Chapter 4
Invertebrates

4.1 Introduction

4.1.1 Diversity of Sessile and Motile Species

There is a high diversity and abundance of sessile and motile invertebrate species associated with nearshore hardbottom reefs (NHRs) along the east Florida coast (Appendix 4.1). A total of 602 species of invertebrates have been identified from this region, and there are likely to be more. Together with macroalgae and turf algae (see Chap. 3), non-motile invertebrates comprise the sessile community of near-shore reefs along the Florida coast. The diversity of sessile species is greatest for cnidarians, bryozoans, and sponges. Tunicates, polychaetes, hydroids, and bivalves are also common in these habitats, but at lower diversities. On a large scale, the diversity and abundance at any location varies dramatically with latitude, depth, and, often, season. Variability in community and population measures can also occur because of site-specific changes in reef relief, local hydro- and lithodynamics, and other biotic and abiotic factors. Often, the highest community biomasses occur in hardbottom reef areas with higher abundances of those sessile invertebrate taxa that enhance local shelter (e.g., corals, worm reef or rock, sponges). Some of these taxa might be considered foundation contributors to the community. Macroalgae that occur in high biomass in the more northern NHRs along the east Florida coast likely serve the same purpose (see Chap. 3). The sabellariid *Phragmatopoma lapidosa (also known as caudata)* provides important shelter and can be very abundant along mid- to northern sections of the east Florida coast. CSA Ocean Sciences Inc. (2014) observed on average 147.2 (SD± 272.2) individual invertebrates per standardized (~20 × 20 × 20 cm) worm reef sample collected in Palm Beach County (Appendix 4.2). Because of the unique shelter provided by this polychaete, it is unlikely that many of the species found within samples would exist in very high abundance in reef areas without worm reef. Further, foundation species such as the *P. lapidosa* may also significantly contribute to local food webs (Gore et al. 1978).

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Consequently, changes in the abundance of such foundation species, whether natural or anthropogenic, will likely have profound effects on local invertebrate and vertebrate diversity and abundance.

The most diverse and abundant motile invertebrates are arthropods and polychaetes (Appendix 4.1). There are over 135 species of crustaceans that are especially abundant on worm reef-dominated hardbottom. These include crabs, stomatopods, shrimp, lobsters, isopods, and amphipods. Over 58 polychaete species along with many gastropods, flat worms, ribbon worms, and echinoderms (e.g. the sea urchins *Echinometra lucunter* and *Arbacia punctulata*) are common in these nearshore reef habitats. Some groups such as brittle stars are probably also both diverse and abundant but have not been extensively studied.

4.1.2 Ecological Functions

The primary ecological functions of invertebrates along the east Florida coast are as: (1) shelter-enhancing organisms that increase local diversity of fishes and invertebrates, and/or (2) either predators or prey in local food webs. Important shelter-enhancing taxonomic groups are hard and soft corals, sponges, tunicates, mollusks, barnacles, and polychaetes (e.g., *P. lapidosa*), while important taxa contributing to local food webs include sponges, crabs, shrimp, polychaetes, echinoderms, and mollusks. In both cases, functional importance may vary dramatically with depth and latitude.

The range of trophic roles is very different between sessile and motile east Florida invertebrates. Many sessile invertebrates are suspension (sponges, sabellariid polychaetes, barnacles, tunicates) or plankton feeders (hard and soft corals, bryozoans, and hydrozoans). These invertebrates might be fed on by motile invertebrates or fishes, but there is little information available on their role as prey. In contrast, there is more trophic diversity among motile invertebrates. Many decapods and gastropods are active carnivores, while others are omnivores, herbivores, and suspension feeders. Echinoids, such as *Echinometra lucunter*, *Arbacia punctulata*, and *Diadema antillarum* can be important herbivores in the areas where they occur (Scott et al. 2018; Lessios 2016). These motile groups are also likely to be fed on by motile invertebrates or fishes, but again there is little information available on their role as prey.

4.1.3 Latitudinal and Depth Gradient

Sessile invertebrate communities change noticeably with latitude and depth along the Florida coast (CSA International, Inc. 2009; Johnson and Roberts 2017). On intertidal hardbottom reefs in northeast Florida (Flagler and St. Johns Counties), dominant conspicuous invertebrates are barnacles, bryozoans, hydroids, and sea anemones. An early description of rocky intertidal zonation along east Florida coast (Stephenson and Stephenson 1952) was at Marineland where *Chthamalus fragilis* was noted on the upper intertidal zone, with other sessile species such as mollusks (*Siphonaria pectinata, Crassostrea virginica, Brachidontes exustus*) and barnacles (*Tetraclita floridana (stalactifera), Amphibalanus (Balanus)* spp.) becoming more prevalent closer to the low tide water line. While much less abundant in this area, some non-native species such as the barnacle *Megabalanus coccopoma* and the bivalve *Perna viridis*, can be found underneath overhanging rocks within the lower intertidal zone (McCarthy, pers. observ. 2019). Further south along the coast, many of these same species exist, although the sabellariid polychaete, *P. lapidosa*, becomes a very important component of the sessile community both intertidally and subtidally to approximately 4 m depth (McCarthy 2001). Throughout permanent tidal pools in these intertidal areas, zoanthids, solitary anemones, hydroids, and the scleractinian coral *Siderastrea* spp., can be encountered. Within the lower intertidal and shallow subtidal zones, the most conspicuous sponge is the rock-boring sponge *Pione* (*Cliona*) *lampa*. On subtidal reefs from Brevard to Martin Counties, the urchins *Echinometra lucunter* and *Arbacia punctulata* can be very abundant although their numbers drastically decrease from Palm Beach County southward (McCarthy, pers. observ. 2008). At these mid-state nearshore reefs, several sponges and two species of gorgonians (*Leptogorgia virgulata* and *Leptogorgia hebes*) can easily be encountered. Also, abundant under overhangs and on edges of steep relief areas is the stoloniferan (*Carijoa* (*Telesto*) *riisei*). In this area, the most abundant stony corals are *Siderastrea* spp., *Oculina diffusa*, and *O. varicosa* (McCarthy, pers. observ. 2008). These two later genera become more abundant on deeper reefs (Reed et al. 1982; Walker and Gilliam 2013; McCarthy, pers. observ. 2008). Continuing southward along the coast, the diversity and abundance of anthozoans, particularly scleractinians, increases on subtidal reefs (Gilliam et al. 2018). Martin County is generally considered the northernmost extent of reef-building corals. Within these deeper areas of coastal reefs, octocorals and sponges are present but in relatively low abundances (Walker and Gilliam 2013). In Palm Beach County, a study by CSA Ocean Sciences Inc. (2014) focusing on reefs at depths less than 6 m revealed that the major taxonomic groups in order of decreasing contribution to cover were sponges, hydrozoans, and byrozoans (Appendix 4.3). Depth related trends included the observations that scleractinian coral richness was higher in water greater than 3 m depth, while counts of the stony coral *Siderastrea* were relatively higher in water less than 2 m depth. Further, it was observed that sponge and octocoral abundance was highest in the deeper range sampled (Table 4.1). In another study in Palm Beach County, Cumming (2017) found small colonies of *Siderastrea* to be the most dominant stony coral encountered in water depths greater than 3 m. In Broward County, there is generally a higher scleractinian richness and density than occurs northward (Gilliam et al. 2018). In this area, Klug (2015) observed higher density and richness of corals with depth. Overall, it has been suggested that there are six distinct benthic habitat types that extend from Martin County southward to Miami-Dade County: Martin, North Palm Beach, South Palm Beach, Deerfield, Broward-Miami, and Biscayne (Walker 2012; Walker and Gilliam 2013).

Table 4.1 Mean percent cover of the most abundant epibiotic taxa in the Palm Beach area, as indicated by mean percent cover at four depth strata on natural reefs

Taxon	Group	Depth stratum				Overall mean
		1	2	3	4	
Mixed epibiota	Sand-over-hardbottom	28.09	43.96	45.98	42.15	40.04
Turf	Turf algae	30.07	21.15	27.43	32.12	27.69
Dictyota sp.	Macroalgae	8.03	3.60	3.75	0.23	3.90
Bryothamnion triquetrum	Macroalgae	–	5.33	0.03	–	1.34
Phaeophyta	Macroalgae	0.04	2.46	1.91	0.24	1.16
Hydroids	Hydrozoans	0.08	0.96	1.03	1.81	0.97
Cliona sp.	Sponges	0.70	0.53	0.90	0.17	0.57
Acanthophora muscoides	Macroalgae	–	1.98	0.13	–	0.53
Caulerpa mexicana	Macroalgae	1.89	0.03	0.01	–	0.48
Padina sp.	Macroalgae	1.04	0.67	0.04	–	0.44
Heterosiphonia gibbesii	Macroalgae	–	0.02	1.50	–	0.38
Siderastrea sp.	Stony corals	0.29	0.29	0.43	0.15	0.29
Caulerpa lanuginose	Macroalgae	0.04	–	1.12	–	0.29
Jania sp.	Macroalgae	0.35	–	0.63	0.09	0.27
Laurencia sp.	Macroalgae	1.01	0.03	–	–	0.26
Avrainvillea rawsonii	Macroalgae	–	1.03	–	–	0.26
Rhodophyta	Macroalgae	–	0.57	0.15	0.25	0.24
Dasycladus vermicularis	Macroalgae	0.01	0.33	0.45	0.17	0.24
Eunicea sp.	Octocorals	–	0.03	0.09	0.82	0.24
Halimeda sp.	Macroalgae	0.15	0.59	0.13	0.05	0.23
Cyanobacteria	Cyanobacteria	0.73	–	0.02	0.17	0.23
Wrangelia sp.	Macroalgae	0.15	0.06	0.11	0.55	0.22
Wrangelia argus	Macroalgae	0.79	0.03	–	0.03	0.21
Pterogorgia sp.	Octocorals	–	0.08	0.48	0.08	0.16

Taxon	Group	Depth stratum				Overall mean
		1	2	3	4	
Millepora alcicornis	Hydrozoans	–	0.03	0.12	0.49	0.16
Chlorophyta	Macroalgae	0.33	0.28	–	–	0.15
Ircinia sp.	Sponges	–	–	0.03	0.55	0.15
Caulerpa sertularioides	Macroalgae	0.29	0.26	0.01	–	0.14
Cinachyra sp.	Sponges	–	0.19	0.27	0.09	0.14
Dasycladus sp.	Macroalgae	–	0.43	0.08	0.02	0.13
Pseudopterogorgia sp.	Octocorals	–	0.06	0.13	0.33	0.13
Liagora sp.	Macroalgae	0.37	0.04	0.10	–	0.13
Phorbas amaranthus	Sponges	0.04	–	0.04	0.43	0.13
Demospongiae	Sponges	–	0.04	0.08	0.38	0.13
Caulerpa racemosa	Macroalgae	0.08	0.38	–	–	0.11
Ircinia strobilina	Sponges	–	–	0.03	0.43	0.11
Halimeda tuna	Macroalgae	–	0.03	0.39	–	0.10
Pseudoplexaura sp.	Octocorals	–	–	0.01	0.38	0.10
All taxa		**75.08**	**86.93**	**88.87**	**85.70**	**84.14**

Depth strata are as follows: Stratum 1 = 0–1 m, Stratum 2 = 1–2 m, Stratum 3 = 2–3 m, Stratum 4 = 4–6 m
CSA Ocean Sciences Inc. (2014)

4.1.4 Reproduction and Life History

In those species that can reproduce asexually and sexually, the relative importance of these modes in maintaining populations is often unclear. Sexual reproduction is essential for dispersal and colonization of new or damaged areas and the maintenance of genetic diversity. Sponges, cnidarians, bryozoans, and colonial tunicates are all important shelter-enhancing invertebrates that have these reproductive capabilities. However, in some cases, such as with the scleractinian *A. cervicornis*, it is suggested that they primarily proliferate via asexual reproduction (Tunnicliffe 1981). The ability to asexually reproduce may be essential for some shelter-enhancing invertebrate species to thrive locally in shallower reefs, where there is generally high disturbance. In contrast, sexually reproducing sessile and motile invertebrates can have seasonal spawning patterns and/or the capability to spawn throughout most of the year. Peaks in seasonal spawning often occur during the spring or summer for most of the invertebrates along the coast. However, there appears to be growing evidence that some stony corals may spawn into the fall (St. Gelais et al. 2016). In contrast, those species that continuously spawn may be adapted to do so to take advantage of space made available by natural disturbances (McCarthy 2001). For most sessile invertebrates, spawning is external and results in planktonic larvae, although there are instances of species that produce brooding and crawl-away young. Overall, it is likely that both sessile and motile invertebrates on east Florida NHRs are mostly short-lived (particularly in intertidal and very shallow subtidal waters).

4.1.5 Dispersal and Genetic Connectivity

Generally, little is known regarding dispersal and genetic connectivity among most populations of invertebrates on NHRs along the east Florida coast. Richards et al. (2007) found high genetic connectivity among populations in the Florida reef tract of two amphipod and one brittle star species that live commensally within the same host sponge (despite one species having direct development). On a larger spatial scale, several studies have shown varying degrees of genetic connectivity among invertebrate populations between Florida and either Central America and/or within the Caribbean (Mitton et al. 1989; Silberman et al. 1994; Baums et al. 2005; Richards et al. 2007; Debiasse et al. 2010; Andras et al. 2013; Staton et al. 2013; Serrano et al. 2016; Nunes et al. 2017; Rippe et al. 2017; Baeza et al. 2019; Bernard et al. 2019). While there are these examples of broad-scale connectivity, the degree of population connection depends on species-specific life history strategies, larval lifespan and behavior, and local hydrodynamics. There clearly needs to be more research on genetic connectivity among invertebrate populations along east Florida NHRs.

4.1.6 Recruitment

There is very limited information on seasonal recruitment patterns for invertebrates along the east Florida coast. McCarthy (2001) studied the recruitment of sessile organisms in the intertidal and subtidal (3–4 m) zones at Boynton Beach, Florida from June 1997 to January 2000. He reported 23 sessile species recruiting to his settlement plates, with *P. lapidosa* being most commonly encountered (Table 4.2). High numbers of species recruited in both zones with recruitment being highest in summer and early fall, and often higher subtidally than intertidally. McCarthy (2001) suggested that, while high numbers of species may recruit into these habitats, most probably do not survive to adulthood. Low survival rates were probably due to a combination of factors. First, there was likely high mortality of recruits that could not tolerate the frequently occurring sand scouring and burial. Second, the high rates of *P. lapidosa* recruitment probably limited growth of other sessile organisms, often growing over them. In this study, predation appeared less important in explaining recruit mortality for most species in both zones.

Worm reef-dominated hardbottom habitats appear to go through predictable patterns of annual change, with high recruitment in early autumn through winter, rapid reef growth (approximately 0.5 cm/day) and maximum structure in spring and summer, and decay by early autumn (McCarthy 2001, 2010; Fig. 4.1). When these data are integrated with those of Lindeman (1997), they reveal important links between the seasonal cycle of sabellariid reef expansion and degradation, and the occupation of those reefs by other juvenile and adult fish and invertebrates.

4.1.7 Economic and Recreational Value

Invertebrates significantly contribute to the economic and recreational value of nearshore reefs along the east Florida coast. Sessile invertebrates such as *P. lapidosa,* and a number of coral and sponge species, provide high aesthetic reef value to recreational scuba divers. Nearshore reefs are also important shelter to many invertebrate and fish species of commercial and recreational value. Species such as corals, sponges, and *P. lapidosa* are able to create structure, which provides important areas of settlement and growth for other sessile invertebrates as well as shelter for many motile invertebrates and fishes. Many of these species may not exist were it not for these foundation invertebrate species. Invertebrates may also contribute to nearshore value via their potential role in the food web that could ultimately support commercially and recreationally important fish species. Finally, some invertebrates (e.g., spiny lobster) add value to the habitat as they are of direct commercial and recreational interest to the public (Collier et al. 2008).

Table 4.2 Species recruitment into intertidal (I) and subtidal (S) nearshore hardbottom habitats from June 1997 through January 2000 at Boynton Beach, Florida

Species	1997										1998														1999												2000	
	Jun		Jul		Aug		Sep		Nov		Jan		Feb		Apr		Jun		Jul		Sep		Oct		Jan		Mar		May		Jun		Aug		Sep		Jan	
Zone	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S
Anomia simplex	a	p	p	p	a	a	a	p	a	a	a	a	a	a	a	p	a	p	a	p	a	p	a	p	a	p	a	a	a	a	a	a	a	a	a	a	a	a
Pinctada imbricata	a	p	p	p	p	p	p	p	a	p	a	a	a	a	p	p	a	p	p	p	p	p	a	p	a	p	a	p	p	a	a	a	p	a	p	a	a	a
Hipporina americana	a	p	a	p	a	a	p	p	a	a	a	p	a	p	a	p	a	p	a	p	a	p	a	p	a	p	a	p	a	a	a	a	a	a	a	a	a	a
Canopeum reticulum	a	p	a	a	a	p	p	p	p	p	a	p	a	p	p	p	a	p	a	a	a	p	p	p	a	p	a	p	a	a	a	a	a	a	p	a	p	a
Balanus eburneus	a	a	a	p	a	a	p	p	p	a	a	p	a	p	a	a	a	a	a	a	a	p	a	p	a	a	a	a	a	a	a	a	p	a	p	a	a	a
Chthalamus fragilis	p	a	p	a	p	a	p	a	p	p	a	a	a	p	a	a	p	a	p	p	p	a	p	a	a	a	a	p	a	a	p	a	p	a	a	a	a	a
Cliona sp.	a	a	a	a	a	a	a	a	p	p	a	p	a	p	a	p	p	p	a	p	p	p	a	p	a	p	a	a	a	a	a	a	a	a	a	a	a	a
Phragmatopoma lapidosa	a	a	p	a	p	a	p	a	p	a	p	p	p	p	p	p	p	a	a	a	p	p	p	p	p	p	p	p	p	a	p	a	p	a	p	a	p	a
Watersipora subviodea	a	p	a	p	a	a	a	a	a	p	a	p	a	p	p	p	a	p	a	p	a	a	a	p	p	p	p	p	p	a	p	a	a	a	a	a	p	a
Didemnum sp.	a	p	a	p	a	p	a	p	a	p	a	p	a	p	a	p	a	p	a	p	a	p	a	p	p	p	a	p	a	a	a	a	a	a	a	a	a	a
Diplosoma sp.	a	p	a	p	a	p	a	p	p	p	p	p	p	p	p	p	p	p	a	p	a	p	a	p	p	p	p	p	a	a	a	a	a	a	p	a	p	a
Balanus amphitrite	a	a	a	a	a	a	p	a	a	p	a	p	a	a	a	p	a	p	a	p	a	p	a	p	a	p	a	a	p	a	a	a	a	a	a	a	a	a
Brachiodontes citrinus	a	p	a	a	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Phallusia nigra	a	p	a	a	a	a	a	p	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Botryllus sp.	a	a	a	a	a	a	p	p	a	a	a	a	a	a	a	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Bugula sp.	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Hydroides dianthus	a	p	a	p	a	a	a	a	a	a	a	p	a	a	a	p	a	a	a	p	a	p	a	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Terebellid sp.	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Actinia bermudensis	a	p	a	a	a	a	a	a	p	p	a	a	a	a	a	a	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Siderastrea radians	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Unknown blue sponge	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Vermicularia sp.	a	a	a	a	a	a	a	a	a	a	a	a	a	a	p	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Turbicellaora avicularis			a	a	a	a	a	a	a	a	a	a	a	a	a	p	a	a	a	p	a	p	a	a	a	p	a	a	a	a	a	a	a	a	a	a	a	a
Species number at each habitat	1	11	4	8	4	4	8	9	8	9	2	10	2	9	6	13	5	9	2	12	4	14	3	14	4	11	3	9	4	ND	3	ND	4	ND	5	ND	4	ND
Species number at both	0		2		1		5		5		2		2		5		2		2		3		2		4		3		0		0		0		0		0	
Total number	12		10		8		12		12		10		9		14		12		12		15		15		11		9		4		3		4		5		4	

Light gray shading indicates simultaneous settlement into intertidal and subtidal habitats. Note that no subtidal recruitment was observed after March 1999 because the habitat was lost to sand cover

a absent, *p* present, *ND* no data

Modified from McCarthy (2001)

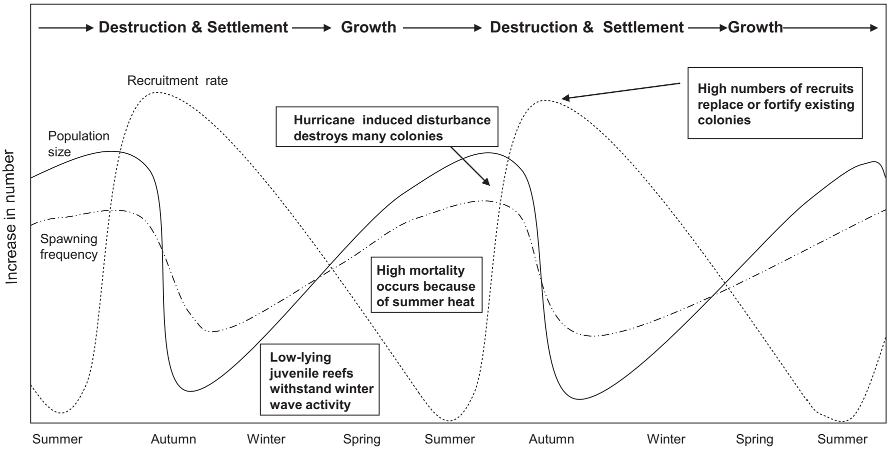

Fig. 4.1 Seasonal reproductive and life history trends of *Phragmatopoma lapidosa* in the Boynton Beach, Florida area. (McCarthy 2001)

4.2 Focal Taxonomic Groups and Species

4.2.1 Polychaetes

4.2.1.1 Diversity and Ecological Function

The diversity and abundance of polychaetes on NHRs from the east Florida coast is high (Appendix 4.1). Nelson (1989) and Coastal Science Associates, Inc. (2000) observed 49 and 53 polychaete species, respectively, on reefs in Indian River County, while Rudolph (1977) identified 85 species from Palm Beach County areas.

Little is known about the ecological function of most polychaetes along the east Florida coast, but a few enhance shelter for other species and many are probably very important in local food webs as both consumers (carnivores, herbivores, suspension or deposit feeders) and prey. Most available research on polychaetes on nearshore reefs has focused on various aspects of the reef-building polychaete *Phragmatopoma lapidosa* (Fig. 4.2), also known as *P. caudata* (Kirtley 1994; Nunes et al. 2017) or *P. l. lapidosa* (Pawlik 1988). This species is clearly a foundation species enhancing the biological diversity of nearshore reefs along the Florida coast. The relief provided by these "worm reefs" supports a higher diversity and abundance of marine species than that of neighboring sand or hardbottom reef habitats. Further, worm reefs are considered important sources of food and shelter for juvenile green turtles (*Chelonia mydas*) (Ernest et al. 1989; Wershoven and Wershoven 1992; Guseman and Ehrhart 1990; Stadler et al. 2015). Prior studies have also identified that the reefs provide shelter for over 423 invertebrate species (Gore et al. 1978; Nelson 1988, 1989; Nelson and Demetriades 1992; CSA International, Inc. 2009) and over 200 fish species (Gilmore Jr. 1977; Gilmore Jr. et al. 1981; Lindeman

Fig. 4.2 Intertidal worm reefs at: (**a**) Coral Cove Beach (Palm Beach County, Florida) and (**b**) Bathtub Reef (Martin County, Florida). (Source: D. McCarthy)

1997; Lindeman and Snyder 1999). The importance of worm reefs in providing food and shelter for juvenile and adult fishes of commercial value resulted in their designation as Essential Fish Habitat-Habitat of Particular Concern (EFH-HAPC) by the National Marine Fisheries Service (NMFS). In addition, worm reefs are important for the maintenance, propagation, and persistence of beaches and barrier islands by retaining sediments within coastal areas (Kirtley 1966, 1967; Multer and Milliman 1967; Gram 1965; Kirtley and Tanner 1968; Mehta 1973; Kirtley 1974).

