Study III: Species richness and abundance of Bivalvia, Cephlapoda, Gastropoda and Polyplacophora in shallow near shore environments in Dominica, Lesser Antilles

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Abstract The waters of Dominica house many mollusc species within its narrow shelf. This study focused on the organisms along the western coastline, specifically gastropods, bivalves and polyplacophoras. Nineteen species of molluscs were recorded in this survey, seven of which were new and added to the species inventory list of Dominica. Species richness and abundance were surveyed at 21 sites, and habitat depth, structure and substrate were noted. *Acanthopleura granulata* had the highest index of species across the sites surveyed. It was evident from this survey that conservation measures, such as collection quotas need to be established to protect the stocks of *Cittarium pica* and *Strombus gigas.* The study also identified two gastropods, *Thais deltoidea* and *Thais rustica,* that are known useful pollution bioindicators.

Keywords Molluscs · Gastropoda · Bivalvia · Polyplacophora · Dominica

Introduction

Within one of the largest animal phyla, members of Mollusca are found in the sea, in fresh water and on land (Barnes 1980). There are approximately 50 000 living species and 60 000 known fossil records of molluscs (Brusca and Brusca 1990), including snails, slugs, scallops, oysters, clams, squids, octopi and nautili. There are eight living classes and two extinct classes. Molluscs are bilaterally symmetrical protostomes whose coelom functions as a hydrostatic skeleton. All are soft-bodied individuals, most with a shell of calcium carbonate for protection; for some, this is an internal remnant (e.g. the squid), while others, like the octopus lack a shell completely.

Molluscan shells have been popular since ancient times and are still used widely amongst cultures all over the world as tools, containers, musical devices, currency and decoration. Many aboriginal groups rely on molluscs for a substantial portion of their diet. Molluscs are still commercially-harvested food products: the annual world squid and octopus fishery, for example, exceeds two million metric tons per year (Brusca and Brusca 1990).

With such a market, there is a great potential for over-harvesting and exploitation giving rise to conservation issues. One concern is the illegal trade of *Strombus gigas* (the queen conch), an endangered, large-shelled species. The conch import and export are regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Environment Canada's recent news release stated that between September 29, 2003 and December 31, 2006 almost 120 000 kilograms of *S. gigas* had been taken from Caribbean waters and unlawfully exported to the United States and Canada. Experts estimate that this weight represents between 798 000 and 1.05 million conch (Environment Canada 2008). With this alarming fact, it is important to update an inventory of mollusc species in Dominica as well as their abundance to determine what needs to be protected.

Species in this phylum are also of particular interest to scientists because they are great models of how nervous system complexity correlates with habitat and evolution. For example, clams are sessile organisms with simple sensory organs whose central nervous system is comprised of a chain of ganglia circling the body; meanwhile, an octopus has the most sophisticated nervous system of all invertebrates. Their large brain, along with their large eyes and rapid conduction along giant axons, correlate well with the active predatory life (Campbell 1993).

The only material available on molluscs in Dominica is an online species list (Steiner 2007). This paper evaluates both species richness and abundance in the shallow water depths along the west coast of Dominica. It now serves as a baseline for monitoring changes in distribution and abundance in the future and provides information to scientists who want to study the molluscs of Dominica. This study's aim was also to determine to what extent species richness was influenced by habitat depth and substrate.

Materials and methods

This survey was conducted at thirty-five sites along the west coast of Dominica. Using snorkelling gear, a survey of the presence and abundance of molluscan species was carried out at depths between zero to five meters. The roaming survey was twenty minutes and was conducted by swimming in a zigzag pattern. Areas ranging from 22 m^2 to 2400 m^2 were covered.

Quantification of presence was done using a nominal ranking system for the time of sighting. A rank of 5 was given to any organism seen within the first five minutes, 4 if seen between five and ten minutes, 3 to any organism seen within ten to fifteen minutes, 2 if seen between fifteen and twenty minutes and a rank of 1 for any species seen after the twenty minute period. An additional ranking system was used for abundance. A species was considered rare if it was only seen once, occasional if it was seen two to ten times and common if it was seen eleven times or more within the survey time frame. Each species at every site was assigned an index expressed as the time of sighting ranking multiplied by the abundance ranking divided by one hundredth of the area[2]. Species identified beyond the twenty minute survey were noted but their abundance not quantified. A depth record was kept during the survey. The substrate and habitat structure were also noted for each organism, where "wall" was a rock ledge or cliff wall that extended into the water, "crevice" was a narrow opening extending lengthwise within but not limited to a rock substrate, "hole" was a hollow place within a solid substrate, "overhang" was an extension of a rock substrate that produced a projection that allowed for individuals to attach or encrust under, a "sea fan" was a *Gorgonia* sp. and "rock." Only living species were recorded (e.g., shells were not). An estimate of the surveyed area was made in the field and compared with satellite imagery using Google Earth (Google).

