Platichthyes stellatus*, *Atherinops affinis*	Hom, 1983
	British Columbia	Fishes including: *Pholis ornate, Gasterosteus aculeatus, Leptocottus armatus*, *Cymatogaster aggregata, Sygnathus griseolineatus*, *Aulorhynchus flavidus*	Butler, 1993
Green heron	Florida	Crayfish Grasshopper Worm Frogs	Baynard, 1912
Black-crowned night heron	Alberta, Canada	Fishes including *Pimephales promelas, Culaea inconstans, Couesis plumbeus*, *Catostomus* sp. Amphibians: *Rana pipiens, Ambystoma tigrinum, Bufo woodhousei, Pseudacris triseriata* Birds (young): *Larus pipixcan, Xanthocephalus xanthocephalus, Agelaius*	Wolford and Boag, 1971

		phoeniceus, Fulica americana, Nycticorax nycticorax Mammals: *Microtus pennsylvanicus* Coleopterans: carabids, dytiscids Hemipterans: water boatman, backswimmers Orthopterans: grasshoppers Odonates: nymphs of damselflies and dragonflies Amphipods Hirudineans Vegetation	
Yellow-crowned night heron	Eastern and Southern U.S.	Polychaeta: *Nereis* Gastropoda: pulmonate snail Bivalva: *Modiolus* Crustacea including: *Cambarus, Uca, Callinectes, Sesarma, Carcinus, Cancer, Ovalipes, Panopeus, Pmphithoe* Insecta including: Dytiscidae, Hydrophilidae, Notonectidae, Gryllidae, Carabidae, Scaracaeidae, Nepidae, Tettigoniidae, Tetrigidae, Stratiomyidae, Belostomatidae Arachnidae Vertebrata including: unidentified fish, *Anguilla, Synganthus, Malaclemys, Peromyscus, Sylvilagus*	Riegner, 1982
White ibis[2]	Southern Florida	*Procambarus alleni* Dragonfly, Odonata *Belostoma lutarium* *Lethocerus americanus* *Pelocoris* sp. *Dytiscus* *Pomacea paludosa* *Helisoma* sp. *Poecilia latipinna*	Kushlan and Kushlan, 1975

[2] Includes dietary items with total percent frequency greater than 5%

Rana grylio
Diemyctylus viridescens
Vegetation

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Appendix 2: Species, sample size and host morphometric data is given here. * denotes white ibis sample size of 20; one individual had a broken beak and beak measurements were not taken.

Species	**n**	**Weight (g; $\bar{x}$ ± SD)**	**Bill from base (mm; $\bar{x}$ ± SD)**	**Bill from feathers (mm; $\bar{x}$ ± SD)**	**Bill from nostril (mm; $\bar{x}$ ± SD)**	**Bill depth (mm; $\bar{x}$ ± SD)**	**Tarsus length (mm; $\bar{x}$ ± SD)**	**Tail length (mm; $\bar{x}$ ± SD)**	**Wing chord (mm; $\bar{x}$ ± SD)**	**Wing span (mm; $\bar{x}$ ± SD)**
Great egret	18	755.55 ± 142. 34	140.94 ± 6.99	112.06 ± 7.15	94.28 ± 10.84	17.42 ± 2.99	138.56 ± 9.50	151.89 ± 12.17	376.33 ± 59.06	1335.5 ± 124.38
Great blue heron	27	1911.11 ± 418.18	185.78 ± 11.96	149.81 ± 10.13	121.44 ± 10.10	28.01 ± 2.33	176.41 ± 19.68	174.85 ± 16.36	487.93 ± 29.25	1632.41 ± 186.88
Green heron	9	140.26 ± 33.66	73.78 ± 3.67	56.33 ± 5.05	46.89 ± 3.98	10.11 ± 1.57	44.67 ± 2.06	58.33 ± 8.09	170.67 ± 12.16	609.44 ± 51.22
Yellow-crowned night heron	4	475 ± 125.83	80.25 ± 5.56	63.75 ± 10.72	51.5 ± 6.86	16.76 ± 0.67	80.75 ± 10.21	96.5 ± 20.24	261 ± 26.01	1065.75 ± 265.22
Black-crowned night heron	3	433.33 ± 57.74	89.33 ± 6.43	72.33 ± 1.15	51.33 ± 6.51	19.23 ± 3.54	80 ± 7.81	101.33 ± 8.02	292 ± 24.58	1040.67 ± 91.14
White ibis	21	700 ± 144.91	141.85 ± 20.10*	151.2 ± 22.88*	124.95 ± 18.32*	17.29 ± 2.99*	82.71 ± 11.45	102.57 ± 10.22	283.24 ± 16.54	936.29 ± 62.33

Appendix 3:

Phylum: Acanthocephala
Class: Paleacanthocephala

Unidentified Acanthocephala

Description: these acanthocephalans could not be identified due to the condition of the specimens. In several specimens, the proboscis was retracted or hooks were unable to be counted due to condition or attached intestinal lining. In several other specimens, the trunk spines were not visible.

Species: great egrets, great blue herons and white ibis

Site of Infection: intestines

Location: Fort Lauderdale, Miami, and Tavernier

Intermediate Hosts: aquatic intermediate hosts usually consist of Amphipoda, Isopoda, Copepoda, and Ostracoda, terrestrial hosts include insects such as Orthoptera and Coleoptera.

References: McDonald 1988; Amin 1998

Family Plagiorhynchidae

Plagiorhynchus sp.

Description: body without trunk spines, no genital spines, unable to identify past genus due to lack of clarity in the reproductive organs, proboscis hooks uniform in shape, 22 longitudinal rows with 8 hooks in each row.

Species: great egrets and great blue herons

Site of Infection: intestines

Location: Fort Lauderdale and Miami

Intermediate Hosts: aquatic intermediate hosts usually consist of Amphipoda, Isopoda, Copepoda, and Ostracoda; terrestrial hosts include insects such as Orthoptera and Coleoptera.

References: McDonald 1988; Amin *et al.* 1999; Forrester and Spalding 2003; Dimitrova 2009

Notes: *Plagiorhynchus* sp. have been previously reported in the great blue heron in Florida. This is a new host record for the great egret.

Family: Polymorphidae

Arhythmorhynchus brevis

Description: slender and elongate, single field of trunk spines, hooks on ventral surface of proboscis not larger than on other surfaces, hooks not more than 0.050 mm, proboscis with 18 rows of longitudinal rows of hooks, the number of hooks in each row is 12, genital spines absent, proboscis receptacle double-walled.

Species: green herons

Site of Infection: intestines and stomach

Location: Tavernier

Intermediate Hosts: aquatic intermediate hosts usually consist of Amphipoda, Isopoda, Copepoda, and Ostracoda; terrestrial hosts include insects such as Orthoptera and Coleoptera. Marsh fishes including *Ictalurus melas* (black bullhead), *Lepomis cyanellus* (green sunfish), *Carassius auratus* (goldfish) are known intermediate hosts.

References: Van Cleave 1916; Van Cleave 1945; Mondl and Rabalais 1972; Amin 1998; Forrester and Spalding 2003; Hannon 2015

Notes: *A. brevis* has been previously reported in green herons collected in California. In Florida, *A. brevis* has been recorded in black-crowned night herons, great blue herons and the great egret.

Arhythmorhynchus sp.

Description: one field of trunk spines, trunk elongate, genital spines absent, proboscis receptacle double-walled, none of the number of hooks or hook arrangement on the proboscis match with previously described *Arhythmorhynchus* species.

Species: great egrets, great blue herons, and white ibis

Site of Infection: intestines

Location: Fort Lauderdale, Miami, and Tavernier

Intermediate Hosts: aquatic intermediate hosts usually consist of Amphipoda, Isopoda, Copepoda, and Ostracoda; terrestrial hosts include insects such as Orthoptera and Coleoptera.

References: Van Cleave 1916; Van Cleave 1924; Van Cleave 1945; Amin 1998; Nickol *et al.* 2002; Forrester and Spalding 2003; Ortega-Olivares *et al.* 2011; Hannon 2015

Notes: *Arhythmorhynchus* species previously found in black-crowned night herons, great blue herons and great egrets in Florida, green herons in California and white ibis in Mexico.

Hexaglandula corynosoma

Description: trunk elongated, swollen anteriorly and tapering to a blunt end posteriorly, genital spines absent, proboscis cylindrical, 16 longitudinal rows of 12-13 hooks each, six cement glands present.

Species: great egrets and white ibis

Site of Infection: intestines

Location: Fort Lauderdale and Tavernier

Intermediate Hosts: crustacean as an intermediate host and a fish as a paratenic (transport) host, typically develop in arthropods, found in fiddler crabs.

References: McDonald 1988; Forrester and Spalding 2003; Guillén-Hernández *et al.* 2008; Ortega-Olivares *et al.* 2011

Notes: previously recorded in white ibis from Mexico and the yellow-crowned night heron in Florida. This is a new host record for the great egret.

Ibirhynchus dimorpha

Description: two fields of trunk spines, 20-22 longitudinal rows of hooks with 10-11 hooks in each row, distinct sexual dimorphism in the size of the proboscis hooks, short proboscis, genital spines absent, proboscis receptacle double-walled.

Species: great egrets, great blue herons, green herons, and black-crowned night-herons

Site of Infection: intestines

Location: Tavernier

Intermediate Hosts: aquatic intermediate hosts usually consist of Amphipoda, Isopoda, Copepoda, and Ostracoda; terrestrial hosts include insects such as Orthoptera and Coleoptera. Crayfish and crawfish are known intermediate hosts.

References: Schmidt 1973; Amin 1998; Forrester and Spalding 2003; Ortega-Olivares *et al.* 2011; García-Varela *et al.* 2011

Notes: *Ibirhynchus dimorpha* has been previously reported in great blue herons in Florida and in white ibis from Florida and Mexico. This is a new host record for the black-crowned night heron, green heron and great egret.

Polymorphus obtusus

Description: trunk more than 3 mm long, one field of trunk spines, 14-16 longitudinal rows of hooks with 8-9 hooks in each row, 4 cement glands, no genital spines, proboscis receptacle double-walled, no dorso-ventral differentiation or abrupt extreme enlargement of hooks, proboscis ovoid-elongate, proboscis exhibiting no sexual dimorphism.

Species: great egrets, great blue herons, yellow-crowned night herons, and black-crowned night herons

Site of Infection: intestines

Location: Fort Lauderdale, Tavernier and Key West

Intermediate Hosts: aquatic intermediate hosts usually consist of Amphipoda, Isopoda, Copepoda, and Ostracoda; terrestrial hosts include insects such as Orthoptera and Coleoptera.

References: Van Cleave 1924; Amin 1998; Amin *et al.* 1992

Notes: *Polymorphus obtusus* has been previously reported in great blue herons in Florida. This is a new host record for the yellow-crowned night heron, black-crowned night heron and the great egret.

Southwellina hispida

Description: hooks gradually increasing in size toward middle of row, two fields of trunk spines, genital spines absent, proboscis receptacle double-walled, 16-18 longitudinal rows of hooks with 12-14 hooks in each row.

Species: great egrets and great blue herons

Site of Infection: intestines

Location: Tavernier

Intermediate Hosts: crustacean decapods; snakes, frogs freshwater and brackish water fish can serve as paratenic hosts; aquatic intermediate hosts usually consist of Amphipoda, Isopoda, Copepoda, and Ostracoda; terrestrial hosts include insects such as Orthoptera and Coleoptera. Found in fish-eating birds.

