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Andres S. Lester-Coll
Nova Southeastern University, al926@nova.edu

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HALMOS COLLEGE OF NATURAL SCIENCES AND OCEANOGRAPHY

Caecidae (Mollusca: Gastropoda) in Broward County, Florida

By

Andres Saul Lester-Coll

Submitted to the Faculty of
Halmos College of Natural Sciences and Oceanography
in partial fulfillment of the requirements for
the degree of Master of Science with a specialty in:

Marine Biology and Coastal Zone Management

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Thesis of
Andres Saul Lester-Coll

Submitted in Partial Fulfillment of the Requirements for the Degree of

Masters of Science:

Marine Biology

Andres Saul Lester-Coll
Nova Southeastern University
Halmos College of Natural Sciences and Oceanography

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Approved:

Thesis Committee

Major Professor:______________________________
Charles G. Messing, Ph.D.

Committee Member:___________________________
Christopher Blanar, Ph.D.

Committee Member:___________________________
José Leal, Ph.D.

ABSTRACT.—Caecidae is a widespread family of minute gastropod snails. Although a few species have previously been found in abundance in a few localized studies in Broward County waters, little is known about their richness, diversity, abundance and distribution in different habitats throughout local waters. This project examined species assemblages both qualitatively and quantitatively in a range of benthic habitats across Broward County. Samples were collected from five different habitat types from northern and southern Broward Country, and included two of each of the following five sites: mangrove, Intracoastal Waterway, creek, reef and rubble. Caecid specimens were removed from general samples, separated by species or developmental stage and preserved in 95% ethanol. Also, as artificial substrates have become an increasingly important resource enhancement technique, this project also compared Caecidae assemblages on artificial vs. natural substrates using a large dataset previously used primarily to examine amphipod crustacean assemblages. Species recorded in Broward County include *Caecum pulchellum, C. imbricatum, C. floridanum, C. textile* and *Meioceras nitidum.* Published records exist for 14 additional species collected elsewhere in South Florida (e.g., Palm Beach County). Descriptions, distributional data and synonymies summarizing available information are given for all 19 species. Nearly 97% of the specimens, including *Caecum pulchellum, Caecum floridanum* and *Meioceras nitidum,* were found on the reef and rubble habitats; approximately 2.5% percent were found in the Intracoastal; approximately 0.5% were found in the creek, and all taxa were absent in both mangrove habitats. A repeated measures MANOVA indicated no significant differences among any of the factors (reef type, substrate or genus) over time; (RM MANOVA, F=0.112, 2.596, 0.018, 4.604), p values = 0.769, 0.248, 0.906, 0.141) suggesting that there were no preferences in substrate material among the species investigated.

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INTRODUCTION

1.1 Family Caecidae – Taxonomic Background:

Caecidae is a family of minute, marine snails known as caecums, which are characteristic of a wide range of chiefly shallow (<100 m) tropical and temperate marine habitats (Moore, 1972). Adults have a straight or gently curved, tubular, tooth- or sausage-shaped shell, 1-6 mm long; no pallial tentacles; cephalic tentacles tipped with long, stiff, sensory cilia and long tracts of motile cilia, and a low rounded swelling on the proximal posterior border of the left tentacle. They exhibit a conic-ovate shell with a complete peristome, wide round aperture, and lack a siphon (Moore, 1962).

The shell develops through three stages, each separated by loss of the preceding portion of the shell, with the rear opening closed by a plug or septum: coiled initial protoconch; expanded, straighter second stage, and adult stage with terminal septum armed with a mucro—a bulge or spike-like projection (Moore 1972, Abbot, 1954; Rehder, 1981; Light & Carlton, 2007; Tunnell et al., 2010). Shells may be smooth or bear axial or spiral sculpture, or both. The operculum is horny and bears a spiral line (Tunnell et al., 2010). The larva is a veliger.

According to the World Register of Marine Species (http://marinespecies.org/), the family currently includes 270 species in 16 genera. The earliest known caecid is *Strebloceras* sp. from the early Eocene of New Zealand (Beu and Maxwell, 1991; Bandel, 1996). Bandel (1996) erected the monogeneric subfamily Streblocerinae (also written, correctly, as Strebloceratinae) for this genus based on retention of the coiled protoconch throughout life and noted that the operculum resembled that of vitrinellids. Finlay (1931) designated *S. cornuoides* Carpenter, 1858, from the Upper Eocene of

Barton and Oligocene of Hampstead (both United Kingdom) as genotype. The genus occurs throughout much of the Tertiary (Bandel, 1996) and includes at least three modern species in the tropical Pacific: *S. subannulatum*, *S. hinemoa*, and *S. kilburni* (http://www.marinespecies.org/aphia.php?p=taxdetails&id=545389).

The family includes phenotypes from coiled to uncoiled as well as elongated and flattened, as opposed to the openly coiled shells of Siliquariidae (Ponder and Lindberg, 2008). According to Bandel (1996), through the Eocene, evolution from *Strebloceras* followed two paths: one to *Caecum* (Caecinae) and the other to *Parastrophia* (Pedumicrinae; now Ctenoceratinae). Evolution in the subfamily Caecinae resulted in a continuously more planispiral coiling of the protoconch and repeated shedding of earlier ontogenetic portions of the shell, leading to what Bandel treated as a single genus, *Caecum*, with multiple subgenera (e.g., *Meioceras*).

Gray (1850) first distinguished family Caecidae and placed it with families Truncatellidae, Pyramidellidae, Acteonidae, and Rissoellidae in his Section Iniophthalma (J. Harasewych, personal communication). Most subsequent researchers followed Clark (1855), who instead linked Caecidae with Vermetidae (Moore, 1962). However, Moore (1962) placed Caecidae in superfamily Rissoacea (now Rissooidea, ICZN art. 29.2) with three other rissooidean families—Rissoidae, Vitrinellidae and Ctiloceratidae—on the basis of similarities in tentacular structure and ciliation, gill filaments, and protoconch. Marcus and Marcus (1963) subsequently treated caecids as most closely related to Hydrobiidae, another rissooidean family.

However, the most recent molecular data distinguishes most rissooidean families, including Caecidae, as superfamily Truncatelloidea, with *Caecum* as sister group to a clade composed of Clenchiellidae and genus *Calopia* (Criscione & Ponder 2013). Truncatelloidea is a member of order Littorinimorpha, although little evidence exists to support the group as a monophyletic clade (http://www.marinespecies.org/aphia.php?p=taxdetails&id=382213).

Caecidae currently contains approximately 270 species in 16 genera worldwide, divided among three subfamilies: Caecinae, Ctiloceratinae and Strebloceratinae (Bouchet and Rocroi 2005; Bouchet and Gofas, 2013). Two genera are found in South Florida: *Caecum* Gray, 1850, and *Meioceras* Carpenter, 1858. *Caecum* contains 190 species worldwide; nine are found in Florida and the Florida Keys and seven more have been recorded from the Texas coast (Tunnell et al., 2010). The close proximity between geographic ranges suggest that additional species may be found locally. *Meioceras* includes nine species worldwide, of which three occur in South Florida: *M. nitidum* (Stimpson, 1851), *M. cubitatum* (de Folin 1868a), and *M. cornucopiae* (Carpenter, 1858).

According to Abbot (1974) and Moore (1972), a total of 12 species between the genera *Caecum* and *Meioceras* include Florida or specifically south Florida as part of their distributions. All are discussed below, but this study found only five species: *Caecum pulchellum* Stimpson, 1851, *C. floridanum* Stimpson, 1851, *C. textile* de Folin, 1867b, *C. imbricatum* Carpenter, 1858, and *Meioceras nitidum*.

1.2 Feeding and Larval Development in Caecidae:

Little is known about caecid development. Earlier work is based chiefly on *Caecum imperforatum* (Kanmacher, 1798) and other unidentified species in British waters (Lebour, 1937). The larva hatches as a veliger with a velum and remains days to weeks, depending on the species, in the plankton (Lebour, 1934). A *C. imperforatum* larva begins life with a tiny spiral protoconch consisting of two and a half whorls 0.32 mm across (Lebour, 1937). However, as the larva grows, the spiral apex is knocked off and the resulting hole sealed with a septum (Tucker, 1954). After a few weeks of development, shell growth in only one direction produces a simple, slightly curved shell unique to the family. As development continues, the animal gradually retreats from the apical end and forms a new internal septum (Lebour, 1937).

More recently, Bandel (1996) described veliger larvae maintained in the laboratory after collection from plankton in the Red Sea. Although unidentified, the protoconchs resembled those of several species of *Parastrophia*: Mediterranean/Atlantic *P*. (*P*.) *asturiana* (de Folin, 1870a), and Indo-Pacific *P*. (*P*.) *cornucopia* (de Folin, 1869) and *P*. (*P*.) *cygnicollis* (Hedley, 1904). The embryonic shell was ~0.07 mm across and was followed by a slightly curved, 0.5-mm-long larval shell that decreased slightly in diameter near the aperture. In addition to a round operculum and larval heart in the "neck" posterior to the head and in the mantle cavity, Bandel (1996) observed a ribbon of cilia that moved water from the neck into the posterior end and along the roof of the mantle cavity past the anus to the outer lip and noted that the system persisted for a time after metamorphosis, because the early benthic juvenile had not yet developed a ctenidium. The densely ciliated foot took over locomotion when the larval velum was lost during metamorphosis. Finally, the first septum formed as the visceral mass withdrew from the embryonic shell.

As in many mollusks, the main feeding structure is a radula, a chitinous ribbon lined with small teeth (Kumbhar and Rivonker, 2012). Caecids and other rissoideans have a taenioglossate radula with numerous transverse rows of lingual teeth, each row consisting of seven teeth: a large central median tooth that often has cusps, flanked by a pair of lateral teeth and two narrow hook-like marginals (Fretter and Patil 1961). Jaws, which are also found in Rissoidae, consist of a series of closely packed cuticular rods that help scrape and break down food particles (Fretted and Patil, 1961). In addition, the pedal gland secretes an abundant viscous secretion that aids feeding by acting as climbing ropes. Based on the investigation of nine species, caecids hang from the surface film of rocks, collecting particles of food and then, when in search of new feeding grounds, can move vertically through the water suspended by the secreted threads. Caecums mainly consume benthic detritus, diatoms and algal filaments, which are gathered by the radula and aided by the jaws (Fretter and Patil, 1961).

1.3 Artificial versus Natural Substrates:

Coral reefs around the world have experienced dramatic, long-term losses in faunal abundance and diversity, and in habitat structure due to anthropogenic stresses (Jameson et al., 1995; Moberg et al., 1999; Graham et al., 2006; Baker et al., 2008; Kheawwongjan et al., 2012; Hooidonk and Huber, 2012). Artificial reefs have become an increasingly important resource-enhancement technique, deployed to increase fish populations and perhaps biodiversity, either in the face of deteriorating natural reefs, or diminishing populations of fishes and other organisms; however, many questions remain regarding optimal design criteria, location, size of habitats, and recruitment success (Bohnsack and Sutherland, 1985; Burt et al., 2009; Hellyer and Poor, 2011; De Aruajo and Da Rocha, 2012). Spieler *et al.* (2001) provided a thorough introduction to the challenges associated with large artificial substrate design and function.

Investigating how assemblages of macroinvertebrates vary on hard substrates (e.g., reef, rubble, rock), either naturally or in response to stresses, can present many challenges. One of the major problems is locating and sampling ecologically comparable habitats both exposed and not exposed to the variables examined in the experiment. This requires finding areas with comparable physical and chemical characteristics, sampling ability and close proximity of sites in order to provide adequate comparative data of the similarities and differences between them (Kusza, 2001). In response to this challenge, a variety of smaller quantitative samplers, here referred to as Artificial Substrate Units (ASUs), have been developed over the last several decades for use in both fresh and marine environments (e.g., Jacobi, 1971; de Pauw et al., 1994; Robinson, 2008). ASUs provide identical structure in which replicate samples can be taken; their uniformity greatly reduces any unquantified and unknown differences between substrates (e.g. shape, size and composition) (Glasby and Connell, 2004). Thus, this greater control over experimental variability greatly improves the validity of comparative data when trying to determine similarities and differences between invertebrate assemblages.

