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# The Impact of Crown Conch on Intertidal Oyster Populations in Mosquito Lagoon

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**ABSTRACT:** Commercial oyster harvesters in Florida have long complained that the Florida crown conch *Melongena corona* is in competition with them for harvestable-sized eastern oysters (*Crassostrea virginica*). Harvesters also suggest that crown conch, rather than overharvesting, has led to a large decline in oyster populations. To determine the role of *M. corona* on oysters in Mosquito Lagoon, we must first better understand the biology and ecology of *M. corona*, and to comprehend crown conch biology in Mosquito Lagoon along the east coast of central Florida, we conducted a three-part experiment in Canaveral National Seashore (northern Mosquito Lagoon). Specifically, we designed a field feeding trial to determine prey oyster size preference. To this end, we executed surveys of oyster reefs to gauge the population density of *M. corona* in Mosquito Lagoon and tracked conch movements in intervals to determine locomotive capabilities. Our results indicate *M. corona*: 1) was uncommon in Mosquito Lagoon, with the exception of hotspots, 2) did not selectively forage based on tested oyster shell lengths, and 3) moved a mean of 63.5 meters in 24 hours. Based on our abundance data, we estimate that there are 5137 *M. corona* across 2802 oyster reefs in Mosquito Lagoon (mean: 0.01 conch/m<sup>2</sup>, with 0.75 conch/m<sup>2</sup> in hotspots). More common were thin stripe hermit crabs (*Clibanarius vittatus*) occupying shells that once housed *M. corona*. Therefore, it is not likely that *M. corona* has played a significant role in oyster population declines in Canaveral National Seashore.

**KEYWORDS:** crown conch, *Melongena corona*, oyster, Mosquito Lagoon, estuary, overharvesting

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## INTRODUCTION

### *Background*

*Crassostrea virginica*, the eastern oyster, is a gregarious, estuarine invertebrate species (Manis et al. 2015). The historical distribution of *C. virginica* ranges from the Gulf of Mexico to the Atlantic coast of the United States as well as the Caribbean (Byers et al. 2015). Oysters form reefs in subtidal and intertidal habitats in the United States (Johnson & Smee 2014), and both reef habitats fill an important ecological niche in estuarine ecosystems (Manis et al. 2015). Oysters improve water quality, promote denitrification, and obtain nutrients via filter-feeding (Byers et al. 2015), while oyster reefs aid in shoreline stabilization by minimizing sediment erosion and by trapping sediments (Manis et al. 2015). In addition, by providing habitat and prey for a myriad of commercially and recreationally important species, oyster reefs also help to maintain high biodiversity levels in estuaries (Byers et al. 2015).

Both vertebrates and invertebrates can be found in abundance on oyster reefs (Solomon et al. 2014, Volety et al. 2014). Wading bird species, such as the American oystercatcher, and invertebrate species including blue crabs, stone crabs, and the Atlantic oyster drill, a small gastropod snail, are all predators of *C. virginica* (Carroll et al. 2015; Carlson-Bremer et al. 2014; Harding et al. 2007). Oysters are also an essential food source for *Melongena corona*, the Florida crown conch (Bowling 1994). *Melongena corona* is an intertidal gastropod, identifiable by the prominent, protruding vertically-curved spines on the whorls of its shells (Ruppert & Fox 1988). Shell coloration appears in thick bands and varies from brown to purple-grey (Ruppert & Fox 1988). This gastropod can grow up to 200 mm in shell length (Kaplan 1988). Its distribution includes Alabama and the entire coastline of Florida (Karl & Hayes 2012). Individuals are temperature sensitive and are vulnerable to mortality during winter months due to decreasing air and water temperatures (Loftin 1987). It is hypothesized that *M. corona* bury into the sediment during winter to escape frigid temperatures (Hathaway 1957). Conch will also bury partially into the sediment during low tide to avoid exposure, only surfacing when the reefs are inundated (Hamilton 1996). The thin stripe hermit crab, *Clibanarius vittatus*, seeks refuge in *M. corona* shells once the gastropod has died. These soft-bodied creatures with no shell of their own need gastropod shells for protection and survival (Tricarico & Gherardi, 2006). Hermit crabs

are attracted to conch shells via chemical cues signaling a nearby injured gastropod (Diaz et al. 1995).