References: Schmidt 1973; Amin 1998; Forrester and Spalding 2003; Ortega-Olivares *et al.* 2011; Hannon 2015

Notes: *Southwellina hispida* has been previously reported in great blue herons in California and in yellow-crowned night herons in Florida. This is a new host record for the great egret.

Phylum: Nematoda

Unidentified Nematode
Description: these nematodes could not be identified because key identifying characteristics were damaged during dissection or nematodes had minimal reproductive structure development

Species: great egrets, green herons, yellow-crowned night herons, and white ibis

Site of Infection: esophagus, intestines, and stomach

Location: Miami and Tavernier

Class: Chromadorea
Subclass: Chromadoria
Family: Acuariidae

Chabaudacuaria multispinosa

Description: anterior end with two triangular pseudolabia, cordons arise dorsally and ventrally and extend posteriorly in a longitudinal direction, cordons do not anastomose, deirids with three cusps, spicules dissimilar and unequal.

Species: great blue herons, green herons, and black-crowned night herons

Site of Infection: esophagus and stomach

Location: Miami and Tavernier

Intermediate Hosts: unknown, found in freshwater habitats.

References: Anderson *et al.* 2009; Forrester and Spalding 2003; Mutafchiev and Kinsella 2012

Notes: previously reported as *Acuaria multispinosa* in the great blue heron and green heron in Florida. This is a new host record for the black-crowned night heron.

Desportesius invaginatus

Description: anterior end with two triangular pseudolabia, cordons with serrated edges originating at dorso-ventral sides of oral opening and extend posteriorly, cordons anastamose near nerve ring and invaginate at one side forming grooves, deirids large and tricuspid, caudal alae with papillae, spicules dissimilar in size and form.

Species: great egrets and great blue herons

Site of Infection: intestines and stomach

Location: Miami and Tavernier

Intermediate Hosts: fish and possibly frogs serve as paratenic hosts, piscivorous birds inhabiting freshwater habitats are the final hosts of several *Desportesius* species.

References: Wong and Anderson 1986; Forrester and Spalding 2003; Anderson *et al.* 2009

Notes: previously recorded in the great egret and in the great blue heron in Florida.

Paracuaria adunca

Description: small, slender worms, small amphids present, deirids tricuspid, cephalic papillae present, caudal alae well developed, pseudolabia triangular and well developed

Species: yellow-crowned night herons and black-crowned night herons

Site of Infection: stomach

Location: Fort Lauderdale and Tavernier

Intermediate Hosts: unknown, common parasite of fish-eating birds.

References: Kinsella 1972; Wong and Anderson 1982; Anderson *et al.* 2009

Notes: previously reported as *Paracuaria tridentata* in black skimmers in Florida. This is a new host record for the yellow-crowned night heron and the black-crowned night heron.

Family: Anisakidae

Contracaecum sp.

Description: unable to identify to species based on the condition of the specimens, identified as *contracaecum* sp. based on three labia hexagonal in shape, long muscular esophagus, bases of lips not spined, lips without tooth-like structures.

Species: great blue herons and green herons

Site of Infection: esophagus, intestines, and stomach

Location: Fort Lauderdale, Miami, and Tavernier

Intermediate Hosts: final hosts are fish-eating birds associated with freshwater and marine habitats, copepods serve as an intermediate host and small fish harboring third stage larvae act as vertebrate intermediate or paratenic hosts.

References: Forrester and Spalding 2003; Amato *et al.* 2006; Anderson *et al.* 2009; Shamsi *et al.* 2009

Notes: *Contracaecum* sp. has been previously described in both the great blue heron and green heron in Florida.

Contracaecum microcephalum

Description: lips consist of three equal labia, lips hexagonal, rounded and distinctly longer than wide, interlabia reach the length of four-fifths of lips with tips not bifurcated but distinctly round, spicules similar, seven pairs of postcloacal papillae, bases of lips not spined, lips without tooth-like structures.

Species: great egrets, great blue herons, and green herons

Site of Infection: esophagus, intestines, and stomach

Location: Fort Lauderdale, Miami and Tavernier

Intermediate Hosts: final hosts are fish-eating birds associated with freshwater and marine habitats, copepods serve as an intermediate host and small fish harboring third stage larvae act as vertebrate intermediate or paratenic hosts.

References: Walton 1927; Rysavy and Ryzhikov 1978; Forrester and Spalding 2003; Anderson *et al.* 2009; Shamsi *et al.* 2009

Notes: previously reported in the great egret, great blue heron and green heron in Florida.

Contracaecum micropapillatum

Description: lips consist of three equal labia, lips slightly longer than wide, interlabia reach three-fourths of length of lips with tips distinctly bifurcated, three pairs of postcloacal papillae, bases of lips not spined, lips without tooth-like structures.

Species: great blue herons and green herons

Site of Infection: esophagus, intestines, and stomach

Location: Fort Lauderdale, Miami, and Tavernier

Intermediate Hosts: final hosts are fish-eating birds associated with freshwater and marine habitats, copepods serve as an intermediate host and small fish harboring third stage larvae act as vertebrate intermediate or paratenic hosts.

References: Walton 1927; Rysavy and Ryzhikov 1978; Forrester and Spalding 2003; Anderson *et al.* 2009

Notes: *Contracaecum micropapillatum* has been previously reported in the great blue heron and green heron in Florida.

Contracaecum multipapillatum

Description: lips consist of three equal labia, lips hexagonal, preanal papillae numerous, up to seven pairs of postanal papillae, interlabia present and well developed, spicules equal in length, bases of lips not spined, lips without tooth-like structures.

Species: great egrets, great blue herons, green herons, and black crowned night herons

Site of Infection: esophagus, stomach, and intestines

Location: Fort Lauderdale and Tavernier

Intermediate Hosts: final hosts are fish-eating birds associated with freshwater and marine habitats, copepods serve as an intermediate host and small fish harboring third stage larvae act as vertebrate intermediate or paratenic hosts; larval stages of *Contracaecum multipapillatum* have been found in largemouth bass, bluegills, sunfish, crappies, bullheads and mosquitofish in Florida.

References: Rysavy and Ryzhikov 1978; Sepúlveda *et al.* 1999; Navone *et al.* 2000; Forrester and Spalding 2003; Anderson *et al.* 2009

Notes: previously reported in great egrets, great blue herons and black-crowned night herons in Florida. This is a new host record for the green heron.

Family: Dioctophymidae

Eustrongylides ignotus

Description: robust nematode, cephalic region not dilated and without rows of spines, oral opening lacking lips, cephalic papillae present-12 in number, six larger inner-circle papillae and six smaller outer circle papillae.

Species: great egret

Site of Infection: stomach

Location: Fort Lauderdale

Intermediate Hosts: in China-swamp eel serves as an intermediate host, oligochaetes serve as the first intermediate host and fish are the second intermediate host,
Coyner et al 2002 found *Eustrongylides ignotus* larvae in Eastern mosquitofish, salifin molly, least killifish, Bluefin killifish, salifin shiner, golden topminnow, flagfish, variable platyfish, brook silverside, bluegill, warmouth, largemouth bass, Florida gar, sheepshead minnow, and the black crappie in fish collected in Florida.

References: Spalding and Forrester 1993; Spalding *et al.* 1993; Sepúlveda *et al.* 1999; Coyner *et al.* 2002; Anderson *et al.* 2009; Xiong *et al.* 2009

Notes: *Eustrongylides ignotus* has been previously reported in the great egret in Florida.

Eustrongylides larvae

Description: minimal reproductive structures developed, cephalic region not dilated and without rows of spines, cephalic papillae present, six inner-circle and six outer-circle papillae present.

Species: great egret

Site of Infection: stomach

Location: Tavernier

Intermediate Hosts: in China-swamp eel serves as an intermediate host, oligochaetes serve as the first intermediate host and fish are the second intermediate host.
Coyner et al 2002 found *Eustrongylides ignotus* larvae in Eastern mosquitofish, salifin molly, least killifish, Bluefin killifish, salifin shiner, golden topminnow, flagfish, variable platyfish, brook silverside, bluegill, warmouth, largemouth bass, Florida gar, sheepshead minnow, and the black crappie in fish collected in Florida.

References: Spalding and Forrester 1993; Spalding *et al.* 1993; Sepúlveda *et al.* 1999; Coyner *et al.* 2002; Anderson *et al.* 2009; Xiong *et al.* 2009

Notes: *Eustrongylides ignotus* has been previously reported in the great egret in Florida.

Family: Tetrameridae

Tetrameres ardamericanus

Description: tail slender, spicules unequal, distal end of left specular sheath prominent as sclerotized crescent, deirids and body spines present, postcloaca papillae present, mouth without labia, six large bifid teeth present.

Species: great egrets and great blue herons

Site of Infection: intestines and stomach

Location: Fort Lauderdale, Miami, and Tavernier

Intermediate Hosts: fish serve as either a paratenic or intermediate host.

References: Boyd 1966; Mollhagen 1976; Forrester and Spalding 2003; Anderson *et al.* 2009

Notes: previously reported in the great blue heron in Florida. This is a new host record for the great egret.

Tetrameres sp.

Description: deirids and body spines present, specimen pulled away from cuticle resulting in distortion of the anterior region, unable to identify to species, mouth without labia, six large bifid teeth present.

Species: great egrets

Site of Infection: stomach

Location: Tavernier

Intermediate Hosts: fish serve as either a paratenic or intermediate host.

References: Boyd 1966; Mollhagen 1976; Sepúlveda *et al.* 1999; Forrester and Spalding 2003; Anderson *et al.* 2009

Notes: *Tetrameres* species (*Tetrameres: elyi, fissispina* and *microspinosa)* have been previously described in great egrets.

Class: Enoplea
Subclass: Dorylaimia
Family Capillariidae

Capillaria contorta

Description: 30+ eggs in the female specimens, eggs are oval shaped with a bottleneck at both ends, small caudal alae, distal end rounded with two lateral lobes.

Species: white ibis

Site of Infection: esophagus

Location: Tavernier

Intermediate Hosts: unknown, intestinal parasites of fishes, amphibians, reptiles, birds and mammals.

References: Bush and Forrester, 1976, Moravec 1982; Forrester and Spalding 2003; Anderson *et al.* 2009; Gibbons 2010

Notes: *Capillaria contorta* has been previously reported in the white ibis in Florida.

Class: Secernentea
Family: Strongyloididae

Strongyloides herodiae

Description: cuticle cross-striated, 14 eggs in uteri, short and blunt tail, anterior ovary is posterior to the end of the esophagus, buccal cavity reduced and without teeth.

Species: green herons

Site of Infection: intestines

Location: Tavernier

Intermediate Hosts: vertebrates

References: Little 1966; Bush and Forrester 1976; Forrester and Spalding 2003; Anderson *et al.* 2009

Notes: previously reported in green herons in Louisiana. Previously reported as junior synonym, *Strongyloides ardeae*, in great blue herons, yellow-crowned night herons and white ibis in Florida.

Phylum: Platyhelminthes
Class: Cestoda
Subclass: Eucestoda

Unidentified Cestodes

Description: cestodes could not be identified; specimens were in poor condition and had degraded. During dissections, only the scolex or only the proglottids were observed. Based on the condition of the specimens and due to the fact that whole tapeworms with mature proglottids were not observed, we were unable to identify the cestodes.

Species: great egrets, great blue herons, green herons, yellow-crowned night herons, black-crowned night herons, and white ibis

Site of Infection: intestines

Location: Fort Lauderdale, Miami, Tavernier and Key West

Class: Trematoda
Subclass: Digenea
Family: Clinostomidae

Clinostomum heluans

Description: genital pore in zone or anterior testis, testes lobed and large and in posterior third of body, vitellaria not extending into pre-acetabular region, ovary not median, situated on the right border of the intertesticular space, anterior testis not U-shaped, posterior testis not V-shaped.