While *P. lapidosa* is important in enhancing shelter on hardbottom reefs, they may also be important within food webs along the east Florida coast. Various decapods (Gore et al. 1978) and gastropods (Watanabe 2002; Watanabe and Young 2006) prey on *P. lapidosa*. It is likely, though not confirmed, that some fish species such as parrotfish may feed on them as well. Further, the rock-boring urchin *Echinometra lucunter* clearly bores into worm reef and limestone, causing worm mortality on nearshore reefs in St. Lucie and Indian River Counties (D. McCarthy, pers. observ. 2008). However, these biotic forms of mortality probably affect *P. lapidosa* abundance and distribution at lower levels than seasonal natural disturbances such as high wave energy and sand scouring/burial (McCarthy 2001).

4.2.1.2 Latitudinal and Depth Gradient

It is unclear how diversity and abundance of most polychaetes change with latitude and depth along NHRs of the east Florida coast. Variable sampling methods for the few available studies make direct comparisons difficult. While Rudolph (1977) found nearly twice as many polychaetes (85 species) as Nelson (1989; 49 species), the latter author suggests that increased sampling in Indian River County is likely to reveal more species than the 49 encountered in his study. Further, both of these studies focused only on species encountered within a depth of 2–4 m. There are no known comparative ecological studies of polychaete assemblages in less than 2 m or greater that 4 m depth along the coast.

The best available research on polychaetes for east Florida NHRs has been conducted on *Phragmatopoma lapidosa* (Family Sabellariidae) (Fig. 4.3). *Phragmatopoma lapidosa* grasps sediment grains from the water column by its oral tentacles, coats them with a proteinaceous cement, and then implants them into tubes with their opercular paleae (Kirtley 1966) (Fig. 4.4). Numerous individuals make tubes that then form vast reefs in intertidal and shallow (generally highest abundances occur in <4 m) subtidal waters from Cape Canaveral to Key Biscayne in Florida and further south to Santa Catarina, Brazil (Kirtley 1994) (Fig. 4.5). Within Florida, there appears to be higher abundances of this species on nearshore reefs north of Palm Beach County (Massey et al. 2013). This may be because this region has the optimal range of sediment sizes, hydrodynamics, and sea water temperature for persistence of this species. For example, juvenile worms most often use small, dark grains of heavy minerals, while adults tend to use larger, light-colored sand grains (Kirtley 1966; Eckelbarger 1976). In Stuart, Florida, a 10-year study by McCarthy (2010) observed the percentage of total intertidal worm reef occupying

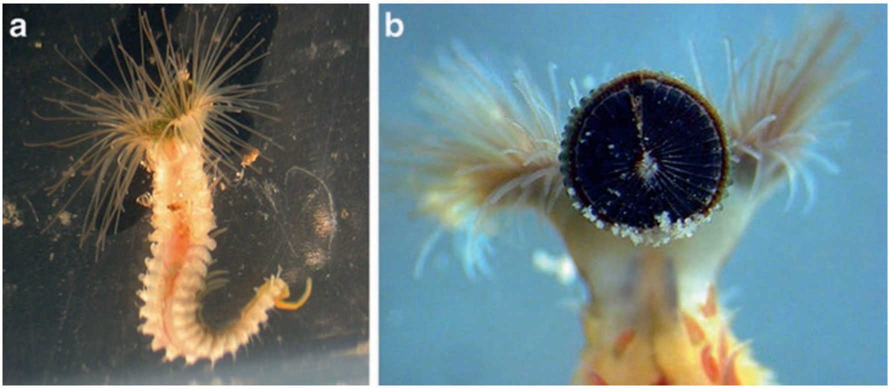

Fig. 4.3 Close-ups of the reef-building polychaete *Phragmatopoma lapidosa* (*caudata*). (**a**) A ventral view showing the whole worm out of its tube. (**b**) The anterior end of the worm showing the crown (structure in black) and tentacles. (Source: D. McCarthy)

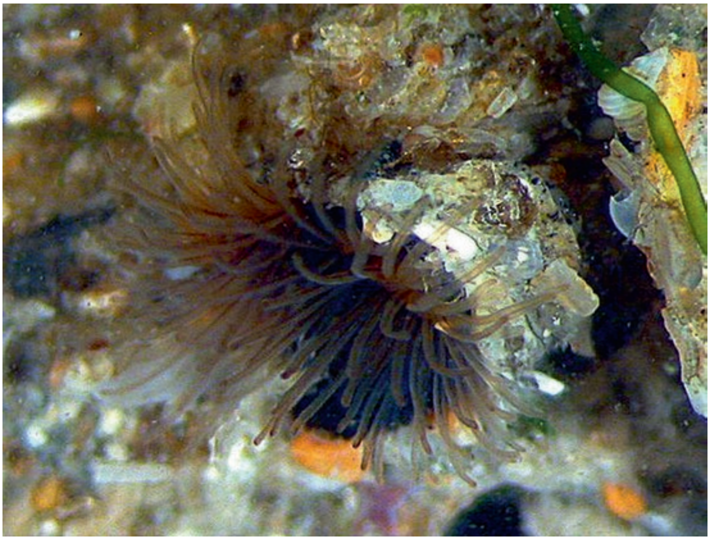

Fig. 4.4 Close up of the anterior tube of an individual *Phragmatopoma lapidosa* (*caudata*). (Source: D. McCarthy)

the hardbottom at Bathtub Reef to vary approximately between 10% and 50% (Fig. 4.6). Northern limits of *P. lapidosa* may be controlled by the cooler sea water temperatures that occur towards Cape Canaveral. Eckelbarger (1976) observed significantly higher mortality (LD_{50}) of *P. lapidosa* larvae at water temperatures below 15.5 °C and above 29.5 °C. Temperatures to the north of St. Lucie County can be as low as 7 °C (Smith 1981). To the south, McCarthy et al. (2008) suggested that *P. lapidosa* might have lower abundance in south Florida and throughout most of the

Fig. 4.5 Small- and large-scale views of worm rock created by the polychaete *Phragmatopoma lapidosa* (*caudata*). (**a**) Close up showing individual worms and structure of sand tubes. (**b**) The honeycomb structure created by hundreds of worms. (**c**) A recently formed worm reef at Walton Rocks, St. Lucie County, Florida. (Sources: M. Daniels, D. McCarthy)

Caribbean because of lack of availability of small sediment sizes for new recruits to build tubes.

4.2.1.3 Reproduction and Life History

A wide range of reproductive and life history strategies for polychaetes have been identified along the east Florida coast. Most polychaetes become reproductive within a year of settlement and probably do not live more than 3 years (Giangrande 1997). They are primarily known to reproduce sexually and have external

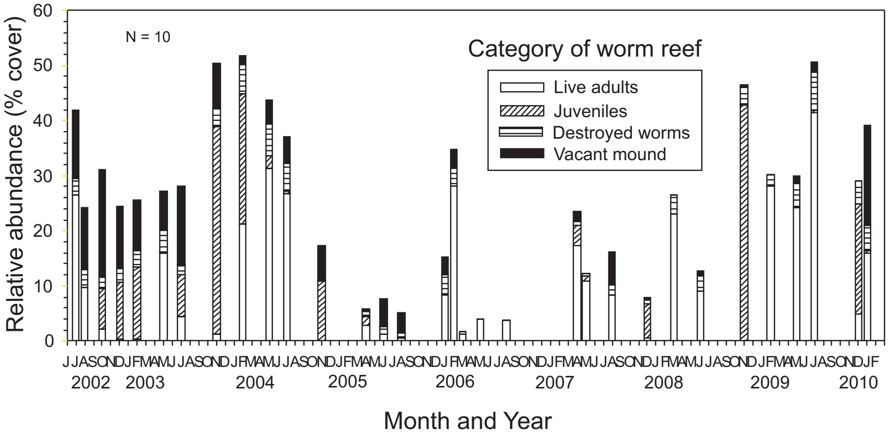

Fig. 4.6 Monthly mean percentage cover of live adults, juveniles, destroyed worms, and vacant mounds for *Phragmatopoma lapidosa* on Bathtub Reef, Stuart, Martin County, Florida. (McCarthy 2010)

fertilization. However, there is little known about seasonal spawning or recruitment patterns of polychaetes along the east Florida coast. Among polychaetes in general, some spawn throughout the year, while others are seasonal reproducers. While most produce trochophore larvae, both planktonic duration (weeks to months) and larval dispersal depends on the species (Pernet et al. 2002; Giangrande 1997).

Like many polychaetes, *P. lapidosa* are dioecious worms that externally spawn gametes into the water, where fertilization results in larvae that could drift in the plankton from 2 to 20 weeks (Eckelbarger 1976; Pawlik and Mense 1994). McCarthy et al. (2003) suggested that spawning could occur year-round but peaks during the summer. It was also suggested that sublethal disturbance such as that provided by increased wave activity may cue spawning from mid-winter through early fall. While it is unclear how long their larvae will drift in the water column, laboratory studies (Pawlik et al. 1991; McCarthy et al. 2002) suggest that competent larvae position themselves deep in the water column and consequently may be more likely to be transported inshore during seaward-directed winds that result in near-bottom return flow. This larval behavior may also serve to limit dispersal among *P. lapidosa* populations within its rather large range. A molecular study by Drake et al. (2007) suggested that *P. lapidosa* sampled in Florida (Miami) and those sampled in the Caribbean (Puerto Rico and Virgin Islands) may be two distinct populations. Staton et al. (2013) conducted another molecular comparison of five populations (Boynton Beach, Shark Reef, Coral Cove, Bathtub Reef, Satellite Beach) along the Florida coast, and observed low gene flow between the centrally located Bathtub Reef and all other sites. This suggests that hydrodynamics and larval behavior within this area of Florida may result in different sources of larvae than at the other locations sampled. Combined, these data support that *P. lapidosa* may have limited dispersal regionally and sometimes even within locations along the Florida coast. Future research is needed to understand genetic connectivity *of P. lapidosa* as well as to establish whether there are important source populations that provide larvae to other populations within the state.

It has been well documented that *P. lapidosa* require hard substrates for settlement and will repeatedly "test" substrates before settling on the preferred one (Eckelbarger 1976; Pawlik 1988). Behavioral preferences for moderate amounts of current have been quantified in laboratory studies with the closely related *P. californica* (Pawlik et al. 1991; Pawlik and Butman 1993). Further, it is well known that *P. lapidosa* often settle and metamorphose in response to contact with the tubes of adult worms (Eckelbarger 1976; Krueger 1976). Chromatographic analysis of the organic content of the tubes of the closely related *Phragmatopoma californica* revealed that a mixture of free fatty acids was responsible for inducing settlement (Pawlik 1986). Additionally, laboratory and field experiments by Jensen and Morse (1990) indicated that *P. californica* larvae also respond to butylated hydroxytoluene (BHT), which they suggest mimics the activity of an unidentified, cross-linked dihydroxyphenylalanine residue used to construct the tubes. Laboratory larval settlement responses of *P. californica* have been found to be identical to those of *P. lapidosa* (Pawlik 1988).

Recruitment occurs throughout most of the year for *P. lapidosa* but peaks during fall and winter (McCarthy 2001). Among five intertidal locations along the Florida coast (Satellite Beach, Stuart, Coral Cove, Palm Beach, Boynton Beach), it appears that *P. lapidosa* recruit at the highest levels in Stuart, followed by Satellite Beach (McCarthy unpubl. data 2008). McCarthy (2001) also investigated subtidal recruitment (~ 4 m depth) and observed similar seasonal recruitment yet at lower levels than those observed intertidally. He suggested subtidal recruitment to be highest during seasons with increased wave activity. However, both intertidal and subtidal worm reefs did appear to go through predictable patterns of annual change (McCarthy 2001). These changes include high recruitment in early autumn through winter, rapid reef growth (approximately 0.5 cm/day) resulting in maximum structure in spring and summer, and decay by early autumn (Figs. 4.7 and 4.8). Based on the annual cycle of reef growth (Fig. 4.1) and decline, it seems that physical processes rather than predator/prey relationships within the food web are more likely to limit the abundance and diversity of flora and fauna on worm reefs (Applied Biology, Inc. 1979; McCarthy 2001). More research is needed to investigate the important links between the predictable seasonal cycle of sabellariid reef expansion and degradation, and the occupation of those reefs by juvenile and adult invertebrates and fish.

4.2.2 Corals and Other Anthozoans

4.2.2.1 Diversity and Ecological Function

Anthozoans are fairly abundant and diverse along NHRs of the east Florida coast (Appendix 4.1). Most species provide shelter (on multiple spatial scales) for various organisms via their external features. Organisms that take refuge in the shelter

Fig. 4.7 *Phragmatopoma lapidosa* (*caudata*) recruits (~ 2 months old) on an intertidal hardbottom reef at Satellite Beach, Brevard County, Florida. (Source: M. Daniels)

Fig. 4.8 High worm reef cover and wave activity at Palm Beach, Palm Beach County, Florida. (Source: D. McCarthy)

created by corals include a number of invertebrates and fishes. Consequently, when corals are abundant, they are very important foundation species that contribute to increased local biodiversity. For example, in the nearby Florida Keys, 517 fish and 2059 invertebrate species have been identified in coral reef habitats (Causey et al. 2002). In addition to their ecological role of providing shelter, anthozoans such as gorgonians and some hard corals, can serve as food sources for reef residents such

Fig. 4.9 A colony of the scleractinian *Siderastrea* sp. in Palm Beach, Palm Beach County, Florida. (Source: D. B. Snyder)

as gastropods, bristle worms, and parrotfish (Birkland 1974; Kinzie 1974; Birkland and Gregory 1975; Preston and Preston 1975; Harvell and Suchanek 1983; Lasker 1985; Rotjan and Lewis 2005, 2008). However, it has been suggested that this function may not be as important on a large scale in some habitats (O'Neal and Pawlik 2002).

4.2.2.2 Latitudinal and Depth Gradient

The diversity and abundance of anthozoans change dramatically with latitude, and depth, along east Florida coast NHRs. Throughout tidal pools in the intertidal and very shallow subtidal zones along the entire coast, there are few of these animals present. In intertidal reefs in Flagler County, the anthozoans *Anthopleura varioarmata* and *Bunodosoma cavernatum*, and the hydrozoan *Ectopleura* (*Tubularia) crocea*, can be encountered under overhangs or within tide pools. Southward, the conspicuous species include the starlet coral *Siderastrea* spp. (Fig. 4.9), two species of zoanthids (*Palythoa caribaeorum* and *Zoanthus pulchellus*) (Fig. 4.10), and several species of solitary anemones (*Bunodosoma cavernatum*, *Actinia bermudnesis*, *Diadumene leucolena*). It is known zoanthids generally have a higher tolerance for the fluctuations in salinity and temperature that occur in these shallow habitats (Muthiga and Szmant, 1987; Lirman et al. 2002). *Palythoa caribaeorum* is a very fast growing, highly aggressive competitor for space among coral species (Suchanek and Green, 1981) in shallower waters (McCarthy pers. observ. 2019). Further, it has been suggested that the high-water flow (indicative of shallow reefs) may reduce stress to this species of zoanthid (Fujimura and Reigl, 2017). Latitudinally, it is more common southward being a dominant organism encountered in intertidal

Fig. 4.10 The zooanthid *Zoanthus pulchellus* and various other sessile invertebrates (and green algae) on intertidal hardbottom in Palm Beach, Palm Beach County, Florida. (Source: D. McCarthy)

areas within inlets of south Florida (Johnson and Roberts 2017). However, overall, most anthozoans are not very abundant within the 0–4 m depth range. In Palm Beach County, CSA Ocean Sciences Inc. (2014) encountered higher stony coral richness and octocoral abundance in the 3–6 m than 0–2 m depth range (Appendix 4.3). Cumming (2017) also found higher stony coral richness and density at depths greater than 3 m. Most likely these trends are attributable to the decreasing sediment movement and burial that can occur with increasing depth. Indeed, Cumming (2017) observed increased coral abundance on hardbottom areas more consistently exposed through time. It is known that the settlement and growth of many anthozoans is adversely affected in areas with significant sediment movement (Yeemin et al. 2006).

Anthozoan diversity in subtidal reefs changes significantly with latitude. However, there are very few studies of anthozoan communities in water depths less than 4 m. North of Martin County, there are generally fewer stony corals. Besides small *Siderastrea* spp., the most frequently encountered hard corals are the *Oculina* species (*O. varicosa* and *O. diffusa*) (Walker and Gilliam 2013). The two *Oculina* species become fairly abundant in water depths in excess of 6 m (Reed et al. 1982; Walker and Gilliam 2013; D. McCarthy, pers. observ. 2008). However, there are occasional occurrences of *Cladocora arbuscula*, grouped polyps of *Phyllangia americana*, and *Astrangia poculata* at this latitude (Brooke and Young 2005; CSA International, Inc. 2009; Coastal Eco-Group Inc. 2008, 2009). At deeper shelf depths, *O. varicosa* forms large individual colonies that create significant habitat for invertebrates and fishes (Reed et al. 1982; Reed and Mikkelsen 1987; Reed 2004). On the edge of the continental shelf (70–152 m), this species forms massive reef structures that support an extremely diverse and abundant invertebrate fauna, and provides spawning habitat for economically valuable fish species (Reed et al. 1982; Reed and Mikkelsen 1987; Reed 2004; Reed et al. 2005; Koenig et al. 2005). The *Oculina* Banks were designated a Habitat Area of Particular Concern (HAPC) in 1984 by the South Atlantic Fish Management Council (Reed et al. 2005). This area has since been expanded to encompass all the known *Oculina* deep reef habitat (NMFS 2007). Finally, at these latitudes, two species of gorgonians (*Leptogorgia virgulata* and *Leptogorgia hebes*), and one species of stoloniferan (*Carijoa* [*Telesto*] *riisei*), are fairly common in deeper reefs in the 4–6 m depth range.

In Martin County, the St. Lucie Inlet Reef appears to be the northernmost extent of several of the reef-building corals (e.g. *Diploria*, *Orbicella*, and *Montastraea*). The reef was designated for protection as part of the St. Lucie Inlet Preserve State Park because of the diversity and abundance of corals, and other shelter-enhancing invertebrate species (polychaetes, sponges, tunicates, algae) present. Within reefs in this County, the number of stony coral and octocoral species increases with depth (Walker and Gilliam 2013; J. Beal, FWC, pers. comm. 2008).

Both diversity and abundance of stony coral and octocoral species on reefs generally increase southward from Martin County (Appendix 4.1; Gilliam et al. 2018). The annual Southeast Florida Coral Reef Evaluation and Monitoring Program (SECREMP), which surveys reef tract sites in Martin, Palm Beach, Broward, and Miami-Dade Counties, observed in their ongoing study that the corals of greatest abundance are *Porites astreoides*, *Montastraea cavernosa*, *Siderastrea siderea*, *Stephanocoenia intersepta, Agaricia (Undaria) agaricites* and *Porites porites* (Gilliam et al. 2018). CSA International, Inc. (2009) compiled available reports, which revealed that 7, 22, 24, and 32 stony coral species and 3, 12, 14, and 14 octocoral species were identified in shallow nearshore reefs in St. Lucie, Martin, Palm Beach, and Broward Counties, respectively. In Palm Beach County, two nearshore reef studies (CSA Ocean Sciences Inc. 2014; Cumming 2017) noted that stony coral richness was highest in water greater than 3 m depth. However, CSA Ocean Sciences Inc.(2014) noted the abundance of the stony coral *Siderastrea* was high in water less than 2 m depth. Both studies observed higher octocoral abundance in the deeper reefs sampled. Overall, 40 octocoral species have been identified in reefs down to 8 m depth from Palm Beach to Miami-Dade Counties (Jaap 1984; Vare 1991). Generally, octocorals with a rod morphology are most commonly encountered on shallow reefs in these counties (Walker and Klug 2014; Cumming 2017).

On shallow hardbottoms less than 7 m depth, Prekel et al. (2007, 2008) and Coastal Planning & Engineering, Inc. (2006) recorded 19 stony coral species on nearshore reefs in Broward County (Table 4.1). They observed that *Siderastrea siderea* was most common (81.3% of observations of corals), followed by *Porites porites*, *Dichocoenia stokesii, Phyllangia americana*, and *Porites astreoides* (accounted for between 1.1% and 4.9% of observations). In Broward and Miami-Dade Counties, there is a very high stony coral richness and abundance (Gilliam et al. 2018). Klug (2015) observed higher density and richness of stony corals with depth in these areas. Interestingly, at 3–7 m depths, there is a high abundance of the federally listed scleractinian *Acropora cervicornis* (Moyer et al. 2003;

Vargas-Angel et al. 2003; Walker and Klug 2014; Klug 2015; Gilliam et al. 2018). The tree-like morphology of this coral offers important shelter value to motile invertebrates and vertebrates. Consequently, in 2006, this species (along with *A. palmata*) was designated by the National Oceanic and Atmospheric Administration (NOAA) as "threatened" under the Endangered Species Act (ESA) because of its significant decline and subsequent risk of extinction within this Florida-Caribbean region. For similar reasons, in 2012, NOAA listed five more species of corals as "threatened" in the eastern Atlantic region: *Mycetophyllia ferox, Dendrogyra cylindrus, Orbicella (Montastraea) annularis, O. (M.) faveolata,* and *O. (M.) franksi.*

Based on latitudinal differences among benthic habitat types, six coral reef ecoregions have been suggested to extend from Martin to Miami-Dade County (Walker 2012; Walker and Gilliam 2013). They encompass areas around Martin County, North Palm Beach, South Palm Beach, Deerfield, Broward-Miami, and Biscayne. These analyses encompassed all reef areas from zero to 30 m and included trends deeper than the nearshore reef focus of this book. However, when comparing benthic assemblages along the coastal depth gradient, they observed high within-habitat variability across the reef profile within their shallowest zone ("Nearshore Ridge Complex"), which they suggested may have been because they did not divide the ridge into separate habitats (e.g. fore-ridge, crest, back-ridge). Such smaller scale reef features may be important in shaping benthic communities within nearshore areas (Walker and Gilliam 2013).

4.2.2.3 Reproduction and Life History

There is high diversity in reproductive strategies among anthozoan species found along east Florida. Most species can reproduce and/or propagate both sexually and asexually (see Fautin 2002 and Harrison 2011 for reviews on anthozoan reproduction). Asexual reproduction via longitudinal fission appears to be the dominant form of vegetative proliferation among sea anemones (Shick 1991). Asexual reproduction is also considered the dominant form of reproduction for *Acropora cervicornis*, whereby propagation occurs when branches break off during a storm and new colonies form (Tunnicliffe 1981). There is less information available on gorgonians, but it has been suggested that *Plexaura* spp. may reproduce via parthenogenesis, whereby larvae develop without fertilization (Brazeau and Lasker 1989). This genus may also asexually reproduce when branches break during storms (Lasker 1984). In contrast to these reproductive methods, non-branching corals like *Orbicella* (*Montastraea) annularis* primarily reproduce sexually through simultaneous release of gametes into the water column (Foster et al. (2007).