Although ASUs do provide some solutions, they also exhibit limitations. Minute variations among replicates face these smaller samplers as well. For example, because ASUs are constructed of a range of materials, the material chosen may affect composition and settlement of larval recruits (Kusza, 2001). Kershner and Lodge (1990) noted strong, species-specific behavior and a morphological relationship between macrophyte habitat and invertebrate density in a laboratory experiment using 2-mm strips of inverted triangles of balsa wood artificial substrates coated with dried creamed spinach. All artificial substrates had equal surface area but differed in shape and degree of contact with the bottom. They determined that the maximum densities of the snails *Lymnaea stagnalis* and *Amnicola* sp. were on the 2-mm strips and were significantly higher than on the inverted triangles. In addition, in a comparison of mesobenthic amphipod diversity between artificial substrate and natural substrate units, Robinson (2008) determined that, despite the advantage of reduced variability, the artificial substrates were still selective. ASUs in that study consisted of synthetic stripping pads, secured by plastic cable ties onto a thin plastic frame and nailed to the rock substrate (See Methods section, below). Robinson (2008) determined that, although all the common species on the ASUs were also present on the natural substrate, the high abundance of certain amphipod species such as *Elasmopus balkomanus*, *Bemlos kunkelae*, and *Bemlos dentischium*, and the lack of others such as *Chevalia carpenteri*, *Globosolembos smithi*, *Leucothoe laurensi* and *Apolochus* sp. on the ASUs demonstrated that the ASU assemblage was a subset of the adjacent natural species assemblage.

Understanding how artificial substrates may differentially select macroinvertebrate assemblages relative to natural substrates will contribute to more accurate assessment of ASU use. By elucidating the degree of substrate preferences among marine invertebrates, the possibility of using artificial materials to create mimics of natural reefs will be more accurately understood.

Robinson (2008) recorded but did not quantify four caecid species on her ASUs and natural substrates: *Caecum carolinianum, Caecum floridanum, Meioceras nitidum and Caecum pulchellum*. How accurately the sampled assemblages reflect the natural substrate type in terms of species composition, diversity and abundance has thus not been investigated. The current study utilized her samples to quantitatively compare caecid assemblages on natural versus artificial substrates, and between reef and rubble habitats. Case studies such as this will add to our understanding of the surrogate properties of artificial reefs to mediate the loss of natural reefs.

2.0 MATERIALS AND METHODS:

2.1 Distribution and Taxonomic Study Collection Sites:

In order to review the taxonomy and investigate the distribution of Caecidae in Broward County, samples were collected from five different habitat types from northern and southern Broward Country accessed either by wading, snorkeling or scuba diving, and included two of each of the following five habitats: mangrove, Intracoastal Waterway, creek, reef and rubble (Figure 1).

Mangrove Habitats

Mangrove habitat samples consisted of sediment collected from Deerfield Island in northern Broward and Ann Kolb Nature Center in southern Broward. Deerfield Island is a 53.3-acre triangular park bordered by the Intracoastal Waterway and is only accessible by boat. The western part of the island has a 0.75-mile trail, including a 1,600-foot boardwalk; it exhibits remnants of a freshwater wetland but now is dominated by red and white mangroves. Ann Kolb Nature Center, in Hollywood, FL, is a 1,501-acre coastal mangrove wetland that supports a variety of native plants and animals, including threatened and endangered species.

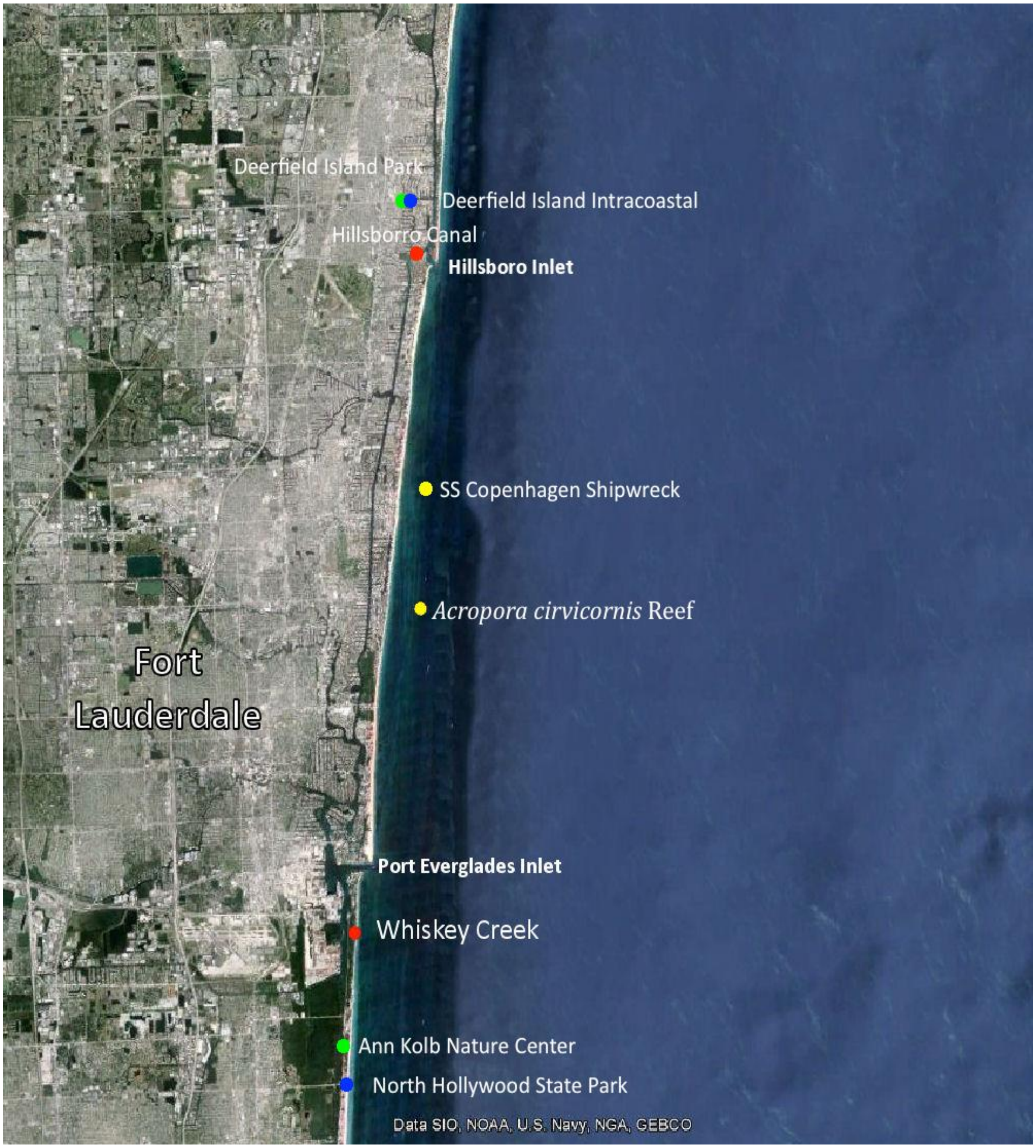

Figure 1: Map of habitats and sites sampled in northern and southern Broward County. Habitats are indicated as follows: Creek (red); Intracoastal Waterway (blue); mangrove (green); reef and (for southern Broward) rubble (yellow).

Intracoastal Waterway Habitats

Intracoastal Waterway habitats were sampled in Deerfield Island in northern

Broward and the Intracoastal Waterway in North Hollywood State Park (southern Broward). This Deerfield site is on the eastern side of the island, where the Intracoastal Waterway runs next to the half-mile-long Coquina Trail, which meanders through what was once a pineland forest. The environment has been converted into a coastal hammock with gumbo limbo and sabal palms dominating the overstory and wild coffee ruling the understory. The Intracoastal Waterway site in North Hollywood State Park has a long boardwalk that runs along barrier island mangroves. Due to its popular location along widely-used Florida State Road A1A, and with access to the beach, the Intracoastal Waterway provides a common spot for recreation activity such as picnicking, kayaking and fishing.

Creek Habitats

Hillsboro Channel, serving as the northern creek site, begins in Lake Okeechobee. However, extended sections of the channel in northern Broward Country have eroded or detached from the bank slope and have fallen into the channel. This has prevented adequate water flow. It is also here that the canal changes from its straight flow path to go around several curves, providing 10 navigable miles popular for recreational use. The southern Broward creek site is Whiskey Creek in John U. Lloyd State Park, in Dania Beach, FL. This is a shallow creek system between the beach and mangrove systems. Its northern end (N 26.0800^{o}, W 80.1117^{o}), which averages 10 m wide and 0.2 m deep, is a popular recreational site for canoeing, fishing, and boating. The study site is located several hundred meters south of the northern end to minimize the influence of anthropogenic effects. Rosch (2007) collected large numbers of several caecid species there.

Reef Habitats

The northern reef site chosen was Copenhagen reef, named after SS *Copenhagen*, which went aground off the Pompano Drop-off in 1898 and now lies about 5-11 m below the surface. With its bow facing south, the remnant of the wrecked ship lies 1.2 km offshore of Lauderdale-by-the-Sea. Between 1898, when the steamer ran aground and sank, and 1994, the area was used for naval target practice but was subsequently named a protected preserve. Today, this site is part of the Florida Underwater Archaeological Preserve and offers a haven for all kinds of marine life, including hard and soft corals, sponges and reef fish. The wreck, which has become part of the reef, is now a popular recreational dive site. The reef habitats in southern Broward County are those studied by Robinson (2008); they lie 0.5 km offshore on the Inshore Ridge Complex (See below). The Reef Site is a shallow coral habitat characterized by beds of staghorn coral, *Acropora cervicornis*, at depths of 3.0-4.0 m, and is divided into three 6-m-long transects (Figures 2-3).

Rubble Habitat

As described by (Robinson, 2008 p. 5-7) the rubble site was located atop a deep sand base, west of the first reef ridge, parallel to the coast, 5 km offshore, and 30 m west of the *Acropora cervicornis*-dominated reef site (Figure 2). According to Robison (2008) both reef and rubble sites are characterized by high wave exposure and experience moderate erosion during severe storms. This is consistent with the description of the rubble habitat consisting of debris derived from the eastern reef ridge.

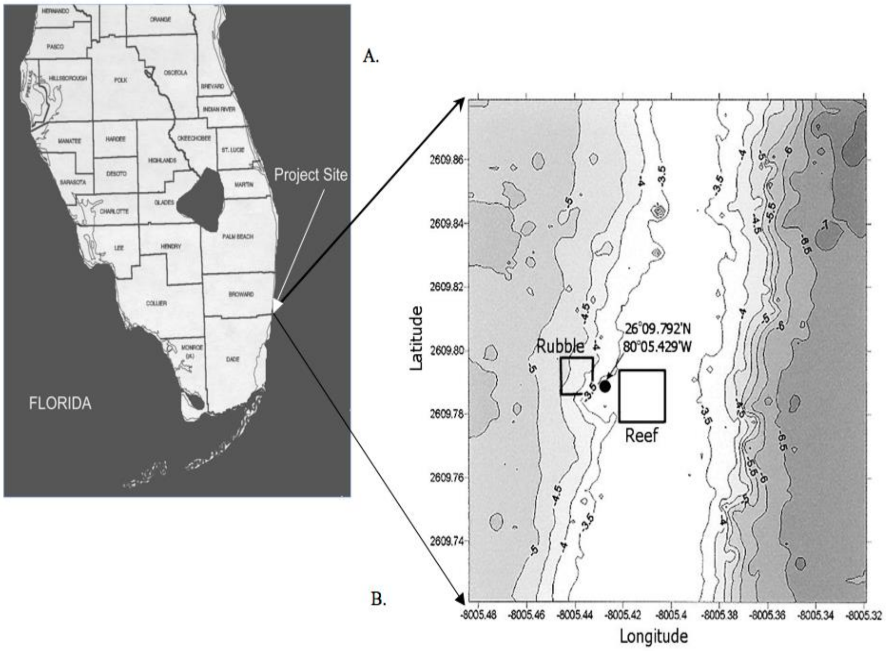

Figure 2: Location of Reef and Rubble natural vs. artificial samples sites (squares) ~0.5 km offshore of the southeast coast of Broward County, Florida, along the Inner Ridge Complex (Robinson 2008).