Species: great blue herons

Site of Infection: esophagus

Location: Miami

Intermediate Hosts: metacercariae of the *Clinostomum* genus are known to encyst in freshwater fish and frogs.

References: Ukoli 1966; Schell 1985; Matthews and Cribb 1998; Forrester and Spalding 2003

Notes: Previously reported in great blue herons in Florida.

Clinostomum sp.

Description: unable to observe adult identifying characteristics, immature specimens, identification based on body size and shape.

Species: great blue heron

Site of Infection: esophagus

Location: Fort Lauderdale

Intermediate Hosts: metacercariae of the *Clinostomum* genus are known to encyst in fish and frogs.

References: Ukoli 1966; Schell 1985; Matthews and Cribb 1998; Forrester and Spalding 2003

Notes: *Clinostomum* species have been previously reported in great blue herons in Florida.

Family: Cyclocoelidae

Polycyclorchis eudocimi

Description: flattened ventrally, scaly or circular openings on one side, numerous testes scattered along most of the inner margin of the intestinal ring, excretory pore dorsal and near posterior portion of the body.

Species: white ibis

Site of Infection: trachea

Location: Miami

Intermediate Hosts: snail intermediate hosts.

References: Pence and Bush 1973; Bush and Forrester 1976

Notes: previously described in white ibis in Florida.

Family Diplostomidae

Diplostomum spathaceum

Description: U-shaped pocket at anterior end, genital bulb absent, testes bilobed, distinct boundary between fore- and hind-body, pseudosuckers present, vitelline follicles present in fore- and hind-body, ovary more posterior, hindbody longer than forebody, acetabulum larger than oral sucker.

Species: white ibis

Site of Infection: intestines

Location: Tavernier

Intermediate Hosts: freshwater and brackish water fish.

References: Kinsella 1972; McDonald 1981; Karvonen *et al.* 2003

Notes: this is a new host record for the white ibis. *Diplostomum spathaceum* has been previously reported in the black skimmer in Florida.

Posthodiplostomum macrocotyle

Description: body distinctly bipartite, forebody linguiform, hindbody fusiform, oral sucker similar in length to pharynx, ventral sucker slightly larger than oral sucker, testes tandem, different in shape and size, vitelline follicles in fore- and hind-body, copulatory bursa evaginable.

Species: great blue herons

Site of Infection: intestines

Location: Fort Lauderdale, Miami, and Tavernier

Intermediate Hosts: fish intermediate hosts likely freshwater or brackish water in origin.

References: Schell 1985; Forrester and Spalding 2003; Brandão *et al.* 2013

Notes: previously reported in the great blue heron in Florida

Family Echinochasmidae

Echinochasmus dietzevi

Description: foremargin of acetabulum 1/3 or less of body length from anterior end, pharynx partially enclosed within notch between ventral lobes of cephalic collar, anterior vitellaria at rear margin of acetabulum, cephalic collar spines 20 in number.

Species: great blue herons

Site of Infection: intestines

Location: Fort Lauderdale and Tavernier

Intermediate Hosts: freshwater fish.

References: Schell 1985; McDonald 1981; Forrester and Spalding 2003

Notes: previously reported in great blue herons in Florida.

Ribeiroia sp.

Description: unable to identify to species because reproductive structures are not visible, vitelline follicles confluent, extend from posterior end to anterior of acetabulum, oral sucker smaller than ventral sucker.

Species: white ibis

Site of Infection: intestines

Location: Fort Lauderdale

Intermediate Hosts: planorbid snails are the first intermediate host; fish or amphibians serve as the second intermediate host.

References: Forrester and Spalding 2003; Schotthoefer *et al.* 2003; Barroso *et al.* 2009

Notes: new host record for the white ibis, previously reported in the great blue heron in Florida.

Stephanoprora denticulata

Description: greatest width in uterine region, posterior end drawn into a conical protuberance, oral sucker almost equal in diameter to pharynx, testes unlobed, vitelline follicles in two lateral fields in posterior region.

Species: great blue herons and green herons

Site of Infection: intestines

Location: Fort Lauderdale and Tavernier

Intermediate Hosts: freshwater fish; known intermediate hosts include the guppy (*Lebistes reticulatus*).

References: Nasir and Scorza 1968; Bush and Forrester 1976; Schell 1985; Sepúlveda *et al.* 1999

Notes: previously reported in the great egret, great blue heron, and white ibis in Florida. This is a new host record for the green heron.

Family Echinostomatidae

Cathaemasia nycticoracis

Description: body elongate, cuticle without spines, oral sucker subterminal, testes small and lobed, vitelline follicles present in hindbody, large ventral sucker, pharynx present, testes and ovary in third quarter of body length.

Species: green herons

Site of Infection: intestines

Location: Tavernier

Intermediate Hosts: *Cathaemasia hians* life cycle includes pulmonate snails and the larvae of *Rana* or *Triton* species.

References: Olsen 1940; Merino *et al.* 2001

Notes: new host record for the green heron and new range extension.

Patagifer bilobus

Description: angle spines smaller than the largest lateral spines, head collar with deep dorsal incision and narrow ventral notch, approximately 20 to 22 spines on each half of head collar (40-44 total), body ribbon-like, vitelline follicles are non-confluent, 4 collar spines on the ventral lappet of head collar.

Species: white ibis

Site of Infection: intestines

Location: Fort Lauderdale and Tavernier

Intermediate Hosts: species of *Patagifer* utilize freshwater habitats, first intermediate hosts include *Planorbis planorbis* and second intermediate hosts include other pulmonate and prosobranch snails.

References: Arlene *et al.* 2005; Faltýnková *et al.* 2008

Notes: Previously reported in the white ibis in Florida.

Patagifer vioscai

Description: angle spines are larger than the largest lateral spines, head collar with deep dorsal incision and narrow ventral notch, approximately 20 to 22 spines on each half of head collar (40-44 total), body ribbon-like, vitelline follicles are non-confluent, 4 collar spines on the ventral lappet of head collar.

Species: white ibis

Site of Infection: intestines

Location: Miami

Intermediate Hosts: species of *Patagifer* utilize freshwater habitats, planorbid snails serve as a first intermediate host and lymnaeid snails serve as a second intermediate host.

References: Bush and Forrester 1976; Arlene *et al.* 2005; Dronen and Blend 2008

Notes: previously reported in white ibis in Florida.

Family Heterophyidae

Ascocotyle diminuta

Description: one row of circumoral spines-16 in number, two additional dorsal spines, body covered in minute tegumental spines, vitellaria joining posterior forming a curve, body elongate to pyriform.

Species: great egrets, great blue herons, and green herons

Site of Infection: intestines

Location: Fort Lauderdale, Tavernier, and Key West

Intermediate Hosts: poeciliid and cyprinodontid fish serve as secondary intermediate hosts.

References: Sepúlveda *et al.* 1999; Scholz *et al.* 2001; Drago and Lunaschi 2011a

Notes: previously reported in the great egret in Florida, Mexico and Argentina. This is a new host record for the great blue heron and the green heron.

Ascocotyle gemina

Description: lateral vitelline follicles do not meet, double row of circumoral spines, 28-32 spines in each row, tegumental spines present, body elongate to pyriform.

Species: great egrets and green herons

Site of Infection: intestines

Location: Tavernier

Intermediate Hosts: fish serve as secondary intermediate hosts; known species of fish intermediate hosts include sheepshead minnow (*Cyprinodon variegatus*) and the Yucatan flagfish (*Garmanella pulchra*).

References: Sepúlveda *et al.* 1999; Forrester and Spalding 2003

Notes: previously described in great blue herons and great egrets in Florida, this is a new host record for the green heron.

Ascocotyle sp.

Description: too degraded to identify, missing circumoral spines, body shape elongate to pyriform, unable to see reproductive structures necessary to identify to species.

Species: great egrets, great blue herons, green herons, black-crowned night herons, and white ibis

Site of Infection: intestines

Location: Fort Lauderdale andTavernier

Intermediate Hosts: metacercariae are typically found in fish.

References: Scholz *et al.* 1997; Scholz *et al.* 2001; Forrester and Spalding 2003

Notes: *Ascocotyle* species have been previously reported in all species of wading birds in this study.

Ascocotyle tenucollis

Description: body pyriform, sucker-spine arrangement is 16 + 16, ventral sucker is spherical and well developed, testes are symmetrical and near posterior extremity, vitelline follicles reach to acetabular level anteriorly and pass the testes posteriorly.

Species: great egrets

Site of Infection: intestines

Location: Tavernier

Intermediate Hosts: cichlids are the most suitable second intermediate hosts for this species but fish of other families may also contain the metacercariae.

References: Scholz *et al*. 1997; Sepúlveda *et al.* 1999; Forrester and Spalding 2003

Notes: previously reported in the great blue heron in Florida and in the great egret in Florida and Mexico.

Family Strigeidae

Apatemon sp.

Description: terminus of uterus not curved and unites with ejaculatory duct to form long hermaphroditic duct (funnel shape at posterior end), body bipartite, forebody cup-shaped, oral and ventral suckers well developed, pharynx present, muscular ring absent, mostly in piscivorous birds

Parasites fit with some characteristics of *A. gracilis* but some of the measurements, such as total length, are longer than the measurements provided in the description, the differences in length may be due to regional differences or this may be a new species

The difficulty associated with identifying these parasites to species level indicates a need for phylogenetic and molecular with for this genus, there is a clear need for new taxonomic redescription of the Apatemon genus and for an updated taxonomic key.

Species: great egrets and great blue herons

Site of Infection: intestines

Location: Fort Lauderdale and Miami

Intermediate Hosts: fish serve as an intermediate host; metacercaria can be found in leeches.

References: Palmieri 1973; McDonald 1981; Schell 1985; Thul *et al.* 1985; Gibson *et al.* 2002

Notes: *Apatemon gracilis* has been previously reported in the white ibis in Louisiana, this is a new host record for the great blue heron and the great egret. *Apatemon gracilis* has been previously reported in the wood ducks, *Aix sponsa*, in Florida.

Apharyngostrigea cornu

Description: testes multi-lobed, body over 4mm in length, definite constriction between fore- and hind-body, pharynx absent, vitelline follicles in fore- and hind- body, proteolytic gland relatively small and centrally placed at the base of the forebody.

Species: great blue herons

Site of Infection: intestines

Location: Miami and Tavernier

Intermediate Hosts: metacercariae are typically found in fish.

References: Ukoli 1967; Dubois 1969; Schell 1985; Gibson *et al.* 2002; Forrester and Spalding 2003; Blasco-Costa *et al.* 2015

Notes: previously reported in the great blue heron in Florida, Massachusetts and Canada.

Parastrigea cincta

Description: body distinctly bipartite, pharynx present, vitelline follicles in fore- and hindbody, genital cone small, copulatory bursa with *Ringnapf*, genital atrium shallow, neck region absent in hindbody, forebody divided in an anterior cephalic region and a posterior collar region, forebody pyriform and expanded laterally, wider than hindbody.

Species: white ibis

Site of Infection: intestines

Location: Fort Lauderdale and Tavernier

Intermediate Hosts: cercariae develop in planorbid snails, cercariae encyst in tadpoles of *Rana arvalis*, *R. temporaria*, *Bufo bufo,* and in larvae and adults of newts.

References: Gibson *et al.* 2002; Drago and Lunaschi 2011b; Ortega-Olivares *et al.* 2011

Notes: previously reported in white ibis from Mexico, this trematode is reported in Florida for the first time.