Few studies have documented the seasonal reproductive patterns of anthozoans along the east Florida coast. Among sexually reproducing corals, some are broadcast spawners with external fertilization, while others brood larvae. A number of the scleractinian species in the region have been noted to spawn during late summer. To the north, *Oculina varicosa* spawns during late summer, producing planulae that can settle in 3 weeks (Brooke and Young 2005). While not confirmed for Florida, *Leptogorgia* spp. and *Pseudoplexaura porosa* may spawn seasonally during this time period as well (Beasley et al. 2003; Kapela and Lasker 1999). In Martin County, it has been suggested that *Montastraea* and *Diploria* colonies do not spawn, because they are at the northern limit of their distribution and do not have the energetic reserves to produce gametes (J. Beal, pers. comm. 2008). Southward in Florida, the reef-building corals *Montastraea annularis*, *M. cavernosa*, *Acropora cervicornis*, and *A. palmata* also synchronously spawn during late summer (Szmant Froelich 1986; Vargas-Angel et al. 2006). However, some corals may spawn a little later in the year. Lueg et al. (2012) suggests spawning in *Solenastrea bournoni* and *Stephanocoenia intersepta* as late as September, while *Siderastrea siderea* has been observed to have peak spawning in October (St. Gelais et al. 2016). In contrast to seasonal spawning, some anthozoans may spawn for most of the year. *Porites astreoides* brood larvae during an extended season and reach maturity at smaller sizes than species such as *Diploria* spp. and *M. cavernosa* (Soong 1991, 1993).

The amount of time that anthozoan larvae can be in the plankton varies and can potentially extend from weeks to months (Richmond et al. 2018). Some species of zoanthids have long-lived larvae that can potentially disperse great distances. However, while some may survive for as long as 22 weeks, their ability to metamorphose may be lost after 11 weeks (Ryland 1997). Brooke (2002) suggests that larvae of the *Oculina varicosa* not only have the potential to be transported between the deep reef tracts but may also contribute to nearshore shallow water populations during summer upwelling events. In contrast, the staghorn coral, *Acropora cervicornis,* likely has a low to moderate level of dispersal and, hence, gene flow, which suggests that this Federally protected species might require local source populations for their recovery (Baums et al. 2005; Vollmer and Palumbi 2007).

Generally, the few studies of nearshore reef recruitment along the east Florida coast have observed infrequent and sporadic seasonal recruitment of anthozoans. Yoshioka (1996) studied recruitment of several gorgonian species on the Atlantic coast of Panama, observing limited, yet highly variable, seasonal recruitment. Both Cummings (1994) and McCarthy (2001) observed seasonal recruitment of sessile invertebrates to nearshore reefs in southeast Florida. McCarthy (2001) sampled plates frequently in Boynton Beach for ~2.5 years, encountering only one scleractinian species (*S. radians*) once out of over 1200 settlement plates sampled (Table 4.2). Cummings (1994) additionally observed the anthozoans *Carijoa* (*Telesto*) *riisei*, *Bunodosoma granuliferum*, and *Palythoa mamillosa*, while McCarthy encountered only the actiniarian *Actinia bermudensis*. Harper (2017) conducted a one-year recruitment study focusing on scleractinians and octocorals on deeper reefs from 5 to 20 m depths in Broward and Miami-Dade Counties. Her results suggested that those taxa that were tolerant of more harsh environmental conditions showed signs of recruitment success. Her study provided evidence that low recruit survivorship may be a bottleneck that structures adult coral populations. Such bottlenecks may prohibit rapid recovery and/or maintenance of coral populations after natural or anthropogenic disturbance events. Recovery may be further reduced by cyanobacteria and macroalgal blooms, which can prohibit coral recruitment and appear to be occurring more frequently along the east Florida coast in recent years (Paul et al. 2005; Ritson-Williams et al. 2005; Kuffner et al. 2006; Tiling et al. 2017).

4.2.3 Sponges

4.2.3.1 Diversity and Ecological Function

Sponges are fairly abundant and diverse on NHRs along the east Florida coast (Appendix 4.1). Most species provide shelter for various organisms via internal spaces as well as their external features. Amphipods, crabs, shrimp, nemertines, polychaetes, mollusks, and brittle stars all take refuge in sponges (Wulff 2006; Richards et al. 2007; Wulff 2016). Consequently, when abundant, sponges are important shelter-enhancing invertebrates that can contribute to increased local biodiversity. Sponges may also serve as an important food source for many of the angelfishes, filefishes, trunkfishes, cowfishes, and butterflyfishes that are particularly common in southeast Florida (Pawlik 1998). Sponges may be important in removing carbon (via food sources), oxygen, silicon, and fixed nitrogen carbon from the water column, and thus significantly affect bentho-pelagic coupling (Peterson et al. 2006; see Bell, 2008 for a review). However, some sponges can have a detrimental effect on neighboring sessile organisms. For instance, the rock-boring species, such *as Cliona delitrix* and *Pione lampa* (formerly *Cliona lampa*), can aid in the fragmentation and disintegration of coral heads (Glynn 1997; Zilberberg et al. 2006; Chaves-Fonnegra and Zea 2011). The rate of this type of coral disturbance can also be accelerated by heavy storms, hurricanes, and any other source of physical stress (Tunnicliffe 1981; Highsmith 1982; Rutzler 2002). Further, the proliferation of clionid sponges has been linked to organic pollution and temperature increases (Rose and Risk 1985; Holmes 1997; Rutzler 2002). For example, Ward-Paige et al. (2005) suggested that sewage contamination in the Florida reef tract results in increases in bioeroding sponges that shift the carbonate balance from one of reef construction (accretion) to that of reef destruction (erosion).

4.2.3.2 Latitudinal and Depth Gradient

The diversity of sponges probably increases with latitude and depth on nearshore reef habitats along the east Florida coast. However, abundance patterns are unclear for most species, with little quantitative information being available for the 0–4 m depth range. Within the 5–8 m depth range, mean percent cover of sponges along the Florida Reef Tract is higher south of Martin County yet highly variable from Palm Beach to Miami-Dade County, ranging between 7.3% and 11.2% (Gilliam et al. 2018). In Palm Beach County, 23 sponge species were documented with nine being more abundant in 4 to 6 m than 0 to 3 m depth (CSA Ocean Sciences Inc.

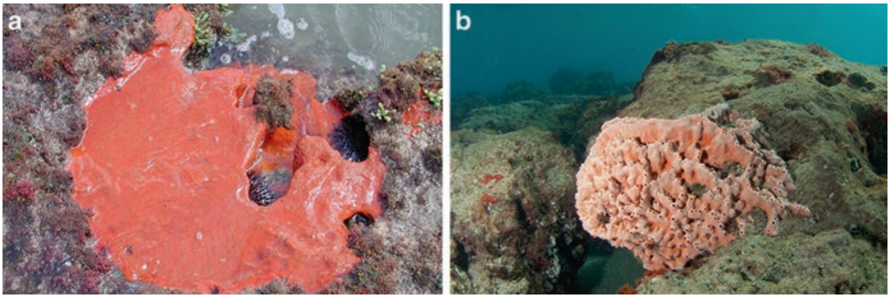

Fig. 4.11 Common reef sponges in reefs along southeast Florida coast. (**a**) An intertidal colony of the rock-boring sponge *Pione (Cliona) lampa* in Stuart, Martin County, Florida. (**b**) The lumpy overgrowing sponge *Desmapsamma anchorata* (*Holopsamma helwigi*) in Boynton Beach, Palm Beach County, Florida. (Sources: D. McCarthy, D. B. Snyder)

Table 4.3 Significant indicator species for sponge taxa from natural reef depth strata (pooled across surveys) in Palm Beach County, Florida

		Depth Stratum				
Group	Taxon	1 (0 to 1 m)	2 (1 to 2 m)	3 (2 to 3 m)	4 (4 to 6 m)	*p*-value
Sponges	*Niphates* sp.	–	–	–	0.417	**0.003**
	Ircinia strobilina	–	–	–	0.406	**0.003**
	Phorbas amaranthus	–	–	–	0.378	**0.009**
	Cliona sp.	0.355	–	–	–	0.127
	Ircinia sp.	–	–	–	0.343	**0.01**
	Ircinia felix	–	–	–	0.334	**0.009**
	Aplysina sp.	–	–	–	0.333	**0.008**
	Holopsamma sp.	–	–	–	0.333	**0.01**
	Demospongiae	–	–	–	0.323	**0.013**
	Niphates digitalis	–	–	–	0.250	**0.048**

Depth strata had 4 levels: stratum 1 (0–1 m), stratum 2 (1–2 m), stratum 3 (2–3 m), and stratum 4 (4–6 m); Significance based on a Monte Carlo test (1000 randomizations)
Significant [$p < 0.05$] results are in bold
CSA Ocean Science Inc. (2014)

2014). Within the lower intertidal and shallow subtidal zones, the most conspicuous sponge is the rock-boring sponge *Pione lampa* (*Cliona lampa*) (Fig. 4.11). Although *P. lampa* appears to be more abundant in less than 4 m, it can continue on to deeper depths where other rock-boring sponges such as *Clione delitrix* can also be encountered (Table 4.3; McCarthy, pers. observ. 2019). Halperin et al. (2017) also observed *C. delitrix* at deeper depths in Broward County. The non-rock boring sponge *Desmapsamma anchorata* (*Hoplosamma helwigi)* can also be frequently encountered in deeper nearshore and intermediate depth areas from Martin County southward (Fig. 4.11).

Fig. 4.12 The demosponge *Aplysina fistularia* on a nearshore reef off Palm Beach, Palm Beach County, Florida. (Source: D. McCarthy)

4.2.3.3 Reproduction and Life History

Sponges can reproduce sexually and asexually, although the relative importance of these strategies in population maintenance is often unclear. Asexual reproduction (e.g., fragmentation and budding) may be important for a number of the shallower sponge species in nearshore reefs because of the increased frequency of stress via waves and sand scour. High environmental stress was suggested to increase bud production in the sponge *Tethya citrina* (Cardone et al. 2010). Further, vertically oriented sponges common off east Florida such as *Aplysina* spp. (Fig. 4.12) and *Lotrochota birotulata*, may propagate almost exclusively by asexual fragmentation (Wulff 1991). Schönberg (2002) suggests that *P. lampa* can produce gemmules (internal buds normally found in freshwater species) that can resist sand burial, heat, and desiccation, and thereby maximize survival in these harsh intertidal and shallow subtidal habitats. Additionally, gemmules may be scattered and dispersed during periods of increased wave activity along the coast. However, sometimes population maintenance may be more dependent on dispersal of sexually produced larvae. Zilberberg et al. (2006) observed low evidence for the incidence of clonality and asexual propagation for *Cliona delitrix* in a study conducted in Lee Stocking Island (Exuma Cays, The Bahamas).

Fertilization in most sponges is internal, with embryos being either brooded or shed immediately into the water column. In both cases, the resultant larvae either swim in the water column or crawl away on the substrate (Maldonado and Bergquist 2002). For species with planktonic larvae, most appear to be short-lived

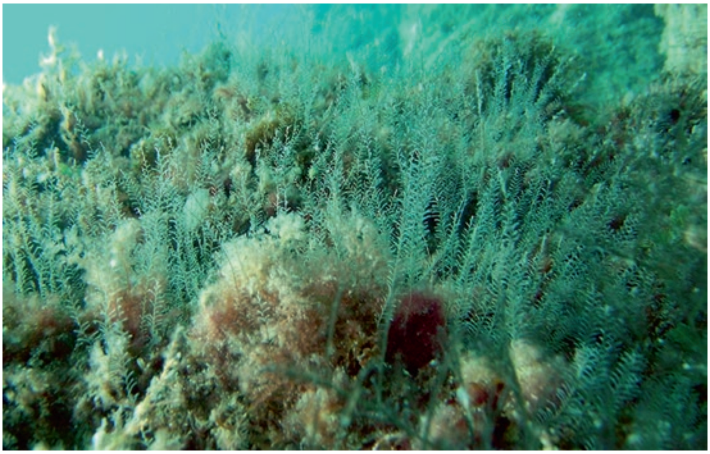

Fig. 4.13 Colonial hydroids on a mitigation reef in Juno Beach, Palm Beach County, Florida. (Source: D. McCarthy)

lecithotrophs living in the plankton from a few hours to several days (Lindquist et al. 1997; Maldonado and Bergquist 2002).

There is very little information on seasonal spawning, dispersal, and recruitment patterns of sponges along shallow nearshore reefs of the Florida coast. In Broward County, the rock boring sponge *Cliona delitrix* has a reproductive cycle that begins in April and terminates in December (Chaves-Fonnegra et al. 2016). Gene flow and dispersal occur along the Florida Reef Tract, although it appears likely that there are two breeding populations that are separated by depth (Chaves-Fonnegra et al. 2015). Cummings (1994) often encountered the rock-boring sponge *Pione (Cliona) lampa* during a recruitment study in 2 m of water off Boca Raton. The recruitment of *Chondrilla nucula*, *Spongia* sp., *Demapsamma* sp., and one unknown species were also observed to recruit yet less frequently.

4.2.4 Hydrozoans

4.2.4.1 Diversity and Ecological Function

Various hydrozoans such as fire corals and hydroids can be abundant along nearshore reefs encountered on the east Florida coast, but are generally lower in diversity compared to some of the other sessile invertebrates discussed (Appendix 4.1). Some species may provide limited shelter for some small organisms such as caprellid amphipods (W. Nelson, pers. comm. 2019) (Fig. 4.13). Hydroids may be prey for some invertebrates and fish, and thus could contribute to the food web, although there are no known studies investigating predation on hydroids in east Florida nearshore reefs.

4.2.4.2 Latitudinal and Depth Gradient

It is unknown how the diversity and abundance of hydrozoans change with latitude and depth along east Florida nearshore reef habitats. Several common species documented on shallow nearshore reefs include *Thyroscyphus ramosus*, *Campanularia* sp., *Eudendrium ramosum*, *Macrorhynchia* (*Lytocarpus) philippina*, *Pennaria* sp., and *Sertularella* sp. CSA Ocean Sciences Inc. (2014) found hydroids to be one of the most abundant sessile invertebrate group for all depths sampled in Palm Beach County. However, the fire coral *Millepora alcicornis* generally is in low abundance at shallow nearshore depths along the coast but has been observed to be more abundant on all deeper reef sites surveyed by SECREMP (Gilliam et al. 2015).

4.2.4.3 Reproduction and Life History

Hydrozoans are primarily colonial organisms that have life cycles that may include polyps, medusae, or both. Generally, most hydrozoans have both polyps and medusae (Ruppert et al. 2004). In this life cycle, the medusa reproduces sexually, while the polyp does so asexually. When reproducing sexually, male and female medusae shed gametes that develop into planulae larvae. Offspring usually drift in the plankton for a relatively short period of time. For instance, *Mitrocomella polydiademata* are ready to settle 3–5 days after fertilization (Martin and Koss 2002). Consequently, there probably is limited dispersal of larvae away from their parents.

There is very little information on seasonal spawning and recruitment patterns of hydrozoans along the Florida coast. If local species have similar reproductive patterns to temperate hydrozoans, they might reproduce asexually throughout the year but sexually on a seasonal basis (Coma et al.1996). Cummings (1994) observed recruitment of *Thyroscyphus marginatus*, *Eudendrium* spp., *Macrorhynchia* (*Lytocarpus) philippina*, *Pennaria* sp., and *Gymnangium* spp. throughout the year. In contrast, Smith et al. (1950) observed very low recruitment of hydroids in the Key Biscayne area, with *Tubularia* sp. being the most common identifiable species.

4.2.5 Sessile Mollusks

4.2.5.1 Diversity and Ecological Function

A number of sessile mollusk species occur on NHRs along the east Florida coast (Appendix 4.1). The sessile forms include primarily bivalves but also two species of vermetid gastropods. Many bivalves are found under ledges and within crevices in somewhat low abundance. The vermetid gastropods occur primarily in the upper intertidal zone (D. McCarthy, pers. observ. 2008), where they sometimes are in high abundance and can enhance shelter on hardbottom that may benefit smaller invertebrates (e.g., sipunculans, xanthid crabs, and shrimp). Many mollusks are likely

Table 4.4 Data summary for mollusks collected from 41 colonies of the scleractinian coral *Oculina varicosa* on four reefs off the east Florida coast

	Water Depth			
	6 m	27 m	42 m	80 m
Mollusks				
Number of individuals	2027	61	594	2450
Average number of individuals/coral	145	15	46	245
Average density	29.3	9.1	3.8	14.7
Gastropod species	(155) 59	9	67	89
Bivalve species	(68) 40	15	24	46
Total species	(230) 101	25	91	140

Numbers in parentheses = total species. Density = number of individuals/100 g coral dry weight. Skeletal volume determined by water displacement. Percent dead coral based on dry weight
Modified from Reed and Mikkelsen (1987)

preyed on by invertebrates and fishes, but no data are available on their trophic importance along the east Florida coast.

4.2.5.2 Latitudinal and Depth Gradient

It is unclear how the diversity and abundance of mollusks change with latitude and depth along nearshore reefs along the east Florida coast. The most conspicuous mollusks are often found in the upper intertidal zones. In Flagler County, this can include the bivalves *Crassostrea virginica* and *Brachidontes exustus.* Much further to the south, the vermetid gastropod *Petaloconchus nigricans* and *P. varians*, can form vast networks of tubes (10–15 cm thickness) that provide significant shelter for a number of invertebrates (xanthid crabs, sipunculans, polychaetes, and nemertines) and fishes (blennies, gobies, and toadfishes). In St. Lucie County, Reed and Mikkelsen (1987) identified 40 bivalve species associated with the scleractinian coral *Oculina varicosa* at 6 m depth (Table 4.4). Applied Biology, Inc. (1979) sampled macroinvertebrates within a worm reef at the St. Lucie Power Plant observing low diversity and high temporal variability among bivalves (Table 4.5). In Stuart, Florida, eight species of bivalves were documented at an intertidal worm reef: *Barbatia domingensis*, *Isognomon radiatus*, *Musculus lateralis*, *Ostrea equestris*, *Sphenia frasilis (antillensis)*, *Anomia* sp., *Pteria* sp., and *Pinctada imbricata* (McCarthy et al. 2008). In Palm Beach County, CSA Ocean Sciences Inc. (2014) identified over 36 bivalve species associated with either macroalgae or worm reef samples in the depth range from zero to 6 m depth (Appendices 4.2 and 4.3). In this study, members of the Family Pteriidae were found to be more abundant within macroalgae in 1–2 m than the other depth ranges compared.

Table 4.5 Abundance of associated macroinvertebrates collected from sabellariid worm reef at the St. Lucie Power Plant from April 1976 through April 1979

	1976			1977				1978				1979	
Species	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr
Molluska													
Gastropoda													
Anachis avara						75	5		3	1			
Anachis floridana				2		15	16	1		11			
Anachis lafresnayi						1				1			
Astraea tuber						1				1			
Barleeia tincta						26				1			
Cypraea sp.												1	
Erato maugeriae							1						
Fissurella barbadensis					1	2							
Lamellaria perspicua												1	2
Lucapinella Iimatula						2							
Mitrella argus				4		36	9					5	
Nudibranchia sp.							1						
Phidiana Iynceus									1				2
Pisania tinctus						1				1			
Thais haemastoma floridana		1			1								
Thais rustica												3	
Tricolia affinis pterocladica						1							
Bivalvia													
Barbatia domingensis													1
Isognomon radiatus						1							
Musculus lateralis						1							
Ostrea equestris						4							
Sphenia antiIlensis			1		1				1				1
Arthropoda													
Pycnogonida													
Tanystylum sp.							2						
Stomatopoda													
Gonodactylus bredini						1							1
Gonodactylus sp.													
lsopoda													
Accalathura crenulata													1
Anthuridae sp.											1		
Asellota sp.							1						
Dynamenella sp.			1			1			1	2			
Excorallana sexticornis		11		5	10	51	9	14	5	56	4		42
Mesanthura decorata		1	4		2	2			3	6			
Paranthura infundibulata		1	1		2	1		1	5				
Sphaeroma walkeri		6	1	27	70	12	1	3	4	41	7		18

Modified from Applied Biology, Inc. (1979)

4.2.5.3 Reproduction and Life History

Vermetid gastropods and bivalves are sexually reproducing invertebrates. Vermetid gastropods are protandrous hermaphrodites that internally fertilize, producing lecithotrophic larvae with a short, free-swimming/crawling phase. Sessile bivalves usually have separate sexes but can be hermaphroditic. They typically spawn externally, although the females of some species retain eggs with fertilization occurring within the mantle or water tubes (Zardus and Martel 2002). In both methods, the resultant larvae swim in the plankton for species-specific periods of time prior to settlement and metamorphosis. Depending on the species, larvae can be planktotrophic or lecithotrophic.

Little is known on seasonal spawning and recruitment patterns of these species along the Florida coast. In Boynton Beach, the worm snail *Vermicularia* sp. and mussel *Brachidontes* sp. recruited very sporadically (McCarthy 2001). In the same area, the pearl oyster *Pinctada imbricata* recruited seasonally, with peak recruitment occurring during the fall (McCarthy 2001). Cummings (1994) and McCarthy (2001) identified the bivalves *Isognomon radiatus*, *Ostrea equestris*, *Anomia simplex*, *Pteria* sp., *Brachidontes citrinus*, and *Pinctada imbricata* on settlement plates in the 4–8 m depth range (Tables 4.2 and 4.6).

4.2.6 Motile Mollusks

4.2.6.1 Diversity and Ecological Function

There is a high diversity and abundance of motile gastropods along the east Florida coast (Appendix 4.1). Reed and Mikkelsen (1987) studied the molluskan community associated with the scleractinian coral *Oculina varicosa* at four sites of varying

Table 4.6 Mollusks recorded during a survey of a newly constructed artificial reef structure in the nearshore (~8 m depth) area off Boca Raton, Florida

Scientific name	December 1988–January 1989	July 1989–August 1989	July 1990
Class Gastropoda			
Order Neogastropoda			
Anachis floridana		•	•
Thais rustica	•	•	•
Iselica fenestrata	•		
Class Bivalvia			
Order Pterioida			
Isognomon radiatus	•	•	•
Ostrea equestris	•	•	
Ostrea sp.			•
Pinctada imbricata	•		

• denotes species presence
Modified from: Cummings (1994)

depth. They identified 230 species-level taxa, including 155 gastropods. The observed taxa utilized four modes of existence: motile (47%), symbiotic (32%), epilithic (18%), and endolithic (3%). There may be as many as 40 gastropod species that are rare and endemic to small nearshore reaches of Florida coastline (USFWS 1999), specifically beach-rock outcrops along Palm Beach and Martin Counties (Petuch 1988).

Motile gastropods are likely very important in food webs along the east Florida coast. They are important as predators of various invertebrates and small fishes (McGraw and Gunter 1972; Carriker 1978; Reed and Mikkelsen 1987; Watanabe and Young 2006). They can also be important herbivores or bioeroders as well (Craig et al. 1969; Ruppert et al. 2004; Rossinni et al. 2014). Watanabe and Young (2006) indicated that the main gastropod predator of *P. lapidosa* was the dog whelk *Stramonita floridana (haemostoma)*. Traditionally, *Stramonita floridana* feed on oysters, like many other boring gastropods, by scraping the surface of shells and also by applying secretions that dissolve the shell, or by injecting toxins (McGraw and Gunter 1972; Carriker 1978). However, *S. floridana* on worm reefs develop a much longer proboscis to feed on *P. lapidosa* worms than conspecifics in other areas that fed on bivalves (Watanabe 2002). They also observed low numbers of the non-shell-boring gastropods *Gemophos tinctus* (*Pollina tinca)* and *Leucozonia nassa* feeding on *P. lapidosa.* Gastropods such as these can not only be predators but also major prey items for other invertebrates such as the stone crab *Menippe mercenaria,* portunid crabs (Butler 1985; Richardson and Brown 1992), spiny lobsters (*Panulirus argus*) (Sultzman 1990), and other snails such as *Pisania tincta* (Watanabe 2002). They can also be fed on by fishes such as puffers, sheepshead, black sea bass, porgies, and yellowtail snapper (Bertness et al. 1981; Cummings 1994; USFWS 1999).