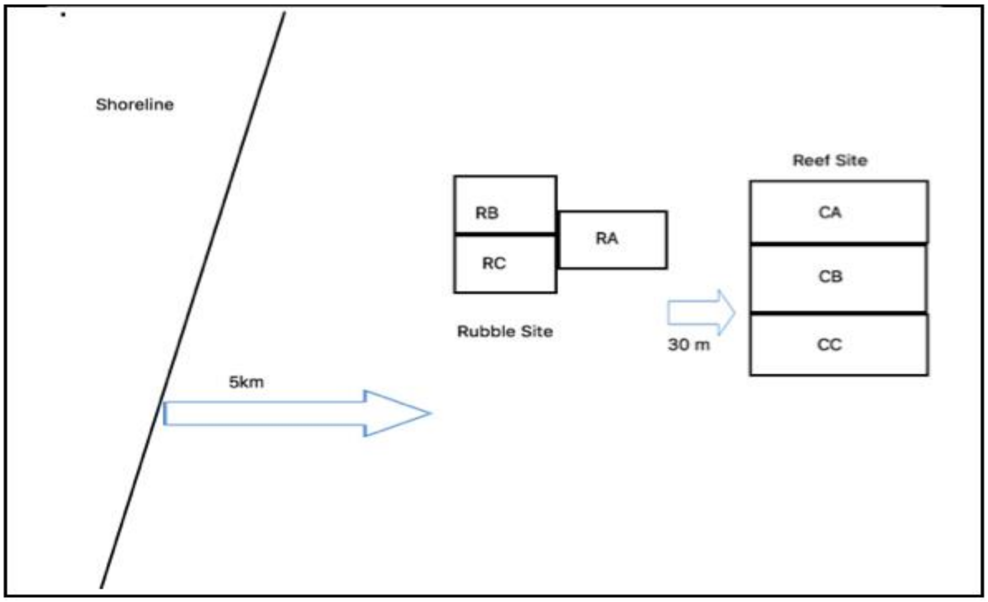

Figure 3: Schematic of experimental design showing the 3 transect natural reef sites CA, CB, CC and the 3 quadrants for artificial rubble sites RA, RB, and RC. Distances not to scale (from Robinson, 2008, p. 7).

2.2 Collection Methodology:

In order to determine species distribution among shallow habitat types through Broward County, quantitative sediment samples were collected using a sediment corer constructed of PVC piping. Quantitative samples were also taken on hard reef and rubble substrates by scraping surfaces with a knife or chisel. Samples collected from Artificial Substrate Units (ASUs) are described below. Both sediment and hard substrate samples were placed in plastic Ziploc bags followed by preservation in 95% ethanol. Caecid assemblages were compared between the various habitats to determine assemblage and species richness.

Robinson (2008, and personal communications) collected samples that included caecid assemblages from natural reef and rubble substrates and ASUs at the southern Broward reef and neighboring rubble sites described above. Robinson's (2008, p. 6) ASUs and natural substrate sampling protocol is as follows: Artificial substrate units (ASUs) were constructed of synthetic 3M Hi Pro stripping pads, 12cm x 25cm x 0.5cm. Each pad was cut in half and each half was then sandwiched together and attached by cable ties to form one ASU. The length of each pad was measured before deployment; however, pad dimensions showed little variation: mean length 12.7 SE ± 0.015cm, mean width 12.0 SE ± 0.005cm, and mean height 2.0 SE ± 0.003cm. Total ASU surface area averaged 307.2 SE ± 0.385cm^{-2}. Each ASU was tightly secured by plastic cable ties onto a thin plastic frame, 2.5cm x 15.5cm, that was nailed to the rock substrate in order to maintain direct contact with the natural substrate. Samples were taken from May to September 1999; four ASUs were retrieved at 2-week intervals over a 14-week period, and four samples of natural substrate were taken from each site per month. During this collection period, 28 ASUs were collected in each of the 3 Reef Site transects and 3 Rubble Site quadrants for a total of 168 units. The natural substrate samples consisted of randomly hand-picked individual pieces of rock rubble. In order to compare samples, area was calculated using the foil wrapping technique (Robinson, 2008 p.8) as described by Tait et al (1994) and Lamberti and Resh (1985), which uses aluminum foil to estimate surface areas through a regression analysis. By using a known amount of aluminum foil and molding it around each substrate, pressing flat into the crevices and trimming the excess foil the surface area of a hard substrate can be estimated. The area is then measured with a planimeter, a device use to determine the area of an arbitrary 2-dimensional shape. Next, the foil is weighed and converted to surface area by a known foil weight/area ratio":

$$A = 164.60wt + 8.50$$

where A is the area of the substrate and wt is the weight of the foil used to wrap the sample substrate.

To compare densities on ASUs with those on the natural rock, all substrates were normalized to 600 cm^{-2} (the area of the largest natural rock sample). Density was calculated by the following formula:

$$\mathrm{D} = \mathrm{SA/count} * \mathrm{SF}$$

where standardized density (D) equals the surface area of the hard substrate (SA) divided by the count of individuals times the standardizing factor (SF), in this case 600. For example, total mean ASU surface area was 307.2 ± 0.385 (SE) cm^{-2}, rounded to 307 cm^{-2} for calculation purposes. One hundred specimens were retrieved from this ASU. Thus, density on this artificial unit was 0.325 specimens cm^{-2}. However, in order to compare this sample with the natural substrate in which the largest sample had an area of 600 cm^{-2}, 0.325 specimens cm^{-2} was multiplied by 600, resulting in a comparable density value of 195 specimens 600 cm^{-2}. Each natural substrate sample was placed in a plastic Ziploc® bag, immediately sealed and placed into a large mesh bag for transport to the surface. Individual organisms were extracted from ASUs and natural substrates by elutriation and captured on a 180-μm mesh sieve. Each ASU was also carefully examined and the fauna picked out. To ensure that all fauna was collected from natural samples, each rock sample was washed with seawater. All organisms were then fixed in 4% seawater-buffered formalin overnight and stored in 70% ethanol.

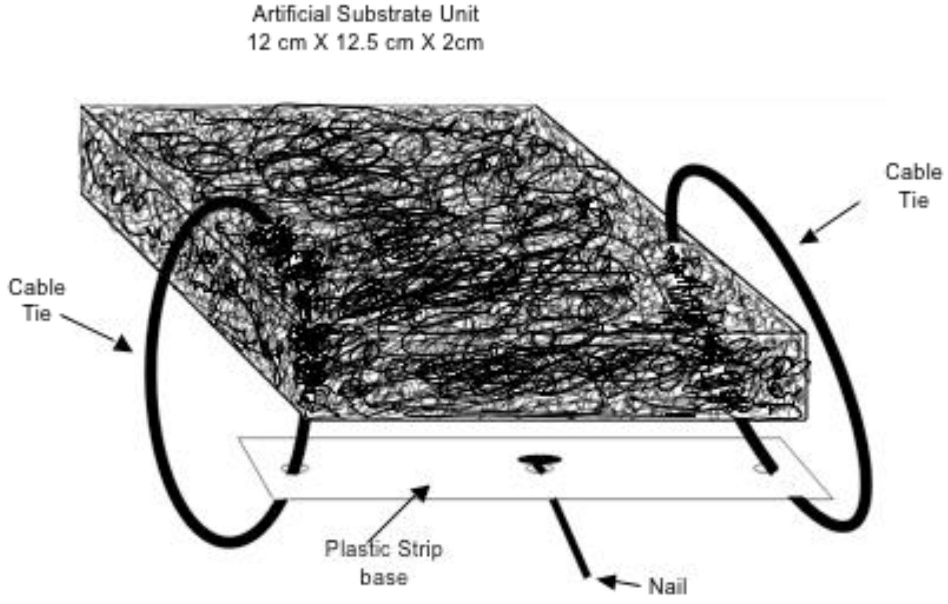

Figure 4: Artificial substrate unit (ASU). See text for dimensions and construction. (From Robinson 2008.)

Caecids were sorted from samples by examining a small portion of each benthic sample at a time under a stereo dissecting microscope. Specimens were removed via pipetting or a fine paintbrush and bottled. Specimens were then placed individually in small Petri dishes, measured using a 10-mm ocular micrometer and preliminarily identified using diagnostic features such as size and shape of the mucro, color and number of axial rings. Each specimen was then placed in a 2-ml glass vial labeled with an identifying number and all data (station number, date, vial number, specimen number, and measurements) and recorded in an Excel spreadsheet. Specimens collected from the same sample and initially considered to be the same species were placed in the same vial and given the same number supplemented by the number of specimens in the vial (e.g., x 2, for two specimens). Initial morphological notes were replaced with scientific names, chiefly using Abbott (1974). Empty shells, characterized by brittle texture, chalky white color, and eroded and abraded surfaces, were considered dead prior to collection and were not counted. The presence of an operculum definitively indicated an animal living when collected.

2.3 Data Analysis:

Because either no caecids or only small numbers of two species, *C. pulchellum* and *M. nitidum*, were collected from the different habitat sites in north and south Broward (except for Robinson's reef and rubble sites), no statistical analyses were carried out on these samples. The raw numbers are given below.

For comparison of caecids in Robinson's (2008) natural reef and rubble samples and ASUs, the data were analyzed using a repeated measures MANOVA with time as the repeated factor , caecid genus (*Caecum*, *Meioceras*), reef type (artificial vs natural), and substrate (reef vs rubble) as the predictor variables, and caecid density as the dependent variable. A repeated measures approach was used because density values from one time period to the next time period in a given sampling unit are likely to be correlated. (in other words, a unit with high density is likely to have a high density the next time period). In order to perform a MANOVA analysis, the assumption of sphericity was tested using the Mauchly's test. This analysis was performed for the time factor only; the remaining factors (genus, reef type, substrate) had only two levels and so by definition they meet the condition of sphericity. Where the assumption of spericity was violated, the Greenhouse-Geisser procedure was used to correct subsequent pairwise post-hoc statistical comparisons.

2.4 Taxonomic treatment

Synonymies are based on current entries in the World Register of Marine Species (www.marinespecies.org) and include only extant accepted taxa and synonyms. Descriptions are based primarily on Lightfoot (1992a, b), with additional information from Abbott (1974) and Bailey-Matthews (2011), and other sources when available.

3.0 RESULTS

3.1 Taxonomic Remarks: Species definitively recorded from or most likely to be found in Broward County, Florida.

Caecum pulchellum Stimpson, 1851

Caecum pulchellum Stimpson, 1851
Caecum capitanum de Folin, 1874a
Caecum conjunctum de Folin, 1867c
Caecum curtatum de Folin, 1867b

Description.—Shell minute, tubular, on average 2.5 mm long, 0.4-0.7 mm wide; axial rings uniform, ~20, about twice as wide as spaces between; septum slightly convex; mucro weak, pointed, projecting slightly; operculum brown, with 6-7 spiral revolutions; periostracum tan, thin, not strongly adherent; aperture with 2-3 additional small rings, terminates with small lip; diameter of aperture slightly smaller than interior tube diameter; no terminal varix (Abbott 1974; Leal, J.H. 2016; Lightfoot 1992a).

Color.—Light tan to white.

Distribution.—New Hampshire to Brazil.

Developmental stages.—Lightfoot (1992, p. 173) described a second stage as: “narrow, tan, rounded narrow rings, striae on sides and tops of rings, strong curve as shell starts to swell.” The meaning of the last character is unclear.

Remarks.—Abundant in seagrass beds in sheltered lagoons, bays and reef habitats; occasionally found in creek systems. Bandel (1996) placed this species in subgenus *Caecum.* In a macroinvertebrate monitoring survey of Port Everglades, Broward County, FL (Messing and Dodge, 1991, 1192a, b, 1993a, b, 1994a, b, 1195a, b, 1996a, b, 1997), *C. pulchellum* was by far the most common gastropod. The survey consisted of three replicate 225-cm^{-2} ponar grab samples taken twice annually (January and August) at eleven sites from Aug 1991 to Jan 1997. *C. pulchellum* was found at least in small numbers at all eleven sites over the course of the survey and was the only caecid recorded at most sites in most samplings. Numbers ranged from 20 to 1316 specimens per seasonal sampling (eight of 12 recorded >500 specimens) with no trend over time or consistent overall difference between January and August samples. As an example, in January 1997, it accounted for 77% of 1063 gastropod specimens and 96% of all caecids. The species was most common in Whisky Creek, a shallow sand-floored mangrove creek, where it was absent from only one seasonal sample and outnumbered by *C. imbricatum* in four. Numbers in the three replicates for any given sampling often varied widely. The maximum collected here (Aug 1996) was 73, 317 and 389 specimens per grab, equivalent to a mean density of 11,540.7±7,360.8 *C. pulchellum* m^{-2} (or 692.3±441.5 individuals 600 cm^{-2}, for comparison with Robinson's sites). Two sites on the east side of the Intracoastal Waterway, chiefly fine muddy sand in 1.0-1.5 m depth, reported the next highest numbers, none during August: sta. 13a, Jan 1995 (143 specimens in three replicates combined), 1996 (260); sta. 18, Jan 1995 (272), 1997 (165). Rosch (2007) collected monthly quantitative core samples at three adjacent sites across Whisky Creek, similar to sta. 17 above, from Apr 2006 to Mar 2007, but found far fewer *C. pulchellum*, and none in any sample during June and July. Individual 7.7-cm-diameter (46.5 cm^{-2}) core samples included only 1-6 specimens. This range is equivalent to 12.9-77.4 individuals 600 cm^{-2} for comparison with Robinson's sites. *C. pulchellum* accounted for 27% of caecids collected overall relative to *C. imbricatum* (65%) and *Caecum* sp. (8%).