### *Research Question*

Commercial oyster harvesters throughout Florida have long complained that *M. corona* competes with them for harvestable-sized oysters (Edwards 2011). This is especially true in Mosquito Lagoon where between 1943 and 2009 oyster reefs have declined by 24% (Garvis et al. 2015). Mosquito Lagoon, the northernmost region of the Indian River Lagoon system, is an estuary located on the east coast of central Florida (Parker et al. 2013). It is 54 km long and 4 km wide with two narrow outlets connecting to the Atlantic Ocean: Ponce de Leon Inlet to the north and Haulover Canal, built in 1887, to the south (Gold & Richardson 1994). This water body separates the barrier island from the mainland. A large portion of the barrier island houses Canaveral National Seashore. Mosquito Lagoon is often hypersaline in contrast to other estuaries, having salinity values equivalent to or higher than that of the Atlantic Ocean (Parker et al. 2013). This estuary contains many habitat types, primarily salt marshes, mangrove stands, seagrass beds, and intertidal oyster reefs.

In Canaveral National Seashore (CANA), shellfish licenses have been historically available to commercial and recreational oyster harvesters. For commercial harvesters, licenses cost \$150 per year and allow them to collect a daily quota of 14 bushels of oysters, over 75 mm in length, per person per day. Licensed recreational harvesters can collect two 5-gallon buckets per day. Although the impact of oyster harvesting has not been explicitly studied in Mosquito Lagoon, oyster fisheries in the United States have resulted in an overall 99.7% decline in oyster population after harvesting practices began in the late 19th century (Wilberg et al. 2011).

Oyster harvesters have observed population declines in Mosquito Lagoon and have suggested to the CANA Research Management Specialist that these declines were the result of *M. corona*, rather than overharvesting, and that predation by large numbers of *M. corona* is the cause of the observed systematic declines in local oyster reef populations. To test this claim, we conducted a three-part experiment to determine the impact of *M. corona* on oyster populations in Mosquito Lagoon. Our study focused on 1) abundance and distribution, 2) feeding preferences, and 3) movement of *M. corona*.

## MATERIALS AND METHODS

Garvis and colleagues (2015) have documented that there are three intertidal oyster reef types in Mosquito Lagoon: functional natural reefs, dead reefs, and functional restored reefs. Natural oyster reefs are reefs with large numbers of live adult oysters, are submerged at high tide, and have minimal, if any, dead margins (bleached white piles of disarticulated oyster shells) on their seaward edges (Garvis et al. 2015). Many oyster reefs near boating channels have accumulated significant dead margins and have since undergone restoration efforts making them, once again, functional reefs (Garvis et al. 2015). Dead reefs are comprised of only disarticulated shell (Campbell 2015; Garvis et al. 2015).

In our field research in CANA, we examined: 1) natural reefs adjacent to boating channels, 2) natural reefs not adjacent to boating channels, and 3) restored oyster reefs. Restored reefs were only located along boating channels as boat wakes cause the development of dead margins (Grizzle et al. 2002; Campbell 2015). We used natural reefs adjacent to and away from boating channels, since intense boating activity (40+ boats per hour) may directly impact *M. corona*.

### *Abundance and Distribution*

We administered detailed surveys to estimate the population of *M. corona* on intertidal oyster reefs in CANA, six of each reef type, for a total of 18 reefs. Teams of observers completely covered each reef type at low tide. Specifically, observers stood one meter apart spanning laterally across the reef starting at one edge. Observers walked in straight lines across the reef. This was repeated until the entire reef was traversed, enabling 100% cover of each reef. To account for any *M. corona* just off the reef footprint, observers also surveyed one meter beyond the edges of all reefs. All large gastropods were identified to species, measured for shell length, and returned live to their original location on the reef. To determine if a shell was empty, observers poked into each shell with a wooden rod or left the shell out of water for a minimum of five minutes to determine if an occupant would become visible. The number of all gastropod egg cases on and within one meter of all reefs was also recorded.

In addition, we conducted our surveys seasonally to determine any variation in population sizes and shell lengths of *M. corona*. The winter survey was conducted

in February/March 2014, the early summer survey took place on 17 May 2014, and the fall survey occurred between the 6 and 7 September 2014. To analyze variation of conch shell size among seasons, we conducted a one-way ANOVA.