4.2.6.2 Latitudinal and Depth Gradient

In the intertidal zone, the chitons *Chaetopleura apiculata*, *Ceratozona squalida*, and *Rhyssoplax* (*Calloplax) janeirensis,* and the pulmonate *Siphonaria pectinata*, can often be found along the east Florida coast (D. McCarthy, pers. comm. 2019). The gastropods *Stramonita* (*Thais*) *rustica* and *floridana*, *Vasula* (*Thais) deltoidea*, *Cerithium literratum*, *Tectarius antonii*, and *Cenchrus muricatus*, also occur frequently along the east Florida coast. The marine opisthobranch *Aplysia* spp. increases in abundance and number of species moving south towards the Florida Keys. Most nerite snails and false limpets are considered tropical, and few are encountered that survive the cold winter months to the north of Palm Beach County. Petuch (1987) describes several endemic intertidal species, including a few new species of small gastropods, some of which include *Nerita fulgurans* and *Cerithium lindae* from Martin, Palm Beach, and Broward Counties. In the rocky intertidal zone along Palm Beach County, it is also possible to find *Nerita peleronta*, *N. versicolor*, and *N. tesselata* (E. Petuch, Florida Atlantic University, pers. comm. 2008).

Applied Biology, Inc. (1979) monitored a sabellariid worm reef at the St. Lucie Power Plant (April 1976 to April 1979) and found 17 gastropod and 5 bivalve species associated with the reef (Table 4.5). The four most common species of gastropods included *Costoanachis (Anachis) avara*, *Mitrella argus*, *Costoanachis (Anachis) floridana*, and *Barleeia tincta*. As with other fauna observed, the number of gastropod species collected was highest in July, when water temperatures peaked, and reef size was largest. Numbers and diversity of organisms were lowest from October to January, when water temperatures were decreasing, and reef size was the smallest. McCarthy (unpubl. data, 2010) and Watanabe (2002) noted the presence of *Stramonita floridana* and *Aplysia dactylomela* in observations at Bathtub Reef. *Stramonita floridana* was significantly abundant all over the worm reef, but only during fall and early winter.

In Palm Beach County, CSA Ocean Sciences Inc. (2014) identified over 52 gastropods associated with either macroalgae or worm reef samples from zero to 6 m depth (Appendices 4.2 and 4.4). There was mostly high variability in abundance of taxa for the four depths compared (0–1 m, 1–2 m, 2–3 m, and 4–6 m). However, members of the Genus *Anachis* were found to be more abundant within macroalgae in 1–2 m versus the other depth ranges compared. Additionally, the gastropod *Phrontis* (*Nassarius*) was statistically found to be most prevalent at the 4–6 m depth range.

4.2.6.3 Reproduction and Life History

Motile mollusk species (mostly gastropods) sexually reproduce and can be dioecious or hermaphroditic. Fertilization can be internal or external, producing offspring that develop directly or indirectly. In direct development, offspring are encapsulated in egg cases that are attached to the seafloor. They undergo metamorphosis within the cases, and hatch as fully developed juveniles. In indirect development, trochophores (only archaeogastropods such as limpets, nerites, and turbans) or veliger larvae (most other gastropods) are produced. In the latter case, veligers can be lecithotrophic and short-lived (days to weeks) in the plankton or planktotrophic and long-lived (up to 3 months) in the plankton. These larvae are among the most abundant nearshore zooplankton, but their occurrence is likely to be both local and brief. However, information about their specific reproductive patterns is limited (Reed and Mikkelsen 1987; Johnson and Allen 2005).

Watanabe (2002) conducted research investigating reproduction of the dog whelk, *Stramonita floridana (haemostoma)* at a population at Marineland (rock boulders) and another at a worm reef at Bathtub Reef from 1999 to 2001. While the snails on the rocks at Marineland persisted for several years, the population on the worm reef at Bathtub Reef was more ephemeral consisting of a new single cohort generated during the fall of each year that completely died off by late summer (after 9–10 months after recruitment). This occurred in concert with the annual cycle of *P. lapidosa* recruitment and demise during the same time period (McCarthy 2001; Watanabe 2002). He also found that female fecundity and egg number per capsule was greater for *S. haemastoma* that fed on oysters versus those that fed on *P. lapidosa*.

In southeast Florida, Cummings (1994) studied the recruitment and community development associated with a newly constructed artificial reef (April 1988 to July 1990) off Boca Raton, Florida. Sixty-four invertebrate species were recorded during the study, of which three were gastropods and four were bivalves. Invertebrate species diversity was significantly higher in July 1990 than during January 1989. However, the seasonality of invertebrates was not confirmed because of a temporary and unexpected burial of four of six sampling locations. Generally, the invertebrate community on the reef never seemed to reach an equilibrium and stayed in an early stage of development because of frequent physical disturbance.

4.2.7 Sessile Crustaceans

4.2.7.1 Diversity and Ecological Function

Sessile crustaceans such as barnacles are encountered throughout the intertidal, and to a lesser extent, subtidal hardbottom reef habitats along the east Florida coast. There are nine species of barnacles found along the coast (Appendix 4.1). Barnacles are active suspension feeders that use cirri to move water and feed. When in large numbers, they can provide reef shelter enhancement (usually in the upper intertidal zone) and serve as a food source for some fishes (e.g., sheepshead) and decapods (stone crabs), and gastropods (oyster drills).

4.2.7.2 Latitudinal and Depth Gradient

Overall, barnacles have a relatively high dispersal ability, and most of these species occur throughout intertidal and shallow subtidal reefs along the east Florida coast. The most conspicuous barnacle, the volcano barnacle *Tetraclita floridana (stalactifera*), is very prominent along the coast at the upper intertidal zone, where its primary competitor for space, *P. lapidosa,* does not often occur (D. McCarthy, pers. observ. 2019; Multer and Milliman 1967; Fig. 4.14). At Boynton Beach, Florida, McCarthy (2001) suggested that *P. lapidosa* consistently recruits in large numbers and out-competes other recruit species such as barnacles by growing over them. However, when *P. lapidosa* is not present, a number of other barnacle species may often be present in these habitats. Other abundant barnacle species which can be observed along the Florida coast on intertidal areas include *Amphibalanus* (*Balanus) eburneus*, *Amphibalanus* (*Balanus) amphitrite*, *Chthamalus fragilis*, and *C. stallatus*. *Amphibalanus* (*Balanus) improvisus* and *Chthamalus stellatus* have been observed as well as far south to the Key Biscayne area (Smith et al. 1950). The barnacle *Balanus tintinnabulum antillensis* has also been observed attached to coquina rock underlying the worm-built structure on Hutchinson Island (Camp et al. 1977) and on an artificial reef in Boca Raton (Cummings 1994). More recently, the barnacle *Megabalanus coccopoma* was identified on intertidal hard

Fig. 4.14 The volcano barnacle *Tetraclita floridana (stalactifera)* on intertidal hardbottom in Marineland, Flagler County, Florida. (Source: D. McCarthy)

bottom in Stuart (McCarthy 2010). Since then, the range expansion of this non-native species northward has been tracked (Spinuzzi et al. 2013).

4.2.7.3 Reproduction and Life History

Most barnacles are simultaneous hermaphrodites that externally fertilize eggs within their mantle cavities. Eggs are brooded there, hatch out into the plankton, and become nauplius larvae that are carried with currents until they settle as cyprids. Many cyprids preferentially settle on conspecifics, cuing in on chemical and topographical features of the adults (Ruppert et al. 2004). Generally, there is high initial post-settlement mortality, with surviving barnacles probably living 1–10 years, depending on various abiotic and biotic factors (Ruppert et al. 2004).

Little is known about seasonal reproductive patterns of most barnacles along the east Florida coast, although some species may have similar patterns as counterparts within the region. McCarthy (2001) observed barnacle recruitment on intertidal and subtidal (4–5 m) reef habitats in Boynton Beach. In the intertidal zone, all three barnacle species encountered (*Amphibalanus eburneus, A. amphitrite,* and *Chthamalus fragilis*) recruited seasonally, with peak recruitment occurring during the summer (May to August). *Chthamalus fragilis* recruited more intertidally rather than subtidally, and generally was the most abundant barnacle recruiter during the study. *Amphibalanus eburneus* was the only barnacle species that recruited equally to both intertidal and subtidal habitats. In contrast, *A. amphitrite* was the most abundant subtidally, recruiting throughout the year. The study also suggested that there might be significant post-settlement mortality by mobile predators (e.g., crabs and fishes) for *C. fragilis* in subtidal habitats but not for any of the other barnacle species. In an older study by Smith et al. 1950 in southeast Florida, *A. amphitrite* and *A. improvisus* had similar seasonal peaks in recruitment as those found by McCarthy (2001) but were also found to recruit more continuously throughout the year. Interestingly, *Tetraclita* spp. were essentially non-existent in both studies, yet are often the most abundant adult barnacles along the coast (McCarthy, pers. observ. 2001). A possible explanation for this may be that settlement plates in both studies were not placed high enough in the intertidal zone to observe recruitment of this species. Larval behavioral preferences may have positioned the competent *Tetraclita* spp. larvae so that they were transported only to these upper reaches of the intertidal zone where most adults are found.

4.2.8 Motile Crustaceans

4.2.8.1 Diversity and Ecological Function

The structure provided by east Florida coast nearshore reefs supports a high diversity and abundance of motile crustaceans such as crabs, stomatopods, shrimp, lobsters, isopods, and amphipods (Appendix 4.1). Sabellariid worm reefs, in particular, support an even higher diversity and abundance of these crustaceans than neighboring sand or hardbottom reef habitats. Van Montfrans (1981) reported that the majority of decapods along the east Florida coast can be regarded as tropical in origin, as can be seen by their associations with southern latitude coral reefs. *Phragmatopoma* worm reefs are a particularly important habitat for tropical marine decapods (Fig. 4.15), especially in the high energy surf zones at more northern lattitudes, where corals tend not to be as abundant.

Trophically, crustaceans are important in food webs along the east Florida coast as major prey for other invertebrates and fishes (Gore et al. 1978). They can also be important as predators of various invertebrates and small fishes (Gore et al. 1978; USFWS 1999). Gore et al. (1978) postulated a possible food sub-web for sabellariid worm reefs on the east Florida coast based on the gut contents of six common species collected (See Chap. 7 for more information). The basis of the food sub-web was the worms on which some species of reef-dwelling crabs forage.

4.2.8.2 Latitudinal and Depth Gradient

The most quantitative research conducted on any invertebrate group along the Florida coast has been done with crustaceans. While most of this research was done over 35 years ago, the combined results provide the bulk of what is known about the nearshore reef community ecology along east Florida coast NHRs. The focus of this past research has been on the smaller decapods more directly associated with worm reefs created by *Phragmatopoma lapidosa* or the ivory bush coral (*Oculina varicosa*), and has rarely included quantitative measures of more motile crustaceans

Fig. 4.15 Tidal spray crab (*Plagusia depressa*) in Palm Beach, Palm Beach County, Florida. (Source: D. McCarthy)

such as swimming crabs (Family Portunidae) and spiny lobsters (Family Palinuridae). However, taxa in both families can be encountered along edges of nearshore reefs along the east coast of Florida. In particular, the spiny lobster (*Panulirus argus*) can be commonly observed from Indian River to Miami-Dade Counties in subtidal nearshore reefs and deeper.

Camp et al. (1977) studied the nearshore ecology at Hutchinson Island, Florida from September 1971 to July 1974. Benthic sampling mostly occurred at five stations at depths of 7–11 m on sand and sand shell substrate, but also at two neighboring worm reefs (collected only qualitative data at these sites). More than 170 species of arthropods were recorded. Thirty-eight arthropods were found on the intertidal worm reefs with 25 being unique to that habitat (Table 4.7). The Cuban stone crab *Menippe nodifrons* was very abundant in worm reefs sampled and was observed physically altering worm reef by breaking off and crushing pieces, and feeding on exposed worms (Fig. 4.16).

At a nearby study, Applied Biology, Inc. (1979) monitored a worm reef at the St. Lucie Power Plant from April 1976 to April 1979. Most of the sabellariid-associated fauna in this study were crustaceans, mollusks, and echinoderms. The crustacean species encountered, in order of abundance, were *Menippe nodifrons*, *Pachycheles monilifer, Excorallana sexticornis*, *Sphaeroma walkeri* (isopods), and *Pachygrapsus transversus* (Table 4.8). The number of associated species collected was maximum in July when water temperatures peaked, and reef size was largest, and lowest in October to January when the opposite conditions were found. The richness of many decapod and crustaceans encountered was similar for most years for results of the Gore et al. (1978), Camp et al. (1977), and Applied Biology Inc. (1979) studies (Table 4.9).

Table 4.7 Comparison of worm reef arthropods found in the vicinity of Hutchinson Island, Florida with arthropod species found offshore in the same area

Species found only at worm reef	Rank	Species found at worm reef and offshore stes	Stations				
			I	II	III[a]	IV	V
			Depths (m)				
			8.4	11.2	7.1	10.9	10.9
Balanus tintinnabulum antillensis		*Tanystylum orbiculare*	•	•			
Paranthura infundibulata		*Balanus trigonus* on *Plagusia depressa*	•	•	•	•	•
Sphaeroma walkeri		*Gonodactylus bredini*	•	•		•	•
Bopyridae sp. D (on *Petrolisthes armatus)*		*Periclimenes americanus*	•	•		•	•
Alpheus malleator		*Alpheus formosus*		•			
A. nuttingi		*A. normanni*	•	•		•	•
A. thomasi		*Synalpheus* sp. B	•				
Synalpheus fritzmuelleri		*Paguroidea* sp.	•	•		•	•
Synalpheus sp. A		*Paguristes hummi*	•	•		•	•
Calcinus tibicen		*Epialtus* sp.	•	•			
Paguristes tortugae		*Mithrax forceps*	•	•			
Pagurus brevidactylus		*Mithrax* sp.	•	•			
Megalobrachium poeyi		*Pitho lherminieri*	•	•			
Pachycheles monilifer	2						
Petrolisthes armatus							
P. galathinus							
Microphrys bicornutus							
Mithrax coryphe							
Eurypanopeus abbreviatus							
Menippe nodifrons	1						
Panopeus bermudensis							
Pilumnus dasypodus							
Xantho denticulatus							
Pachygrapsus transversus	2						
Plagusia depressa							

Underline indicates species in common with Gore et al. (1978) study
[a]Station III had no hard substrate
• denotes species presence
Modified from: Camp et al. (1977)

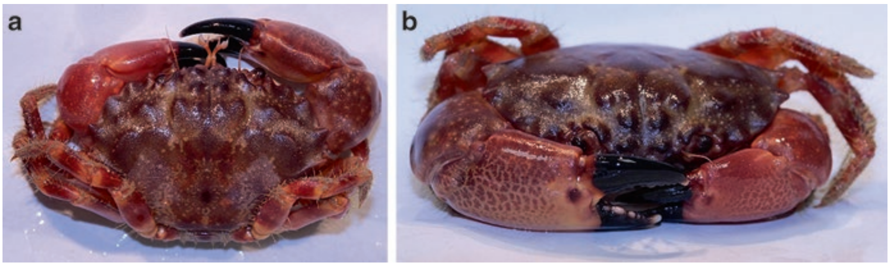

Fig. 4.16 Top (**a**) and front (**b**) views of a Cuban stone crab (*Menippe nodifrons*). Collected in Palm Beach, Palm Beach County, FL. (Source: S. Brehm)

Table 4.8 Abundance of associated decapods collected from sabellariid worm reef (Stations 9 and 10 combined) at the St. Lucie Power Plant from April 1976 through April 1979

	1976			1977				1978				1979	
Species	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr
Alpheus formosus	1			2		1	6	5	1	1			3
Alpheus malleator							2						
Alpheus normanni											1		
Alpheus nuttingi						1	4		3				
Alpheus thomasi			2				2						
Alpheus sp. A					1								
Alpheus sp.								2				2	
Calcinus tibicen						1							
Epialtus sp.							1						
Eriphia gonagra													
Hippolytidae sp.													1
Lysmata intermedia				2			1						
Lysmata wurdemanni											1		
Lysmata wurdemanni?													
Majidae sp.													1
Menippe mercenaria	2	4	3			3	3	1		6	6	2	
Menippe nodifrons	26	11	172	27	19	114	198	159	19	58	99	93	35
Microphrys bicornutus						1							
Pachycheles monolifer	107	101	42	3	66	71	39	86	74	36	1	15	69
Pachygrapsus transversus	23	5	28	4	4	22	23	8	4	10	14	13	32
Pagurus carolinensis		1			1	4	3				1		2
Panopeus bermudensis		1	2		3	6		2	2	16		2	
Pelia mutica				1									
Petrolisthes armatus			1	1			1		1				
Petrolisthes galathinus							1	2					
Pilumnus dasypodus				2		19	11	14	10	22	3	3	3
Pilumnus sp.		2	1		2								2
Pitho lherminieri										2			
Pitho sp.								1					
Plagusia depressa					1						1		
Synalpheus fritzmuelleri		6	6	2	2	3	74	15	4	13	1	1	2
Synalpheus townsendi							1						
Synalpheus sp.						1							
Upogebia affinis										1			
Xantho denticulatus						2			1	1			
Xanthidae sp.							1						3

Modified from Applied Biology, Inc. (1979)

Table 4.9 Comparison of associated decapod and stomatopod crustaceans from studies at Walton Rocks and the St. Lucie Power Plant

	Florida department of natural resources[a] Within 2 km South of St. Lucie Power Plant June 1975	Smithsonian Institution Fort Pierce Bureau[b] Walton Rocks		Applied Biology, Inc. St. Lucie Power Plant		
		1974	1975	April 1976 through January 1977	April 1977 through January 1978	April 1978 through January 1979
Number of genera	22	15	11	12	18	14
Number of species	30	20	13	15	29	18
Diversity (d)	—	1.88	1.62	1.88	2.3	2.28
Equitability (e)	—	0.1	0.31	0.33	0.24	0.39

[a] Camp et al. (1977)
[b] Gore et al. (1978) and R.H. Gore (pers. comm. 2008)
Modified from Applied Biology, Inc. (1979)

Gore et al. (1978) investigated latitudinal changes in crustaceans in a 2-year study of four worm reef sites on the central east Florida coast from St. Lucie Inlet north to Sebastian Inlet (1974–1975). A total of 96 species of decapod and stomatopod crustaceans representing 52 genera and 22 families was identified. Two surveys occurred, with sampling conducted both on the worm reef itself and in areas adjacent to the reef. Specifically associated with the worm reef were 24 common species, of which the first 11 species comprised 90%, and the next 13 species comprised 4–7%, of the collected samples. The remaining 3% (27 species) were considered uncommon (Table 4.10). The six most common species (80% of the samples) were the porcellanid crab *Pachycheles monilifer*, the grapsid crab *Pachygrapsus transversus*, the aphid pistol shrimp *Synalphus fritzmuelleri*, and the xanthid crabs *Menippe nodifrons*, *Pilumnus dasypodus*, and *Acantholobulus* (*Panopeus) bermudensis*. *Pachycheles monilifer* and *M. nodifrons* were found to be restricted to worm reefs along the east coast of Florida. The abundance of the dominant species was relatively similar at all sites, but the less dominant species varied among sites (Table 4.11). Species richness was highest at St. Lucie Inlet south, intermediate (53%) towards the north from Walton Rocks to Fort Pierce Inlet, and lowest (13%) at Sebastian Inlet north.

Reed et al. (1982) studied the composition and abundance of decapod crustaceans on east Florida oculinid coral reefs. A total of 50 species were identified with four locations of varying depth being examined: Fort Pierce Inlet (6 m), north of Fort Pierce (27 m), south of Fort Pierce (42 m), and offshore east of Fort Pierce Inlet (80 m depth). Species showed strong clustering by station with a gradual decrease in density as depth increased. At the 6-m depth, there were discrete species clusters that were considerably different from all the other stations. Stations at 42- and 80-m depths showed little species differences. Species composition was relatively stable

Table 4.10 The 51 most recurrent species of decapod and stomatopod crustaceans encountered from sabellariid worm reefs in the Indian River region of Florida, 1974 to 1975

	St. Lucie			Walton Rocks			Fort Pierce			Sebastian			
Taxon	1974		1975	1974		1975	1974		1975	1974[a]	Abundance		60% to 80% Spawning
1. *Pachycheles monilifer*		127			163			256		None	C	MC	Year round
2. *Menippe nodifrons*		98			216			107		22	C	MC	May-Aug
3. *Synalpheus fritzmuelleri*		54			64			42		None	C	MC	Year round
4. *Pachygrapsus transversus*		51			48			56		66	C	MC	Year round
5. *Pilumnus dasypodus*		17			15			64		None	C	MC	May-Aug
6. *Pitho lherminieri*		14			4			None		None	C		
7. *Mithrax coryphe*		14			2			6		None	C		
8. *Gonodactylus bredini*		11			4			None		None	C		
9. *Pilumnus sayi*		9			None			18		None	C		Jan-Aug
10. *Petrolisthes galathinus*		8			1			14		None	C		Jan-Aug
11. *Alpheus formosus*		8			None			8		None	C		Jan-Jul
12. *Pagurus carolinensis*		8			1			1		None	C		May-Aug?
13. *Xantho denticulatus*		7			3			None		None	C		
14. *Gonodactylus oerstedii*		7			None			None		None	C		
15. *Menippe mercenaria*		6			20			24		3	C		
16. *Synalpheus* sp. A		6			None			4		None	C		
17. *Epialtus bituberculatus*		6			None			10		None	C		Jan-Aug
18. *Alpheus nuttingi*		5			4			9		None	C		Nov-Aug
19. *Microphrys bicornutus*		4			None			4		None	C		
20. *Plagusia depressa*		3			2			1		1	C		May-Aug?
21. *Panopeus bermudensis*		2			15			44		4	C	MC	May-Oct
22. *Alpheus thomasi*		2			4			2		None	C		Jan-Aug?
23. *Synalphells minus*		2			None			7		None	C		

(continued)

Taxon	St. Lucie			Walton Rocks			Fort Pierce			Sebastian	Abundance		60% to 80% Spawning
	1974		1975	1974		1975	1974		1975	1974[a]			
24. Synalpheus townsendi		2			2			3		None	C		Jan-Aug
25. Uhlias limbatus		2			None			None		None	UC		
26. Processa fimbriata		2			None			1		None	UC		
27. Metalpheus rostratipes		1			2			None		None	UC		
28. Lysmata intermedia		1			None			1		None	UC		
29. Petrolisthes armatus		1			1			1		None	UC		
30. Alpheus normanni		1			None			None		None	UC		
31. Epialtus dilatatus		1			None			None		None	UC		
32. Alpheus paracrinitus		1			None			None		None	UC		
33. Megalobrachium soriatum		1			None			None		None	UC		
34. Mithrax acuticornis		1			None			None		None	UC		
35. Neopontonides beaufortensis		1			None			None		None	UC		
36. Mithrax pleuracanthus		1			None			None		None	UC		
37. Upogebia affinis		1			None			None		None	UC		
38. Platyactaea setigera		1			None			None		None	UC		
39. Micropanope granulimanus		1			None			None		None	UC		
40. Mithrax hispidus		None			2			None		None	UC		
41. Alpheus armillatus		None			1			4		None	UC		
42. Periclimenes americanus		None			1			1		None	UC		
43. Eurypanopeus dissimilis		None			1			None		None	UC		
44. Lysmata wurdemanni		None			None			1		None	UC		
45. Synalpheus brevicarpus		None			None			1		None	UC		
46. Alpheus bouvieri		None			None			1		1	UC		
47. Paguristes tortugae		None			None			1		None	UC		

Taxon	St. Lucie			Walton Rocks			Fort Pierce			Sebastian	Abundance		60% to 80% Spawning
	1974		1975	1974		1975	1974		1975	1974[a]			
48. Eurypanopeus abbreviatus		None			None			1		None	UC		
49. Alpheus heterochaelis		None			None			1		None	UC		
50. Panopeus occidentalis		None			None			None		5	UC		
51. Panopeus herbstii		None			None			None		1	UC		

[a]Sebastian Inlet station not sampled in 1975. C = common (97%); MC = most common (80%); UC = Uncommon (3%)
Modified from Gore et al. (1978)

Table 4.11 Species richness of decapod and stomatopod crustaceans collected from sabellariid worm reefs in the Indian River region of Florida, 1974 to 1975

St. Lucie	Walton Rocks	Fort Pierce	Sebastian[a]
Most species richness	49% common with St. Lucie	56% common with St. Lucie	13% common with St. Lucie
39 species	19 of 39 species	22 of 39 species	5 of 39 species

[a]Sebastian Inlet station not sampled in 1975
Modified from Gore et al. (1978)

Table 4.12 Order of commonly abundant decapod species at *Oculina varicosa* coral reef stations at depths of 6, 27, 42, and 80 m

Order of abundance	6 m Fort Pierce Inlet	27 m North of Fort Pierce	42 m South of Fort Pierce St. Lucie Inlet	80 m Offshore East of Fort Pierce
1	*Megalobrachium soriatum*	*Pagurus carolinensis*	*Pagurus carolinensis*	*Pagurus carolinensis*
2	*Pachycheles monilifer*	*Megalobrachium soriatum*	*Megalobrachium soriatum*	*Megalobrachium soriatum*
3	*Mithrax forceps*	*Pelia mutica*	*Pagurus piercei*	*Pagurus piercei*
4	*Thor manningi*	*Mithrax forceps*	*Synalpheus townsendi*	*Synalpheus townsendi*
5	*Synalpheus fritzmuelleri*	*Synalpheus townsendi*	*Periclimenes iridescens*	*Galathea rostrata*
6	*Synalpheus minus*	*Stenorhynchus seticornis*	*Pseudomedaeus distinctus*	*Micropanope scuptipes*
7	*Synalpheus* cf. *townsendi*	*Micropanope nuttingi*	*Pseudomedaeus agassizii*	*Thor manningi*
8		*Paguristes tortugae*		*Pseudomedaeus distinctus*
9				*Pseudomedaeus agassizii*
10				*Nematopaguroides pusillus*
11				*Euchirograpsus americanus*

Modified from: Reed et al. (1982)

at each depth, and there were no dramatic seasonal overturns of assemblages. However, there was a degree of trophic partitioning between the shallow station (Fort Pierce: 6 m), which was numerically dominated by the filter-feeding porcellanid crab *Megalobrachium soriatum*, and the 27-m station, which was dominated by the carnivorous hermit crab *Pagurus carolinensis* (Table 4.12). Two species that were found at all study sites included *M. soriatum* and *Synalpheus townsendi* (Table 4.12).