Species identification of molluscs was based on Humann and Deloach (2002). Some samples were collected in the field and were later identified by Ross Mayhew.

Results

Species richness

Nineteen species of molluscs were recorded during this survey. Fifteen have been identified, four have not (Table 1); two are bivalves, a limpet from the order Patellogastropoda and a *Neritina* sp. Unidentified Bivalve 1 was approximately 6cm in length (from hinge to opening), had box-shaped valves and had heavy algae growth. Bivalve 2 was approximately 4cm in length (from hinge to opening), resembled a heart when the valves were closed and was covered in algae. The limpet shell was pink in colour and approximately 1cm at its widest diameter. Unidentified Bivalve 1, Unidentified Bivalve 2 and Unidentified Limpet were found at site 23, Mero to St. Joseph #2. The Unidentified *Neritina* was a black snail with yellow spots, approximately 0.5cm in length and was seen at sites 14 and 23, Rodney's Rock and Mero to St. Joseph #2, respectively. Eleven species (*Thais deltoidea, Thais rustica, Micromelo undata, Elysia crispate, Dendosrea frons, Spondylus americanus,* Unidentified Bivalve 1, *Isognomon bicolour,* Unidentified Bivalve 2, Unidentified Limpet and Unidentified *Neritina*) were documented for the first time during surveys. The site with the highest species richness was Mero to St. Joseph #2 with nine species present (Table 1). No molluscs were recorded at Dou Dou Reef or Mero to ECD #1 (Table 1).

Species abundance

T. deltoidea had the greatest distribution, with a presence at fourteen out of the twenty-one sites (Table 1). The species with the highest average abundance was *A. granulata* with an index value of 19.4 (Fig 1).

Habitat substrate and structure

The species always found on rock substrates during the survey were *Cittarium pica, Lithopoma tectum*, *Micromela undata,* Unidentified *Neritina,* Unidentified Bivalve 1, Unidentified Bivalve 2 and Unidentified Limpet. *A. granulata*, *T. deltoidea* and *Lima scabra* were predominant on rock walls 51%, 66% and 90% of the time, respectively. *Pinna carnea* was found mostly in crevices between rocks and rock walls by 87%, while *Octopus vulgaris* chose rock holes 76% of the time. *Spondulus americanus* and D*ensodtrea frons* preferred rocky overhangs 88% and 100% of the time, respectively. *Cyphoma gibbosum* was the only mollusc species surveyed to live on sea fans. *Thais rustica* had the most diverse habitats with 47% on rock, 44% in holes and 9% in crevices (Fig 2).

Habitat depth and abundance

A. granulata, C. pica, I. bicolour, Unidentified *Neritina,* Unidentified Bivalve 1, Unidentified Bivalve 2 and Unidentified Limpet were always found between zero and one meter. *C. gibbosum, D. frons, L. scabra, L. tectum, Micromelo undata* and *Pinna carnea* were seen at depths between one and three meters. No species surveyed was found solely at depths between three and five meters. *T. deltoidea* was the only species identified at all three depth ranges (Table 2). *Elysia crispate* and *Sepioteuthis sepioidea* were not seen during survey time but were observed to be at depths between three and five meters and between one and three meters, respectively (Table 2).

Discussion

Species inventory

With many new additions to the species inventory, it is apparent that there is much to learn about molluscs in Dominica. *M. undata*, for example, was recorded on the species inventory for the first time. This could be due to the fact that they usually only forage at night, and hide under rocks during the day, making them difficult to record during the daytime (Humann and Deloach 2002).

Common snails such as *T. deltoidea* and *T. rustica* were not previously identified either; however, their shells have been collected in Dominica, hence if more time were allotted for mollusc surveys and identification, more species could be recorded. Both of these *Thais* snails are important biological indicators of pollution in the marine ecosystem, specifically against the chemical tributylin (TBT) that is used in antifouling paints on ship hulls (Barcellos da Costa et al.