### *Feeding Trials*

To determine the relative feeding preferences of *M. corona* for live oysters of different sizes, we also conducted an *in-situ* cage experiment in CANA waters. The goal was to examine the relationship between shell lengths of *M. corona* and the sizes of the oysters they can consume. Twelve 0.5 x 0.25 x 0.25 meter rectangular mesh cages (mesh diameter: 1.9 cm) were placed in Mosquito Lagoon at a depth that ranged from 0.5 to 1.0 meter below water, depending on the tide. Concrete irrigation weights were used to secure the cages in place, and one *M. corona* and one oyster were placed in each cage. Three cages contained one small oyster (2.5 - 4.4 cm in length), three contained one medium-sized oyster (4.5 - 6.4 cm in length), and three contained one large oyster (6.5 - 8.4 cm) (Table 1). We randomized the shell length of each *M. corona* relative to cage number and conducted three trials between 1 and 30 June 2014, each having a duration of 72 hours. At the end of each trial, oysters were recorded as fully consumed (hinged oyster shell separated, no soft tissue of oyster remaining), partially consumed (hinged oyster shell intact but open, some soft tissue removed, oyster dead), or not consumed (oyster shell intact, oyster alive). Each *M. corona* was only used in one feeding trial and then was released on an oyster reef after the trial ended. Using JMP Pro 11 software, we conducted a regression analysis using a linear fit model to determine if there was a significant correlation between conch shell length and consumed oyster shell length.

### *Conch Movements*

Lastly, we conducted a tracking experiment to determine the distance and speed at which *M. corona* travels on and between reefs. Specifically, we conducted three replicate trials on intertidal oyster reefs at high tide when conch are most active. A trial consisted of five *M. corona* on each of the three reef types. Each *M. corona* within a trial was considered a single replicate, and each trial lasted 60 minutes with observations made at six 10-minute intervals. *Melongena corona* were individually identified with tags created from plastic disks (diameter: 0.5 cm) that were attached to the top (dorsal region) of the shell with super glue. In preliminary trials where individual

movements were tracked before and after tag placement, we determined that the tags did not interfere with locomotion after they were attached.

At the beginning of each trial, each *M. corona* was placed at the center of a reef. No con-specific individuals or hermit crabs were nearby to avoid any responses to chemical cues. We placed flags attached to wire stakes adjacent to *M. corona* to mark the start location of an individual, and we marked the subsequent location at each 10-minute interval. Flags did not obviously impact conch movements, nor did the presence of an observer stationed a minimum of four meters away. The linear distance between flags was measured with metric transect tape measures. The distance moved in each 10-minute interval was averaged per individual conch and then by reef type. After averaging the distance traveled per 10 minutes for each reef type, the values were scaled up by a factor of 6 to acquire an hourly locomotion rate, and then by 24 to determine how far *M. corona* are capable of traveling in one day. Individuals were then released at the end of each trial.

## RESULTS

### Abundance

A total of 33 live *M. corona* were found during our surveys when all observation dates were combined. No *M. corona* were found in the winter, six were found during early summer, and 27 were counted in early fall. More than half (61%) of these observed individuals were located on one reef in fall 2014. Hence this location was considered to be a hotspot for *M. corona*. A total of 108 shells of *M. corona* (no live animal) were found when all surveys were combined (Figure 1). Forty-one of these shells were encountered off the reefs, but within one meter of the reef edges. Shells without *M. corona* were either occupied by *C. vittatus* (55.3%) or were extensively damaged and appeared empty (30). Six shells of the Florida horse conch, *Triplofusus giganteus*, were found when all reefs were combined. Four of these were apparently empty shells. Two live tulip snails, *Fasciolaria tulipa*, were found on natural reefs not along a boating channel. Five shells of the Atlantic moon snail, *Polinices duplicatus*, were also found on natural reefs, both on and not along boating channels. All five shells were occupied by *C. vittatus*. No egg cases were found on any reef in any season. However *M. corona* egg cases were found outside of the monitoring areas during the early summer and fall surveys.

There was no seasonal effect on *M. corona* densities (ANOVA:  $p = 0.107$ ) or shell lengths (ANOVA:  $p = 0.930$ ). Individuals found during the early summer surveys had a mean shell length ( $\pm$  S.E.) of  $9.0 \pm 0.4$  cm compared to  $8.3 \pm 0.3$  cm in the fall (Figure 2). During the summer, the smallest *M. corona* found was 4.0 cm, while the largest 12.6 cm. Live *M. corona* ranged in size from 3.9 cm to 13.5 cm in the fall.