In the current study, *C. pulchellum* was again the most abundant caecid observed (~52% of all specimens) but was absent from mangrove, creek and Intracoastal Waterway sites. Robinson (2008) recorded (but did not quantify) this species in virtually all samples on reef and rubble habitats and on natural and artificial substrates at her study sites off southern Broward County (see section 2.2 below). The current study recorded 1,204 specimens from the reef and rubble habitats, with *C. pulchellum* contributing 34 % and 30% of caecids collected from natural substrates and 20% and 16% on ASUs. *C. pulchellum* was slightly more abundant in the rubble habitat that in the reef habitat (54% vs. 46%).

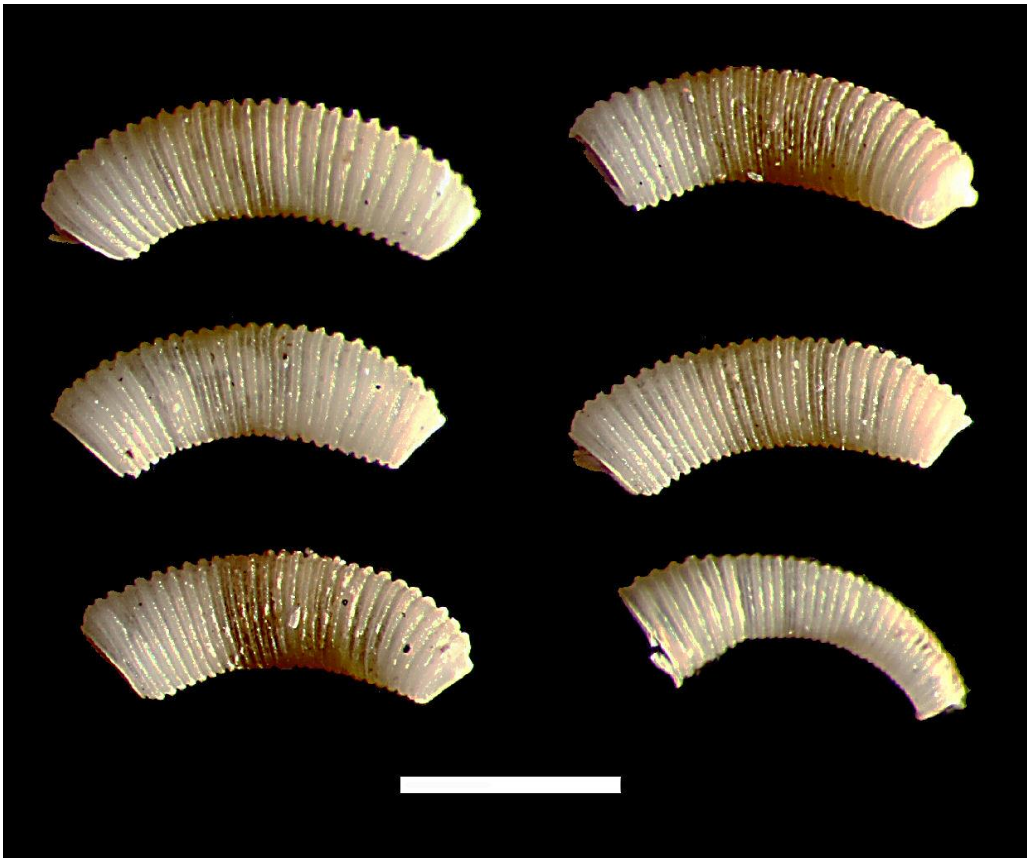

Figure 5. *Caecum pulchellum,* scale 1 mm.

Caecum floridanum **Stimpson, 1851**

Caecum floridanum Stimpson, 1851
Caecum irregulare de Folin, 1867a
Caecum phronimum de Folin, 1867a
Caecum crassicostum Gabb, 1881
Caecum cayosense Rehder, 1943

Description of neotype.—Adult shell (teleoconch IV) small, 3.85 mm long, tubular, rather thick, moderately and regularly arched, with slight increase in caliber from apical region to aperture; length from aperture to point of maximum arc 1.0 mm; maximum arc = 0.30 mm. Surface sculptured with longitudinal striae, faint to well-defined longitudinal threads and 26 prominent, wide, low, rounded, closely arranged and regularly spaced axial ribs, except last three preceding aperture, which are larger and more widely separated. Striae and threads cross ribs and interspaces; threads producing very slightly beaded effects on ribs. Axial interspaces very narrow and shallow, except the last two to three preceding the aperture, which become wider and deeper. Apical region circular; diameter of posterior extremity 0.57 mm. Septum slightly convex, deeply recessive. Mucro finger-shaped, conical, straight, moderately slender, 0.12 mm long, 0.15 mm wide, on dorsal margin. Aperture circular, 0.75 mm across, surrounded by prominent varix. Operculum horny; outer surface concave, with nucleus subcentral, and about eight slight coils; inner surface convex, smooth (modified from Lima and Christofferson, 2016).

Color.—Opaque-white to cream–white with brownish markings, sometimes observed as transparent. Operculum yellowish-brown.

Distribution.—North Carolina to Brazil (Abbott, 1974; Lima and Christofferson, 2016); collected off Delray Beach (Lightfoot, 1992a), and Palm Beach and Deerfield Beach (Lima and Christofferson, 2016); depth range 0-96 m (Lima and Christofferson, 2016).

Remarks.—*C. floridanum* has previously been reported from reef habitats (Lightfoot, 1992a). However, Lima and Christofferson (2016) reported it from depths as great as 96 m. Of their 44 records including depths, 33 were from Brazilian waters with 14 from depths between 40 and 60 m.

This species differs from other local *Caecum* species in the significant enlargement and spacing of the 3-4 axial rings adjacent to the aperture. However, Lima and Christofferson (2016) noted that Stimpson's (1851) original description does not conform to subsequent widely recognized descriptions. They redescribed the species based on specimens from the type locality (Florida) and designated a neotype, deposited in the Academy of Natural Sciences of Philadelphia, Philadelphia, USA (cat. no. 407671). Lightfoot (1992a), followed by Bandel (1996), placed this species in subgenus *Elephantulum* Carpenter, 1857. However, Lima and Christofferson (2016) gave no subgeneric assignment.

Robinson (2008) recorded (but did not quantify) this species in virtually all reef and rubble samples on natural and artificial substrates at her study sites off southern Broward County. However, it accounted for only approximately 3% percent of her entire collection (2,744 specimens): ~4.9% and ~3.6% of caecids on natural substrates and 0.7% and 2.0% on artificial substrates. The species was about equally abundant in both reef (~3.2%) and rubble habitat (~3.4%). It was absent from all mangrove, creek and Intracoastal Waterway sites.

Figure. 6. *Caecum floridanum*. Scale: 1 mm.

Caecum textile **Folin, 1867b**

Caecum textile de Folin, 1867b
Caecum leptoglyphos de Folin, 1881a

Description.—Shell of almost even width, varying from narrow to fat, with 35-45 low, close-set axial rings created by narrow transversely cut grooves, so that most specimens appear smooth, to 2.0 mm long, 0.5 mm wide; numerous fine longitudinal striations or threads, chiefly visible between rings; aperture simple with slight thickening; septum nearly flat; no varix visible; mucro low and slightly pointed (Abbott 1974; Lightfoot 1992a).

Color.—Varies from almost transparent white to dark brown.

Distribution.—Bahamas, Caribbean Sea, SE Florida and Florida Keys (Lightfoot 1992a).

Remarks.—Bandel (1996) placed *C. textile* in subgenus *Caecum.* The species is most easily distinguished from the other local caecids by its almost smooth appearance as a result of dramatically low, close-set axial rings. Lightfoot's (1992a) description of the septum (swelling slightly to strongly convex) and mucro (strong blunt point) differ from those of Abbott (1974) (septum flat; mucro low and slightly pointed). The species is restricted to stenohaline warm waters and is moderately common in sandy shallow coral reefs and creek systems. Messing and Dodge (1996a, b, 1997) found *C. textile* only at their station 17 in Whisky Creek: in small numbers in their January 1996 and 1997 samples, and accounting for 9% of Ccaecids (36, 36, and 32 in the three replicates) in Aug 1996. They found none from 1991 through 1995, and Rosch (2007) found none in Whisky Creek in 2006-2007. Neither Robinson (2008) nor this study recorded any specimens. Figure 7 illustrates specimens from Everglades National Park for comparison with other species. Lightfoot (1992a) recorded this species in southeastern Florida from Stuart (Martin County), Delray Beach (Palm Beach Co.) and Marathon (Monroe Co.).

Figure 7. *Caecum textile*, scale 1 mm.

***Caecum imbricatum* Carpenter, 1858**

Caecum imbricatum Carpenter, 1858

Caecum sculptum de Folin, 1881b

Caecum insigne de Folin, 1867a

Caecum coronatum de Folin, 1867a

Caecum formulosum de Folin, 1869a

Caecum formulosum var. paucicostata de Folin, 1869a

Caecum formulosum var. simplex de Folin, 1869a

Caecum formulosum var. sulcata de Folin, 1869b

Description.—Shell gradually enlarged toward aperture; curve varying from moderate to almost none, 3-4 mm long, 0.8-1.0 mm wide; 30 low rings; 20-25 narrow fairly strong longitudinal cords, not always evenly spaced, creating small beads; longitudinal striae covering entire shell; appearance varying from evenly cancellate to roughly and irregularly beaded; aperture with 3-6 transverse slightly enlarged and beaded terminal ridges; septum not recessed; mucro varying from long narrow prong to inflated triangle (Abbott, 1974; Bailey-Matthews, 2011; Lightfoot, 1992a).

Color.—Off-white, brownish-white to reddish tan, mottled, with zigzag rings (Bailey-Matthews, 2011; Lightfoot, 1992a).

Distribution.—Florida, Texas, Bahamas, West Indies and Brazil. Reported from southeastern Florida off Stuart (Martin County), Delray Beach (Palm Beach Co.) and Little Torch Key (Monroe Co.) (Lightfoot 1992a).

Developmental stages.—Lightfoot (1992a, p. 181) described a second stage as: "translucent, narrow, curved; covered with many bumpy, irregular transverse ridges; longitudinal cords appearing on later growth."

Remarks.—*C. imbricatum* is clearly distinguished by the flattened axial rings and the only slightly enlarged terminal rings. Lightfoot (1992a) noted the distinctive clearly defined ribs and alternating square and oblong beads on the ridges adjacent to the aperture. The adult stage is distinguished from the secondary stage by the presence of longitudinal cords. This species is common in shallow waters but can be found as deep as 183 m. Carpenter (1858) tentatively placed *C. imbricatum* in his Section *Elephantulum*, subsequently treated as a subgenus (Lightfoot 1992a; Bandel 1996). Messing and Dodge (1997) found *C. imbricatum* in every sampling at sta. 17 in Whisky Creek except in January 1992. Numbers ranged from 14 in August 1995 to 1,113 in January 1994, although no consistent differences were found in the January versus August numbers. Numbers per replicate varied widely. The maximum mean density (extrapolated from the 225-cm^{-2} ponar grab) recorded (Jan 1994) was 16,472.4±1,720.2 m^{-2}. *C. imbricatum* outnumbered *C. pulchellum* in three of the eleven samplings at this site, accounting for up to 53% of caecids. The species was also collected in one replicate each at Intracoastal Waterway sites 9 and 11 (1 and 2 specimens, respectively). At Rosch's (2007) Whisky Creek site, *C. imbricatum*, *C. pulchellum* and *Caecum* sp. accounted for 66.6%, 24.4% and 9% of all specimens. *C. imbricatum* was absent in the June and July samples and was most abundant at the mid-creek site in winter. It was not collected by Robinson (2008) or at any site in the current study.