Parastrigea diovadena

Description: body distinctly bipartite, pharynx present, vitelline follicles in fore- and hindbody, forebody not divided, neck region absent, proteolytic gland similar in size to ovary, forebody pyriform and expanded laterally, wider than hindbody.

Species: white ibis

Site of Infection: intestines

Location: Fort Lauderdale

Intermediate Hosts: cercariae develop in planorbid snails, cercariae encyst in tadpoles of *Rana arvalis*, *R. temporaria*, *Bufo bufo*, and in larvae and adults of newts.

References: Dubois and Macko 1972; Bush and Forrester 1976; Schell 1985; Gibson *et al.* 2002; Drago and Lunaschi 2011b; Ortega-Olivares *et al.* 2011

Notes: previously reported in the white ibis in Cuba, Florida and Mexico.

Parastrigea mexicana

Description: vitelline follicles in fore-and hindbody, pharynx present, copulatory bursa without *Ringnapf*, body less than 5 mm, proteolytic gland smaller than ovary, neck regeion absent, forebody pyriform and expanded laterally, wider than hindbody.

Species: great egret and white ibis

Site of Infection: intestines

Location: Fort Lauderdale

Intermediate Hosts: cercariae develop in planorbid snails, cercariae encyst in tadpoles of *Rana arvalis*, *R. temporaria*, *Bufo bufo*, and in larvae and adults of newts.

References: Schell 1985; Gibson *et al.* 2002; Drago and Lunaschi 2011b

Notes: new host record for the great egret and the white ibis, this trematode is reported in Florida for the first time.

Parastrigea robusta

Description: copulatory bursa with *Ringnapf* (muscular ring), body less than 5 mm, hindbody is ovoid/sacciform, forebody with lateral expansions that are well developed, the proteolytic gland is smaller than the ovary, body is distinctly bipartite, pharynx present, vitelline follicles present in fore- and hindbody, forebody pyriform and expanded laterally, wider than hindbody.

Species: great egrets and great blue herons

Site of Infection: intestines

Location: Fort Lauderdale

Intermediate Hosts: cercariae develop in planorbid snails, cercariae encyst in tadpoles of *Rana arvalis, R. temporaria, Bufo bufo,* and in larvae and adults of newts.

References: Schell 1985; Gibson *et al.* 2002; Drago and Lunaschi 2011b

Notes: new host record for the great blue heron and the great egret, this trematode is reported in Florida for the first time.

Pseudoapatemon sp.

Description: hindbody is less than 4x longer than the forebody, vitelline follicles restricted to the hindbody, terminus of uterus is curved forward and opens into the posterior wall of the copulatory bursa

Unable to get to species due to the lack of keys or descriptions for this species, similar to Apatemon sp.-need for additional molecular work and clear need for new taxonomic descriptions and taxonomic key for the Pseudapatemon species.

Two different species of Pseudapatemon present but unable to identify the two different groups to species level. Pseudapatemon sp. 1 is from GBHE 2103 and Pseudapatemon sp. 2 is from GBHE 1000.

Species: great blue herons

Site of Infection: intestines

Location: Fort Lauderdale and Miami

Intermediate Hosts: cercaria develop in aquatic snails

References: Schell 1985; Gibson *et al.* 2002

Notes: new host record for the great blue heron, this trematode is reported in Florida for the first time.

Strigea pseudibis

Description: forebody cupshaped, not expanded laterally and not wider than hindbody, vitelline follicles in fore- and hindbody, pharynx present.

Species: great egrets and white ibis

Site of Infection: intestines

Location: Fort Lauderdale, Miami and Tavernier

Intermediate Hosts: cercariae develop in planorbid snails, cercariae penetrate tadpoles and transform to mesocercariae, infected tadpoles are eaten by garter and water snakes

References: Schell 1985; Gibson *et al.* 2002

Notes: previously reported in great egrets. This is a new host record for the white ibis. This is reported in Florida for the first time.

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Appendix 4:

Endoparasites found within great egrets, great blue herons, green herons, yellow-crowned night herons, black-crowned night herons and white ibis from this study and previous studies. * Denotes new host record; + denotes geographic range extension. Abbreviation of site: AC=abdominal cavity; BD=bile duct; BV=blood vessel; CE=cecum; CC=coelomic cavity; CJ=conjunctiva; CL=cloaca; DU=duodenum; ES=esophagus; GB=gall bladder; GI=gizzard; GL=gizzard lining; HT=heart; INT=intestine; IPV=intrahepatic portal vein; KD=kidney; LI=large intestine; LS=lower small intestine; LU=lung; LV=liver; OC=under nictitating membrane of eye; OR=oral cavity; PA=pancreas; PR=proventriculus; RE=rectum; SI=small intestine; SQ=subcutaneous; ST=stomach; TR=trachea; UR=ureter; VE=ventriculus; NG=not given.

	Parasite species	**Site within host**	**Geographic location**	**Reference**
Family: Ardeidae				
***Ardea alba*[3]**				
Great Egret				
Phylum: Acanthocephala				
	Unidentified Acanthocephala	NG INT	California Florida	Hannon 2015 This study
Class: Paleacanthocephala				
Family: Plagiorhynchidae				
	Plagiorhynchus sp. Lühe, 1911	INT	Florida	*This study
Family: Polymorphidae				
	Arhythmorhynchus brevis (Van Cleave,	SI	Florida	Forrester and Spalding 2003[4]

[3] Past scientific names include *Casmerodius albus* and *Egretta alba*

	1916)			
	Arhymorhynchus pumilirostris Van Cleave, 1916	SI	Florida	Forrester and Spalding 2003
	Arhythmorhynchus sp. Lühe, 1911	INT	Florida	This study
	Centrorhynchus sp. Lühe, 1911	NG	Japan	Reported in Yoshino *et al.* 2009
	Hexaglandula corynosoma (Travassos, 1915)	INT	Florida	*This study
	Ibirhynchus dimorpha (Schmidt, 1973)	INT	Florida	*This study
	Polymorphus obtusus Van Cleave, 1918	INT	Florida	*This study
	Southwellina hispida (Van Cleave, 1925)	INT	Florida	*This study
Phylum: Nematoda				
	Unidentified Nematoda	INT NG	Florida California	This study Hannon 2015
	Unidentified Spiruida	NG	California	Hannon 2015
Class: Chromadorea				
Subclass: Chromadoria				
Family: Acuariidae				
	Chabaudacuaria multispinosa (Pérez	PR, VE	Florida	Sepúlveda *et al.* 1999[5]

[4] Reported as junior synonym *Polymorphus brevis*
[5] Reported as junior synonym *Acuaria multispinosa*

	Vigueras, 1938)			
	Chandleronema longigutturata (Chandler, 1942)	PR, VE	Florida	Sepúlveda *et al.* 1999
	Desportesius brevicaudatus (Dujardin, 1845) Chabaud & Campana, 1949	NG	Ukraine, USSR	Smogorzherskaya 1964, reported in Wong and Anderson 1968
	Desportesius invaginatus (Linstow, 1901)	ST, INT NG GI, CL, PR, VE NG NG NG NG	Florida California Florida Azerbaidzhan, USSR Madagascar Turkmenia Ukraine, USSR	This study Hannon 2015 Sepúlveda *et al.* 1999 Kasimov and Feizullaev 1965; Shakhtakhtinskaya 1953, reported in Wong and Anderson 1968 Vassiliades 1970 Babaev 1970, reported in Wong and Anderson 1968 Smogorzherskaya 1964, reported in Wong and Anderson 1968
	Desportesius triaenucha (Wright, 1879) Gibson, 1968	PR, VE	Florida	Sepúlveda *et al.* 1999
	Desportesius larvae	PR, VE	Florida	Sepúlveda *et al.* 1999
Family: Anisakidae				
	Contracaecum	ST	Florida	This study

	microcephalum (Rudolphi, 1809)	INT NG	Brazil Florida	Vicente *et al.* 1995 Walton 1927
	Contracaecum multipapillatum (von Drasche, 1882)	ST ES, ST ES, PR, OR, VE	Florida Argentina Florida	This study Navone *et al.* 2000 Sepúlveda *et al.* 1999
	Contracaecum sp. Railliet & Henry 1912	INT NG	Brazil Japan	Vicente *et al.* 1995 Yoshino *et al.* 2009
Family: Ascarididae				
	Porrocaecum reticulatum (Linstow, 1899)	NG	Brazil	Vicente *et al.* 1995
Family: Desmidocercidae				
	Desmidocercella numidica Seurat, 1920	NG CL, GI, HT, SI, CC	California Florida	Hannon 2015 Sepúlveda *et al.* 1999
Family: Dioctophymidae				
	Eustrongylides ignotus Jägerskiöld, 1909	ST NG AC, INT, ST PR, VE INT, ST	Florida California Delaware Florida Louisiana	This study Hannon 2015 Wiese *et al.* 1977 Sepúlveda *et al.* 1999; Spalding *et al.* 1993 Roffe 1988
	Eustrongylides larvae Jägerskiöld, 1909	ST	Florida	This study
Family: Dracunculidae				
	Avioserpens galliardi Chabaud & Campana,	PR, VE	Florida	Sepúlveda *et al.* 1999

	1949			
Family: Tetrameridae				
	Tetrameres ardamericanus Boyd, 1966	INT, ST	Florida	*This study
	Tetrameres elyi Mollhagen, 1976	NG	Louisiana	Mollhagen 1976
	Tetrameres fissispina (Diesing, 1861)	NG	NG	
	Tetrameres microspinosa Vigueras, 1935	PR, VE	Florida	Sepúlveda *et al.* 1999
	Tetrameres sp. Creplin, 1846	ST PR, VE NG	Florida Florida Louisiana	This study Sepúlveda *et al.* 1999 Mollhagen 1976
	Unidentified Tetrameridae	NG	California	Hannon 2015
Class: Enoplea				
Subclass: Dorylaimia				
Family: Capillariidae				
	Capillaria herodiae (Boyd, 1966)	SI	Florida	Sepúlveda *et al.* 1999
Phylum: Platyhelminthes				
Class: Cestoda				
	Unidentified Cestoda	INT NG	Florida California	This study Hannon 2015
Subclass: Eucestoda				
Family: Dilepididae				
	Cyclustera ibisae	NG	Cuba	Rysavy and Mako 1971,

		SI	Florida	reported in Sepúlveda *et al.* 1999 Sepúlveda *et al.* 1999
Family: Gryporhynchidae				
	Dendrouterina ardeae (Rausch, 1955) Bona, 1975	SI	Florida	Sepúlveda *et al.* 1999
	Dendrouterina pilherodiae (Fuhrmann, 1908) Baer & Bona, 1960	NG	Mexico	Ortega-Olivares *et al.* 2008
	Glossocercus aurita (Rudolphi, 1819) Bona, 1994	NG	Mexico	Ortega-Olivares *et al.* 2008; Scholz *et al.* 2002[6]
	Glossocercus caribaensis (Rysavy & Macko, 1973) Bona, 1994	SI	Florida	Sepúlveda *et al.* 1999
	Valipora campylancristrota (Wedl, 1855) Baer & Bona, 1960	NG	Mexico	Ortega-Olivares *et al.* 2008
	Valipora sp. Linton 1927	NG	Cuba	Rysavy and Mako 1971, reported in Sepúlveda *et al.* 1999
Class: Trematoda				
Subclass: Digenea				