### Feeding

During the three feeding trials, 50% of the oysters were consumed. There was no correlation between consumed oyster shell length and shell length of *M. corona* ( $r^2 = 0.1237$ , Figure 3). Two conch were dead at end of the 72-hour trial; one shell already housed a hermit crab. The oysters in these cages had not been consumed and were thus not included in the analyses. On one occasion, the *M. corona* laid an egg case on the cage mesh.

### Tracking

Individuals were found to travel fastest on reefs along boating channels, averaging 47.8 centimeters per 10-minute interval. In contrast, *M. corona* were slowest, at 39.5 centimeters per 10-minutes, on reefs not along boating channels. Conch averaged 45.2 centimeters per 10-minutes on restored reefs. Hence, overall, *M. corona*, traveled a mean of 44.1 centimeters in 10 minutes. The longest distance an individual traveled in a 10-minute interval was 184 centimeters. There were 52 instances when *M. corona* did not move during a 10-minute interval, but all individuals moved some distance during the 60-minute trials. *M. corona* were able to travel between 2.37 meters per hour and 2.87 meters per hour, with a mean of 2.64 meters per hour.

## DISCUSSION

Oyster harvesters attribute oyster population declines in Mosquito Lagoon to predation by *M. corona*. To test this, we conducted a three-part experiment in CANA to determine the impact of *M. corona* on intertidal oyster populations. We found that individuals tested in this study were not selective when feeding and consumed all sizes of oysters presented to them. Conch traveled approximately 0.5 meters in a 10-minute interval or 5 cm/minute. Although harvesters insist *M. corona* are abundant enough to cause declines in oyster reef populations, this study revealed that *M. corona* can only be found in detectable numbers in a few hotspots, but are



absent otherwise or their shells are occupied by hermit crabs (Table 2).

Our data suggest that *M. corona* likely did not decimate large numbers of oysters in CANA. Garvis et al. (2015) reported that there are an average of 100 live oysters per square meter in Mosquito Lagoon. As there are 2,802 oyster reefs in Mosquito Lagoon (Garvis et al. 2015), and if one in 18 reefs are hotspots, then 156 reefs should be hotspots. Based on our observations and the number of reefs, it is estimated that 5137 live *M. corona* were present in Mosquito Lagoon during fall at peak density. Using this density and the aerial extent of oysters in Mosquito Lagoon, we calculated that there are approximately 14,800,000 live oysters in the waterbody. If 50% of conch eat an oyster in three days, this equates to one conch eating five oysters in a 30-day period. If approximately 25,000 oysters are consumed per month by *M. corona* (5,137 *M. corona* x 5 oysters per month), then their total consumption of oysters equates to only 0.17% of the oyster population consumed monthly, or 2.09% annually, by *M. corona* in Mosquito Lagoon. This conclusion assumes the oyster population is static. It is not, and there are new recruits entering the system each year from April to December (Garvis et al. 2015). In 2014, the mean was 222 new oysters per square meter (L. Walters, unpublished data). Combined, the data suggest that the *M. corona* have very little impact on the oyster population.

Most of the *M. corona* (61 %) were found on one of the surveyed reefs in fall 2014. It was a restored reef adjacent to a boating channel. Thus, we predict that in Mosquito Lagoon, *M. corona* is patchily distributed, and most obvious when located in hotspots, where higher densities could lead to misinterpretation of overall numbers in the lagoon. Abiotic factors, such as water flow or turbidity, or biotic factors, such as recent mating aggregations or recent hatching events, could also impact distributions.