2008). TBT acts as an endocrine disruptor in these gastropods and causes imposex. Imposex is the occurrence of induced male sex characteristics on normal female gastropods with the development of male sex organs (i.e. the penis and/or vas deferens) (Brady et al. 2008). This is due to the fact that these molluscs "posses only a limited metabolic capacity to eliminate such composites and thus present a great potential [for] organotin bioaccumulation" (Barcellos da Costa et al. 2008). In a TBT sampling study on gastropods in Brazil, it was shown that *T. deltoidea* females became sterile after contact with the chemical, causing concern about the potential for mass mortality if communities are contaminated (Barcellos da Costa et al. 2008).

According to the World Wildlife Fund, TBT is toxic to fish, birds and mammals and "demonstrated to have hormone disruption properties in these animals" (OSPAR 1999). The Dominica tourism website (Discover Dominica: The Natural Island 2008) boasts that Dominica is the "Whale Watching Capital of the Caribbean." The two whales (*Megaptera novaeangliae* and *Physeter macrocephalus*) and two dolphins (*Stenella frontalis* and *Stenella longirostris*) most commonly sighted have been contaminated with organotins in other parts of the world. A case study from the Baltic Sea showed a widespread contamination in nine fish species. Studies suggest that organotins may threaten humans who consume large quantities of fish in their normal diet. The human immune system is affected by TBT because the chemical disrupts the immune cells, particularly those that fight infection (OSPAR 1999).

Several ports in Dominica serve the shipping and tourism industries, increasing the potential for pollution caused by international ships. A case study should be conducted in order to determine to what extent the waters are polluted, which could then urge decision-makers to introde bans on the use of antifouling agents on vessels that travel through the waters of Dominica. Since most Dominicans rely heavily on the resources of the sea for both food and economy, the health and livelihood of the people are at stake.

Abundance and distribution

The abundance and distribution varied among species identified within the survey; however, for *C. gibbosum, D. Frons, I. bicolour, L. scabra, M. undata, O. vulagaris, S. americanus,* Unidentified Bivalve 1, Unidentified Bivalve 2, Unidentified Limpet and Unidentified *Neritina* there was not enough data to draw conclusions.

Species such as *C. pica* showed distinctive patterns. Randal (1964) stated that *C. pica* is "probably the most common large gastropod of the exposed rocky littoral region" in the West Indies. However, in Dominica it was rare and was only identified at three sites. One possible reason is overexploitation. *C. pica* is harvested for its muscular foot for local consumption and bait. These molluscs are limited to the accessible rocky littoral zone, making them easy to collect. The meat yield is relatively low per shell and therefore requires the collection of many individuals. Their low mobility rate leaves them vulnerable to predators and it limits their distribution. Their short larval phase limits their dispersal and increases local settlement which also aids in ease of collection by fishermen (Toller and Gordon 2005).

Another predatory point is that both *T. deltoidea* and *T. rustica,* shallow rock drilling snails, prey upon *C. pica*. Overall, *T. deltoidea's* abundance per m^2 was 4.43 as compared to *C. pica's* which was 1.06 (Fig 2). *T .rustica* also had a higher abundance per m^2 than *C. pica's* with 1.74 and 1.06, respectively (Fig 2). *C .pica, T. deltoidea* and *T. rustica* were identified together at three sites: Anse Mulatre #3, Mero to St. Joseph #2 and Grand Savanne to ECD #3 (Table 1). Anse Mulatre #3 was the only site where *C. pica* had a higher index rating than *T. rustica.* At no site did *C. pica* have a greater index rating than *T .deltoidea.* At Anse Mulatre #3, *T. deltoidea* had an index rating of 20.0, *T. rustica* had an index rating of 6.7 and *C. pica* had an index rating of 10.7 (Fig 2). At site 23, *T. deltoidea* and *T. rustica's* index ratings both equalled 12.5, doubling that of *C. pica's* which was 6.3. *T. deltoidea* had an index rating of 10.0, *T. rustica* had an index rating of 6.7 and *C. pica* had an index rating of 5.3 at site Grand Savanne to ECD #3 (Fig 2). Another predator of *C. pica* is *O. vulgaris* which was evident from the shells found next to rock dens and the personal observation of this organism consuming *C. pica.*

Toller (2003) believed that natural predation was an unlikely explanation for the disappearance of *C. pica* in the Virgin Islands because of the infrequency in which his team observed this happening. The U.S. Virgin Islands have regulated the collecting of *C. pica* with a ban from April 1 to September 30 each year, protecting *C. pica* during its reproductive phase. A size limitation has also been implemented to protect juvenile *C. pica* (Toller 2003). The Dominican Ministry of Agriculture, Fisheries and Forestry should consider these legislations as well as create another marine reserve to protect the rocky intertidal zone that *C. pica* inhabits.