Table 4.13 Physical parameters measured between 1976 and 1979 at *Oculina varicosa* coral reef stations at depths of 6, 27, 42, and 80 m

Parameter	6 m Fort Pierce Inlet	27 m North of Fort Pierce	42 m South of Fort Pierce St. Lucie Inlet	80 m Offshore East of Fort Pierce
Salinity (%)	28.2–36.4 (32.5 ± 3.4)	No data available	35.9–36.2 (only 2 values)	35.7–36.4 (36.0 ± 0.2)
Temperature (°C)	13.7–31.0 (24.6 ± 3.1)		8.0–27.8 (18.4 ± 2.7)	7.4–26.7 (16.2 ± 3.7)
Current (cm/sec)	0–70.5 (8.9 ± 2.1)		0–49.5 (8.7 ± 2.4)	0–58.5 (8.6 ± 1.7)
Visibility (m)	0–9 (3 ± 2)		0–21 (9 ± 5)	0–25 (9 ± 5)
Sedimentation (mg/cm^2/day)	137–1640 (846 ± 593)		No data available	15–78 (53 ± 34)

Range (mean and ± 1 standard deviation)
Modified from: Reed et al. (1982)

Crustacean species found on oculinid corals at a depth of 6 m included *Epialtus* spp., *Pagurus* spp., and *Synalpheus* spp. (which was often associated with sponges and algae) (Reed et al. 1982). In addition, there were 14 species that appeared to be shared between oculinid and sabellariid worm reefs mentioned in Gore et al. (1978). Reed et al. (1982) reported that on oculinid reefs, *Pachycheles monolifer* and *Synalpheus fritzmuelleri* were abundant, and *Pagurus carolinensis* was common. On sabellariid reefs, *Syalpheus minus*, *S. townsendi*, and *Megalobrachium soriatum* were considered rare. Species common on the sabellariid reefs but rare on oculinid reefs included *Pilumnus dasypodus*, *Petrolisthes galathinus*, *Epialtus* sp., *Alpheus formosus*, and *Synalpheus fritzmuelleri*.

The gradient in species assemblages was attributed to a gradient of environmental factors across the shelf (Table 4.13). At a depth of 6 m, the environment was characterized as having variable wave surge and sedimentation. The mean temperature was about 25 °C and varied less relative to other sites, which accounted in part for the highest diversity of species (11 species uniquely associated with this depth). At 42 m, temperature was more variable, averaging about 18 °C, with relatively less wave energy and sedimentation. As a result, diversity and number of endemic species was relatively low but individual numbers were high. At the 80-m depth, the physical parameters were similar to those at the 42-m station, but there were relatively high numbers of species and endemic species but lowest individual numbers of each species. Temperature changes caused by upwelling events that occur periodically were considered to be an important factor controlling the community structure on these oculinid reefs.

In Palm Beach County, CSA Ocean Sciences Inc. (2014) separately compared invertebrate communities associated with macroalgae and worm reef at four different depth ranges (0–1, 1–2, 2–3, 4–6 m depth) from 2012 through 2013. Combined, over 50 decapod taxa were observed (Appendices 4.2 and 4.4). In both studies, amphipods composed most of the invertebrates collected (~30%). However, various brachyuran crabs and shrimp accounted for 2–17% of the total invertebrates encountered. Most crustaceans encountered were the same as those observed in previous studies of invertebrates in worm reef.

Further south along the coast, Cummings (1994) reported the presence of six species of crustaceans associated with the colonization of a newly constructed artificial reef structure in a nearshore (~8 m depth) area off Boca Raton, Florida (April 1988 to July 1990). Decapod species observed from December to January 1988 included *Eurypanopeus abbreviatus* and *Percnon gibbesi.* From July to August 1989, *Mithrax (Mithraculus) forceps*, *Pagurus carolinensis*, and *Percnon gibbesi* were identified. In addition to these species, Sultzman (1990, 1997) encountered penaeid shrimp and blue crabs in the nearshore areas along the Florida coast.

Encompassing a larger geographical area along the Florida coast, van Montfrans (1981) studied decapod crustaceans associated with worm reefs at five sites from Miami north to Cape Canaveral. There were a few species that accounted for the majority of individuals inhabiting intertidal and subtidal zones (Tables 4.14 and 4.15). The four most abundant of the 15 species identified in the intertidal zone included *Pachygrapsus transversus, Menippe nodifrons, Acantholobulus (Panopeus) bermudensis*, and *Pilumnus lacteus.* In the subtidal zone, the four most abundant of the 10 species included *Synalpheus fritzmuelleri, Pilumnus dasypodus, M. nodifrons,* and *Petrolisthes galathinus.* Furthermore, species common to both subtidal and intertidal habitats included *M. nodifrons, A. bermudensis, P. transversus, Petrolisthes armatus,* and *P. lacteus.* In terms of cross-shelf distribution, the diversity and abundance of decapods tended to increase with depth. In terms of latitudinal distribution in the subtidal zone, total numbers were highest at Deerfield Beach (610) but decreased towards the north at Hutchinson Island (394), Fort Pierce (202), and Satellite Beach (71). However, total numbers decreased south of Deerfield Beach at Miami (296) (Table 4.16). Towards the southern two study sites (Miami and Deerfield Beach), *Pilumnus dasypodus, Petrolisthes galathinus,* and *S. fritzmuelleri* were dominant, although their order of dominance varied. In the central two study sites (Hutchinson Island and Fort Pierce), the dominant species mix consisted of *M. nodifrons* (which occurs subtidally and intertidally)*, S. fritzmuelleri, Pachycheles monilifer*, and *Petrolisthes galathinus.* At the most northern study site (Satellite Beach), the species mix changed to the following three dominant species: *Menippe nodifrons, Pachygrapsus transvenus,* and *P. armatus.* Many tropical species (Families: Alpheidae, Palaemonidae, Hippolytidae, Stenopodidae, Paguridae, Palinuridae, Porcellanidae, Xanthidae, Grapsidae, and Majidae) decrease in abundance and diversity from south to north, probably due to higher variability in sea surface temperature near Cape Canaveral versus Miami (van Montfrans 1981).

There is limited data available on the pericarid crustaceans (e.g., amphipods, isopods, and tanaids) associated with nearshore hardbottom reefs. Nelson and Demetriades (1992) sampled the worm reef attached to jetties at Sebastian Inlet, Florida, for a period of 1 year (April 1984 to March 1985) at daytime low tides. They collected six isopod species, of which *Paradella dianae* (53,000/m^2) and *Sphaeroma walkeri* (35,000/m^2) represented 98% of the total number of 6136

Table 4.14 Rank analysis of intertidal decapods from the east Florida coast

Species	Biol. index (3-pt. system)	Frequency as one of top three species in nine samples	Frequency in nine samples	Total number collected	Greater numbers occurring in a sample	Overall density/1000 m of reef sampled
Pachygrapsus transversus	26	9	9	324	97	1.969
Menippe nodifrons	11	5	5	113	91	0.687
Panopeus bermudensis	4	3	4	23	17	0.140
Pilumnus lacteus	4	2	2	11	10	0.067
Alpheus bouvieri	2	1	3	7	3	0.043
Clibinarius tricolor	2	1	2	3	2	0.018
Eriphia gonagra	2	1	2	3	2	0.018
Paguristes tortugae	2	1	1	2	2	0.012
Pagurus carolinensis	2	1	1	20	20	0.121
Petrolisthes armatus	2	2	4	10	6	0.061
Alpheus malleator	1	1	1	1	1	0.006
Cyclograpsus integer	1	1	1	2	2	0.012
Eurypanopeus abbreviatus	1	1	1	2	2	0.012
Menippe mercenaria	1	1	4	5	2	0.030
Plagusia depressa	1	1	2	3	2	0.018

Species marked in undereline occur in both intertidal and subtidal habitats
Modified from van Montfrans (1981)

isopods present (Table 4.17). Two peaks in abundance occurred for both species during the year (February–March and August–October) although recruitment was year-round for both species. Total monthly isopod density was negatively correlated with percent algal coverage on worm reef, and *S. walkeri* density was negatively correlated with air and water temperature on the north jetty site (which received more sunlight) but not on the south jetty site. *Paradella danae* density was not significantly correlated with physical parameters. Filamentous algal coverage by species such as *Enteromorpha* sp. tended to restrict access to suitable crevices in the

Table 4.15 Rank analysis of the dominant subtidal decapods from the east Florida coast

Species	Biol. index (3-pt. system)	Frequency as one of top three species in nine samples	Frequency in nine samples	Total number collected	Greater number occurring in a sample	Overall density/1000 m of reef sampled
Synalpheus fritzmuelleri	11	6	7	443	131	1.727
Pilumnus dasypodus	10	5	6	255	84	0.994
Menippe nodifrons	9	4	7	330	241	1. 287
Petrolisthes galathinus	6	3	4	399	308	1. 556
Panopeus bermudensis	5	2	6	131	65	0.51
Pachycheles monilifer	5	3	6	101	56	0.218
Pachygrapsus transversus	5	2	5	34	15	0.132
Petrolisthes armatus	1	1	7	27	6	0.105
Pilumnus lacteus	1	1	3	87	62	0.339
Lysmata wurdemianni	1	1	2	11	7	0.027

Species marked in underline occur in both intertidal and subtidal habitats
Modified from van Montfrans (1981)

Table 4.16 Total number of the three most common subtidal decapod species at stations along the east Florida coast

Station A Dade Miami		Station B Broward Deerfield Beach		Station E St. Lucie Hutchinson Island		Station C St. Lucie Fort Pierce		Station D Brevard Satellite Beach	
Pilumnus dasypodus	106	*Petrolisthes galathinus*	328	*Menippe nodifrons*	247	*Pachycheles monilifer*	71	*Menippe nodifrons*	44
Petrolisthes galathinus	103	*Synalpheus fritzmuelleri*	165	*Synalpheus fritzmuelleri*	137	*Petrolisthes galathinus*	71	*Pachygrapsus transvenus*	20
Synalpheus fritzmuelleri	87	*Pilumnus dasypodus*	117	*Pachycheles monilifer*	10	*Synalpheus fritzmuelleri*	60	*Petrolisthes armatus*	7
Totals	**296**		**610**		**394**		**202**		**71**
All common to the subtidal zone		All common to the subtidal zone		*M. nodifrons* common to both zones		All common to the subtidal zone		All common to both subtidal and intertidal zones	
Southern sites			Middle sites				Northern range		

Species marked in underline occur in both intertidal and subtidal **habitats**
Modified from van Montfrans (1981)

Table 4.17 Abundance of isopods and amphipods from sabellariid worm reef samples with percentage of contribution of species to total abundance of each order at Sebastian Inlet, Florida, April 1984 to March 1985

Species	Abundance	Percentage of relative abundance
Isopoda		
Paradella dianae	4244	69.0
Sphaeroma walkeri	1757	28.7
Paranthura infundibulata	79	1.3
Jaeropsis sp. nov.[a]	39	0.7
Excorallana spp.[b]	19	0.3
Amphipoda		
Hyale perieri	2189	57.5
Elasmopus pectinicrus	966	25.4
Ampithoe pollex	396	10.4
Corophium acutum	145	3.8
Ericthonius sp.	55	1.4
Jassa cf. falcata	21	0.5
Ampithoe longimana	18	0.5
Stenothoe georgiana	11	0.3
Podocerus brasiliensis	2	0.1
Cymadusa compta	1	0.1

[a]Undescribed species, T.E. Bowman (pers. comm. 2008)
[b]Includes two species, one of which is probably *Excorallana sexlicornis*. Positive identifications could not be made because few fully differentiated males were present T.E. Bowman (pers. comm. 2008)
Modified from Nelson and Demetriades (1992)

worm reef. Nelson and Demetriades (1992) also collected 10 amphipod species, of which *Apohylae* (*Hyale*) *perieri* (22,000/m^2), *Elasmopus pectenicrus* (10,000/m^2), and *Ampithoe pollex* (4000/m^2) represented 91% of the total number of 3801 amphipods (Table 4.17). Maximum abundance was observed to occur in late summer and early spring for *A. perieri* and was negatively correlated with salinity. For *E. pectenicrus*, maximum abundance occurred during October to November while numbers for *A. pollex* appeared to be lowest during November to January and was positively correlated with air temperature.

Sphaeroma walkeri has been observed to be more widely distributed than *P. danae* along the east Florida coast (Camp et al. 1977). Carlton and Iverson (1981) described its natural history and suggested that its distribution is temperature-limited at a minimum surface winter isotherm of 15 °C, which is typical at Sebastian Inlet (December to January). *Paradella danae* is typically cryptic in its habitat and found under stones, in empty barnacle tests, under chitons, in empty *Phragmatopoma* tubes, or in crevices of worm reefs.

4.2.8.3 Reproduction and Life History

Most motile crustaceans have separate sexes and reproduce sexually. Depending on the species, fertilization can be internal or external with eggs being either shed directly into the sea or brooded by the females (brooding occurs more commonly with crabs and shrimp). In either case, most crustaceans produce larvae (nauplius or zoea) that eventually end up as part of the plankton. They can be lecithotrophic or planktotrophic and can be in the plankton from a few weeks (e.g. xanthid crabs, penaeid shrimp) to almost a year (e.g., spiny lobster) (Lyons et al. 1981; Young and Chia 1987; Bourgeois et al. 2015). In contrast, isopods, amphipods, and other peri-carids lack larval stages. Their young emerge as miniature versions of the adults. Consequently, there is a wide range of dispersal capabilities among crustaceans. Most crustacean larvae may develop offshore but generally are returned to estuarine and nearshore areas by tides, wind-driven currents, and unexpected upwelling events (Pitts and Smith 1997; Pitts 1999). Upon recruitment, some become reproductive quickly and are short-lived like the amphipods and isopods (Nelson and Demetriades 1992), while others, such as stone crabs (Lindberg and Marshal 1984; Restrepo 1989; Bert 1989) and spiny lobster (Lyons et al. 1981), may live several years.

General reproduction and life history are fairly well known for commercially important crustacean groups such as penaeid shrimp and blue crabs. Penaeid shrimp *(Litopenaeus setiferus, Farfantepenaeus duorarum, F. aztecus)* have a short life span of less than 2 years and spawn offshore in deeper waters (Gracia 1997; Browder and Robblee 2009; Bourgeois et al. 2015). The larvae develop in the plankton and later move back into the salt marshes and tidal creeks. Blue crabs *(Callinectes sapidus)* have a life span of about 4 years, reaching sexual maturity in 1 year (Tagatz, 1968a). Females generally mate during March to July or October to December (Tagatz 1968a, b). After mating in the upper reaches of estuaries, female blue crabs migrate to inlet mouths and nearshore areas to spawn (Carr et al. 2004). Zoea drift in continental shelf waters for as long as 35 days (Epifanio 1995), although this can vary with water temperature.

The Cuban stone crab *(Menippe nodifrons)* spawns from May to August (Gore et al. 1978) with larval development time to the megalope stage being either 16–17 days at 30 °C or 37 days at 20 °C (Scotto 1979). Cuban stone crabs are closely allied to their commercially exploited counterpart – the Florida stone crab, *Menippe mercenaria,* which also has abbreviated zoeal stages (five or atypically six), depending on the ambient water temperature (Scotto 1979). Ong and Costlow (1970) suggested 30 °C was the optimum survival temperature for *M. mercenaria* larvae, with optimal salinity of 30–35 ppt. Stone crabs may live as long as 8 years (Restrepo 1989).

Spiny lobsters (*Panulirus argus*) spawn in late spring and early summer on the outer reefs and offshore along the east Florida coast (FWRI 2017). Their phyllosome larvae drift offshore for 6–12 months. Post-larval (puerulus) recruitment occurs year-round (FWRI 2017) with larvae positioning within 1 m of surface waters and moving from the open ocean towards nearshore. Movement is aided by wind-driven surface currents and/or flood tides at night following the new moon. Upon recruitment to the benthos, juvenile spiny lobsters take refuge in the shelter provided in nearshore habitats with structure. As their size increases, they typically move offshore becoming about 86 mm carapace length (legal size for harvesting) when about 3 years old (FWRI 2017).

Along the east Florida coast, some crustaceans spawn year-round, while others do so only seasonally (Table 4.10). Notable year-round spawners are *Pachycheles monilifer, P. transversus,* and *Synalpheus fritzmuelleri.* Ovigerous females of *P. dianae* and *S. walkerii* were present year-round (Nelson and Demetriades 1992), so they probably spawn year-round as well. In contrast, *Menippe nodifrons*, *Pilumnus* spp., *Pagurus* sp., *Petrolisthes galathinus*, and *Alpheus* spp. appear to spawn seasonally during the spring or summer time periods.

Reed et al. (1982) suggested that crustacean recruitment to *Oculina* coral reefs in shallow areas (6 m depth) along the east Florida coast may occur from two directions, the surrounding algae-sponge habitat and adjacent sabellariid worm reefs. They suggested several examples for species colonization that may occur from inshore to offshore, and vice versa. These included the two porcellanid crab species: (1) *Pachycheles monilifer*, which was dominant on sabellariid worm reefs, and restricted to 6-m depth on oculinid reefs, and (2) *Megalobrachium soriatum*, which was rare on worm reef (Gore et al. 1978), yet present on all oculinid stations (6-, 27-, 42-, and 80-m depths). They also noted that five species (*Synalpheus fritzmuelleri*, *Pilumnus dasypodus*, *Petrolisthes galathinus*, *Alpheus formosus*, and *Epialtus* sp.) were observed on both sabellariid worm reef and the 6-m oculinid reef but not at the deeper stations. Finally, and considered least likely, they speculated that colonization could occur as larvae settle out of the plankton from offshore at 80-m depths moving shoreward, and are selectively eliminated by thermal tolerances to periodic cold-water upwelling events. In terms of pericarids, Nelson and Demetriades (1992) observed the recruitment of dominant isopods associated with worm reefs occurring most months of the year.

4.2.9 Echinoderms

4.2.9.1 Diversity and Ecological Function

Echinoderms can be abundant along some sections of NHRs along the east Florida coast. While echinoids are often most visible offshore on reefs, there are a number of holothurians, ophiuroids, asteroids, and crinoids that can be encountered along the coast (Appendix 4.1). Overall, most echinoderms do not provide significant shelter for many species. Some exceptions to this may occur with small animals such as shrimp, mysids, copepods, porcellanid crabs, brittle stars, blennies, gobies, and pearlfish (Randall et al. 1964: Schoppe 1991). However, some echinoderm species may be very important herbivores that influence abundance or diversity of macroalgae that, in turn, affects the amount of either: (1) shelter or food for other species, and/or (2) space availability for recruitment of other sessile organisms such as stony corals (see Duffy and Hay 2001 for a review). North of Palm Beach County, the echinoid *Echinometra lucunter* can be very abundant and significantly reduce biomass of macroalgae and cyanobacteria (D. McCarthy, pers. observ. 2008). The echinoid *Arbacia punctulata* can also be commonly encountered in these areas. Echinoid removal of macroalgae and cyanobacteria may be important in providing recruitment opportunities for sessile invertebrates such as *Oculina* and *Siderastrea*. Removal of macroalgae by urchins was documented during monitoring of the Indian River County Ambersand mitigation reef. The results indicated an eight-fold increase in urchin populations on the mitigation artificial reef between 2006 and 2008 with removal of macroalgae and mud cover increasing recruitment opportunities for the scleractinian *Oculina* (Miller and Kosmynin 2008; Coastal Eco-Group Inc. 2009).

Other echinoderms, such as some holothurians and many brittle stars, are deposit-feeders that may convert detrital food sources into macroorganism biomass that is available to higher trophic levels. In this capacity, they can also sometimes enhance sediment resuspension and nutrient exchange within the water column (Bertness 2007).

Echinoderms can be important as a food sources to key species in a number of marine ecosystem food webs (see Duffy and Hay 2001 for a review), but this role of echinoderms has not been studied along the east Florida coast. It is very likely that sea urchins are important prey components of food webs, as there are several predators found along the coast that are relatively abundant and known to prey on sea urchins. Examples of these predators include spiny lobsters, spider crabs, grunts, jacks, wrasses, triggerfishes, and birds (Abbott et al. 1974; Hendler 1977).