[6] Reported as junior synonym *Glossocercus auritus*

Family: Cathaemasiidae				
	Riberiora ondatrae (Price, 1931)	NG PR, VE	Brazil Florida	Yamaguti 1971, reported in Sepúlveda *et al.* 1999 Sepúlveda *et al.* 1999
Family: Clinostomidae				
	Clinostomum attenuatum Cort, 1913	OR, ES	Florida	Sepúlveda *et al.* 1999
	Clinostomum complanatum (Rudolphi, 1814) Braun, 1899	NG NG OR, ES	Colombia Mexico Florida	Rietschel and Werding 1978, reported in Sepúlveda *et al.* 1999 Ramos Ramos, 1995, reported in Sepúlveda *et al.* 1999 Sepúlveda *et al.* 1999
	Clinostomum detruncatum Braun, 1899	NG	Venezuela	Braun 1899, reported in Sepúlveda *et al.* 1999
	Clinostomum sp. Leidy, 1856	NG	California	Hannon 2015
Family: Diplostomidae				
	Diplostomum ardeae Dubois, 1969	SI	Florida	Sepúlveda *et al.* 1999
	Dolichorchis lacombeensis Lunaschi & Drago, 2006	INT	Argentina	Drago and Lunaschi 2011
	Posthodiplostomum boydae Dubois, 1969	SI	Florida	Sepúlveda *et al.* 1999
	Posthodiplostomum minimum (MacCallum,	SI	Florida	Lumsden and Zischke 1963

	1921)	NG	Mexico	Ponce de León 1995
	Posthodiplostomum nanum Dubois 1937	NG	Argentina	Boero *et al.* 1972, reported in Sepúlveda *et al.* 1999
	Posthodiplostomum opisthosicya Dubois, 1969	SI	Florida	Sepúlveda *et al.* 1999
	Posthodiplostomum sp. Dubois, 1936	NG SI	California Florida	Hannon 2015 Sepúlveda *et al.* 1999
Family: Echinochasmidae				
	Echinochasmus dietzevi Issaitschikoff, 1927	SI	Florida	Sepúlveda *et al.* 1999
	Microparyphium facetum Dietz, 1909	CL	Florida	Sepúlveda *et al.* 1999
	Stephanoprora denticulata (Rudolphi, 1802) Odhner, 1910	SI	Florida	Sepúlveda *et al.* 1999[7]
Family: Echinostomatidae				
	Ignavia venusta Teixeira & Freitas, 1948	NG KD	Brazil Florida	Freitas and Teixeira 1948 Sepúlveda *et al.* 1999
	Riberiora ondatrae (Price, 1931)	NG PR, VE	Brazil Florida	Yamaguti 1971, reported in Sepúlveda *et al.* 1999 Sepúlveda *et al.* 1999
Family: Heterophyidae				

[7] Reported as junior synonym *Mesorchis denticulatus*

	Ascocotyle angrense Travassos, 1916	INT	Louisiana	Sogandares-Bernal and Lumsden 1963
	Ascocotyle diminuta Stunkard & Haviland, 1924	INT SI NG INT	Florida Florida Mexico Argentina	This study Sepúlveda *et al.* 1999 Scholz *et al.* 1997a Drago and Lunaschi 2011
	Ascocotyle gemina Font, Heard & Overstreet, 1984	INT LI	Florida Florida	This study Sepúlveda *et al.* 1999
	Ascocotyle longa Ransom, 1920	NG	Florida	Hutton and Sogandares-Bernal 1960a, 1960b[8]
	Ascocotyle mcintoshi Price, 1936	SI	Florida	Sepúlveda *et al.* 1999
	Ascocotyle megalocephala Price 1932	NG	Mexico	Scholz *et al.* 1997a
	Ascocotyle nana Ransom, 1920	SI NG	Florida Mexico	Sepúlveda *et al.* 1999 Scholz *et al.* 1997a
	Ascocotyle nunezae Scholz, Vargas-Vázquez, Vidal-Martínez & Aguirre-Macedo, 1997	NG	Mexico	Scholz et al 1997a; Scholz 1997b
	Ascocotyle sp. Looss, 1899	INT LI, SI	Florida Florida	This study Hutton 1964; Hutton and Sogandares-Bernal 1960a

[8] Reported as junior synonym *Phagicola longa*

	Ascocotyle tenucollis Price, 1935	INT LI NG	Florida Florida Mexico	This study Sepúlveda *et al.* 1999 Scholz *et al.* 1997
	Pholeter anterouterus Fischthal & Nasir, 1974	SI	Florida	Sepúlveda *et al.* 1999
Family: Liliatrematidae				
	Liliatrema sp. Gubanov, 1953	NG	Japan	Reported in Yoshino *et al.* 2009
Family Opisthorchiidae				
	Amphimerus interruptus (Braun, 1901) Barker, 1911	NG	Mexico	Ramos Ramos 1995, reported in Sepúlveda *et al.* 1999
	Cladocystis trifolium (Braun, 1901)	NG	Mexico	Ramos Ramos 1995, reported in Sepúlveda *et al.* 1999
	Diasiella diasi (Travassos, 1922)	PA	Florida	Sepúlveda *et al.* 1999
	Euamphimerus sp.	INT	Louisiana	Lumsden and Zischke 1963
Family: Philophthalmidae				
	Philophthalmus lacrymosus Braun, 1902	NG	Brazil	Freitas 1995, reported in Sepúlveda *et al.* 1999
Family: Prosthogonimidae				
	Renicola sp. Cohn, 1904	KD	Florida	Sepúlveda *et al.* 1999
Family: Strigeidae				
	Apatemon sp. Szidat,	INT	Florida	*This study

	1928			
	Apharyngostrigea ardearum (Lutz, 1928) Dubois, 1968	INT NG NG	Argentina Argentina Venezuela	Drago and Lunaschi 2011 Boero *et al.* 1972, reported in Sepúlveda *et al.* 1999[9] Dubois 1968, reported in Sepúlveda *et al.* 1999[10]
	Apharyngostrigea cornu (Zeder, 1800)	NG NG	Georgia, Mississippi, Tennessee Mexico	Byrd and Ward 1943 Blasco-Costa *et al.* 2015
	Apharyngostrigea pipientis (Faust, 1918)	CL, LI, SI	Florida	Sepúlveda *et al.* 1999
	Parastrigea mexicana Coil, 1957	INT	Florida	*+This study
	Parastrigea robusta Szidat, 1928	INT	Florida	*+This study
	Strigea pseudibis Odening, 1962	INT INT	Florida Germany	+This study Dubois 1968, reported in Sepúlveda *et al.* 1999
Ardea herodias				
Great Blue Heron				
Phylum: Acanthocephala				
	Unidentified Acanthocephala	INT	Florida	This study
Class:				

[9] Reported as junior synonym *Apharyngostrigea brasiliana*
[10] Reported as junior synonym *Apharyngostrigea brasiliana*

Paleacanthocephala				
Family: Plagiorhynchidae				
	Plagiorhynchus sp. Lühe, 1911	INT ST	Florida Florida	This study Forrester and Spalding 2003
Family: Polymorphidae				
	Arhythmorhynchus brevis (Van Cleave, 1916)	SI NG	Florida Minnesota, Illinois	Forrester and Spalding 2003[11] Van Cleave 1945
	Arhythmorhynchus duocinctus Chandler 1935	NG	Minnesota	Van Cleave 1945
	Arhythmorhynchus sp. Lühe, 1911	INT	Florida	This study
	Ibirhynchus dimorpha (Schmidt, 1973)	INT SI	Florida Florida	This study Forrester and Spalding 2003[12]
	Polymorphus obtusus Van Cleave, 1918	INT NG	Florida Florida	This study Van Cleave 1924
	Southwellina hispida (Van Cleave, 1925)	INT NG	Florida California	This study Hannon 2015
Phylum: Nematoda				
	Larval spiruids	PR	Florida	Forrester and Spalding 2003
Class: Chromadorea				

[11] Reported as junior synonym *Polymorphus brevis*
[12] Reported as junior synonym *Southwellina dimorpha*

Subclass: Chromadoria				
Family: Acuariidae				
	Chabaudacuaria multispinosa (Pérez Vigueras, 1938)	ES, ST ST	Florida Florida	This study Forrester and Spalding 2003[13]; Mutafchiev and Kinsella 2012
	Chandleronema longigutturata (Chandler, 1942)	PR	Florida	Forrester and Spalding 2003
	Cosmocephalus obvelatus (Creplin, 1825)	PR	Florida	Forrester and Spalding 2003
	Desportesius invaginatus (Linstow, 1901)	INT, ST ST	Florida Florida	This study Forrester and Spalding 2003
	Desportesius triaenucha (Wright, 1897) Gibson 1968	NG	Quebec, Canada	Mawson 1956[14]
	Syncuaria ardeae (Smith, Fox and White, 1908)	NG	Pennsylvania	Wong *et al.* 1986
Family: Anisakidae				
	Contracaecum microcephalum (Rudolphi, 1809)	ES, ST ST	Florida Florida	This study Forrester and Spalding 2003
	Contracaecum	ES, INT, ST	Florida	This study

[13] Reported as junior synonym *Acuaria multispinosa*
[14] Reported as junior synonym *Synhimantus (Desportesius) canadensis*

	micropapillatum (Stossich, 1890)	ST	Florida	Forrester and Spalding 2003
	Contracaecum multipapillatum (Drasche, 1882)	ES, INT ST	Florida Florida	This study Forrester and Spalding 2003
	Contracaecum sp. Railliet & Henry 1912	ES, INT, ST NG ES, ST	Florida California Florida	This study Hannon 2015 Forrester and Spalding 2003
Family: Ascarididae				
	Porrocaecum reticulatum (Linstow, 1899)	ST, SI	Florida	Forrester and Spalding 2003
Family: Desmidocercidae				
	Desmidocercella numidica Seurat, 1920	NG BC NG	California Florida Massachusetts	Hannon 2015 Forrester and Spalding 2003 Boyd 1966
Family: Dioctophymidae				
	Eustrongylides ignotus Jägerskiöld, 1909	ST NG	Florida Delaware	Spalding *et al.* 1993; Forrester and Spalding 2003 Wiese *et al.* 1977
Family: Tetrameridae				
	Microtetrameres canadensis (Mawson, 1956)	NG	Quebec and Ontario, Canada	Mawson 1956
	Tetrameres	ST	Florida	This study

	ardamericanus Boyd, 1966	PR PR	Florida Massachusetts; Ontario, Canada	Forrester and Spalding 2003 Boyd 1966
	Tetrameres flehartyi Mollhagen, 1976	NG	Florida	Mollhagen 1976
	Tetrameres microspinosa Vigueras, 1935	PR	Florida	Forrester and Spalding 2003
Class: Enoplea				
Subclass: Dorylaimia				
Family: Capillariidae				
	Capillaria herodiae (Boyd, 1966)	INT INT	Massachusetts Florida	Boyd 1966 Forrester and Spalding 2003
	Capillaria obsignata Madsen, 1945	ES	Florida	Forrester and Spalding 2003
	Capillaria sp. Zeder, 1800	ES, SI	Florida	Forrester and Spalding 2003
Class: Secernentea				
Family: Onchocercidae				
	Cardiofilaria ardae (Mawson, 1957)	NG	Massachusetts	Boyd 1966[15]
	Paronchocerca tonkinensis (Chow, 1939)	ES, LU, KD, LV	Florida	Forrester and Spalding 2003
Family: Strongyloididae				