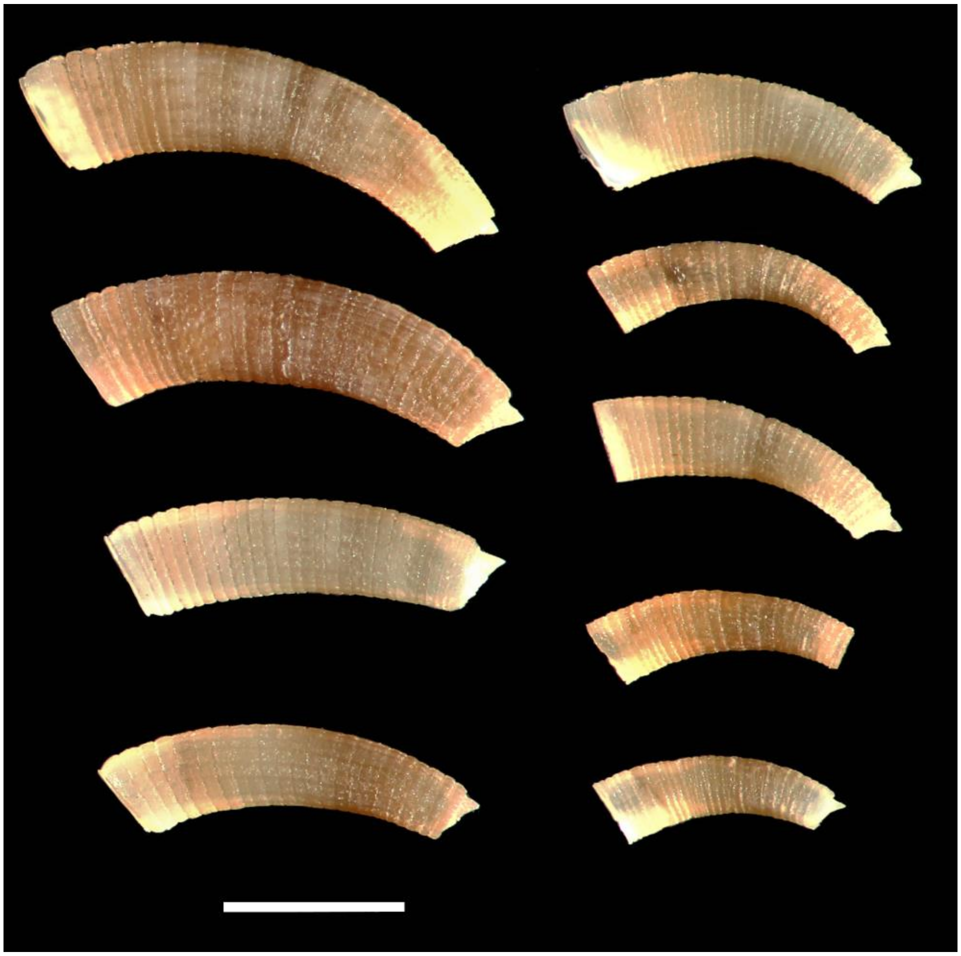

Figure 8. *Caecum imbricatum,* scale 1 mm.

Meioceras nitidum **(Stimpson, 1851)**

Caecum nitidum Stimpson, 1851

Caecum rotundum de Folin, 1868

Caecum bitumidum de Folin,1869c

Caecum deshayesi de Folin, 1869c

Caecum subinflexum, de Folin 1869b

Meioceras carpenteri de Folin, 1869c

Caecum moreleti de Folin, 1869c

Caecum undulosum de Folin, 1869c

Caecum coxi de Folin, 1869c

Caecum subinflexum, de Folin 1869b

Caecum fischeri de Folin 1870b

Meioceras contractum de Folin 1874

Caecum cingulatum Dall, 1892

Caecum imikilis de Folin, 1870b

Caecum lermondi Dall, 1924

Caecum (Meioceras) nitidum: Lightfoot, 1992b

Description.—Shell minute, cylindrical, swollen in middle, smooth; some shells marked by strong growth lines; 2-3 mm long on average, 0.5-1.0 mm wide; septum even with edge of shell on ventral side, or slightly projecting, angling rather flatly upwards to meet mucro; mucro projecting prominently as thin rounded point, flat on dorsal side, positioned variously between 12 and 2 o'clock; operculum yellow-tan, rings visible but not prominent (Abbott 1974; Bailey-Matthews 2011, Lightfoot 1992b).

Color.—White or semi-transparent, with irregular opaque white and tan mottling.

Distribution.—Southern Florida, eastern Gulf of Mexico, Bahamas to Brazil (Lightfoot (1992b).

Developmental stages.—Three developmental stages are recognized (Lightfoot, 1992b; Ecological Association, Inc. 2009): juvenile, intermediate, and adult. Juvenile stage: shell completely smooth; aperture end enlarged and funnel-shaped; vestige of ancestral spiral coil retained adjacent to apex; mucro very weak. Intermediate stage: 2-3 mm long; partly twisted into a spiral; slightly bulbous through the middle (Bandel, 1996). Adult characteristics described above.

Remarks.—Adult *M. nitidum* is most easily distinguished among local caecids by its smooth surface and bulbous middle. The species is normally found in shallow marine habitats where the salinity is close to that of the ocean, such as protected lagoons and bays, and may be especially common among brown algae on rocky shores (Moore, 1972). The species was originally placed in genus *Caecum* and subsequently in subgenus *Meioceras* by Carpenter (1858). Bandel (1996) ranked *Meioceras* as a genus. Messing and Dodge (1991, 1192a, b, 1993a, b, 1994a, b, 1195a, b, 1996a, b, 1997) found 1-2 specimens in isolated replicates at nine of eleven sites (Intracoastal Waterway and Whisky Creek) during eight of twelve samplings between August 1991 and January 1997, with an isolated maximum of 32 specimens in one grab sample (Jan 1993) at their station 8, a fine muddy sand and mangrove detritus substrate on the west side of the Intracoastal Waterway at a depth of 3 m. Only two specimens were found in one replicate at station 17 in Whisky Creek. Rosch (2007) found none in his Whisky Creek study. By contrast, *M. nitidum* was the second most abundant species in the current study and contributed ~36% of all caecids collected. The species was most commonly found in shallow reef habitats but was also found in shallow creek systems. Robinson (2008) recorded (but did not quantify) this species in virtually all samples on reef and rubble habitats and on natural and artificial substrates at her study sites off southern Broward County. *Meioceras nitidum* accounted for 44% of the 2,744 caecid specimens collected by Robinson (2008): ~31.5% and ~51.5% of caecids on natural substrates and ~51.6% and 46.4% on artificial substrates. The species was more abundant on rubble habitat (~39%) vs. reef habitat (~20%). It was absent from mangrove and Intracoastal Waterway sites.

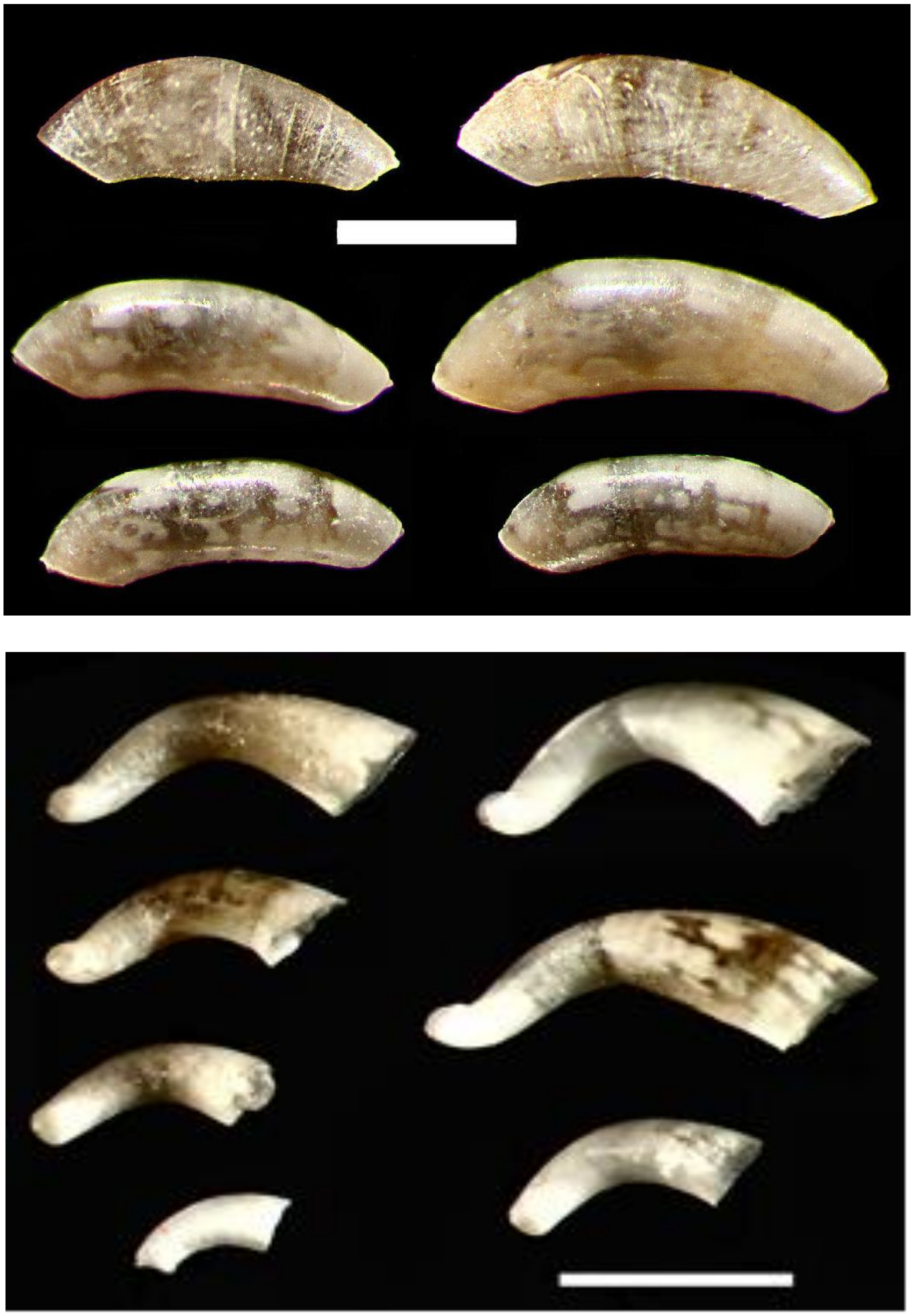

Figure 9. *Meioceras nitidum*. Top: adults. Bottom: juveniles. Scales: 1 mm.

3.2 Taxonomic Review: species recorded from southeastern Florida but not yet recorded in Broward County.

Caecum bipartitum de Folin, 1870b

Caecum bipartitum de Folin, 1870b
Caecum bipartitum var. *maculata* de Folin, 1870c
Caecum contractum de Folin, 1870b
Caecum instructum de Folin, 1870b
Caecum triornatum de Folin, 1870b

Description.—Shell moderately curved, gradually increasing in diameter toward aperture; average length 2 mm, width 0.4 mm; sculpture variable, depending on number and strength of rings; rings usually present only posteriorly, ranging from 0 to ~15; first ring bordering the septum, may be double; rings rarely completely absent; interspace as wide as rings; fine longitudinal striae most visible in smooth areas; aperture plain, terminating in small lip; some specimens slightly reduced in diameter at the aperture septum varying from flat to strongly convex; mucro sturdy, tapered, normally at 1 o'clock; (Lightfoot 1992a; Bailey-Matthews 2011).

Color.—Off white.

Distribution.—Georgia, Texas and both sides Florida, but apparently much less common on the east coast. Lightfoot (1992a) collected one specimen from Delray Beach (Palm Beach County).

Developmental stages.—Secondary stage with narrow, rounded and widely spaced rings; development leads to wider, lower, flat-topped, more closely packed rings (Lightfoot 1992a).

Remarks.—Abbott (1974) treated *C. bipartitum* as a synonym of *C. pulchellum*, but Lightfoot (1992a) restored it to species level. Although the range has been recorded as including both sides of Florida, *C. bipartitum* is much less common on the east coast. It is distinguished from other local species by the combination of smooth areas and different forms of rings on the same shell (Lightfoot, 1992a).