4.2.9.2 Latitudinal and Depth Gradient

How abundance and diversity of echinoderms change along east Florida nearshore reefs is generally unclear for most groups. The clearest patterns occur with echinoids, with a much higher biomass of echinoids occurring towards the northern half of the east Florida reef tract. To the north of Palm Beach County, nearshore reefs can have high densities of the echinoids *Echinometra lucunter* (Fig. 4.17) and *Arbacia punctulata*. Kosmynin (pers. comm. 2013) suggests that the highest densities of echinoids may occur in Indian River County. McCarthy (unpubl. data 2004) observed densities varying between 2 and 16 urchins/m^2 at several locations off Vero Beach. Approximately 80% were *E. lucunter*, 19% *A. punctulata*, and 1% the pencil urchin *Eucidaris tribuloides*. *Echinometra lucunter* can also found in tidal pools in the intertidal zone and in the very shallow subtidal zone along the entire coast. In this region, there may be an increase in abundance of *A. punctulata* with depth. This potential trend might be explained by the colder temperature tolerances of this species, as it is found much further north on the eastern coast than any of the other species (Hendler et al. 1995). The echinoid *Tripneustes ventricosus* also has been recorded as far north as Indian River County but generally occurs in low densities (C. Miller, pers. comm. 2013; D. McCarthy, pers. observ. 2008). Progressing

Fig. 4.17 The rock-boring urchin *Echinometra lucunter* on shallow reef habitat in Vero Beach, Indian River County, Florida. (Source: D. McCarthy)

southward, in Martin County, several other species of sea urchins may be encountered on nearshore reefs. These include *Diadema antillarum*, *Lytechinus variegatus*, and *T. ventricosus*. Of these three species, *D. antillarum* is typically encountered on coral reefs and hardbottom, whereas the other two are more common on seagrass habitats. *D. antillarum* have been observed throughout the east Florida coast but often are most abundant at the St. Lucie Reef (Gilliam 2012). Generally, south of Martin County, echinoid biomass decreases significantly, with only occasional observations of *E. tribuloides* and very rare encounters with *D. antillarum* (D. McCarthy, pers. observ. 2008).

The most conspicuous and abundant sea cucumber in the intertidal and shallow subtidal zones along the east Florida coast is *Halodeima* (*Holothuria) grisea* (Fig. 4.18) (Hendler et al. 1995). It can be found within cracks and crevices on worm reefs or associated hardbottom. It appears to occur in highest densities from Martin County and northward (McCarthy, pers. observ. 2008), although this has not been confirmed. The diversity of holothurians probably increases with depth yet the only available information to date is the identification of five holothurian species at deeper depths at the St. Lucie Reef in Martin County (J. Beal, pers. comm. 2008).

Very little is known about the brittle stars, sea stars and crinoids that occur along the east coast of Florida. To the north in Flagler County, the sea star *Echinaster* spp. has been occasionally encountered (D. McCarthy, pers. observ. 2019). Along the central and southern sections of Florida nearshore reefs, there are likely a number of brittle star species present as they are commonly encountered upon dissection of worm reef samples (D. McCarthy, pers. observ. 2014). Within shallow worm reef samples collected in Palm Beach County, Knight et al. (2013) identified ten brittle stars (*Amphiuria stimpsonii, Hemipholis elongata, Ophiactis algicola, Breviturma paucigranulata, Ophiocoma pumila, Ophionereis reticulata, Ophiopsila riisei, Ophiostigma isocanthum, Ophiactis savignyi, and Ophiothrix angulata*). The

Fig. 4.18 The sea cucumber *Halodeima* (*Holothuria) grisea* on shallow hardbottom habitat in Ambersands Beach, Indian River County, Florida. (Source: D. McCarthy)

number of individuals per worm reef clump collected varied highly from zero to 18 per sample. The most commonly observed species (~22–33%) in this study were *A. stimpsonii and O. angulata.* While not significant, there was a trend of increasing richness at the deeper (4–6 m) depths sampled. Finally, the crinoids *Davidaster rubiginosa* and *Nemaster grandis* have been identified at a depth of ~6 m at the St. Lucie Reef (J. Beal, pers. comm. 2008).

4.2.9.3 Reproduction and Life History

All of the echinoderm species found along east Florida reproduce sexually. Most are slow egg producers (Eckelbarger 1994) that seasonally spawn. While some do brood their young and have crawl-away larvae, many broadcast spawn, where fertilization results in either planktotrophic or lecithotrophic larvae. Larval time spent in the plankton varies from a few hours to months. After settlement and metamorphosis, many may live for several years (Ruppert et al. 2004).

While there is some information available on seasonal spawning patterns of echinoderms along the east Florida coast, there is little known on their dispersal and recruitment patterns. *Echinometra lucunter* probably spawns during late summer/early fall, whereas *A. punctulata* spawns during late spring/early summer (Serafy 1979). *Lytechinus variegatus* populations in Key Biscayne have two spawning periods—one during late spring and a second smaller peak in fall (McCarthy and Young 2002). *Diadema antillarum* spawning periods appear somewhat variable throughout the Caribbean populations studied, but often have a well-defined lunar rhythm

(Hendler et al. 1995). At Walton Rocks in Fort Pierce, the sea cucumber *Halodeima* (*Holothuria) grisea* occurs in low abundance during winter, when the animals are thought to migrate offshore (Hendler et al. 1995). While most echinoderms found along the east Florida coast produce planktonic larvae that may spend several months in the plankton before settling and recruiting to hardbottom, there may be high dispersal and connectivity among echinoderm populations in the Florida-Caribbean region. There is no substantial research that has documented recruitment patterns for any echinoderm species along the east Florida coast.

4.2.10 Other Sessile Fauna (Tunicates and Bryozoans)

4.2.10.1 Diversity and Ecological Function

Tunicates and bryozoans are abundant and diverse along all NHRs of the east Florida coast (Appendix 4.1). Most occur in colonies (branching or encrusting forms), although there are some solitary forms of tunicates that are abundant (e.g., *Phallusia* spp. and *Mogula* spp.). Both groups are particularly abundant under ledges and within crevices of nearshore reefs. Most species probably do not provide very large shelter enhancement to the habitat, but some do provide shelter to smaller species such as amphipods, crabs, shrimp, nemertines, polychaetes, mollusks, and brittle stars that may take refuge along the edge of colonies or within some branching forms (e.g., *Bugula* spp.) (Voultsiadou et al. 2007; D. McCarthy, pers. observ. 2008). It is unlikely that many of the tunicates are important in the diets of hardbottom predators, as many are documented to produce secondary metabolites that deter at least fish predators (Pisut and Pawlik 2002; Odate and Pawlik 2007). Bryozoans may be more susceptible to predation, although some have morphological defenses to deter predators as well (Harvell 1992; Ruppert et al. 2004).

4.2.10.2 Latitudinal and Depth Gradient

There is not a great deal of information available on how the diversity and abundance of tunicates and bryozoans change with latitude and depth along the nearshore reefs of the east Florida coast. The most conspicuous animals of these types found in tide pools of the lower intertidal zones and shallow subtidal habitats (Fig. 4.19) are the colonial tunicates *Botryllus planus*, *Botrylloides niger*, *Didemnum* spp. (probably most common), and the bryozoan *Watersipora subvoidea (cucullata)*. The non-native *Bugula neritina* also is very abundant north of the Port Everglades Inlet (Johnson and Robert 2017). Progressing into the shallow subtidal area, diversity may slightly increase but abundance appears to remain fairly low. Essentially all bryozoans remain within crevices and under ledges, while several species of tunicate can be found on top of hardbottom. Some common tunicate species encountered subtidally include *Eudistoma* sp., *Diplostoma* sp., *Distaplia* sp., *Mogula* sp., and *Phallusia* (*Ascidia*) *nigra*, with the latter species clearly more abundant from St. Lucie southward (D. McCarthy, pers. observ. 2001).

Fig. 4.19 A colonial tunicate on hardbottom in Stuart, Martin County, Florida. (Source: D.B. Snyder)

4.2.10.3 Reproduction and Life History

Most tunicates and bryozoans along the east Florida coast have colonial forms and can reproduce asexually and sexually. Asexually, many tunicates and bryozoans proliferate via budding (Ruppert et al. 2004). The success of bryozoans to outcompete other sessile species for limited hardbottom space might be largely related to their capacity for clonal growth via budding (Seed and Hughes 1992). Budding might be equally important for tunicates as well. Sexually, individuals in both groups are hermaphrodites that, depending on the species, fertilize internally or externally. A few families of tunicates have direct development, however, in most cases, lecithotrophic larvae are produced that live in the plankton for a few minutes to a few hours (Clooney et al. 2002). Consequently, their dispersal distance from parent populations should not be very great. Bryozoan larvae may be either planktotrophic or lecithotrophic, but also have a very short planktonic period (Temkin and Zimmer 2002).

There is very little available information on seasonal spawning and recruitment patterns of tunicates and bryozoans in the study region. In Boynton Beach, the colonial ascidians *Didemnum* sp. and *Diplosoma* sp., and the bryozoans *Conopeum reticulum* and *Watersipora cucullata* appear to recruit throughout most of the year (McCarthy 2001). In the same study, *Bugula* sp., *Phallusia nigra*, and *Botryllus* sp. sporadically recruited just a few times during a several year study.

Appendices 4.1 Presence/absence of invertebrates encountered in available studies of hardbottom habitats in seven counties along the east Florida coast. ● denotes species identified in at least one study within noted county; blank cell denotes species not encountered in any study in noted county. Note that species are listed as identified in the respective study. Synonyms may be listed afterward in parentheses. Those species marked in underline were not used to determine species counts for the taxonomic groups listed in this Chapter (modified from CSA International, Inc. 2009)

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Hydrozoa							
Aglaophenia latecarinata					●		
<u>*Aglaophenia* sp.</u>						●	
Campanularia marginata (hincksii)						●	
<u>*Campanularia* sp.</u>						●	
Eudendrium ramosum						●	
<u>*Eudendrium* sp.</u>						●	
<u>*Feather hydroids*</u>							●
Gymnangium sp.							●
<u>*Hydroida undet.* sp.</u>						●	
Lytocarpus (Macrorhynchia) philippina						●	
Millepora alcicornis					●	●	●
Millepora complanata					●		
<u>*Millepora* sp.</u>						●	
Obelina hyalina				●			
Pennaria sp.						●	
Sertularia flowersi				●			
<u>*Sertularella* sp.</u>						●	
Sertularella speciose (diaphana)					●		
Thyroscyphus ramosus						●	
Thyroscyphus marginatus						●	
<u>*Thyryoscyphus* sp.</u>						●	
Tubularia (Ectopleura) crocea	●						
<u>Unidentified branching hydroid</u>						●	
<u>Unidentified hydroid</u>		●		●			
<u>Yellow branch hydroid</u>					●		
<u>Unidentified star-shaped</u>						●	
Anthozoa							
Acropora cervicornis							●

Taxon		Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Acropora palmata								•
Actinia bermudnesis						•	•	•
Agaricia (Undaria) agaricites								•
Agaricia fragilis								•
Agaricia sp.							•	
Anthopleura varioarmata		•						
Astrangia poculata					•	•		
Briareum asbestinum						•	•	•
Bunodosoma caver natum		•				•	•	•
Bunodosoma granuliferum								•
Carijoa riisei				•		•	•	•
Cladocora arbuscula							•	•
Colpophyllia natans							•	•
Dendrogyra cylindrus								•
Diadumene leucolena						•	•	•
Dichocoenia stokesii						•	•	•
Diploria (Pseudodiploria) clivosa						•	•	•
Diploria labyrinthiformis								•
Diploria sp.							•	
Diploria (Pseudodiploria) strigosa					•	•	•	•
Erythropodium caribaeorum							•	•
Eunicea calyculata							•	•
Eunicea fusca							•	
Eunicea sp.						•	•	•
Favia fragum						•	•	•
Gorgonia sp.							•	
Gorgonia ventalina						•	•	•
Isophyllia sinuosa						•	•	•
Isophyllia sp.							•	
Leptogorgia hebes				•	•	•	•	•
Leptogorgia virgulata				•	•	•	•	•
Madracis decactis						•	•	•
Meandrina meandrites						•	•	•
Montastraea (Orbicella) annularis								•
Montastraea (Orbicella) franksi								•

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Montastraea cavernosa					●	●	●
Montastraea (Orbicella) faveolata					●	●	●
Muricea sp.					●	●	●
Mycetophyllia aliciae					●	●	●
Mycetophyllia danaana							●
Oculina diffusa			●	●	●	●	●
Oculina robusta						●	●
Oculina varicosa			●	●	●	●	●
Palythoa caribaeorum					●	●	●
Phyllangia americana			●	●	●	●	●
Plexaura (Eunicea) flexuosa						●	●
Plexaurella grisea					●	●	●
Plexaurella sp.					●		
Porites astreoides					●	●	●
Porites porites					●	●	●
Porites sp.						●	
Pseudoplexaura sp.						●	
Pseudopterogorgia (Antillogorgia) americana						●	●
Pseudopterogorgia (Antillogorgia) bipinnata						●	
Pseudopterogorgia sp.				●	●	●	
Pterogorgia anceps					●	●	●
Pterogorgia citrina					●	●	●
Pterogorgia guadalupensis					●	●	●
Pterogorgia sp.					●	●	
Scolymia sp.					●		
Siderastrea radians			●	●	●	●	●
Siderastrea siderea			●	●	●	●	●
Siderastrea sp.		●	●			●	
Solenastrea bournoni				●	●	●	●
Solenastrea hyades					●	●	●
Solenastrea sp.						●	
Stephanocoenia intersepta					●	●	●
Unidentified sea rod					●		
Zoanthus pulchellus						●	●

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Zoanthus sp.						●	●
Porifera							
Agelas conifera						●	
Agelas schmidtii						●	
Agelas sp.						●	
Aiolochroia crassa						●	
Amphimedon compressa					●	●	
Anthosigmella (Cliona) varians				●	●		●
Aplysina cauliformis						●	
Aplysina fistularis					●	●	
Aplysina insularis						●	
Aplysina sp						●	
Dysidea etheria							●
Calcispongiae (Calcarea) sp.				●			
Callyspongia sp.					●	●	
Callyspongia(Cladochalina) vaginalis						●	
Chondrilla nucula						●	
Cinachyra (Cinchyrella) alloclada				●		●	
Cinachyra sp.				●	●		
Cliona celata						●	
Cliona delitrix					●	●	
Cliona (Pione) lampa			●	●	●	●	
Cliona lampa forma flavida						●	
Cliona lampa forma lampa						●	
Cliona sp.		●		●	●	●	
Cliona viridis						●	
Desmapsamma sp.						●	
Diplastrella sp.					●		
Encrusting sponges				●	●		
Euryspongia rosea						●	
Euryspongia sp.						●	
Geodia sp.					●		
Haliclona sp.						●	
Haliclona (purple)						●	
Haliclona (red)						●	

Taxon		Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Haliclona rubens							●	
Hymeniacidon heliophila		●						
Holopsamma sp.						●		
Lotrochota birotulata							●	
Lotrochota sp.							●	
Ircinia campana					●	●	●	
Ircinia (Sarcotragus) fasciculatus						●		
Ircinia felix						●		
Ircinia sp.							●	
Ircinia strobilina						●	●	
Ircinia variabilis					●			
Microciona sp.						●	●	
Microciona (Clathria) spinosa					●			
Monanchora unguifera (arbuscula)							●	
Niphates digitalis							●	
Niphates erecta						●	●	
Niphates sp.						●	●	
Niphates (purple)							●	●
Phorbas amaranthus							●	
Phorbas sp.							●	
Pione lampa							●	
Plakortis angulospiculatus								●
Poecilosclerida spp.						●		
Pseudaxinella (Dragmacidon) lunaecharta					●	●	●	
Sigmadocia (Haliclona) caerulea						●		
Spheciospongia vesparium						●	●	
Spheciospongia sp.							●	
Spinosella (Callyspongia) plicifera							●	
Spinosella (Callyspongia) vaginalis							●	
Spirastrella coccinea							●	
Spongia sp.							●	
Stylotella sp.							●	
Symplegma sp.							●	
Tedania sp.							●	
Teichaxinella sp.							●	

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Tethya sp.				•		•	
Ulosa (Scopalina) ruetzleri						•	
Unidentified orange sponge					•		
Unidentified red sponge				•		•	
Unidentified sponge 1		•		•		•	
Unidentified tube-type						•	
Unidentified yellow sponge					•	•	
Verongula sp.				•			
Xestospongia muta						•	
Platyhelminthes							
Polycladia sp.			•				
Turbellaria sp.		•					
Nematoda							
Unidentified sp.			•				
Nemertea							
Amphiporus ochraceus				•			
Amphiporus texanus				•			
Baseodiscus delineatus				•		•	•
Emplectonema osceolai							•
Nemertopsis bivittata				•		•	•
Prosorhochmus americanus		•					•
Prosorhochmus belizeanus						•	
Tetrastemma enteroplecta				•		•	
Tetrastemma worki				•		•	
Tubulanus pellucidus				•			
Zygonemertes cocacola				•			
Zygonemertes simoneae				•			
Zygonemertes virescens				•			
Polychaeta							
Anaitides (Phyllodoce) longipes			•				
Anamobaea oerstedii			•		•		
Arabella sp.			•				
Aricidea sp.			•				
Armandia agilis			•				
Axiothella sp.			•				

Taxon		Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Branchiomma nigromaculatum				●		●	●	
Clymenella torquata				●				
Decamastus sp.				●				
Dendropoma corrodens			●	●	●	●	●	●
Dispio uncinata				●				
Dorvilleidae sp.				●				
Euclymene sp.				●				
Eunicidae							●	
Eupolymnia crassicornis				●		●		
Exogone atlantica				●				
Genetyllis sp.				●				
Glycera sphyrabrancha				●				
Goniadella sp.				●				
Haplosyllis spongicola				●				
Hermodice carunculata				●				
Kefersteinia cirrata (Psamathe fusca)				●		●		
Leitoscoloplos fragilis				●		●		
Lumbrineris sp.				●				
Macroclymene sp.				●				
Magelona sp.				●				
Maldanidae							●	
Marphysa sanguinea				●				
Mediomastus californiensis				●				
Megelonna sp.				●				
Myriochele (Galathowenia) oculata				●				
Naineris grubei				●				
Nematonereis (Lysidice) hebes				●				
Nephtys squamosa				●				
Nereis falsa (spendida)				●				
Nereis lamellosa				●				
Nereis pelagica				●				
Notomastus sp.				●				
Odontosyllis enopla				●				
Pectinaria gouldii				●				
Peresiella sp.				●				

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Pherusa (Semiodera) inflata			●				
Phragmatopoma lapidosa (caudata)		●	●	●	●	●	●
Pista sp.		●					
Prionospio cirrifera			●				
Prionospio cristata			●				
Prionospio fallax			●				
Prionospio pygmaeus			●				
Pseudovermilia occidentalis			●				
Sabella sp. A			●				
Sabella sp. B			●				
Sabellari idae Species A						●	
Sabellaria vulgaris (floridensis)	●						
Sabellastarte magnifica					●		
Sabellidae				●			
Saccocirrus sp.			●				
Salmacina sp.						●	
Scolelepis squamata			●				
Serpulidae Species A						●	
Serpulidae Species B						●	
Sicyonia brevirostris			●				
Spiophanes bombyx			●				
Spiophanes missionensis (duplex)			●				
Spirobranchus giganteus					●		
Terribellidae sp.						●	
Unknown species			●				
Websterinereis tridentata			●				
Sipuncula							
Antillesoma antillarum			●	●	●		
Aspidosiphon (Paraspidosiphon) fisheri			●	●	●		
Aspidosiphon (Paraspidosiphon) parvulus			●	●	●		
Aspidosiphon (Paraspidosiphon) spinososcutatus			●	●	●		
Aspidosiphon (Paraspidosiphon) steenstrupii			●	●	●		
Nephasoma pellucidium			●	●	●		
Phascolosoma perlucens			●	●	●		

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Phascolosoma varians			●	●	●		
Themiste alutacea			●	●	●		
Aspidosiphon sp.			●	●	●		
Themiste lageniformis			●	●	●		
Mollusca							
Ischnochiton janeirensis		●	●	●	●	●	●
Anachis (Costoanachis) avara					●		
A. (Costoanachis) floridana				●	●	●	
Anachis (Suturoglypta) iontha						●	
Anachis (Cotonopsis) lafresnayi				●	●		
Anachis (Costoanachis) sparsa						●	
Anadara sp.						●	
Anomia simplex					●	●	
Antalis sp.						●	
Aplysia brasiliana			●	●	●	●	
Aplysia dactylomela					●	●	
Aplysia morio			●	●	●	●	
Arca zebra						●	
Astraea tuber				●	●	●	
Atrina rigida					●		
Barbatia domingensis				●	●		
<u>*Barbatia* sp.</u>						●	
Barleeia tincta				●	●		
Boonea seminuda						●	
Brachidontes sp.	●					●	
Buccinidae						●	
Bulla (Retusa) umbilicata						●	
<u>Bullidae</u>						●	
Calloplax (Rhyssoplax) janeirensis			●	●	●	●	
Calotrophon ostrearum						●	
Calotrophon <u>sp.</u>						●	
Callucina keenae						●	
Calyptraeidae						●	

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Cardidae						•	
Caribachlamys sp.						•	
Cenchrus muricatus			•	•	•	•	
Ceratozona squalida	•	•	•	•	•	•	
Cerithium eburneum						•	
Cerithium lindae					•	•	
Cerithium litteratum						•	
Cerithium sp.						•	
Cerithiopsis (Retilaskeya) emersonii						•	
Chaetopleura apiculata	•	•	•	•	•	•	
Chama macerophylla						•	
Chione cancellata						•	
Chione elevata						•	
Chione sp.						•	
Chiton tuberculatus		•	•	•	•	•	
Chlamys sp.						•	
Columbella mercatoria						•	
Columbella sp.						•	
Conus floridanus (anabathrum)						•	
Costellariidae						•	
Costoanachis avara						•	
Costoanachis (Cotonopsis) lafresnayi						•	
Costoanachis semiplicata						•	
Costoanachis sertulariaum						•	
Costoanachis sp.						•	
Crassispira sp.						•	
Crassostrea virginica	•						
Cyclinella tenuis						•	
Cymatium (Monoplex) pileare						•	
Cypraea sp.				•	•	•	
Dentaliidae						•	
Dentalium antillarum (Antalis antillaris)						•	
Diodora cayenensis						•	
Diodora sp.						•	

Taxon		Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Diplodonta sp.							•	
Donacidae							•	
Echinolittorina placida		•						
Engina turbinella							•	
Epitonium sp.							•	
Erato (Hespererato) maugeriae					•	•		
Favartia cellulosa							•	
Fissurella barbadensis					•	•		
Fissurellidae							•	
Geukensia sp.							•	
Gregariella coralliophaga							•	
Hastula hastata							•	
Hiatella solida (arctica)						•		
Iselica fenestrata						•	•	
Isognomon radiatus					•	•		
Isognomon sp.							•	
Lamellaria perspicua					•	•		
Lasaeidae							•	
Leucozonia nassa						•		
Lima pellucid (Limaria pellucida)							•	
Lithophaga sp.							•	
Littorina sp.						•		
Littorina (Echinolittorina) ziczac		•					•	
Loligo (Doryteuthis) pealeii							•	
Lucapinella limatula					•	•	•	
Lucinidae							•	
Marginellidae							•	
Mitrella argus (ocellata)					•	•	•	
Mitrella sp.							•	
Modiolus sp.							•	
Morula (Trachypollia) didyma							•	
Morula (Claremontiella) nodulosa							•	
Muricidae							•	

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Musculus lateralis				●	●		
Mytilidae						●	
Nassarina sp.						●	
Nassarius albus (Phrontis alba)						●	
Nassarius sp.						●	
Nassarius (Phrontis) vibex						●	
Nerita fulgurans (lindae)					●	●	●
Nerita peleronta						●	●
Nerita tesselata						●	●
Nerita versicolor						●	●
Nitidella nitida						●	
Unknown *Nudibranch*				●	●		
Octopus briareus					●		
Octopus joubini					●		
Octopus vulgaris						●	
Olivella floralia						●	
Olivella sp.						●	
Olividae						●	
Ostrea equestris		●		●		●	
Ostrea sp.						●	
Papyridea semisulcata						●	
Pectinidae						●	
Perna viridis	●						
Persicula pulcherrima						●	
Petaloconchus sp.						●	
Petaloconchus nigricans				●	●	●	
Petaloconchus varians		●		●	●	●	
Phasianellidae						●	
Phidiana lynceus				●	●		
Pinctada imbricata						●	
Pinnidae						●	
Pisania (Gemorphos) sp.						●	
Pollina tinca (Gemophos tinctus)				●	●		
Polinices sp.					●	●	