[15] Reported as junior synonym *Pseudaproctella ardae*

	Strongyloides herodiae Little, 1966	SI	Massachusetts	Boyd 1966[16]
	Strongyloides sp. Grassi, 1879	SI	Florida	Forrester and Spalding 2003
Phylum: Platyhelminthes				
Class: Cestoda				
	Unidentified Cestoda	INT	Florida	This study
Subclass: Eucestoda				
Family: Gryporhynchidae				
	Dendrouterina ardeae (Rausch, 1955)	SI INT	Florida Mexico	Forrester and Spalding 2003 Scholz *et al.* 2002; Ortega-Olivares *et al.* 2008
	Glossocercus aurita (Rudolphi, 1819) Bona, 1994	NG	Mexico	Ortega-Olivares *et al.* 2008[17]
	Glossocercus caribaensis (Rysavy & Macko, 1973) Bona, 1994	SI NG	Florida Mexico	Forrester and Spalding 2003 Ortega-Olivares *et al.* 2008
	Glossocercus sp. Chandler, 1935	NG	Mexico	Ortega-Olivares *et al.* 2008
	Neogryporhynchus cheilancristrotus (Wedl,	SI	Florida	Forrester and Spalding 2003

[16] Reported as junior synonym *Strongyloides ardeae*
[17] Reported as junior synonym *Glossocercus auritus*

	1855) Baer & Bona, 1960	NG	Mexico	Ortega-Olivares *et al.* 2008
	Parvitaenia cochlearii Coil, 1955	NG	Mexico	Ortega-Olivares *et al.* 2008
	Parvitaenia heardi Schmidt & Courtney 1973	SI	South Carolina	Schmidt and Courtney 1973
	Valipora mutabilis Linton 1927	SI	Florida	[18]Forrester and Spalding 2003
	Valipora sp. Linton 1927	SI	Florida	Forrester and Spalding 2003
Class: Trematoda				
Subclass: Digenea				
Family: Clinostomidae				
	Clinostomum attenuatum Cort, 1913	OR	Florida	Forrester and Spalding 2003
	Clinostomum complanatum (Rudolphi, 1814) Braun, 1899	OR	Florida	Forrester and Spalding 2003
	Clinostomum heluans Braun, 1899	ES OR	Florida Florida	This study Forrester and Spalding 2003
	Clinostomum sp. Leidy, 1856	ES	Florida	This study
Family: Cyathocotylidae				
	Mesostephanus appendiculatoides	SI	Florida	Forrester and Spalding 2003

[18] Reported as *Valipora mutabile*

	(Price, 1934)			
Family: Diplostomidae				
	Diplostomum ardeae Dubois, 1969	SI INT	Florida Massachusetts	Forrester and Spalding 2003 Dubois 1969
	Neodiplostomum orchilongum Noble, 1936	INT	California	Noble 1936
	Posthodiplostomum boydae Dubois, 1969	DU	Florida	Forrester and Spalding 2003
	Posthodiplostomum macrocotyle Dubois 1937	INT SI	Florida Florida	This study Forrester and Spalding 2003
	Posthodiplostomum minimum (MacCallum, 1921)	NG SI INT	California Florida Massachusetts	Hannon 2015 Forrester and Spalding 2003 Dubois 1969
	Posthodiplostomum nanum Dubois 1937	SI	Florida	Forrester and Spalding 2003
	Posthodiplostomum opisthosicya Dubois, 1969	SI INT	Florida Massachusetts	Forrester and Spalding 2003 Dubois 1969
	Posthodiplostomum sp. Dubois, 1936	SI	Florida	Forrester and Spalding 2003
Family: Echinochasmidae				
	Echinochasmus dietzevi Issaitschikoff, 1927	INT SI	Florida Florida	This study Forrester and Spalding 2003
	Microparyphium	CL	Florida	Forrester and Spalding

	facetum Dietz, 1909			2003
	Stephanoprora denticulatua (Rudolphi, 1802) Odhner, 1910	INT SI	Florida Florida	This study Forrester and Spalding 2003[19]
Family: Echinostomatidae				
	Cathaemasia nycticoracis Olsen, 1940	SI	Minnesota and Michigan	Olsen 1940
	Ignavia venusta Teixeira & Freitas, 1948	KD	Florida	Forrester and Spalding 2003
	Ribeiroia ondatrae (Price, 1931)	PR, SI	Florida	Forrester and Spalding 2003
Family: Heterophyidae				
	Ascocotyle diminuta (Stunkard & Haviland, 1924)	INT	Florida	*This study
	Ascocotyle gemina Font, Heard & Overstreet, 1984	LI	Florida	Forrester and Spalding 2003
	Ascocotyle longa Ransom, 1920	SI	Florida	Forrester and Spalding 2003[20]
	Ascocotyle nana (Ranson, 1920)	NG	Mississippi	Font *et al.* 1984[21]
	Ascocotyle sp. Looss, 1899	INT NG	Florida California	This study Hannon 2015

[19] Reported as junior synonym *Mesorchis denticulatus*
[20] Reported as junior synonym *Phagicola longa*
[21] Reported as junior synonym *Phagicola nana*

		SI	Florida	Forrester and Spalding 2003[22]
	Ascocotyle tenuicollis Price, 1935	INT	Florida	Forrester and Spalding 2003
	Pygiodopsis pindoramensis Travassos, 1929	SI	Florida	Forrester and Spalding 2003
Family Opisthorchiidae				
	Diasiella diasi (Travassos, 1922)	PA	Florida	Forrester and Spalding 2003
Family: Philophthalmidae				
	Philophthalmus hegeneri Penner & Fried, 1963	OC	Florida	Forrester and Spalding 2003
Family: Prosthogonimidae				
	Prosthogonimus ovatus (Rudolphi, 1803)	CL	Florida	Forrester and Spalding 2003
	Renicola sp. Cohn, 1904	KD	Florida	Forrester and Spalding 2003
Family: Strigeidae				
	Apatemon sp. Szidat, 1928	INT	Florida	*This study
	Apharyngostrigea bilobata Olsen, 1940	SI	Minnesota	Olsen 1940

[22] Reported as junior synonym *Phagicola* sp.

	Apharyngostrigea cornu (Zeder, 1800)	INT LS INT NG	Florida Florida Massachusetts Canada	This study Forrester and Spalding 2003 Dubois 1969 Blasco-Costa *et al.* 2015
	Apharyngostrigea multiovata (Vigueras, 1944)	INT	Massachusetts	Dubois 1969
	Apharyngostrigea pipientis (Faust, 1918)	INT	Massachusetts	Dubois 1969
	Apharyngostrigea simplex (Johnston, 1904)	SI	Florida	Forrester and Spalding 2003
	Apharyngostrigea sp. Ciurea, 1927	SI	Florida	Forrester and Spalding 2003
	Parastrigea brasiliana (Ukoli, 1967)	SI	Florida	Forrester and Spalding 2003
	Parastrigea robusta Szidat, 1928	INT	Florida	*+This study
	Pseudoapatemon sp.	INT	Florida	*+This study
Butorides virescens				
Green Heron				
Phylum: Acanthocephala				
Class: Paleacanthocephala				
Family: Polymorphidae				

	Arhythmorhynchus brevis (Van Cleave, 1916)	INT, ST NG	Florida California	This study Hannon 2015[23]
	Ibirhynchus dimorpha (Schmidt, 1973)	INT	Florida	*This study
Phylum: Nematoda				
	Larval spiruids	SI	Florida	Forrester and Spalding 2003
	Unidentified Nematoda	ES, ST NG	Florida California	This study Hannon 2015
Class: Chromadorea				
Subclass: Chromadoria				
Family: Acuariidae				
	Chabaudacuaria multispinosa (Pérez Vigueras, 1938)	ST PR	Florida Florida	This study Forrester and Spalding 2003[24]
	Chandleronema longigutturata (Chandler, 1942)	PR	Florida	Forrester and Spalding 2003
	Desportesius invaginatus (Linstow, 1901)	PR	Florida	Forrester and Spalding 2003
Family: Anisakidae				
	Contracaecum microcephalum (Rudolphi, 1809)	ES, INT, ST NG ST	Florida California Florida	This study Hannon 2015 Forrester and Spalding

[23] Reported as junior synonym *Polymorphus brevis*
[24] Reported as junior synonym *Acuaria multispinosa*

		NG	Massachusetts	Boyd 1966
	Contracaecum micropapillatum (Stossich, 1890)	ES, INT, ST ST	Florida Florida	This study Walton 1927
	Contracaecum multipapillatum (Drasche, 1882)	ST	Florida	*This study
	Contracaecum sp. Railliet & Henry 1912	INT, ST NG	Florida California	This study Hannon 2015
Family: Desmidocercidae				
	Desmidocercella numidica Seurat, 1920	NG	Massachusetts	Boyd 1966
Family: Dioctophymidae				
	Eustrongylides ignotus Jägerskiöld, 1909	ST	Florida	Forrester and Spalding 2003
Family: Tetrameridae				
	Tetrameres ardamericanus Boyd, 1966	NG	Massachusetts	Boyd 1966
	Tetrameres butorides Mollhagen, 1976	NG	Florida Louisiana	Mollhagen 1976
	Tetrameres sp. Creplin, 1846	PR	Florida	Forrester and Spalding 2003
Class: Enoplea				
Subclass: Dorylaimia				
Family: Capillariidae				
	Capillaria sp. Zeder, 1800	SI	Florida	Forrester and Spalding 2003

		NG	Massachusetts	Boyd 1966
Class: Secernentea				
Family: Onchocercidae				
	Cardiofilaria pavlovskyi Strom, 1937	LS	Florida	Forrester and Spalding 2003
Family: Physalopteridae				
	Physaloptera sp. Gupta & Kazim, 1979	PR	Florida	Forrester and Spalding 2003
Family: Strongyloididae				
	Strongyloides herodiae Little, 1966	INT SI	Florida Louisiana	This study Little 1966[25]
Phylum: Platyhelminthes				
Class: Cestoda				
	Unidentified Cestoda	INT	Florida	This study
Subclass: Eucestoda				
Family: Dilepididae				
	Dilepis unilateralis (Sapozhnikov, 1975)	SI	Florida	Forrester and Spalding 2003
Family: Gryporhynchidae				
	Glossocercus caribaensis (Rysavy & Macko, 1973) Bona, 1994	NG	Mexico	Ortega-Olivares *et al.* 2008
	Parvitaenia cochlearii	NG	Mexico	Ortega-Olivares *et al.*

[25] Reported as junior synonym *Strongyloides ardeae*

	Coil, 1955			2008
	Valipora minuta (Coil, 1950) Baer and Bona, 1960	NG	Mexico	Ortega-Olivares *et al.* 2008
	Valipora mutabilis Linton 1927	SI NG	Florida Mexico	Forrester and Spalding 2003 [26] Ortega-Olivares *et al.* 2008
Class: Trematoda				
Subclass: Digenea				
Family: Diplostomidae				
	Posthodiplostomum macrocotyle Dubois 1937	SI	Florida	Forrester and Spalding 2003
	Posthodiplostomum nanum Dubois, 1937	NG	Brazil, Cuba, Colombia	Reported in Drago and Lunaschi 2011
	Posthodiplostomum sp. Dubois, 1936	NG	California	Hannon 2015
Family: Echinochasmidae				
	Stephanoprora denticulata (Rudolphi, 1802) Odhner, 1910	INT	Florida	*This study
Family: Echinostomatidae				
	Cathaemasia mycticoracis Olsen, 1940	INT	Florida	*+This study