O. vulgaris and *S. speioida* were not abundant during the survey, with *O. vulgaris* having an index rating of 0.08 and *S. speioida* with 0. This is because most cephalopods are nocturnal species. *O. vulgaris* is the only octopus usually found in the open on reefs during the day (Humann & Deloach 2002).

Habitat substrate and structure

This study showed that mollusc species can inhabit a variety of substrates and structures, but are primarily influenced by their food source. While *C. gibbosum* was only identified once during the survey, these gastropods live on gorgonians because they feed on the polyps (Humann and Deloach 2002).

Pinna carnea is a suspension feeder and therefore requires being buried upright, usually in mud or sand, where it attaches with byssal threads to a solid substrate beneath (Becker C et al. 2008). However, in the survey conducted it appeared to attach directly to rock substrates. The surrounding rock then provided support and the shell, often covered in algae and organism growth, blended into its surroundings. *P. carnea* may have greater survival rates in turbulent waters in this habitat.

C. pica is found in the rocky intertidal zone, feeding on filamentous algae that grow along the rocks and cliff walls (Toller 2003). This is an optimal location to feed because it is protected by the surf from grazing fish and echinoderms that would compete for this algae as well as from marine animals that would prey on *C. pica*. However, it does make the organism more vulnerable to terrestrial predators, such as birds and humans. Fortunately for *C. pica*, crevices and holes of the rocky substrate provide some protection from these predators. This is supported by the personal observation of a large *C. pica* (~20cm) that was found within a crevice in an emergent rock in the Scotts Head/Soufriere Marine Reserve. The emergent rock, surrounded by water, provides protection because it is not easily accessible by humans and the marine reserve makes it illegal to collect the organism. The crevice also provides a safe habitat from other predators such as birds and fish. This is another example of why the marine reserve's regulations should be better enforced and another reserve should be established that includes the rocky intertidal region in Dominica.

Habitat depth and abundance

Habitat depth is also affected by food preference. The intertidal zone protects *A. granulata's* food source (algae), from grazing fish and echinoderms. The morphology of *A. granulata* supports the organism to reside in such a habitat. Eight transverse, overlapping plates provide protection from the wave impact and allow the organism to move across uneven surfaces (Brusca and Brusca 1990).

T. deltoidea was found at all three depth regions and this suggests that they are very adaptable. *Thais* species feed upon other molluscs by boring into their shell to obtain the underlying flesh (Brusca and Brusca 1990). These results would suggest that *Thais deltoidea* is able to consume molluscs that inhabit a variety of depths.

Strombus gigas was not seen because its principal habitat in Dominica, seagrass beds, was not surveyed. However, it was sighted at depths deeper than five meters (pers.obs. 2008). The amount of *S. gigas* indentified at these deep depths implies overharvesting by local fisherman at depths between zero and five meters due to the ease in collecting these organisms. CITES proposed that the import of *S. gigas* from three Caribbean countries (Honduras, Haiti and the Dominican Republic) be suspended due to overexploitation. On September 29, 2003, the National Marine Fisheries Service (NOAA Fisheries) supported this decision. The lack of shallow water (0-5m) *S. gigas* in Dominica is a possible indicator that stocks are beginning to deplete and may begin to draw the attention of both government and environmental groups world wide. CITES also stressed that tourists visiting Caribbean destinations should not purchase conch meat or shells as United States law enforcement officials have the right to confiscate these items at the border (Barclay 2003). With this ban, it is hoped that the lack of demand will result in fewer conchs being harvested.

There is much to learn from the study of Mollusca. They are very useful not only as bioindicators of pollution, but also for medical purposes. Recently, the toxin from *Conus magus* has been used in the development of the strong pain medication, Prialt. Many scientists believe other *Conus* species may yield more medicines in treating disease such as Alzheimer's, Parkinson's and epilepsy (BBC News 2006). According to Humann and Deloach (2002) species such as *Conus floridanus, Conus cedonulli* and *Conus regius*, all of which secrete a neurotoxic venom, are located in the eastern Caribbean waters surrounding Dominica. During the survey time frame, the shells from both a *Conus floridanus* and *Conus regius* were collected from the beaches of Dominica. This proves that the greater the knowledge base of molluscs in Dominica, the greater the justification for conservation of this phylum.