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Pseudochama sp.						●	
Pteria sp.					●	●	
Pteria colymbus						●	
Seila adamsi						●	
Sepioteuthis sepioidea					●	●	
Siphonaria pectinata	●	●	●	●	●	●	●
Sphenia antillensis (fragilis)				●	●		
Spondylus sp.						●	
Stramonita haemostoma (floridana)	●			●	●		
Tectarius antonii (nodulosus)						●	
Terebra dislocata						●	
Terebridae						●	
Tellinidae						●	
Thais deltoidea (Vasula deltoidea)			●	●	●	●	
Thais (Stramonita) floridana							
Thais (Stramonita) rustica	●				●	●	
Thracia sp.						●	
Torcula (Turritella) acropora						●	
Tricolia affinis (Eulithidium pterocladicum)				●	●		
Tricolia (Eulithidium) bella						●	
Tricolia sp.						●	
Trivia (Pseudopusula) antillarum						●	
Trivia (Pusula) pediculus						●	
Trivia sp.						●	
Turbinidae						●	
Turbonilla sp.						●	
Ungulinidae						●	
Veneridae						●	
Vermicularia						●	
Vexillum hanleyi (Atlantilux exigua)						●	
Volutidae						●	
Chelicerata							
Pycnogonida						●	
Crustacea							

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Acanthonyx petiverii				•			
Alpheus armillatus				•			
A. bouvieri			•	•			
A. formosus				•			
A. heterochaelis				•			
A. malleator				•			
A. normanni				•			
A. nuttingi				•			
A. paracrinitus				•			
A. peasei				•			
A. thomasi				•			
A. viridari				•			
Amphiopoda						•	
Ampithoe longimana			•	•			
Ampithoe pollex			•	•			
Arenaeus cribrarius				•			
Calappidae						•	
Calcinus tibicen				•			
Callinectes ornatus				•			
Callinectes sapidus	•	•	•	•	•	•	•
C. similis				•			
Cataleptodius floridanus				•			
Chorinus heros				•			
Clibanarius antillensis				•			
C. sclopetarius				•			
C. tricolor				•			
C. vittatus				•			
Corophium (Apocorophium) acutum			•	•			
Cronius ruber				•			
Cymadusa compta			•	•		•	
Dromiidae						•	
Elasmopus pectenicrus			•	•			
Emerita talpoida				•			
Epialtus bituberculatus				•			

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Epialtus dilatatus				•			
Epialtus sp.						•	
Ericthonius sp.			•	•			
Eriphia gonagra				•			
Eriphia granulosa						•	
Eriphia sp.						•	
Excorallana spp.			•	•			
Eurypanopeus abbreviatus				•		•	
E. depressus				•			
E. dissimilis				•			
E. planus						•	
Gecarcinus lateralis				•			
Glyptoxanthus erosus						•	
Glyptoxanthus sp.						•	
Gonodactylus (Neogonodactylus) bredini				•			
G. (Neogonodactylus) oerstedii				•			
G. (Neogonodactylus) spinulosus				•			
Grapsidae						•	
Hexapanopeus angustifrons				•			
H. paulensis				•			
Hippolytidae						•	
Hyale (Apohyale) perieri			•	•			
Isopoda						•	
Jaeropsis (Joeropsis) sp.			•	•			
Jassa cf. *falcata*			•	•			
Lepidopa benedicti				•			
Leucosiidae						•	
Ligia exotica	•						
Lysmata intermedia				•			
Lysmata wurdemanni				•			
Lysmata sp.						•	
Macrocoeloma subparallelum				•			
Majidae						•	

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Megalobrachium poeyi				•			
M. soriatum				•			
Menippe mercenaria	•		•	•			
Menippe nodifrons		•	•	•			
Menippe sp.						•	
Metalpheus rostratipes				•			
Metapenaeopsis goodei				•			
M. smithi				•			
Micropanope granulimanus				•			
Microphrys (Omalacantha) bicornuta				•			
M. (Omalacantha) antillensis				•			
Microprosthema semilaeve				•			
Mithrax (Nemausa) acuticornis				•			
M. (Mithraculus) coryphe				•			
M. (Mithraculus) forceps				•		•	
M. hispidus				•			
M. pleuracanthus				•			
M. (Teleophyrus) ruber				•			
M. (Mithraculus) sculptus						•	
M. verrucosus (Amphithrax aculeatus)				•			
Neopanope packardii						•	
Neopanope sp.						•	
Neopontonides beaufortensis				•			
Ocypode quadrata	•			•			
Ostracoda						•	
Pachycheles monilifer			•	•			•
Pachycheles sp.						•	
Pachygrapsus transversus		•	•	•			
Paguristes (Areopaguristes) hummi				•			
Paguristes tortugae				•			
Pagurus brevidactylus				•			
Pagurus carolinensis				•		•	

Taxon		Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Pagurus pollicaris					●			
Panopeus (Acantholobulus) bermudensis				●	●			
P. herbstii				●				
P. occidentalis				●				
Panulirus argus					●			
Paradella dianae				●	●			
Paranthura infundibulata				●	●			
Pelia mutica					●			
Penaeus sp.					●			
Percnon gibbesi					●			
Periclimenes (Cuapetes) americanus					●			
Petrochirus diogenes					●			
Petrolisthes armatus					●			
P. galathinus				●	●			
Pilumnus dasypodus					●			●
P. gemmatus							●	
P. lacteus					●			
P. sayi					●			
Pinnotheres (Tumidotheres) maculatus							●	
Pinnotheridae							●	
Pitho lherminieri					●			
Pitho mirabilis							●	
Pitho quadridentata							●	
Plagusia depressa		●		●	●			
Platyactaea setigera					●			
Podocerus brasiliensis				●	●			
Podochela (Coryrhynchus) riisei					●			
P. (Coryrhynchus) sidneyi					●			
Porcellanidae							●	

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Portunus (Achelous) gibbesii				•			
Processa fimbriata				•			
Sicyonia dorsalis				•			
Sphaeroma walkeri			•	•			
Stenorhynchus seticornis				•			
Stenothoe georgiana			•	•			
Stomatopoda						•	
Synalpheus brevicarpus				•			
Synalpheus cf. clarionensis				•			
Synalpheus fritzmuelleri				•			•
Synalpheus minus				•			
Synalpheus sp.				•			
Synalpheus townsendi				•			
Tanaidacea						•	
Tanystylum orbiculare				•			
Uhlias limbatus				•			
Unknown Peracarida						•	
Upogebia aftinis				•			
Xantho (Williamstimpsonia) denticulatus				•			
Xanthidae						•	
Cirripedia							
Amphibalanus reticulatus	•						
Balanus (Amphibalanus) amphitrite	•	•	•	•	•	•	•
B. (Amphibalanus) eburneus	•	•	•	•	•	•	•
B. (Amphibalanus) improvisus	•					•	•
Balanus t. antillensis				•	•		
Balanus (Amphibalanus) venustus			•				
Chthamalus fragilis	•	•	•	•	•	•	•
Chthamalus stellatus	•					•	•
Megabalanus coccopoma	•		•	•	•		
Tetraclita stalactifera	•	•	•	•	•	•	•
Bryozoa							
Aetea sica		•		•			
Aetea truncata		•		•			

Taxon		Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Aeverrillia armata			•		•			
Aimulosia pusilla					•			
Aimulosia uvulifera					•			
Alcyonidium polypylum					•			
Alcyonidium capronae					•			
Alderina smitti					•			
Amathia alternata			•		•			
Amathia distans					•			
Amathia vidovici			•		•			
Anguinella palmata		•	•		•			
Antropora (Akatopora) leucocypha			•		•			
Bartensia minuata					•			
Beania hirtissima					•			
Beania intermedia					•			
Beania klugei			•		•			
Beania mirabilis					•			
Bellulopora bellula					•			
Bowerbankia (Amathia) gracilis			•		•			
Bowerbankia (Amathia) imbricata					•			
Bowerbankia (Amathia) maxima			•		•			
Bryozoan sp.					•			
Bugula minima					•			
Bugula neritina		•	•		•			
Bugula (Bugulina) stolonifera			•		•	•		
Bugula (Crisularia) turrita					•			
Bugula uniserialis					•	•		
Conopeum reticulum							•	
Caulibugula pearsei					•			
Celleporella carolinensis					•			
Celleporina hassalli (caliciformis)					•			
Crisia elongata			•		•			
Cryptosula pallasiana			•		•			
Cupuladria (Reussirella) doma					•			
Cymulopora uniserialis					•			

Taxon		Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Discoporella depressa					•			
Discoporella umbellata					•			
Disporella plumosa					•			
Drepanophora torquata					•			
Electra (Arbocuspis) bellula					•			
Escharina (Bryopesaner) pesanseris					•			
Exechonella antillea					•	•		
Floridina parvicella					•			
Floridinella (Ammatophora) typica					•	•		
Hippaliosina rostrigera					•			
Hippoporina (Schizobrachiella) verrilli					•			
Hippothoa balanophila					•			
Membranipora (Biflustra) arborescens					•			
Membranipora (Biflustra) savartii			•		•			
Membranipora triangularis					•			
Membranipora (Jellyella) tuberculata					•			
Microporella umbracula (coronata)					•			
Nolella stipata			•		•			
Parasmittina nitida					•			
Parasmittina (Pleurocodonellina) signata					•			
Pasythea tulipifera					•			
Phylactella ais					•			
Phylactellipora (Pacificincola) aviculifera					•			
Reginella (Rosulapelta) repangulata					•			
Retevirgula caribbea					•			
Savignyella lafontii			•		•			
Schizoporella cornuta (corualis)			•		•			
Schizoporella rugosa					•			
Schizoporella sp.							•	
Schizoporella unicornis					•			
Scrupocellaria (Licornia) regularis					•			
Spathipora brevicauda					•			
Stylopoma spongites					•			
Sundanella sibogae					•			
Synnotum aegyptiacum			•		•			

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Thalamoporella floridana		•		•			
Trematooecia (Cigclisula) psammophila				•			
Trypostega venusta				•			
Tubulanus riceae				•			
Valkeria ap.				•			
Vibracellina laxibasis				•			
Vittaticella (Catenicella) contei		•		•			
Vittaticella (Catenicella) uberrima				•			
Watersipora sp.				•	•		
Watersipora subovoidea (cucullata)		•		•		•	
Zoobotryon (Amathia) verticillata		•		•			
Tunicata							
Aplidium lobatum			•				
Botrylloides niger				•	•	•	•
Botryllus planus				•	•	•	•
Didemnum sp.		•	•	•	•	•	•
Didemnum candidum			•				
Diplosoma macdonaldi (listerianum)			•				
Diplosoma sp.						•	
Distaplia bermudensis			•				
Ecteinascidia turbinata			•				
Eudistoma capsulatum			•				
Eudistoma obscuratum						•	
Eudistoma sp.						•	
Mogula sp.				•			
Perophora viridis			•				
Phallusia (Ascidia) nigra					•	•	•
Rhopalaea sp.						•	
Trididemnum orbiculatum			•				
Trididemnum savignii			•				
Echinodermata							
Amphipholis squamata			•				

Taxon	Flagler	Brevard	Indian River	St. Lucie	Martin	Palm Beach	Broward
Amphiura stimpsonii						•	
Arbacia punctulata	•		•	•	•		
Asterias forbesi	•						
Cucumariidae sp.			•				
Davidaster rubiginosus					•		
Dendrochirotida sp.			•				
Diadema antillarum				•	•	•	•
Echinaster sp.	•						
Echinometra lucunter		•	•	•	•	•	•
<u>*Echinometra* sp.</u>						•	
Eucidaris tribuloides			•	•	•	•	•
Hemipholis elongata						•	
Holothuria (Halodeima) grisea		•	•	•	•		
<u>Holothuroidea</u>						•	
Isostichopus badionotus						•	
<u>*Isostichopus* sp.</u>						•	
Lytechinus variegatus				•	•	•	•
Nemaster grandis					•		
Ophiactis algicola						•	
Ophiactis savignyi						•	
Ophiocoma (Breviturma) paucigranulata						•	
Ophiocoma (Ophiocomella) pumila						•	
Ophionereis reticulata						•	
Ophiopsila riisei						•	
Ophiostigma isocanthum						•	
Ophiuroidea sp.			•				
Ophiothrix (Acanthophiothrix) suensonii			•			•	
Ophiothrix angulata						•	
Tripneustes ventricosus			•	•	•	•	•
<u>Unidentified sp.</u>			•				
Phoronida							
Unidentified phoronid species				•	•		

Studies reviewed to compile this species list were Smith et al. (1950), Stephenson and Stephenson (1952), Kirtley (1966), Multer and Milliman (1967), Eckelbarger (1976), M. Rice, pers.comm. (2019), Rudolph (1977), Gore et al. (1978), Applied Biology, Inc. (1979), Van Montfrans (1981), Reed et al. (1982), Reed (1982), Winston (1982), Continental Shelf Associates, Inc. (1984), Jaap (1984), Petuch (1987), Reed and Mikkelsen (1987), Nelson(1988), Nelson (1989), Vare (1991), Nelson and Demetriades (1992), PalmBeach County Department of Environmental Resources Management (1993, 1994), Cummings (1994), Coastal Science Associates Inc. (2000), McCarthy (2001), Brooke (2002), Watanabe (2002), McCarthy (2006), McCarthy et al. (2008), Moyeret al.(2003), U.S. Army Corps of Engineers (2003b), Brooke and Young (2005), J. Beal, pers. comm. (2008), McCarthy, pers. observ. 2019, Coastal Planning & Engineering, Inc.(2006), Harris(2006), Watanabe and Young (2006), Continental Shelf Associates, Inc. (2002a, b, 2003, 2004, 2005, 2006), Vargas-Angel et al. (2006), NCRI (2007), and Prekel at al. (2008), CSA International, Inc. 2009, and CSA Ocean Sciences Inc. 2014

Appendix 4.2 Number of invertebrates collected per worm rock sample taken from artificial and natural reef types across depth strata 1–4 during Surveys 1–6. Note that species are listed as identified in the respective study, and that those marked in underline were not used to determine species counts for the taxonomic groups listed in this Chapter (CSA Ocean Sciences Inc. 2014)

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
Bivalves	Anomidae	--	--	--	--	12	--	--	--
	Arcidae	--	1	--	2	1	--	--	--
	Barbatia spp	--	--	--	2	1	--	--	--
	Bivalves	6	58	32	10	125	64	35	25
	Caribachlamys spp	--	--	1	--	--	--	--	--
	Cariidae	--	3	--	1	1	--	1	
	Chlamys sentis	--	--	1	--	--	--	--	--
	<u>*Chlamys* spp.</u>	--	--	1	--	--	--	--	--
	Isognomon radiatus	--	--	--	--	3	--	--	--
	Isognomon spp.	--	13	1	1	57	--	--	--
	Isognomonidae	--	13	1	1	57	--	--	--
	Mytilidae	--	1	--	--	6	3	--	1
	Pectinidae	--	--	3	--	--	1		--
	Unidentified clam	--	1	--	--	--	--	--	--
	Unidentified mussel	--	--	--	--	2	--	--	--
	Unidentified oyster	1	--	--	--	48	2	--	--
Decapods	*Acanthonyx* spp.	--	1	--	--		--	--	--
	<u>Alpheidae</u>	9	85	96	27	4	8	66	--

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	Alpheus malleator	--			3	--	--	--	--
	Alpheus normanni	--	1	1	--	--	--	--	--
	Alpheus paracrinitus	--	--	--	--	1	--	--	--
	Alpheus spp.	2	3	4	11	1	--	--	--
	Alpheus thomasi	--	--	2	1	--	--	--	--
	Unknown Brachyura	9	2	6	6	3	--	--	--
	Unknown Decapoda	--	108	60	--	68	75	138	4
	Epialtidae	2	1	15	9	4	--	--	--
	Epialtus bituberculatus	--	--	--	1	--	--	--	--
	Epialtus spp.	--	--	--	1	--	--	--	--
	Eriphia granulosa	--	--	--	--	1	--	--	--
Decapods (contd.)	*Eriphia* spp	--	--	--	--	1	--	--	--
	Eurypanopeus abbreviates	1	1	--	3	--	--	--	--
	Eurypanopeus depressus	--	--	1		--	--	--	--
	Eurypanopeus planus	--	1	--	--	--	--	--	--
	Eurypanopeus spp.	1	2	1	3	--	--	--	--
	Glyptoxanthus erosus	--	--	1	--	--	--	--	--
	Glyptoxanthus spp.	--	--	1	--	--	--	--	--
	Grapsidae	--	--	2	--	14	--	--	--
	Hippolytidae	6	--	5	8	--	--	--	--

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	Leucosiidae	--	--	1		--	--	--	--
	Lysmata spp	6	--	5	8	--	--	--	--
	Majidae	13	31	70	27	1	2	1	--
	Megalobranium soriatum	--	4	13	2	--	--	--	--
	Megalobranium spp.	--	12	26	11	--	--	--	--
	Menippe mercenaria	--	2	2		--	--	--	--
	Menippe nodifrons	2	2	13	10	1	--	--	--
	Menippe spp.	11	21	24	15	5	--	--	--
	Mennipidae	11	44	31	15	6	2	21	--
	Mithrax coryphe	--	--	1	--	--	--	--	--
	Mithrax forceps	--	2	17	4	--	--	--	--
	Mithrax pleuracanthus	--	--	--	5	--	--	--	--
	Mithrax sculptus	--	--	5	8	--	--	--	--
	Mithrax spp.	4	4	26	17	--	--	--	--
	Neopanope packardii	--	--	1	2	--	--	--	--
	Neopanope spp.	--	--	1	2	--	--	--	--
	Pachycheles monilifer	1	4	45	28	--	--	--	--
	Pachycheles spp.	1	11	79	32	--	--	--	--
	Pachygrapsus spp.	--	1	--	--	30	--	--	--
	Pachygrapsus transversus	--	1	--	--	30	--	--	--

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	Paguroidea	4	29	14	4	3	8	51	
Decapods (cont'd.)	Panopeidae	1	3	2	5	--	--	--	--
	Penaeidae	--	98	29	--	6	60	304	--
	Petrolisthes armatus	--	--	3	9	1	--	--	--
	Petrolisthes galathinus	3	--	19	1	--	--	--	--
	Petrolisthes spp.	7	26	40	15	1	--	--	--
	Phyllocidae	--	--	8	1	--	--	--	--
	Pilumnidae	5	13	41	15	2	--	--	--
	Pilumnus dasypodus	--	1	16	4	--	--	--	--
	Pilumnus gemmatus	--	1	1	--	--	--	--	--
	Pilumnus sayi	--	1	22	12	--	--	--	--
	Pilumnus spp.	5	13	39	20	2	--	--	--
	Pinnotheres maculatus	--	1	--	--	--	--	--	--
	Pinnotheres spp.	--	1	--	--	--	--	--	--
	Pinnotheridae	--	2	--	--	--	--	1	--
	Pitho iherminieri	--	--	2	--	3	--	--	--
	Pitho mirabilis	--	--	10	7	--	--	--	--
	Pitho quadridentata	--	--	3	1	--	--	--	--
	Pitho spp.	2	--	15	8	3	--	--	--
	Porcellanidae	5	108	196	60	31	--	21	--

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	Portunus spp.	--	--	--	--	--	1	--	--
	Processa spp.	7	11	13	1	--	--	--	--
	Processidae	7	11	21	3	1	--	--	--
	Unknown Shrimp		1	19	5	--	--	--	--
	Stomatopoda	2	19	3	--	1	1	17	3
	Synalpheus brevicarpus	--	--		1	--	--	--	--
	Synalpheus fritzmueller	--	--	20	11	--	--	--	--
	Synalpheus minus	2	3	9	--	--	--	--	--
	Synalpheus spp.	9	3	41	15	--	--	--	--
	Synalpheus townsendi	2	--	3	--	--	--	--	--
	Uhlias limbatus	--	--	1	--	--	--	--	--
Decapods (cont'd.)	*Uhlias* spp	--	--	1	--	--	--	--	--
	Xanthidae	--	--	5	2	--	--	--	--
	Xantho denticulata	--	--	--	1	--	--	--	--
	Xantho spp.	--	--	--	1	--	--	--	--
Echinoids	Echinoidea	16	26	30	5	3	10	5	--
Gastropods	*Bulla* spp.	--	--	--	1	--	--	--	--
	Bulla umbilicata	--	--	--	1	--	--	--	--
	Bullidae	--	1	--	1	--	--	--	--
	Cerithiidae	--	1	--	3	--	--	--	--

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	Cerithium eberneum	--	--	--	1	--	--	--	--
	Cerithium litteratum	--	--	--	2	--	--	--	--
	Cerithium spp.	--	--	--	3	--	--	--	--
	Columbellidae	6	5	11	31	34	11	64	5
	Costoanachis avara	3	3	6	12	--	--	--	--
	Costoanachis layfresnayi	--	--	--	1	--	--	--	--
	Costoanachis semplicata	--	--	--	7	--	--	--	--
	Costoanachis sertularium	--	--	1	2	--	--	--	--
	Costoanachis spp.	5	3	9	28	--	--	--	--
	Diodora cayenensis	--	--		1	--	--	--	--
	Diodora spp.	--	--	1	1	--	--	--	--
	Epitonidae	--	--	--	1	1	--	--	--
	Epitonium spp.	--	--	--	1	1	--	--	--
	Fissurellidae	--	--	4	1	6		--	--
	Unknown Gastropod	10	67	23	18	41	66	144	9
	Littorinidae	--	4	--	--	--	2	12	--
	Marginellidae	--	--	--	--	1	--	--	2
	Mitrella ocellata	1	--	--	--	--	--	--	--
	Mitrella spp.	1	2	2	--	7	--	--	--
	Morula nodulosa		1	2	--	--	--	--	--

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	Morula spp.	1	--	2	--	1	--	--	--
	Nassaridae	--	--	--	2	--	--	--	--
Gastropods (contd.)	*Nassarius albus*	--	--	--	2	--	--	--	--
	Nassarius spp.	--	--	--	2	--	--	--	--
	Olivella spp.	--	--	1	1	1	--	--	--
	Olivellidae	--	--	1	1	1	--	--	--
	Stramonita haemastoma floridana	10	20	14	9	3	--	--	--
	Stramonita spp.	10	20	25	46	8	--	--	--
	Trivia pediculus	--	--	2	--	--	--	--	--
	Trivia spp.	--	--	2	--	--	--	--	--
	Triviiadae	--	--	2	--	--	--	--	--
	Volutidae	--	3	--	3	--	--	--	--
Holothuroids	Holothuroidea	--	3	2	2	--	--	--	1
Nemerteans	Nemertea	--	--	2	--	--	--	--	--
Ophiuroids	Ophiuroidea	22	115	187	50	4	11	4	3
Peracarids	Amphipoda	352.25	1358	3892	2717.5	1199.25	184	2836	38
	Isopoda	88.25	405	889.25	1265.5	406.5	33	54	12
	Unknown Peracarida	101.75	128.25	476.75	250	88.5	--	--	--
Polychaetes	Eunicidae	--	--	--	--	--	--	1	--
	Maldanidae	2	10	15	11	13	--	1	--

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	Muricidae	11	21	27	44	9	--	--	--
	Nereidae	--	--	--	--	--	--	1	--
	Polychaeta	1	68	84	19	71	70	108	13
Pycnogonids	Pycnogonida	--	--	15	--	2	--	--	--
Sipunculids	Sipunculida	7	190	232	25	479	253	33	56