[26] Reported as *Valipora mutabile*

Family: Heterophyidae				
	Ascocotyle diminuta (Stunkard & Haviland, 1924)	INT	Florida	*This study
	Ascocotyle gemina Font, Heard & Overstreet, 1984	INT	Florida	*This study
	Ascocotyle leighi Burton, 1956	SI	Florida	Forrester and Spalding 2003
	Ascocotyle sp. Looss, 1899	INT	Florida	This study
Family: Strigeidae				
	Apharyngostrigea cornu (Zeder, 1800)	INT	USA	Byrd and Ward 1943
	Apharyngostrigea pipientis (Faust, 1918)	INT	Massachusetts	Dubois 1969
	Unidentified Strigeidae	NG	California	Hannon 2015
***Nyctanassa violacea*[27]**				
Yellow-Crowned Night Heron				
Phylum: Acanthocephala				
Class: Paleacanthocephala				
Family: Polymorphidae				
	Hexaglandula corynosoma (Travassos,	SI NG	Florida Puerto Rico	Nickol *et al.* 2002 Cable and Quick 1954[28]

[27] Past scientific names include *Nycticorax violacea*

	1915)	NG	Brazil	Travassos 1915; 1926, Reported in Nickol *et al.* 2002
	Polymorphus obtusus Van Cleave, 1918	INT	Florida	*This study
	Southwellina hispida (Van Cleave, 1925)	SI	Florida	Forrester and Spalding 2003
Phylum: Nematoda				
	Unidentified Nematoda	ES, ST	Florida	This study
Class: Chromadorea				
Subclass: Chromadoria				
Family: Acuariidae				
	Chabaudacuaria multispinosa (Pérez Vigueras, 1938)	PR	Florida	Forrester and Spalding 2003[29];Mutafchiev and Kinsella 2012
	Desportesius invaginatus (Linstow, 1901)	PR	Florida	Forrester and Spalding 2003
	Paracuaria adunca (Creplin, 1846) Anderson & Wong, 1981	ST	Florida	*This study
	Synhimantus magnipapillatus Vicente, Pinto & Noronha 1996	GI ES, PR, SI	Brazil Florida	Vicente *et al.* 1996 Forrester and Spalding 2003

[28] Reported as junior synonym *Polymorphus corynosoma*
[29] Reported as junior synonym *Acuaria multispinosa*

Family: Anisakidae				
	Contracaecum larvae	SI, GI	Florida	Forrester and Spalding 2003
	Contracaecum micropapillatum (Stossich, 1890)	GI	Florida	Forrester and Spalding 2003
	Contracaecum sp. Railliet & Henry, 1912	INT	Brazil	Vicente *et al.* 1995
Family: Dioctophymidae				
	Eustrongylides ignotus Jägerskiöld, 1909	ST	Florida	Forrester and Spalding 2003
Family: Tetrameridae				
	Tetrameres micropenis Travassos, 1915	GI PR NG	Brazil Florida NG	Vicente *et al.* 1995 Forrester and Spalding 2003 Yamaguti 1961, Reported in Mollhagen 1976[30]
	Tetrameres microspinosa Vigueras, 1935	PR	Florida	Forrester and Spalding 2003
Class: Enoplea				
Subclass: Dorylaimia				
Family: Capillariidae				
	Capillaria sp. Zeder, 1800	SI	Florida	Forrester and Spalding 2003
Class: Secernentea				

[30] Reported as junior synonym *Tropisurus micropenis*

Family: Ancylostomatidae				
	Uncinaria sp. Froelich, 1789	SI	Florida	Forrester and Spalding 2003
Family: Strongyloididae				
	Strongyloides herodiae Little, 1966	SI	Louisiana	Little 1966[31]
	Strongyloides sp. Grassi, 1879	SI, LI	Florida	Forrester and Spalding 2003
Phylum: Platyhelminthes				
Class: Cestoda				
	Unidentified Cestoda	INT	Florida	This study
Subclass: Eucestoda				
Family: Gryporhynchidae				
	Glossocercus aurita (Rudolphi, 1819) Bona, 1994	NG	Mexico	Ortega-Olivares *et al.* 2008[32]
	Glossocercus caribaensis (Rysavy & Macko, 1973) Bona, 1994	SI, LI	Florida	Forrester and Spalding 2003
	Glossocercus sp. Chandler, 1935	NG	Mexico	Ortega-Olivares *et al.* 2008
Class: Trematoda				

[31] Reported as junior synonym *Strongyloides ardeae*
[32] Reported as junior synonym *Glossocercus auritus*

Subclass: Digenea				
Family: Clinostomidae				
	Clinostomum complanatum (Rudolphi, 1814) Braun, 1899	OR	Florida	Forrester and Spalding 2003
Family: Diplostomidae				
	Posthodiplostomum minimum (MacCallum, 1921)	SI	Louisiana	Lumsden and Zischke 1963
	Posthodiplostomum nanum Dubois 1937	SI	Florida	Forrester and Spalding 2003
Family: Echinostomatidae				
	Ignavia venusta Texeira de Freitas, 1948	UR	Louisiana	Lumsden and Zischke 1963
Family: Heterophyidae				
	Ascocotyle angrense Travassos, 1916	NG	Louisiana	Sogandares-Bernal and Lumsden 1963
	Ascocotyle gemina Font, Heard & Overstreet, 1984	SI, LI	Florida	Forrester and Spalding 2003
	Pygiodopsis pindoramensis Travassos, 1929	SI	Florida	Forrester and Spalding 2003
Family: Microphallidae				
	Microphallus turgidus (Leigh, 1958)	Si	Florida	Forrester and Spalding 2003
Family Opisthorchiidae				

	Amphimerus interruptus (Braun, 1901)	LV	Louisiana	Lumsden and Zischke
Family: Philophthalmidae				
	Parorchis acanthus (Nicoll, 1906) Nicoll, 1907	RE	Louisiana	Lumsden and Zischke 1963
	Philophthalmus hegeneri Penner & Fried, 1963	CJ	Florida	Penner and Fried 1963
Family: Schistosomatidae				
	Ornithobilharzia sp.	IPV	Louisiana	Lumsden and Zischke 1963
Family: Stomylotrematidae				
	Stomylotrema vicarium Braun, 1901	CL	Louisiana	Lumsden and Zischke 1963
Nycticorax nycticorax				
Black-Crowned Night Heron				
Phylum: Acanthocephala				
Class: Paleacanthocephala				
Family: Polymorphidae				

	Arhythmorhynchus brevis (Van Cleave, 1916)	NG ES, SI, ST NG	California Florida Minnesota	Hannon 2015[33] Forrester and Spalding 2003[34] Van Cleave 1945
	Andracantha mergi (Lundström, 1941)	SI	New Hampshire	Schmidt 1975
	Centrorhynchus elongates Yamaguti, 1935	NG	Japan	Reported in Yoshino *et al.* 2009
	Centrorhynchus magnus Kukui, 1929	NG	Japan	Reported in Yoshino *et al.* 2009
	Centrorhynchus sp. Lühe, 1911	NG	Japan	Reported in Yoshino *et al.* 2009
	Corynosoma sp. Lühe, 1904	NG	Japan	Reported in Yoshino *et al.* 2009
	Ibirhynchus dimorpha (Schmidt, 1973)	INT	Florida	*This study
	Polymorphus obtusus Van Cleave, 1918	INT	Florida	*This study
	Polymorphus spindlatus	INT	Peru	Amin and Heckman 1991
	Southwellina hispida (Van Cleave, 1925)	NG SI	California Hokkaido, Japan	Hannon 2015 Yoshino *et al.* 2009
Phylum: Nematoda				
	Larval spiruids	ST	Florida	Forrester and Spalding 2003
	Unidentified Nematoda	NG	California	Hannon 2015

[33] Reported as junior synonym *Polymorphus brevis*
[34] Reported as junior synonym *Polymorphus brevis*

Class: Chromadorea				
Subclass: Chromadoria				
Family: Acuariidae				
	Chabaudacuaria multispinosa (Pérez Vigueras, 1938)	ES	Florida	*This study
	Desportesius brevicaudatus (Dujardin, 1845) Chabaud & Campana, 1949	NG	Cairo, Egypt	Wong and Anderson 1986[35]
	Desportesius groffi (Li, 1934)	NG	Japan	Reported in Yoshino *et al.* 2009
	Desportesius sagittatus (Rudolphi, 1809) Chabaud & Campana, 1949	NG	Germany	von Linstow 1901, reported in Wong and Anderson 1986
	Paracuaria aduncta (Creplin, 1846) Anderson & Wong, 1981	ST	Florida	*This study
Family: Anisakidae				
	Contracaecum sp. Railliet & Henry, 1912	ST	Florida Japan	Forrester and Spalding 2003 Yoshino *et al.* 2009
	Contracaecum microcephalum (Rudolphi, 1809)	NG	Florida	Walton 1927

[35] Reported as junior synonym *Dispharagus brevicaudatus*

	Contracaecum multipapillatum (Frasche, 1882) Lucker 1941	ST NG ES, PR INT	Florida California Florida Brazil	This study Hannon 2015 Forrester and Spalding 2003 Vicente *et al.* 1995
	Contracaecum plagiaticium Lent & Freitas, 1948	ST	Brazil	Vicente *et al.* 1995
	Contracaecum rudolphii Hartwich, 1964	ES, GI, PR	Florida	Hutton 1964[36]
Family: Dioctophymidae				
	Eustrongylides ignotus Jägerskiöld, 1909	ST NG	Florida Delaware	Spalding *et al.* 1993 Wiese *et al.* 1977
Family: Tetrameridae				
	Tetrameres fissispina (Diesing, 1861)	NG	NG	Mollhagen 1976
	Tetrameres gynecophila (Molin, 1859)	NG	Algeria	Mollhagen 1976[37]
	Tetrameres sp. Creplin, 1846	NG PR	California Florida	Hannon 2015 Forrester and Spalding 2003
Class: Enoplea				
Subclass: Dorylaimia				
Family: Capillariidae				
	Capillaria contorta Creplin, 1839	ES	Florida	Forrester and Spalding 2003

[36] Reported as junior synonym *Contracaecum spiculigerum*
[37] Reported as junior synonym *Tropidocerca gynecophila*

Class: Secernentea				
Family: Ascarididae				
	Ascaridia sp. (Dujardin, 1845)	NG	Hyogo, Japan	Reported in Yoshino *et al.* 2009
	Porrocaecum reticulatum (Linstow, 1899)	NG GI	Brazil Japan	Vicente *et al.* 1995 Yoshino *et al.* 2009
Family: Gnathostomatidae				
	Gnathostoma spingerum Levinsen, 1889	NG	Japan	Reported in Yoshino *et al.* 2009
Phylum: Platyhelminthes				
Class: Cestoda				
	Unidentified Cestoda	INT NG	Florida California	This study Hannon 2015
Subclass: Eucestoda				
Family: Dilepididae				
	Unidentified Delepididae	NG	California	Hannon 2015
Family: Gryporhynchidae				
	Gryporhynchus nycticoracis Yamaguti, 1956	NG	Japan	Reported in Yoshino *et al.* 2009
	Parvitaenia nycticoracis Yamaguti, 1953	NG	Japan	Reported in Yoshino *et al.* 2009
	Valipora mutabilis Linton 1927	INT	Mexico	Scholz *et al.* 2002
Class: Trematoda				

Subclass: Digenea				
Family: Cyathocotylidae				
	Mesostephanus sp. Lutz, 1935	NG	Florida	Hutton 1964
Family: Diplostomidae				
	Bolbophorus confuses (Krause, 1914) Dubois 1935	SI	Florida	Forrester and Spalding 2003
	Posthodiplostomum minimum (MacCallum, 1921)	NG	Florida	Ponce de León 1995
	Posthodiplostomum nanum Dubois 1937	LI, SI	Florida	Forrester and Spalding 2003
	Posthodiplostomum sp. Dubois 1936	NG	California	Hannon 2015
Family: Echinochasmidae				
	Echinochasmus japonicas Tanabe, 1926	NG	Japan	Reported in Yoshino *et al.* 2009
	Echinochasmus perforiatus (Ratz, 1908)	NG	Japan	Reported in Yoshino *et al.* 2009
Family: Echinostomatidae				
	Cathaemasia nycticoracis Olsen, 1940	SI	Minnesota and Michigan	Olsen 1940
	Unidentified Echinostomatidae	NG	California	Hannon 2015
Family: Heterophyidae				
	Apophallus sp. Lühe,	NG	Japan	Reported in Yoshino *et*