Caecum breve **de Folin, 1867a**

Description.—Short stout tube with little curve, 1.5 mm long, 0.7 mm wide; about 30 slightly raised longitudinal ridges, narrower than interspaces, crossed by fine transverse threads, strongest on apertural third; aperture with moderately raised and abrupt varix consisting of 5-6 small beaded rings, tapering slightly toward opening; septum blistered, recessed hemispherical, culminating in large rounded point; mucro with pinched top, creating a ridge or coin edge (Lightfoot 1992a; Bailey-Matthews 2011).

Color.—Semi-transparent to opaque white.

Distribution.—Florida, Jamaica, Virgin Islands and Brazil. Lightfoot (1992b) collected one specimen off Delray Beach (Palm Beach County).

Remarks.—Lightfoot (1992b) placed *C. breve* in subgenus *Brochina*.

Caecum carolinianum **Dall, 1892**

Description.—Shell smooth, large, glossy, relatively heavy, moderately curved, with moderate swelling adjacent to aperture; on average 4.0-4.5 mm, 1 mm wide; weak annulations and longitudinal striae; aperture simple, with slight narrowing; simple clear lip protruding from inner side of tube; septum deeply recessed, rising in a narrow hill; mucro rising close to center as narrow, rounded, elongated prong filling space between 1 and 2 o’clock (Lightfoot, 1992a; Moore, 1972).

Color.—Creamy-white to glossy.

Distribution.—Although Lightfoot (1992a) listed the range as North Carolina to southern Florida, the only specimen recorded was from St. Augustine, in northern Florida. This is the only species discussed here with no specific southeastern Florida records.

Developmental stages.—Lightfoot (1992a) described a second stage as having a miniature adult shape, translucent, with opaque streaking; septum deeply recessed; mucro microscopic; periostracum thick, brown, covered with longitudinal striae.

Remarks.—Robinson (2008) recorded this species in abundance although she did not quantify it in her comparison of mesobenthic amphipod diversity on 3-dimensional artificial substrates versus natural substrates on a shallow reef ecosystem. However, the examination of her specimens in the current study identified none as this species. Lightfoot (1992a) gave no subgeneric assignment.

Caecum clava **de Folin, 1867a**

Description.—Shell short, straight, solid and strong, 2-3 mm long, 0.5 mm wide; apertural end bulging and curved; ribs longitudinal, ~14, equally spaced and sized, but smaller and more crowded ventrally; longitudinal striae covering entire shell; transverse raised threads prominent on either end (strongest apically), creating beads on ribs, but becoming striae in middle of shell; aperture narrowed by large dorsal and ventral swelling; septum minutely inset; mucro swelling slightly to small prong oriented more horizontally than vertically, between 2 and 3 o’clock (Lightfoot 1992a).

Color.—Glistening, semi-translucent to opaque white.

Distribution.—East coast of South Florida, Gulf of Mexico, Texas, West Indies and lower Caribbean. Lightfoot (1992a) collected specimens off Delray Beach (Palm Beach County) and off Key West. Apparently, it is uncommon and found in deeper water.

Remarks.—Lightfoot (1992a) placed it in subgenus *Elephantulum*, whereas Bandel included it in subgenus *Bambusum* Olsson and Harbison, 1954. The apertural swelling is unique among local *Caecum* species.

***Caecum cooperi* Smith, 1860**

Caecum cooperi Smith, 1860

Caecum costatum Verrill, 1872

Caecum smithi Cooper, 1872

Description.—Shell gently curved, increasing slightly in diameter toward aperture, 4-5 mm long, 1 mm wide at aperture; ribs longitudinal, 11-15, widely spaced; three to nine transverse grooves at apical end, weak or absent in middle of shell, deeper and wider toward apertural end, creating raised flat square beads on ribs, producing angular, geometric sculpturing; septum even or slightly recessed, slightly mounded to form base of typically long, narrow, pointed mucro between 12 and 2 o'clock; mucro varying from small prong to thick triangular bulging projection; operculum brown, thick, concave, with six sharp sinistral spiral ribs (Lightfoot 1992a).

Color.—Unknown.

Distribution.—South of Cape Cod to Western Florida, Texas and Caribbean. Lightfoot (1992a) collected specimens off Stuart (Martin County) and Delray Beach (Palm Beach Co.).

Remarks.—Caecum cooperi is most easily distinguished by the raised, clearly defined ribs and alternating square and oblong beads on the apertural ridges. Lightfoot (1992a) and Bandel (1996) placed it in subgenus *Elephantulum*.

***Caecum multicostatum* de Folin, 1867d**

Caecum multicostatum de Folin, 1867d

Caecum heladum Olsson & Harbison, 1953

Description.—Shell evenly cylindrical with moderate to strong curves; smaller shells delicate; between 2 mm long and 0.2 mm wide to 3.8 mm long and 0.9 mm wide; shell covered with 30-40 raised annulations and 30-40 longitudinal ridges, neither evenly strong or spaced; shell sometimes faintly beaded; aperture with transverse annulations enlarged and crowded, followed by few smaller rings and ending in simple lip; longitudinal ridges tend to fade; septum recessed, forming three intergrading shapes: prominent hemisphere, lower rounded cap, and oblique flattened cap; septum irregularly blistered; mucro between 12 and 3 o'clock; periostracum tan, observed only in second stage (Lightfoot 1992a).

Color.—Translucent to opaque white.

Distribution.—Both coasts of Florida, Bermuda, Yucatan, Tobago. Lightfoot (1992b) collected nine specimens from Delray Beach (Palm Beach County).

Remarks.—Rosenberg *et al.* (2009) treated *C. heladum* as a synonym of *C. multicostatum,* although Lightfoot (1992a) treated *C. heladum* as accepted and did not mention *C. multicostatum*. Lightfoot (1992a) placed the species in subgenus *Brochina* Gray, 1857 but Bandel (1996) did not mention this species, and WoRMS lists no subgeneric assignment

(http://www.marinespecies.org/aphia.php?p=taxdetails&id=419591)

***Caecum subvolutum de* Folin, 1874b**

Description.—Shell evenly cylindrical, slender, moderately curved, glassy, thicker at apertural end, smooth with incipient annulations; on average 2.2 mm long, 0.3 mm wide smooth wide budding annulations; aperture with low to moderate abrupt varix bearing several small rings; septum moderately to deeply recessed and blistered, sloping up; mucro tongue-shaped, between 12 and 3 o'clock; mucro forms a prong like a coin edge raised above the septum (Lightfoot 1992b).

Color.—Translucent to opaque white, glossy.

Distribution.—Florida, Bermuda, Virgin Islands and Barbados. Lightfoot (1992b) collected five specimens from Delray Beach (Palm Beach County).

Developmental stage.—Lightfoot (1992b, p. 23) described a second stage as an "elongate, narrow tube, long mucro, septum heavily blistered."

Remarks.—Distinguished from *C. circumvolutum* (*C. vestitum* in Lightfoot (1992b)) by its narrower, glassier shell, more swollen varix and distinctive tongue-shaped mucro (Lightfoot 1992b). Lightfoot (1992b) placed *C. subvolutum* in subgenus *Brochina* (1992a), but Bandel (1996) indicated no subgeneric assignment.

***Caecum strigosum de* Folin, 1868b**

Description.—Shell evenly cylindrical, moderately curved, with no appreciable swelling, smooth to naked eye; 1.8 mm long, 0.4 mm wide; many fine transverse growth striae and stronger longitudinal striae covering entire shell visible under magnification;

periostracum adherent and tan, peels off in sheets when dry; septum broadly rounded mound, flush with sides of shell, minutely granular; mucro extremely small nub, often worn off with no visible projection, shaped like coin edge in fresh specimens (Lightfoot, 1992b).

Color.—Semi-translucent to white.

Distribution.—Florida, Bahamas and West Indies. Lightfoot (1992b) collected specimens off both Delray Beach (Palm Beach Co.) and Little Torch Key (Monroe Co.)

Remarks.—*C. strigosum* is rarely found in beach drift and is more commonly found offshore. It is smaller than *C. circumvolutum* and lacks both annulations and the abrupt downward turn and swelling at the aperture. Lightfoot (1992b) placed it in subgenus *Fartulum* Carpenter, 1857.

***Caecum johnsoni* Winkley, 1908**

Description.—Shell narrow, elongated, smooth and cylindrical, of even width; gently curve with abrupt downward (ventral) trend at aperture, 2.2 mm long, 0.4 mm wide; many crowded weak annulations packed together over entire shell, stronger and minutely raised at aperture; extremely fine longitudinal wavy striations; septum minutely inset; mucro evenly rounded dome, coin edge barely protrudes; operculum flat, with no visible spiral turns (Lightfoot, 1992b).

Color.—Transparent to opaque white.

Distribution.—Massachusetts to both sides of Florida. Lightfoot (1992b) collected specimens at Stuart (Martin County).

Remarks.—*C. johnsoni* differs from *C. strigosum* in having a longer shell, larger domelike septum, apertural curve, and annulations. Lightfoot (1992b) placed *C. johnsoni* in subgenus *Fartulum*. A junior synonym of *C. johnsoni* listed in www.marine.species.org as *C. putnamense* Mansfield, 1924, was spelled *C. putnamensis* in the original publication. Because Mansfield (1924, p. 47) treated it as "Upper Pliocene or Lower Pleistocene", it is not included in the synonymy here.

Caecum regulare **Carpenter, 1858**

Description.—Shell sturdy, moderately to strongly curved and of even width; 2 mm long and 0.5 mm wide on average; 22-28 flat topped, crowded rings, uniform along shell; sides of rings forming squared regular interspaces; size of interspaces differ from narrow to ring width; sides of rings and interspaces covered by strong regular longitudinal striae., creating serrated ring edges; aperture with 1-3 small rings that narrow opening; opening terminating with a small lip; septum flat to moderately convex, connected to double first ring; mucro pointing upwards in straight line, ending in small, blunt point between little after 12 o'clock to just after 1 o'clock; periostracum brown, persistent; operculum centrally concave, brown, with 8 spiral revolutions (Moore, 1972; Lightfoot, 1992a).

Color.—White to tan; opaque blotches common.

Distribution.—Florida, Bahamas, Virgin Islands, Cancun, Mexico Lightfoot (1992a) collected specimens at Lake Worth and Delray Beach (Palm Beach County).

Developmental stages.—Lightfoot (1992a, p. 175) described a second stage as: "narrow, flat-topped rings, longitudinal striae cover entire shell, even curve where it starts to swell," No periostracum observed.

Remarks.—*C. regulare* is most commonly found in shell sand from sponges. However, correct identification has been problematic, because *C. regulare* closely resembles many other species such as *C. gurgulio* and *C. pulchellum*. Also, its distribution is not well understood. It has been poorly documented in the West Indies (Moore, 1972). Lightfoot (1992a) placed this species in subgenus *Caecum*, but Bandel (1996) mentioned no subgeneric assignment.

Caecum gurgulio **Carpenter, 1858**

Description.—Similar to *C. pulchellum*; shell sturdy, evenly cylindrical, moderately curved, increasing minimally in anterior one-fifth, 1.8 mm long, 0.4 mm wide on average; 28-36 closely-spaced, slightly raised, narrow rings, flattish round-topped; aperture with about three small rings, last being the largest, terminating in small plain lip; septum adjacent to first ring, flattish to moderately swollen; mucro a small rounded prong at 1 o'clock; periostracum tan (Moore, 1972; Lightfoot, 1992a).

Color.—White.

Distribution.—Southeastern Florida, Bahamas, Virgin Islands, Aruba, Cancun, Mexico. Lightfoot (1992a) collected specimens at Delray Beach (Palm Beach County).

Remarks.—*C. gurgulio* differs from *C. regulare* in having more rings that are narrower and more crowded on a smaller shell, and in its finer sculpture around the aperture (Lightfoot (1992a). Lightfoot (1992a) placed this species in subgenus *Caecum.*

Caecum circumvolutum **de Folin, 1867e**

Caecum circumvolutum de Folin, 1867e

Caecum buccina de Folin, 1870b

Caecum carmenese de Folin, 1870b

Caecum veracruzanum de Folin, 1870b

Caecum vestitum de Folin, 1870b

Caecum vestitum var. *inornatum* de Folin, 1870b

Description.—Shell evenly cylindrical, moderately to abruptly downturned at apertural end; width varying from slender to robust; 2.2 mm long, 0.6-0.8 mm wide on average; covered with weak annulations, wavy longitudinal striations may be seen over entire shell; septum slightly recessed; low rounded or flattened mound, variable projection; mucro a rounded bulge, fills the space between 1 and 2 o'clock; no blistering; varix weak; annulations on aperture become stronger and closer over varix; definite downward slope of the aperture, narrowing a the opening; no operculum mentioned (Lightfoot, 1992b; Bandel, 1996).