Appendix 4.3 Mean percent cover of epibiota sampled in quadrats (0.5 m^2) from artificial and natural reef types across depth strata 1–4 during Surveys 1–6 (CSA Ocean Sciences Inc. 2014)

Group	Taxon	Natural Reef Stratum				Artificial Reef Stratum			
		1	2	3	4	1	2	3	4
Cyanobacteria	Cyanobacteria	0.73	--	0.02	0.17	--	--	--	--
Macroalgae	*Acanthophora.muscoides*	--	1.98	0.13	--	--	--	--	--
Macroalgae	*Acanthophora* sp.	--	0.13	--	--	--	--	--	--
Macroalgae	*Amphimedon* sp.	--	--	0.03	--	--	--	--	--
Macroalgae	*Amphiroa* sp.	--	0.13	0.04	--	--	--	--	--
Macroalgae	*Asparagopsis* sp.	--	--	--	--	0.03	--	0.04	0.17
Macroalgae	*Avrainvillea rawsonii*	--	1.03	--	--	--	--	--	--
Macroalgae	*Bryopsis* sp.	0.01	--	--	--	--	--	--	--
Macroalgae	*Bryothamnion triquetrum*	--	5.33	0.03	--	--	--	--	--
Macroalgae	*Caulerpa cupressoides*	0.24	0.01	--	--	--	--	--	--
Macroalgae	*Caulerpa laetevirens*	0.05	--	--	--	--	--	--	--
Macroalgae	*Caulerpa lanuginosa*	0.04	--	1.12	--	--	--	0.09	--
Macroalgae	*Caulerpa mexicana*	1.89	0.03	0.01	--	--	--	0.02	--
Macroalgae	*Caulerpa prolifera*	--	0.29	0.03	--	--	--	--	--
Macroalgae	*Caulerpa racemosa*	0.08	0.38	--	--	0.04	--	0.02	--
Macroalgae	*Caulerpa sertularioides*	0.29	0.26	0.01	--	0.12	0.09	0.10	0.09

Group	Taxon	Natural Reef Stratum				Artificial Reef Stratum			
		1	2	3	4	1	2	3	4
Macroalgae	*Caulerpa* sp.	--	0.08	--	--	--	--	--	--
Macroalgae	*Centrocerus V*	0.01	--	--	--	--	--	--	--
Macroalgae	Chlorophyta	0.33	0.28	--	--	--	--	--	--
Macroalgae	*Codium intertextum*	--	--	--	--	0.05	--	--	--
Macroalgae	*Codium* sp.	0.01	--	--	--	--	0.01	0.02	--
Macroalgae	*Crustose coralline*	0.01	0.19	0.08	0.05	--	0.01	--	--
Macroalgae	*Dasycladus* sp.	--	0.43	0.08	0.02	--	--	--	--
Macroalgae	*Dasycladus vermicularis*	0.01	0.33	0.45	0.17	--	--	--	--
Macroalgae	*Dictyota* sp.	8.03	3.60	3.75	0.23	0.06	0.38	0.10	0.07
Macroalgae	*Digenia simplex*	--	0.10	--	--	--	--	--	--
Macroalgae	*Digenia* sp.	--	0.13	--	--	--	--	--	--
Macroalgae	*Dysidea.sp.*	--	--	0.03	0.18	0.01	0.08	0.01	0.07
Macroalgae	*Halimeda* sp.	0.15	0.59	0.13	0.05	0.10	0.16	0.25	0.21
Macroalgae	*Halimeda tuna*	--	0.03	0.39	--	--	--	--	--
Macroalgae	*Heterosiphonia gibbesii*	--	0.02	1.50	--	--	--	--	--
Macroalgae	*Hypnea* sp.	--	0.04	--	--	--	1.48	--	--
Macroalgae	*Jania* sp.	0.35	--	0.63	0.09	--	0.02	--	--
Macroalgae	*Laurencia* sp.	1.01	0.03	--	--	1.60	1.23	2.51	1.83

Group	Taxon	Natural Reef Stratum				Artificial Reef Stratum			
		1	2	3	4	1	2	3	4
Macroalgae	*Liagora* sp.	0.37	0.04	0.10	--	--	0.01	--	--
Macroalgae	*Neomeris annulata*	0.01	0.01	--	0.02	--	--	--	--
Macroalgae	*Padina* sp.	1.04	0.67	0.04	--	0.13	0.25	0.14	0.07
Macroalgae	Phaeophyta	0.04	2.46	1.91	0.24	--	--	--	--
Macroalgae	Rhodophyta	--	0.57	0.15	0.25	1.75	0.65	0.54	--
Macroalgae	*Udotea flabellum*	--	--	0.03	--	--	--	--	--
Macroalgae	*Udotea* sp.	--	0.04	0.04	0.05	--	--	--	--
Macroalgae	*Wrangelia argus*	0.79	0.03	--	0.03	1.00	1.44	1.58	1.43
Macroalgae	*Wrangelia* sp.	0.15	0.06	0.11	0.55	2.29	1.73	1.20	0.37
Turf algae	Sediment over hardbottom(Turf algae)	28.09	43.96	45.98	42.15	29.46	32.95	35.57	33.36
Turf algae	Turf	30.07	21.15	27.43	32.12	22.33	34.43	41.12	35.20
Sponges	*Aplysina fistularis*	--	--	--	0.25	--	--	--	--
Sponges	*Aplysina insularis*	--	--	--	0.01	--	--	--	--
Sponges	*Aplysina* sp.	--	--	--	0.05	--	--	--	--
Sponges	*Callyspongia* sp.	--	--	--	0.15	--	--	--	--
Sponges	*Cinachyra* sp.	--	0.19	0.27	0.09	--	--	--	--
Sponges	*Cliona* sp.	0.70	0.53	0.90	0.17	2.52	2.25	1.63	0.19
Sponges	Demospongiae	--	0.04	0.08	0.38	0.09	0.28	0.16	0.01
Sponges	*Holopsamma* sp.	--	--	--	0.09	0.03	0.96	1.08	0.09

Group	Taxon	Natural Reef Stratum				Artificial Reef Stratum			
		1	2	3	4	1	2	3	4
Sponges	*Iotrochota birotulata*	--	--	--	0.02	--	--	--	--
Sponges	*Iotrochota* sp.	--	--	0.04	0.01	--	--	--	--
Sponges	*Ircinia felix*	--	0.02	0.01	0.28	--	--	--	--
Sponges	*Ircinia* sp.	--	--	0.03	0.55	--	--	--	--
Sponges	*Ircinia strobilina*	--	--	0.03	0.43	--	--	--	--
Sponges	*Monanchora unguifera*	--	--	--	0.02	--	0.01	0.01	--
Sponges	*Niphates digitalis*	--	--	--	0.06	--	--	--	--
Sponges	*Niphates erecta*	--	--	0.05	--	--	--	--	--
Sponges	*Niphates* sp.	--	--	--	0.11	0.09	0.08	0.02	--
Sponges	*Phorbas amaranthus*	0.04	--	0.04	0.43	0.48	0.39	0.60	0.61
Sponges	*Phorbas* sp.	--	--	--	0.18	--	--	--	--
Sponges	*Pione lampa*	0.09	--	0.06	0.06	3.49	3.33	1.20	0.59
Sponges	*Spirastrella* sp.	--	--	0.03	0.03	--	--	--	--
Sponges	*Stylotella* sp.	--	--	0.01	--	--	--	--	--
Sponges	*Symplegma* sp.	--	--	--	--	--	--	0.04	--
Sponges	*Tedania* sp.	--	--	--	0.33	--	--	--	--
Hydrozoans	Hydroids	0.08	0.96	1.03	1.81	0.50	0.86	1.23	1.07
Hydrozoans	*Millepora alcicornis*	--	0.03	0.12	0.49	0.24	0.21	0.27	0.07

Group	Taxon	Natural Reef Stratum				Artificial Reef Stratum			
		1	2	3	4	1	2	3	4
Hydrozoans	*Millepora* sp.	--	0.02	--	0.03	0.05	0.18	0.23	--
Hydrozoans	*Thyroscyphus* sp.	--	0.13	--	--	--	--	--	--
Octocorals	Eunicea fusca	--	--	0.03	0.01	--	--	--	--
Octocorals	*Eunicea* sp.	--	0.03	0.09	0.82	--	--	--	--
Octocorals	*Muricea* sp.	--	0.01	0.01	0.30	--	--	--	--
Octocorals	*Plexaura flexuosa*	--	--	--	0.02	--	--	--	--
Octocorals	*Plexaura* sp.	--	--	--	0.15	--	--	--	--
Octocorals	*Pseudoplexaura* sp.	--	--	0.01	0.38	--	--	0.01	--
Octocorals	*Antillogorgia americana*	--	--	--	0.23	--	--	0.01	--
Octocorals	*Antillogorgia bipinnata*	--	--	0.03	0.21	--	--	--	--
Octocorals	*Antillogorgia* sp.	--	0.06	0.13	0.33	--	--	--	--
Octocorals	*Pterogorgia anceps*	--	--	0.03	0.01	--	--	--	--
Octocorals	*Pterogorgia citrina*	--	--	--	0.01	--	--	--	--
Octocorals	*Pterogorgia* sp.	--	0.08	0.48	0.08	--	--	--	--
Zooanthids	*Palythoa caribaeorum*	--	--	--	--	--	--	0.05	--
Scleractinian corals	*Oculina* sp.	--	--	0.02	0.01	--	--	--	0.01
Scleractinian corals	*Siderastrea radians*	0.01	0.02	0.03	0.02	0.06	--	--	--
Scleractinian corals	*Siderastrea siderea*	0.08	0.09	0.11	0.05	0.04	0.03	0.02	--
Scleractinian corals	*Siderastrea* sp.	0.29	0.29	0.43	0.15	0.01	0.02	0.04	0.03

Group	Taxon	Natural Reef Stratum				Artificial Reef Stratum			
		1	2	3	4	1	2	3	4
Scleractinian corals	*Solenastrea bournoni*	--	--	--	0.10	--	--	--	--
Scleractinian corals	*Solenastrea* sp.	--	--	0.01	0.03	--	0.00	--	--
Anemones	Anemone	--	--	--	0.01	--	0.01	--	--
Bryozoans	Bryozoans	--	0.02	--	0.01	--	--	--	--
Bryozoans	Encrusting bryozoan	--	--	0.08	--	--	0.01	0.03	--
Bryozoans	*Hippoporina verrilli*	--	--	0.04	0.15	--	0.06	0.83	--
Bryozoans	*Schizoporella* sp.	--	--	0.07	0.12	0.07	0.12	0.97	1.16
Worm rock	*Phragmatopoma lapidosa*	--	0.02	0.33	--	0.82	1.50	1.22	1.11
Mollusks	Bivalve	--	--	--	--	0.01	--	--	--
Mollusks	Cypraea	--	--	--	0.00	--	--	--	--
Mollusks	Gastropod	--	--	--	--	0.01	--	0.01	--
Mollusks	Oyster	--	0.02	0.01	--	0.02	0.03	0.02	0.06
Mollusks	Scallop	--	--	--	0.01	--	--	--	--
Mollusks	*Spondylus* sp.	--	--	--	--	--	0.01	0.01	--
Crustaceans	Barnacles	--	--	--	--	--	--	0.07	--
Crustaceans	Thoracica	--	--	--	--	--	0.04	--	--
Echinoderms	*Echinometra* sp.	0.02	--	--	--	0.04	0.03	0.01	--
Echinoderms	*Eucidaris tribuloides*	--	--	--	0.01	0.01	0.03	0.01	--

Group	Taxon	Natural Reef Stratum				Artificial Reef Stratum			
		1	2	3	4	1	2	3	4
Tunicates	*Botrylloide nigrum*	--	--	--	--	0.02	0.02	0.04	0.01
Tunicates	Didemnidae	--	--	--	0.02	0.07	0.04	0.04	--
Tunicates	*Eudistoma* sp.	--	0.01	0.01	0.11	--	--	0.03	--
Tunicates	*Rhopalaea* sp.	--	--	0.01	0.05	0.02	0.02	0.05	0.17
Substrate	Rubble	0.08	0.12	0.03	0.28	0.17	0.11	0.24	0.04
Substrate	Sand	0.94	4.41	1.31	3.31	17.70	2.07	1.42	15.96
Substrate	Shell hash	1.53	1.33	0.43	0.88	0.40	0.36	0.35	0.14

Appendix 4.4 Mean number of invertebrates associated with macroalage collected within 0.15-m^2 quadrats from artificial and natural reef types across depth strata 1–4 during Surveys 2–6. Note that species are listed as identified in the respective study, and that those underlined were not used to determine species counts for the taxonomic groups listed in this chapter (modified from CSA Ocean Sciences Inc. 2014)

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
Amphipods	Amphipoda	5.26	5.60	6.84	6.38	9.38	6.88	9.79	8.20
	Caprellidae	--	1.50	--	--	--	--	--	--
Bivalves	*Anadara* spp.	--	--	1.00	--	--	1.00	--	--
	<u>Arcidae</u>	1.00	1.00	1.00	--	1.33	1.22	1.00	1.00
	<u>Bivalvia</u>	2.00	1.50	1.00	--	1.00	2.00	1.33	2.00
	Brachidontes spp.	--	--	--	--	2.60	1.67	1.00	--
	Callucina keenae	--	--	--	--	--	--	1.00	--
	Cardidae	--	1.00	1.00	--	--	--	--	--
	Chama spp.	1.00	1.29	1.60	--	--	--	1.00	1.43
	<u>Chamidae</u>	--	--	--	--	--	--	1.00	1.00
	Chione cancellata	--	--	1.00	1.00	2.50	--	2.00	1.00
	Chione elevata	--	--	--	--	2.00	--	1.00	--
	<u>*Chione* spp.</u>	--	1.00	1.00	1.33	2.13	1.44	1.70	1.00
	Cyclinella tenuis	1.00		1.00	--	--	--	1.00	--
	Diplodonta spp.	--	1.00	--	--	2.00	1.00	1.00	--
	Donacidae	--	--	--	--	--	--	1.00	--
	Geukensia spp.	--	--	--	--	1.00	1.50	--	--

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
Bivalves (cont'd.)	*Greganella coralliophaga*	--	--	1.00	--	--		--	--
	Lasaeidae	--	--	--	--	--	1.00	--	1.00
	Limidae	--	1.00	2.00		--	--	--	--
	Lithophaga spp.	--	--	--	--	--	--	1.00	1.00
	Lucinidae	1.25	1.00	1.00	1.00	1.33	1.00	1.60	1.22
	Modiolus spp.	1.00	1.00	--	--	1.50	1.00	1.00	1.00
	Musculus lateralis	1.00	1.00	1.00	1.00	2.00	--	--	1.00
	Mytilidae	1.50	1.00	1.00	--	2.25	1.33	1.00	1.00
	Ostreidae	1.00	1.20	1.00	--	2.17	--	--	1.33
	Papyridea semisulcata	1.00	1.25	1.65	1.60	1.00	--	1.00	1.50
	Pectinidae	--	--	1.00	--	--	--	--	1.00
	Pinctada spp.	--	1.00	--	--	1.00	--	1.00	--
	Pinnidae	--	--	--	--	--	1.00	--	--
	Pseudochama spp.	1.00	--	--	--	--	--	--	1.33
	Pteriidae	--	--	1.00	--	--	1.50	--	--
	Spondylidae	--	--		--	--	--	1.00	2.50
	Tellenidae	--	1.00	1.14	--	8.13	--	1.33	1.17
	Thracia spp.	--	--		--	--	--	2.00	--
	Ungulinidae	--	--	1.00	--	1.33	1.00	1.00	2.00
	Veneridae	1.00	--	1.57	--	1.50	1.00	1.50	1.00

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
Crabs	Calappidae	--	--	--	--	--	--	1.00	1.00
	Unknown Crab Megalops	1.00	1.00	1.00		1.00	3.00	1.00	--
	Dromiidae	--	--	--	--	--	--	--	1.00
	Grapsidae	1.00	--	--	--	--	1.00	--	--
	Majidae	1.53	2.21	2.43	1.75	2.14	2.80	1.57	2.08
	Pinnotheridae	--	1.00	--	--	--	--	1.00	1.00
	Porcellanidae	1.00	--	2.00	--	--	--	1.00	2.00
	Unknown Brachyura	--	2.50	1.67	4.00	--	12.00	1.00	1.00
	Xanthidae	1.00	1.00	1.25	1.00	1.75	--	1.00	1.00
Echinoids	Echinoidea	1.00	1.64	1.75	4.67	4.00	2.00	1.00	2.22
Gastropods	*Anachis avara*	1.00	1.00	1.00	--	2.00	1.00	1.00	--
	Anachis iontha	--	1.00	1.00	--	--	--	--	--
	Anachis sparsa	1.00	1.00	--	2.00	1.00	1.00	--	--
	Anachis spp.	--	--	--	--	--	1.20	--	--
	Antalis spp.	--	--	--	--	--	1.00	--	--
	Boonea seminuda	--	--	--	--	1.00	--	--	--
	Buccinidae	--	--	--	--	--	--	1.00	1.00
	Bulla umbilicata	1.00	1.40	1.00	1.60	--	1.00	1.00	1.67
	Bullidae	--	--	1.00	--	--	--	1.00	1.00
	Calatrophon ostrearum	--	--	1.00	--	--	--	1.00	--

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	<u>*Calatrophon* spp.</u>	--	--	--	--	--	--	1.00	--
	Calyptraeidae	--	1.00	--	--	--	--	--	--
	<u>Cerithiidae</u>	1.00	1.00	1.00	--	--	3.20	--	1.00
Gastropods (cont'd.)	Cerithiopsidae	--	--	--	--	--	--	1.00	1.00
	Cerithium eburneum	2.00	1.40	3.00	1.00	--	1.00	1.60	1.00
	Cerithium litteratum	2.40	2.33	5.29	1.00	1.60	2.00	1.67	--
	<u>*Cerithium* spp.</u>	--	1.00	--	--	--	1.00	1.00	2.50
	Cerithium spp.1	--	--	--	--	--	--	1.00	--
	Cerithopsis emersoni	--	--	--	--	--	--	1.00	1.00
	Columbella mercatoria	--	--	--	--	--	--	1.00	--
	<u>*Columbella* spp.</u>	--	1.00	--	--	--	--	--	1.00
	<u>Columbellidae</u>	1.00	1.00	--	--	1.33	15.27	1.00	--
	Conus floridanus	--	--	--	--	--	--	--	1.00
	Costellariidae	--	--	--	--	--	--	1.00	2.00
	Crassispira spp.	--	--	--	--	--	--	--	1.00
	Cymatium pileare		--	--	--	--	--	--	1.00
	<u>Dentaliidae</u>	--	--	1.00	--	--	1.00	--	--
	Dentalium antillarum	--	--	--	--	--	--	2.25	2.00
	Diodora spp.	--	--	--	--	2.67	1.00		1.00
	Engina turbinella	--	--	1.00	--	--	--	1.00	1.00

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	Epitoniidae	--	1.00	1.00	--	--	--	--	--
	Epitonium spp.	--	--	1.00	--	1.00	--	--	--
	Favartia cellulosa	--	--	--	--	--	--	1.00	1.00
	Fissurellidae	1.00	1.00	--	--	2.00	--	--	--
	Gastropoda	1.50	1.00	2.00	--	1.00	--	3.00	2.67
	Hastula hastata	--	--	--	--	--	--	--	1.00
	Littorina ziczac	--	--	--	--	1.00	--	--	--
	Littorinidae	--	--	--	--	2.00	1.00	--	--
	Lucapinella limatula	1.00	1.00	--	--	--	2.00	--	--
	Marginellidae	1.00	--	--	--	--		--	1.00
	Mitrella ocellata	1.00	1.00	1.50	--	1.64	3.50	--	
	Morula nodulosa	--	--	1.00	--	--		--	1.00
	Muricidae	1.00	1.00	--	1.00	2.00	1.00	--	1.00
	Nassariidae	--	1.00	--	--	--	1.00	1.00	1.00
Gastropods (cont'd.)	*Nassarina* spp.	--	--	--	--	--	1.00	--	--
	Nassarius albus	1.00	--	1.00	--	--	2.00	1.50	1.67
	Nassarius spp.	--	--	--	--	--	--	1.00	--
	Nassarius vibex	2.75	1.00	3.38	1.71	--	1.33	1.83	2.22
	Nitidella nitida	--	1.00	1.00	--	1.00	--	--	--
	Olivella floralia	--	--	--	--	--	--	--	1.00

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
	Olividae	--	--	1.00	--	--	--	--	1.00
	Persicula pulcherrima	--	1.33	--	1.00	--	2.00	1.00	1.29
	Petaloconchus varions	--	--	--	--	--	--	--	1.00
	Phasianellidae	--	--	--	--	--	6.00	--	--
	Pisania spp.	--	--	--	--	1.00	--	1.00	--
	Polinices spp.	--	--	--	--	--	--	1.00	--
	Seila adamsi	--	--	1.00	--	1.00	--	--	--
	Stramonita haemastoma	--	1.00	1.50	1.17	--	1.00	--	1.00
	Terebra dislocata	--	--	--	--	--	1.00	--	--
	Terebridae	--	1.00	--	--	--	1.00	--	--
	Torcula acropora	--	--	1.00	--	--	--	--	--
	Tricolia bella	3.00	--	--	--	2.00	--	--	--
	Tricolia spp.	1.00	--	--	--	--	1.00	--	--
	Trivia antillarum	--	--	--	--	--	--	--	1.00
	Turbinidae	--	--	--	--	1.00	2.20	--	--
	Turbonilla spp.	--	--	1.00	--	--	--	1.00	--
	Vexillum hanleyi	--	--	1.00	--	--	--	--	1.00
Hermit crabs	Paguroidea	1.50	1.00	1.00	1.00	2.00	4.00	1.00	1.10
Holothuroids	Holothuroidea	2.00	--	1.00	--	--	--	2.00	1.50
Isopods	Isopoda	2.00	2.00	2.00	2.33	2.25	1.86	1.75	1.25

Group	Taxon	Artificial Reef Stratum				Natural Reef Stratum			
		1	2	3	4	1	2	3	4
Mantis-shrimps	Stomatopoda	--	2.00	1.00	2.00	1.00	--	--	1.00
Nematodes	Nematoda	--	--	--	--	1.00	--	1.00	--
Nudibranchs	Nudibranch ia	1.18	1.80	2.00		1.00	--	1.00	1.50
Ophiuroids	Ophiuroidea	1.33	1.40	1.17	1.00	--	--	1.00	1.33
Ostracods	Ostracoda	--	1.00	1.00	1.00	1.50	--	1.00	--
Polychaetes	Polychaeta	4.80	5.32	6.24	5.91	9.27	3.92	3.13	4.78
	Worm rock	--	1.00	1.00	--	--	--	--	--
Polyplacophorans	Polyplacophora	1.41	1.47	2.67	2.10	2.05	--	1.54	2.04
Sea spiders	Pycnogonida	1.00	1.33	2.00	1.00	1.00	--		1.00
Shrimps	Shrimp	2.63	2.33	3.00	2.40	1.79	2.00	1.60	2.62
	Snapping shrimp	--	--	--	--	4.00	--	2.00	1.67
Sipunculids	Sipuncula	7.80	4.46	5.79	6.00	8.72	2.00	2.44	11.23
Tanaids	Tanaedacea	--	--	--	1.00	1.00	--	--	--
Trematodes	Trematoda	--	--	--	--	--	--	4.50	3.00
Grand Total		**3.30**	**2.84**	**3.49**	**3.14**	**4.70**	**3.69**	**2.71**	**3.08**

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