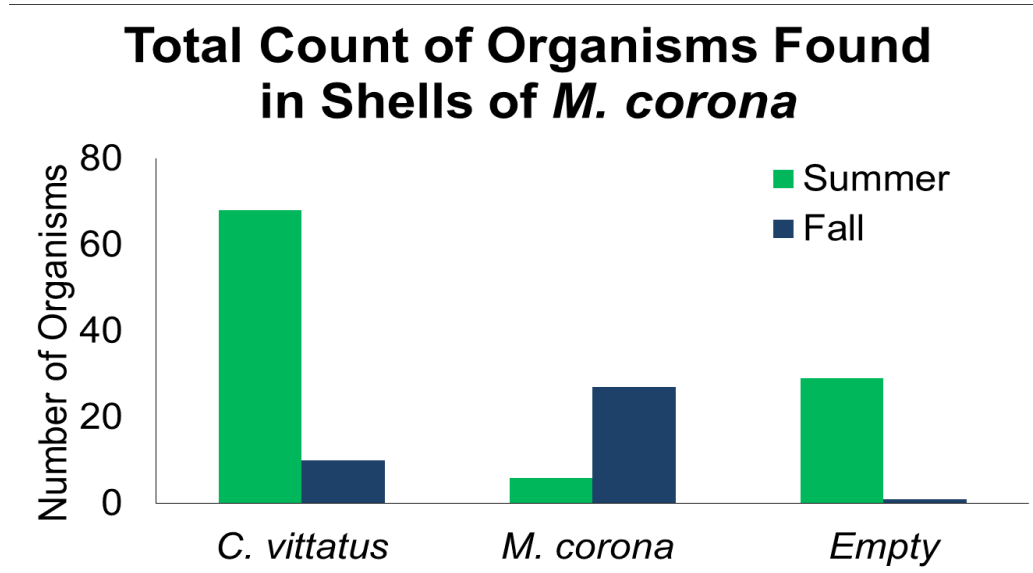
Oyster harvesters likely mistake empty *M. corona* shells or shells occupied by the striped hermit crab, *C. vittatus*, for live conch. This mistake is easy to make, unless you examine each shell individually. There were approximately 2.4 *C. vittatus* occupying *M. corona* shells for every one conch in Mosquito Lagoon. Empty *M. corona* shells were often disintegrating or acting as substrate for oysters or sessile fouling organisms, such as barnacles and anemones. Shells were often empty if there was any visible damage to the shell.

The results from our tracking experiment also illustrate *M. corona* is capable of traveling among oyster reefs that are considerable distances apart. After averaging the distance traveled per 10 minutes for each reef type, the values were scaled up by a factor of 6 to acquire an hourly locomotion rate, and then by 24 to determine how far *M. corona* are capable of traveling in one day. In a 24-hour period, our results suggest that *M. corona* is capable of traveling 63.5 meters. However, no conch were observed leaving the reefs during the tracking experiment. If resources were not sufficient on a particular reef or abiotic variables were problematic, an individual should be capable of relocating to a more hospitable reef.

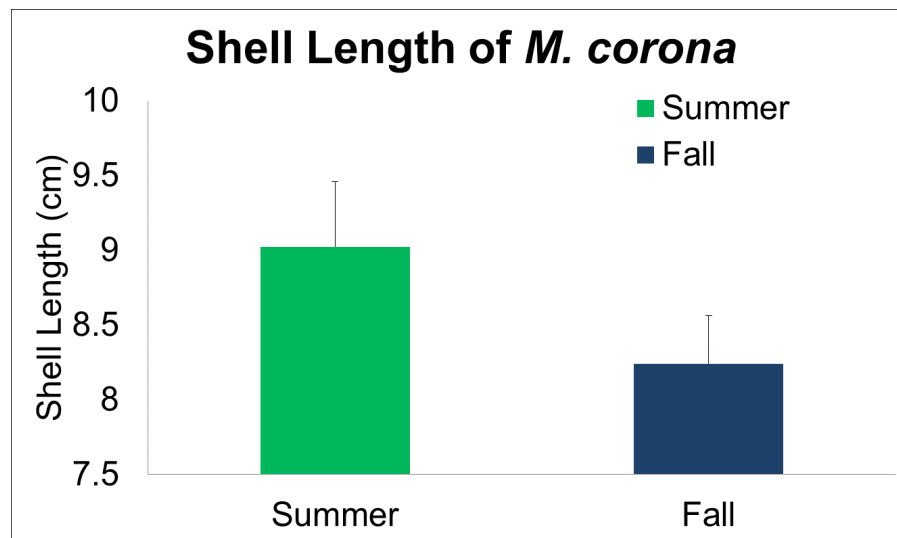
In summary, our results suggest that any observed declines in Mosquito Lagoon oyster populations are not primarily the result of ecological stress associated with *M. corona* predation. While this is true for Mosquito Lagoon, live conch numbers need to be assessed location by location. A question is now raised for Mosquito Lagoon resource managers: what is responsible for oyster population declines? Garland and Kimbro (2015) suggest that high salinity, due to a prolonged drought, is to blame because disease and predator populations flourish in these conditions. Brown tide (*Aureoanmbra lagunensis*) has also been linked to lower oyster growth and survival (Gobler et al. 2013; Makris 2016). In addition, with oyster harvesting being on record for having negative impacts on oyster reefs in national surveys, we recommend reviewing existing harvesting regulations and licensing laws to better determine the extent of this anthropogenic influence.