	1909			*al.* 2009
	Ascocotyle longa Ransom, 1920	INT	Florida	Forrester and Spalding 2003[38]
	Ascocotyle mollienesicola (Sogandares-Bernal and Bridgman, 1960)	CE, SI	Florida	Forrester and Spalding 2003[39]
	Ascocotyle sp. Looss, 1899	INT NG INT	Florida California Florida	This study Hannon 2015 Forrester and Spalding 2003; Hutton 1964; Hutton and Sogandares-Bernal 1960a
	Ascocotyle felippei Travassos, 1929	NG	California	Hannon 2015
	Metagonimus yokogawai (Katsurada, 1912)	NG	Japan	Reported in Yoshino *et al.* 2009
	Pygiodopsis pindoramensis Travassos, 1929	SI	Florida	Forrester and Spalding 2003
	Pygidiopsis summa Onji and Nisho, 1916	NG	Japan	Reported in Yoshino *et al.* 2009
	Centrocestus armatus (Tanabe, 1922)	NG	Japan	Reported in Yoshino *et al.* 2009
Family: Liliatrematidae				
	Liliatrema sp. Gubanov,	NG	Japan	Reported in Yoshino *et*

[38] Reported as junior synonym *Phagicola longa*
[39] Reported as junior synonym *Pseudascocotyle mollienesicola*

	1953			*al.* 2009
Family: Opisthorchiidae				
	Clonorchis sinensis Looss, 1907	NG	Japan	Reported in Yoshino *et al.* 2009
Family: Strigeidae				
	Apharyngostrigea ardeolina Vidyarthi, 1937	SI	Hokkaido, Japan	Yoshino *et al.* 2009
	Apharyngostrigea bilobata Olsen, 1940	SI	Minnesota	Olsen 1940
	Apharyngostrigea cornu (Zeder, 1800)	NG	Mississippi, Georgia, Tennessee	Byrd and Ward 1943
	Apharyngostrigea pipientis (Faust, 1918)	NG	North Dakota	Blasco-Costa *et al.* 2015
	Unidentified Strigeidae	NG	California	Hannon 2015
Family: Threskiornithidae				
Eudocimus albus				
White Ibis				
Phylum: Acanthocephala				
	Unidentified Acanthocephala	INT	Florida	This study
Class: Paleacanthocephala				
Family: Polymorphidae				
	Arhythmorhynchus frassoni (Molin, 1858)	NG	Mexico	Ortega-Olivares *et al.* 2011

	Arhythmorhynchus sp. Lühe, 1911	INT	Florida	This study
	Corynosoma sp. Lühe, 1904	SI	Florida	Hutton 1964
	Hexaglandula corynosoma (Travassos, 1915)	INT NG	Florida Mexico	This study Ortega-Olivares *et al.* 2011
	Ibirhynchus dimorpha (Schmidt, 1973)	SI NG	Florida Mexico	Forrester and Spalding 2003; Amin 1998; Schmidt 1973[40] Ortega-Olivares *et al.* 2011
	Southwellina hispida (Van Cleave, 1925)	NG	Mexico	Ortega-Olivares *et al.* 2011
Phylum: Nematoda				
	Unidentified Nematoda	ST	Florida	This study
	Larval spiruids	GL	Florida	Bush and Forrester 1976
Class: Chromadorea				
Subclass: Chromadoria				
Family: Acuariidae				
	Ancyracanthopsis coronata (Molin, 1860) Chabaud & Petter, 1959	NG	Florida	Bush and Forrester 1976
	Sciadiocara chabaudi Schmidt & Kinsella, 1972	GL	Florida	Bush and Forrester 1976
	Sciadiocara umbellifera	GL	Florida	Bush and Forrester 1976

[40] Reported as junior synonym *Southwellina dimorpha*

	(Molin, 1860) Skrjabin, 1916			
	Skrjabinoclava thapari Freitas, 1953	PR	Florida	Bush and Forrester 1976
	Syncuaria sp. Gilbert, 1927	GL	Florida	Bush and Forrester 1976
	Synhimantus sp. Railliet, Henry & Sisoff, 1912	ES	Florida	Bush and Forrester 1976
	Viktorocara sp. Guschanskaja, 1950	GL	Florida	Bush and Forrester 1976
Family: Anisakidae				
	Contracaecum sp. Railliet & Henry, 1912	ES	Florida	Bush and Forrester 1976
Family: Dioctophymidae				
	Eustrongylides ignotus Jägerskiöld, 1909	CC	Florida	Spalding *et al.* 1993
Family: Tetrameridae				
	Tetrameres (Gynaecophila) williamsi Bush, Pence & Forrester 1973	PR PR	Florida Louisiana	Bush and Forrester 1976; Bush 1973 Bush 1973
Class: Enoplea				
Subclass: Dorylaimia				
Family: Capillariidae				
	Capillaria contorta Creplin, 1839	ES ES	Florida Florida	This study Bush and Forrester 1976
	Capillaria sp. Zeder, 1800	SI	Florida	Bush and Forrester 1976
Class: Secernentea				

Family: Gnathostomatidae				
	Gnathostoma procyonis Chandler, 1942	SI	Florida	Bush and Forrester 1976
Family: Strongyloididae				
	Strongyloides sp. Grassi, 1879	SI	Florida	Bush and Forrester 1976
Family: Syngamidae				
	Cyathostoma sp. Blanchard, 1849	TR, LU	Florida	Bush and Forrester 1976
	Syngamus trachea (Montagu, 1811)	TR	Florida	Bush and Forrester 1976
Phylum: Platyhelminthes				
Class: Cestoda				
	Unidentified Cestoda	INT	Florida	This study
Subclass: Eucestoda				
Family: Dilepididae				
	Cyclustera capito (Rudolphi, 1819) Fuhrmann, 1901	NG	Mexico	Ortega-Olivares *et al.* 2008
	Cyclustera ibisae (Schmidt & Bush 1972) Bona, 1975	SI NG	Florida Mexico	Bush and Forrester 1976; Schmidt and Bush 1972[41] Ortega-Olivares *et al.* 2011

[41] Reported as junior synonym *Parvitaenia ibisae*

Family: Hymenolepididae				
	Microsomacanthus sp. Lopez-Neyra, 1942	SI	Florida	Bush and Forrester 1976
Class: Trematoda				
Subclass: Digenea				
Family: Clinostomidae				
	Clinostomum marginatum (Rudolphi, 1819)	OR	Florida	Bush and Forrester 1976
Family: Cyathocotylidae				
	Mesostephanus sp. Lutz, 1935	NG	Florida	Forrester and Spalding 2003
Family: Cyclocoelidae				
	Polycyclorchis eudocimi Pence & Bush, 1962	TR TR TR	Florida Florida Louisiana	This study Bush and Forrester 1976 Pence and Bush 1973
	Ophthalmophagus sp. (Stossich, 1902)	ES	Florida	Bush and Forrester 1976
Family: Dicrocoeliidae				
	Lyperosomum sinuosum Travassos, 1917	PA	Florida	Bush and Forrester 1976
	Zonorchis petiolatus (Raillet, 1900)	LV, GB	USA	Yamaguti 1971, reported in Dronen and Blend 2008
Family: Diplostomidae				
	Diplostomum spathaceum (Rudolphi, 1819)	INT	Florida	*This study

	Fibricola cratera (Barker & Noll, 1915) Dubois, 1937	INT	Louisiana	Lumsden 1961
	Posthodiplostomum minimum (MacCallum, 1921)	SI SI	Florida Louisiana	Bush and Forrester 1976; Forrester and Spalding 2003 Lumsden and Zischke 1963
Family: Echinochasmidae				
	Microparyphium facetum Dietz, 1909	CL	Florida	Bush and Forrester 1976
	Ribeiroia sp.	INT	Florida	*This study
	Stephanoprora denticulata (Rudolphi, 1802) Odhner, 1910	NG	Florida	Bush and Forrester 1976
	Stephanoprora sp. Odhner, 1902	SI	Florida	Forrester and Spalding 2003
Family: Echinostomatidae				
	Patagifer bilobus (Rudolphi, 1819)	INT INT	Florida Florida	This study Faltýnková *et al.* 2008
	Patagifer lamothei Dronen & Blend, 2008	NG INT	Mexico Texas	Ortega-Olivares *et al.* 2011 Dronen and Blend 2008
	Patagifer vioscai Lumsden, 1962	INT SI, GL	Florida Florida	This study Bush and Forrester 1976
Family: Eucotylidae				
	Tanaisia fedtschenkoi Skrjabin, 1924	KD	Florida	Bush and Forrester 1976

Family: Gymnophallidae				
	Parvatrema sp. Cable, 1953	SI	Florida	Bush and Forrester 1976
Family: Heterophyidae				
	Ascocotyle ampullacea Miller & Harkema, 1962	SI	Florida	Bush and Forrester 1976
	Ascocotyle mcintoshi Price, 1936	SI	Florida	Bush and Forrester 1976
	Ascocotyle sp. Looss, 1899	INT	Florida	This study
Family: Himasthlidae				
	Acanthoparyphium sp. Dietz, 1909	SI	Florida	Bush and Forrester 1976
Family: Microphallidae				
	Gynaecotyla adunca (Linton, 1905) Yamaguti, 1939	SI	Florida	Bush and Forrester 1976
	Levinseniella sp. Stiles & Hassall, 1901	SI	Florida	Bush and Forrester 1976
	Maritrema sp. Nicoll, 1907	SI	Florida	Bush and Forrester 1976
	Microphallus turgidus (Leigh, 1958)	SI	Florida	Bush and Forrester 1976[42]
	Probolocoryphe glandulosa (Coil, 1955)	SI	Florida	Bush and Forrester 1976; Forrester and Spalding 2003

[42] Reported as junior synonym *Carneophallus turgidus*

Family: Philophthalmidae				
	Parorchis acanthus (Nicoll, 1906) Nicoll, 1907	CL	Florida	Bush and Forrester 1976
	Zonorchis petiolatum (Railliet, 1900) Denton & Byrd, 1951	BD	Louisiana	Lumsden and Zischke 1963
Family: Strigeidae				
	Apatemon gracilis (Rudolphi, 1819)	SI	Louisiana	Palmieri 1973
	Parastrigea cincta Brandes 1888	INT NG	Florida Mexico	+This study Ortega-Olivares *et al.* 2011
	Parastrigea diovadena Dubois & Macko, 1972	INT SI NG NG	Florida Cuba Florida Mexico	This study Dubois and Macko 1972 Bush and Forrester 1976 Ortega-Olivares *et al.* 2011
	Parastrigea mexicana Coil, 1957	INT	Florida	*+This study
	Strigea pseudibis Odening, 1962	INT	Florida	*+This study
Family: Schistosomatidae				
	Ornithobilharzia sp. Odhner, 1912	BV	Florida	Bush and Forrester 1976
Family: Stomylotrematidae	*Stomylotrema* sp. Looss, 1900	CL	Florida	Hutton 1964; Hutton and Sogandares-Bernal 1960
	Stomylotrema vicarium	CL	Florida	Bush and Forrester 1976

	Braun, 1901			

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