Color.—Yellowish to white, semi-translucent.

Distribution.—East Florida from Ft. Pierce to Little Touch Key, lower Gulf of Mexico and Caribbean.

Developmental stage.—Narrow elongated tube; strong constriction, where next stage begins with abrupt swelling.

Remarks.—*C. circumvolutum* is an epifaunal grazer at depths of 1.5 to 40 m (Lightfoot, 1992b). Lightfoot (1992) placed *C. circumvolutum* (as *C. vestitum*) in subgenus *Brochina*.

***Meioceras cubitatum* de Folin, 1868a**

Meioceras cubitatum de Folin, 1868a

Meioceras tenerum de Folin, 1869c

Description.—Shell small, slender cylindrical, tapering strongly downward and prominently swollen or humped in apertural one-fourth, 1.8 mm long, 0.3 mm wide on average; completely smooth by naked eye, but with microscopic transverse incremental lines; aperture narrower than swollen interior tube diameter, surrounded by simple, slightly reinforced lip; septum recessed on fresh specimens and flush when worn; mucro a small narrow prong, rounded when worn, at 1 or 2 o'clock (Lightfoot, 1992b).

Color.—White, occasionally with white mottling.

Distribution.—North Carolina to Texas and Brazil. Lightfoot (1992b) collected specimens off Delray Beach (Palm Beach County).

Remarks.—Found only offshore. Lightfoot (1992b) wrote that a new species, *Caecum butoti* DeJong and Coomans, 1988, was obviously *M. cubitatum*. However, WoRMS (http://www.marinespecies.org/aphia.php?p=taxdetails&id=545155) lists this species as a junior synonym of *Caecum marmoratum* de Folin, 1869, without comment. A Global Biodiversity Information Facility search (http://www.gbif.org/occurrence/search?taxon_key=5192973&dataset_key=d962a7dc-2183-4824-bb88-5e0ba14ec62d) returned two location results for *C. marmoratum* in the Naturalis Biodiversity Centre collection (Leiden, Netherlands): Aruba and Brazil.

Meioceras cornucopiae **Carpenter, 1858**

Meioceras cornucopiae Carpenter, 1858

Fartulum nebulosum Rehder, 1943

Meioceras bermudezi Pilsbry and Agauyo, 1934

*Meioceras cornubovi*s Carpenter, 1858

*Meioceras cornubovi*s var. *marmorata* de Folin, 1869b

Meioceras cornubovis var. *subvitrea* de Folin, 1869b

Meioceras trachea var. *tincta* de Folin, 1869b

Meioceras mariae de Folin, 1881b

*Description.—*Shell sturdy, evenly swollen, smooth, with apical (posterior) portion narrowest; curve strong, angular, giving some shells a U-shape, 1.5-2.0 mm long, 0.4-0.5 mm wide; weak to strong transverse growth lines and wrinkles; aperture simple, slightly narrower than tube, or not; septum minutely recessed or flush around edge of shell, rising in rounded or flattened swelling to meet mucro; mucro a small sharp point, between just after 12 o'clock to 2 o'clock; operculum yellow to tan, with 7-8 rings, concave in middle, with dark ring near edge; (Lightfoot, 1992b; Bandel, 1996).

Color.—glossy; reddish brown, tan or white, with opaque white mottling (Lightfoot 1992b).

Distribution.—South Florida, Bermuda, Bahamas, West Indies to Brazil. Lightfoot (1992b) collected specimens off Delray Beach (Palm Beach County) and off Grassy Key and Little Torch Key (Monroe County).

Developmental stage.—Lightfoot (1992b, p. 30) described a second stage as: "narrow straight tube marked with incremental transverse lines, septum flat, deeply recessed; mucro a sharp prong." Abbott (1974) referred to a second stage as short and straight.

Remarks.—This species lacks the swelling of *M. nitidum. Meioceras cornucopiae* is most common under flat rock imbedded in tough sticky marl, mud consisting of mainly calcium carbonate or lime rich mud. This species can be found at depths between 0.75 and 96 m with a minimal water temperature of 23°C (Moore, 1972). Abbott (1974) and

Lightfoot (1992b) treated *Meioceras* as a subgenus. It is accepted as a genus in Bandel (1996). Both Moore (1970) and www.marinespecies.org incorrectly gave the date of authorship of genus *Meioceras, M. cornucopiae,* and the junior synonym *M. cornubovis* as 1859.

3.3 Statistical Analysis:

Appendices 3 and 4 list summary and raw data for specimens collected on natural and artificial substrates at Reef and Rubble sites from Robinson’s (2008) dataset. Due to the nature of the study design, a repeated measures MANOVA was used to test whether there were differences in caecid density in relation to genus (*Caecum* vs. *Meioceras*), reef type (artificial vs natural), substrate (reef vs rubble) and times of observations (12 weeks). The Mauchly's test for time failed (Mauchly's W=0.022, $X^2(20)=15.9$, p<0.001), and as a result any subsequent statistical comparisons involving time were corrected using the Greenhouse-Geisser procedure. Table 1 summarizes the results of the MANOVA. There were no significant differences among any of the factors. Consequently no post-hoc tests were necessary.

Table 1: Illustrates the results of the repeated measures MANOVA test on the effect of Genus, Reef Type, Substrate and Time on caecid density. Guide to column abbreviations: GHG used? indicates whether Greenhouse-Geisser correction was necessary; Type III sum of squares, df, degrees of freedom, MS is mean squares, F is the F statistic for that factor, and Sig. provides the p value associated with that F value / df combination. Note that none of the factors had a statistically significant effect on Caecid density.

Factor	GHG used?	Type III SS	df	MS	F	Sig.
Genus	N	4106.4	1	4106.4	0.112	0.769
Reef type	N	10544.4	1	10544.4	2.596	0.248
Substrate	N	8.2	1	8.2	0.018	0.906
Time	Y	40696.9	1.26	32229.3	4.604	0.141

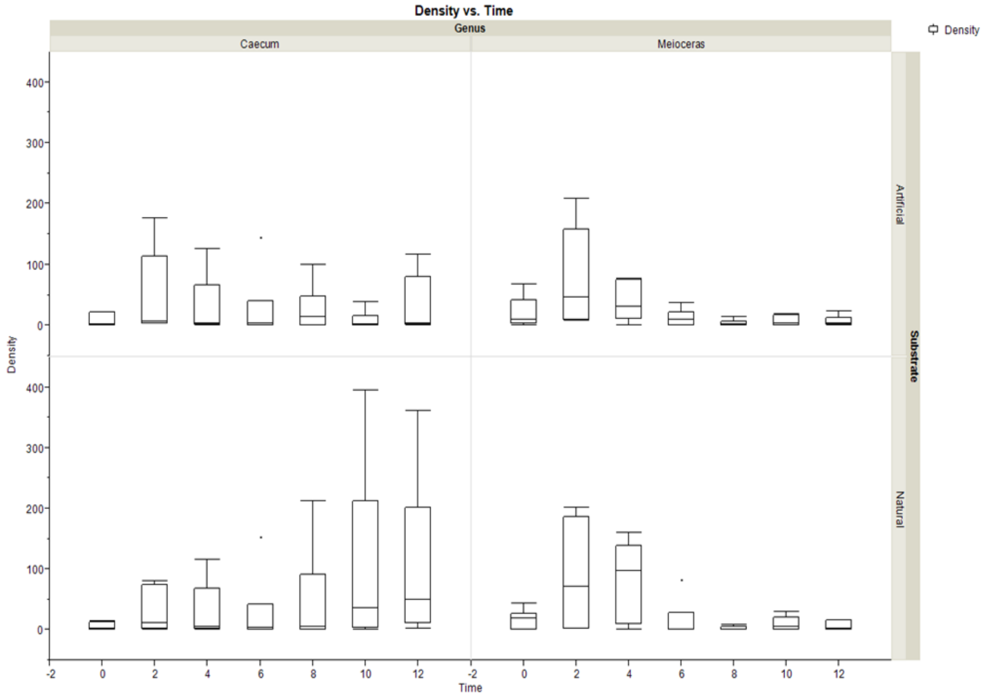

Figure 10: Illustrates the means and standard deviations by genera (*Caecum and Meioceras)* vs. substrate type (Artificial and Natural) along the 12-week sample period.

4.0: DISCUSSION:

4.1: Taxonomic Remarks: Species definitively recorded, most likely to be found and not recorded in Broward County:

As previously mentioned, nineteen species have been documented in Florida waters, eighteen of which have been documented specifically in southern Florida and possibly within areas sampled in this study. These species include *Caecum pulchellum, C. floridanum, C. textile, C. imbricatum, C. bipartitum, C. cooperi, C. clava, C. multicostatum, C. strigosum, C. breve, C. johnsoni, C. subvolutum, C. regulare, C. gurgulio, C. circumvolutum, Meioceras cubitatum, M. nitidum,* and *M. cornucopiae.* Of these 19 species, only *Caecum pulchellum, C. floridanum*, and *M. nitidum* were observed in the current study.

Because all of these species have been documented in the same geographical region in this study, resemblances among species may have led to mis-identification. For example, Moore (1972) noted that smaller specimens of *M. cornucopiae* and *M. nitidum* are difficult to distinguish. In particular, *M. cornucopiae* greatly resembles the typical second-stage *M. nitidum* with broadly open spirals. As the second stage was common in this study, it is possible that some specimens identified as *M. nitidum* were actually *M. cornucopiae.*

4.2: Comparing species density between reef, rubble and artificial substrate:

As previously mentioned, coral reefs around the world have experienced dramatic, long-term losses in faunal abundance and diversity, and in habitat structure due to anthropogenic stresses (Jameson et al., 1995; Moberg et al., 1999; Graham et al., 2006; Baker et al., 2008; Kheawwongjan et al., 2012; Hooidonk and Huber, 2012). As a result, artificial reefs have become an increasingly important resource-enhancement technique. However, many questions such as substrate preference remained unanswered (Bohnsack and Sutherland, 1985; Burt et al., 2009; Hellyer and Poor, 2011; De Aruajo and Da Rocha, 2012). This study examined whether densities of *Caecum* and *Meioceras* differed on artificial vs. natural substrates and between rubble and reef habitats. Apart from possible habitat differences, this permitted an examination of the functionality of one type of artificial substrate—does caecid density on the ASU reflect that on the natural substrate. According to a repeated measures MANOVA, in the fourteen-week sample period, no significant results were obtained. In other words, the two genera examined in this study exhibited no substrate preferences (reef, rubble or artificial) among the sites during the sampling period. These results suggest that the artificial substrate units utilized in this study reflect the natural proportions and densities characteristic of the two genera examined. However, it is important to recognize that, given the diversity of artificial substrates available, these findings should not be generalized either to other taxa or other artificial substrate designs. It is noteworthy to state, however, that even though there were no statistically significant differences between species density in artificial vs. natural substrates, numerical differences where observed. These numerical differences suggest that species observed in the genera *Caecum* (Appendices 1 and 2) show a preference for natural substrate. The fact that these numerical differences did not reach statistical significance is perhaps as a result of the limited number of replicas utilized in this study and could be avoided in future investigations by increasing the number of replicas.

5.0 CONCLUSIONS:

With the exception of a few localized studies, the taxonomy and life history of caecids has not been revised in several decades. Information on caecids is even scarcer for Broward County waters, where little is known about their taxonomy, richness, diversity, abundance and distribution in different habitats. The primary purpose of this study was to revise the taxonomic understanding of the members of caecids found in Broward County. This qualitative and quantitative examination of caecid species assemblages in a wide range of benthic habitats provides a more accurate catalogue of the family in South Florida. However, there are several caveats that should be noted. This study recorded only three caecid species (*C. pulchellum*, *C. floridanum* and *M. nitidum*) of the 19 previously reported as occurring in southeastern Florida waters (Lightfoot, 1992a, b), despite sampling a diversity of habitats. Two additional species (*C. imbricatum* and *C. textile*) have been recorded locally in two unpublished studies (Messing and Dodge 1997; Rosch 2007). Lightfoot (1992a, b) described many species from dredge samples but without recording depths, so it is unclear how many of the remaining 14 species should be treated as occurring in shallow water, e.g., <30 m). Lightfoot (1992a, b) also treated several taxa as unnamed (i.e., *Caecum* (*Caecum*) spp. 1 through 4, and *Caecum* (*Brochina*) spp. 5-7) that are not addressed in this paper. Some may represent undescribed taxa, whereas others might represent known taxa, e.g., *Caecum* (*Caecum*) sp. 3 might be a deep-water form of *C. regulare* (Lightfoot, 1992a).