Acknowledgments I would like to thank Sascha Steiner for his guidance and assistance as well as coordinating access to the sites. Keira Macfarlane and Lori Price must be gratefully acknowledged for their advice and assistance both in the field and on this presentation. Thanks also to Robert Brewer, Alexandra Clermont, James Ritzmann and Ashley Walchuk for their participation and assistance in data collection. Also, thanks to Ross Mayhew for his identification of the shells, *Thais deltoidea, Thais rustica* and *Neritina sp.*

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Table 1 – Distribution of mollusc species across surveyed sites. A black circle (•) indicates that the species was abundant (more than 10 sightings), a circle with a line through (□) indicates that the species was occasional (2-10 sightings) and an open circle (o) indicates that the species was rare (seen only once). A triangle (Δ) indicates that the species was identified but not during the survey timeframe. Site 1: Scotts Head, 2: Lauro Shallow, 3: Douglas Bay, 4: Cabrits Pier, 5: Espagnole Bay Shallow, 6: Espagnole Bay Deep, 7: Fond Cole, 8: Champagne, 11: Anse Mulatre #1, 12: Anse Mulatre #2, 13: Anse Mulatre #3, 14: Rodney's Rock, 18: Mero to East Carib Dive #2, 19: Mero to East Carib Dive #3, 22: Mero to St. Joseph's #1, 23: Mero to St. Joseph's #2, 28: Colihaut, 31: Grand Savanne to East Carib Dive #1, 32: Grand Savanne to East Carib Dive #2 and 33: Grand Savanne to East Carib Dive #3.

	SITES																			
SPECIES	1	2	3	4	5	6	7	8	11	12	13	14	18	19	22	23	28	31	32	33
Acanthopleura granulata									•		•	•		•		•	Δ			•
Cittarium pica											□					o				□
Cyphoma gibbosum							Δ												□	
Dendosrea frons								Δ					o							
Elysia crispata						Δ														
Isognomon bicolour												□		o		□				
Lima scabra							Δ		Δ				□	□			o			
Lithopoma tectum					o			Δ				o								
Micromelo undata	o																			
Octopus vulgaris				o				Δ		o					o					
Pinna carnea	o			Δ			o	□												
Sepioteuthis speioida																	Δ			
Spondylus americanus													o		□				o	
Thais deltoidea	□	•	□				o	•	•	o	•	•		□		□	o	□		•
Thais rustica			□					Δ	□		o	o				□				□
Unidentified Bivalve 1																o				
Unidentified Bivalve 2																□				
Unidentified *Limpet*																□				
Unidentified *Neritina* sp												□				□				

Table 2 – Species sighted at estimated depth ranges from 0-5m.

Species	**Depth Range** 0-1m	1-3m	3-5m
Acanthopleura granulata	•		
Cittarium pica	•		
Cyphoma gibbosum		•	
Dendostrea frons		•	
Elysia crispate			•
Isognomon bicolour	•		
Lima scabra		•	
Lithopoma tectum		•	
Micromela undata		•	
Octopus vulgaris		•	•
Pinna carnea		•	
Sepioteuthis spedioida		•	
Spondylus americanus		•	•
Thais deltoidea	•	•	•
Thais rustica	•	•	
Unidentified Bivalve 1	•		
Unidentified Bivalve 1	•		
Unidentified Limpet	•		
Unidentified *Neritina* sp.	•		