**APPENDIX A**

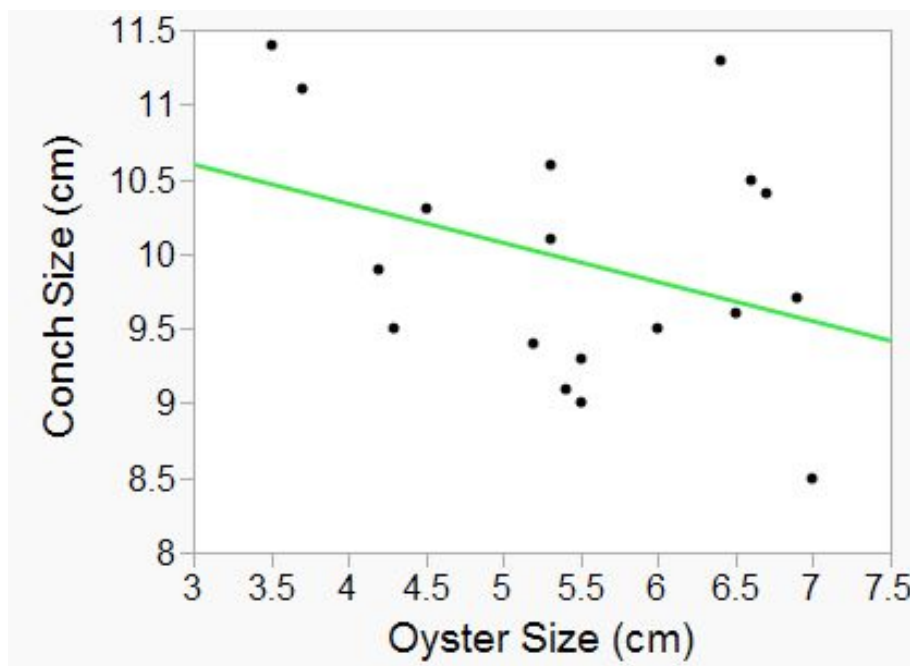
**Figure 1:** Total count of all live *M. corona*, the hermit crab *C. vittatus* in shells of *M. corona*, and empty shells of *M. corona* by season. No individuals were found during winter surveys.



**Figure 2:** Mean shell lengths of live *M. corona* ( $\pm$  SE) from summer and fall surveys. There was no significant difference in shell lengths between seasons (ANOVA:  $p = 0.107$ ).



**Figure 3:** Regression model illustrating no significant correlation between live *M. corona* shell length (cm) and prey oyster shell length (cm) ( $r^2 = 0.123685$ ; conch size =  $11.390006 - 0.262133 \times$  oyster size).





**APPENDIX B**

**Table 1:** Feeding trial oyster size categories and size ranges. Minimum size to harvest oysters in Florida is 7.5 cm. *M. corona* shell length varied from 8.1 cm to 11.4 cm, with a mean value of 9.9 cm.

Oyster Size Category	Size Range
Small	2.5 - 4.4 cm
Medium	4.5 - 6.4 cm
Large	6.5 - 8.4 cm

**Table 2:** Number of *M. corona* shell occupants in Mosquito Lagoon extrapolated from survey findings. The number of *M. corona* per reef was calculated based on survey findings (# found/18 reefs) and then scaled up by a factor of 2,802 (the number of oyster reefs in Mosquito Lagoon) to find the estimated number of each occupant in Mosquito Lagoon.

<i>M. corona</i> Shell Occupant	# Found	Percent	# in Mosquito Lagoon (estimated)
<i>M. corona</i>	33	23.4%	5,137
<i>C. vittatus</i>	78	55.3%	12,142
Empty	30	21.3%	4,670

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