Another component of this study was to examine substrate preference among the species observed to better understand the effectiveness of artificial reef as a management tool for dying coral reefs. The comparison of caecid assemblages on artificial substrates vs. natural substrates and in reef vs. rubble habitats showed no significant conclusion. As previously mentioned, it is noteworthy to state, however, that even though there were no statistically significant differences between species density in artificial vs. natural substrates and in rubble vs. reef habitat, numerical differences where observed. These numerical differences suggest that species observed in the genera *Caecum* (Appendices 1 and 2) show a preference for natural substrate but vary between reef and rubble habitat. The fact that these numerical differences did not reach statistical significance is perhaps as a result of the limited number of replicas utilized in this study and could be avoided in future investigations by increasing the number of replicas. Finally, care must thus be taken in selecting artificial substrates as a means of reflecting natural assemblages as any part of research and management of reef systems that include artificial substrates. Empirical studies such as this increase understanding of the limits of artificial substrates and illustrate substrate preferences among marine organisms, providing a better understanding of such substrates as a management resource tool.

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Appendices

Appendix 1. Means and standard deviation of natural vs artificial substrate for each week.

Week	Group	Mean	Std. Deviation	N
2	Artificial	14.67	13.216	6
	Natural	19.67	7.257	6
	Total	17.17	10.495	12
4	Artificial	60.83	25.047	6
	Natural	64.67	21.695	6
	Total	62.75	22.430	12
6	Artificial	35.00	11.009	6
	Natural	58.17	27.953	6
	Total	46.58	23.593	12
8	Artificial	15.83	14.972	6
	Natural	29.00	17.401	6
	Total	22.42	16.935	12
10	Artificial	17.17	11.514	6
	Natural	18.50	18.229	6
	Total	17.83	14.553	12
12	Artificial	8.33	5.279	6
	Natural	56.17	23.464	6
	Total	32.25	29.781	12
14	Artificial	12.33	5.854	6
	Natural	47.00	13.624	6
	Total	29.67	20.681	12

Appendix 2: Means and standard deviations of the raw, non-normalized data collected from the 4 variable substrates (Artificial Rubble, Artificial Cervicornis, Natural Rubble and Natural Cervicornis) over a 14-week period. Statistical analysis showed no significant relationship between time and the remaining factors (genus, substrate type, reef type) on caecid abundance.

Week	Group	Mean	Std. Deviation	N
2	Art. Cervicornis	22.00	16.093	3
	Art. Rubble	7.33	4.041	3
	Nat. Cervicornis	14.00	4.359	3
	Nat. Rubble	25.33	4.041	3
	Total	17.17	10.495	12
4	Art. Cervicornis	39.33	110.017	3
	Art. Rubble	82.33	9.018	3
	Nat. Cervicornis	48.00	8.888	3
	Nat. Rubble	81.33	16.258	3
	Total	62.75	22.430	12
6	Art. Cervicornis	28.33	12.662	3
	Art. Rubble	41.67	3.055	3
	Nat. Cervicornis	81.67	14.012	3
	Nat. Rubble	34.67	10.017	3
	Total	46.58	23.595	12
8	Art. Cervicornis	29.00	6.000	3
	Art. Rubble	2.67	2.082	3
	Nat. Cervicornis	42.00	15.000	3
	Nat. Rubble	16.00	5.000	3
	Total	22.42	16.935	12
10	Art. Cervicornis	8.33	4.041	3
	Art. Rubble	26.00	9.000	3
	Nat. Cervicornis	2.33	2.082	3
	Nat. Rubble	34.67	6.506	3
	Total	17.83	14.553	12
12	Art. Cervicornis	12.33	3.512	3
	Art. Rubble	4.33	3.055	3
	Nat. Cervicornis	38.33	14.048	3
	Nat. Rubble	74.00	15.000	3
	Total	32.25	29.781	12
14	Art. Cervicornis	9.33	2.887	3
	Art. Rubble	15.33	7.095	3
	Nat. Cervicornis	57.67	6.429	3
	Nat. Rubble	36.33	9.018	3
	Total	29.67	20.681	12

Appendix 3: Raw counts of caecids collected in 8 marine habitats. No caecids where found in Mangroves, Inshore Hard Bottom and Inshore Sediment and thus are absent from the table.

	Reef	**Natural Substrate**	**Artificial Substrate**	**Intracoastal Waterway**	**Creek**
C. pulchellum	1742	334	553	82	13
C. floridanum	762	13	77	0	0
***Meioceras nitidum* (juvenile stage)**	869	78	156	2	0
***Meioceras nitidum* (in-between)**	13	9	4	0	0
Meioceras nitidum	465	206	237	54	7

Appendix 4: Caecid densities normalized per 600 cm^2 in quantitative natural and artificial substrate samples on Reef and Rubble habitats.

				Density per 600cm^2		
Site	**TYPE**	**Treatment**	**Time**	***Caecum pulchellum***	***Caecum floridanum***	***Meioceras nitidum***
CA	**ASU Reef**	**Artificial/Reef**	2wk	9	0	17
CA	**ASU Reef**	**Artificial/Reef**	4wk	41	0	10
CA	**ASU Reef**	**Artificial/Reef**	6wk	8	1	29
CA	**ASU Reef**	**Artificial/Reef**	8wk	21	1	16
CA	**ASU Reef**	**Artificial/Reef**	10wk	4	0	1
CA	**ASU Reef**	**Artificial/Reef**	12wk	6	1	5
CA	**ASU Reef**	**Artificial/Reef**	14wk	2	0	12
CB	**ASU Reef**	**Artificial/Reef**	2wk	1	0	14
CB	**ASU Reef**	**Artificial/Reef**	4wk	21	2	8
CB	**ASU Reef**	**Artificial/Reef**	6wk	11	1	13
CB	**ASU Reef**	**Artificial/Reef**	8wk	11	1	9
CB	**ASU Reef**	**Artificial/Reef**	10wk	9	0	8
CB	**ASU Reef**	**Artificial/Reef**	12wk	11	2	6
CB	**ASU Reef**	**Artificial/Reef**	14wk	2	0	4
CC	**ASU Reef**	**Artificial/Reef**	2wk	1	0	24
CC	**ASU Reef**	**Artificial/Reef**	4wk	28	0	8
CC	**ASU Reef**	**Artificial/Reef**	6wk	5	1	16
CC	**ASU Reef**	**Artificial/Reef**	8wk	17	0	11
CC	**ASU Reef**	**Artificial/Reef**	10wk	2	0	1
CC	**ASU Reef**	**Artificial/Reef**	12wk	3	1	2
CC	**ASU Reef**	**Artificial/Reef**	14wk	2	0	6
RA	**ASU Rubble**	**Artificial/Rubble**	2wk	9	0	3
RA	**ASU Rubble**	**Artificial/Rubble**	4wk	19	0	76
RA	**ASU Rubble**	**Artificial/Rubble**	6wk	25	0	22
RA	**ASU Rubble**	**Artificial/Rubble**	8wk	1	0	0
RA	**ASU Rubble**	**Artificial/Rubble**	10wk	29	0	11
RA	**ASU Rubble**	**Artificial/Rubble**	12wk	0	0	2
RA	**ASU Rubble**	**Artificial/Rubble**	14wk	15	1	6
RB	**ASU Rubble**	**Artificial/Rubble**	2wk	1	0	4
RB	**ASU Rubble**	**Artificial/Rubble**	4wk	12	2	58
RB	**ASU Rubble**	**Artificial/Rubble**	6wk	19	0	15
RB	**ASU Rubble**	**Artificial/Rubble**	8wk	0	0	5

RB	**ASU Rubble**	**Artificial/Rubble**	10wk	9	0	9
RB	**ASU Rubble**	**Artificial/Rubble**	12wk	0	0	7
RB	**ASU Rubble**	**Artificial/Rubble**	14wk	8	0	2
RC	**ASU Rubble**	**Artificial/Rubble**	2wk	1	0	4
RC	**ASU Rubble**	**Artificial/Rubble**	4wk	16	0	64
RC	**ASU Rubble**	**Artificial/Rubble**	6wk	20	1	23
RC	**ASU Rubble**	**Artificial/Rubble**	8wk	0	0	2
RC	**ASU Rubble**	**Artificial/Rubble**	10wk	13	0	7
RC	**ASU Rubble**	**Artificial/Rubble**	12wk	0	0	4
RC	**ASU Rubble**	**Artificial/Rubble**	14wk	12	0	2
CA	**Nat Reef**	**Natural/Reef**	2wk	4	0	4
CA	**Nat Reef**	**Natural/Reef**	4wk	14	0	42
CA	**Nat Reef**	**Natural/Reef**	6wk	11	1	58
CA	**Nat Reef**	**Natural/Reef**	8wk	33	0	20
CA	**Nat Reef**	**Natural/Reef**	10wk	3	0	1
CA	**Nat Reef**	**Natural/Reef**	12wk	45	0	9
CA	**Nat Reef**	**Natural/Reef**	14wk	54	9	6
CB	**Nat Reef**	**Natural/Reef**	2wk	2	0	8
CB	**Nat Reef**	**Natural/Reef**	4wk	6	0	38
CB	**Nat Reef**	**Natural/Reef**	6wk	6	0	46
CB	**Nat Reef**	**Natural/Reef**	8wk	19	1	10
CB	**Nat Reef**	**Natural/Reef**	10wk	1	0	0
CB	**Nat Reef**	**Natural/Reef**	12wk	9	0	13
CB	**Nat Reef**	**Natural/Reef**	14wk	39	11	3
CC	**Nat Reef**	**Natural/Reef**	2wk	1	0	0
CC	**Nat Reef**	**Natural/Reef**	4wk	17	0	27
CC	**Nat Reef**	**Natural/Reef**	6wk	10	1	49
CC	**Nat Reef**	**Natural/Reef**	8wk	26	0	17
CC	**Nat Reef**	**Natural/Reef**	10wk	2	0	0
CC	**Nat Reef**	**Natural/Reef**	12wk	24	0	15
CC	**Nat Reef**	**Natural/Reef**	14wk	42	8	1
RA	**Nat Rubble**	**Natural/Rubble**	2wk	21	0	2
RA	**Nat Rubble**	**Natural/Rubble**	4wk	16	1	94
RA	**Nat Rubble**	**Natural/Rubble**	6wk	12	0	22
RA	**Nat Rubble**	**Natural/Rubble**	8wk	16	0	1
RA	**Nat Rubble**	**Natural/Rubble**	10wk	37	0	11
RA	**Nat Rubble**	**Natural/Rubble**	12wk	47	12	15
RA	**Nat Rubble**	**Natural/Rubble**	14wk	34	11	5

RB	**Nat Rubble**	**Natural/Rubble**	2wk	12	0	7
RB	**Nat Rubble**	**Natural/Rubble**	4wk	3	1	60
RB	**Nat Rubble**	**Natural/Rubble**	6wk	32	0	13
RB	**Nat Rubble**	**Natural/Rubble**	8wk	15	0	0
RB	**Nat Rubble**	**Natural/Rubble**	10wk	29	0	4
RB	**Nat Rubble**	**Natural/Rubble**	12wk	56	4	14
RB	**Nat Rubble**	**Natural/Rubble**	14wk	25	8	2
RC	**Nat Rubble**	**Natural/Rubble**	2wk	23	0	4
RC	**Nat Rubble**	**Natural/Rubble**	4wk	23	0	7
RC	**Nat Rubble**	**Natural/Rubble**	6wk	15	1	1
RC	**Nat Rubble**	**Natural/Rubble**	8wk	16	0	0
RC	**Nat Rubble**	**Natural/Rubble**	10wk	16	0	5
RC	**Nat Rubble**	**Natural/Rubble**	12wk	68	3	2
RC	**Nat Rubble**	**Natural/Rubble**	14wk	17	4	3