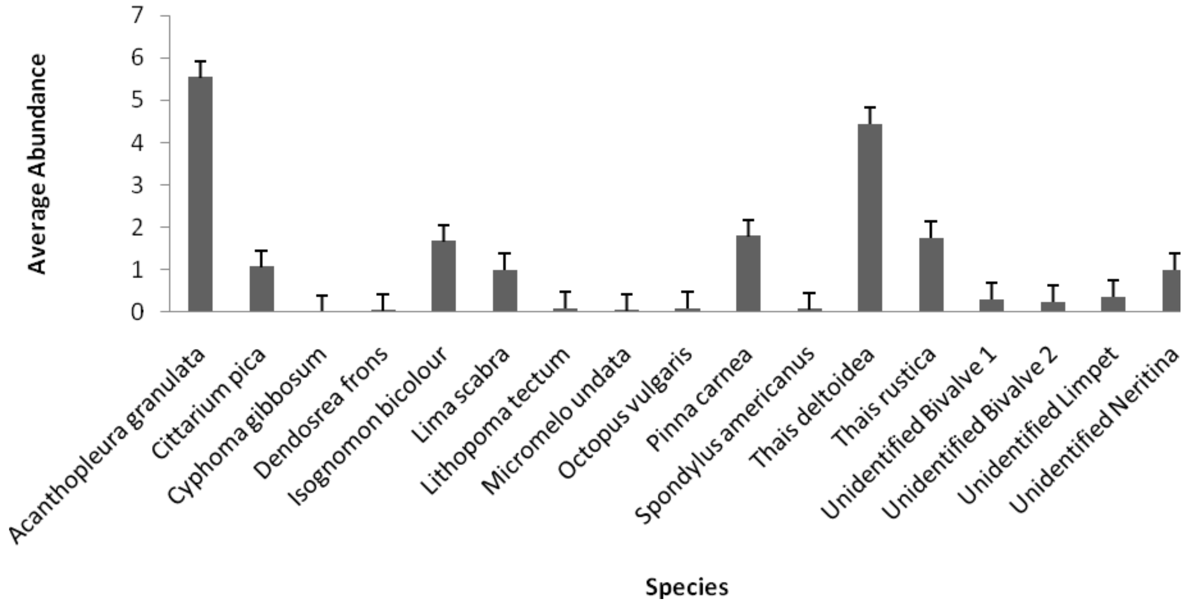

Figure 1 – Average abundance ± S.E. of species across surveyed sites.

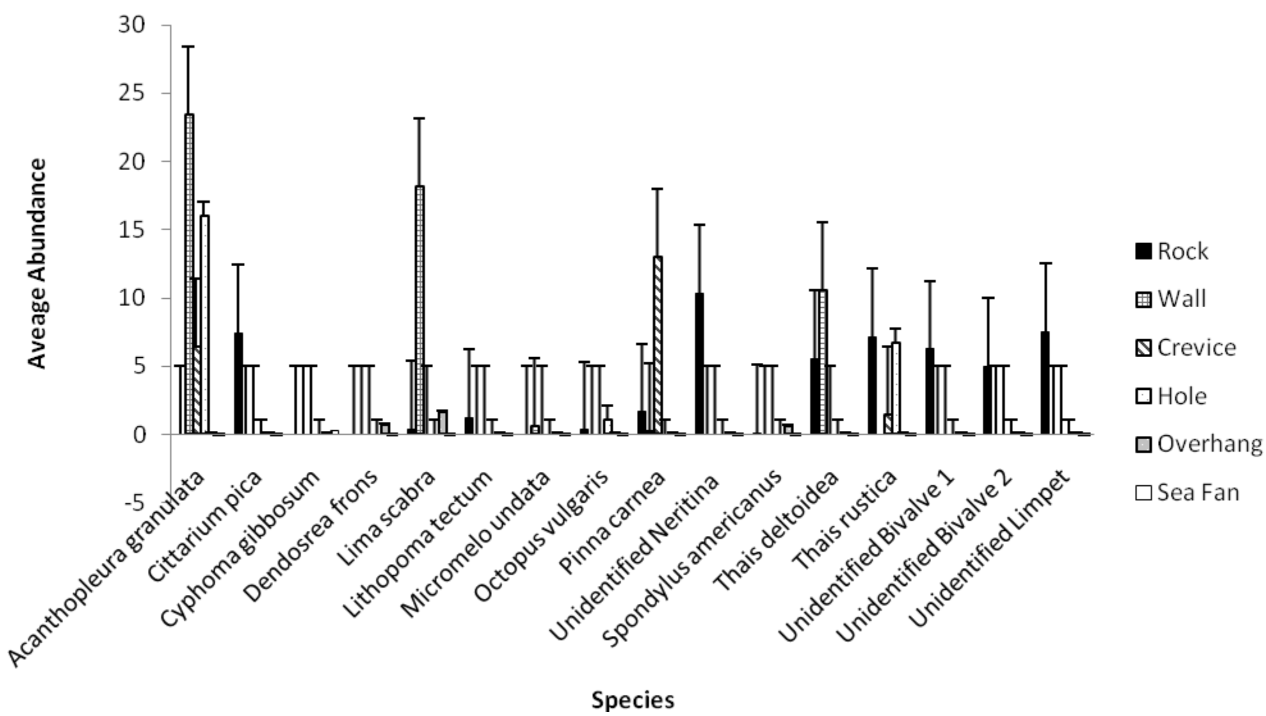

Figure 2 – Average abundance of molluscs ± S.E. depicting habitat preference.