Species abundance and distribution of squid in the eastern Gulf of Mexico and Tampa Bay with a focus on biology

By

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- Abstract -

Cephalopods were sampled in the eastern Gulf of Mexico and Tampa Bay and examined in terms of distribution, abundance, and biology. Preserved specimens collected in 2007 and 2012 were identified and catalogued to produce local maps of cephalopod abundance and distribution. Factors such as water temperature and salinity were taken into account when comparing these findings with past findings. This study improves upon knowledge of squid populations in the eastern Gulf of Mexico and the Tampa Bay region. In accordance with previous studies, *Doryteuthis plei* was the most abundant squid found in the eastern Gulf of Mexico. Also in accordance with previous studies, *Lolliguncula brevis* was the most abundant squid found in Tampa Bay, but particularly in the tributaries of Tampa Bay. The results of this study suggest there is a possible relationship between dorsal mantle length and water temperature. Particularly, the statistics suggest the higher the water temperature, the smaller the dorsal mantle length. However, the sample size is a limiting factor in making any concrete conclusions. There is a need for more research on major squid species in coastal waters, particularly in light of rising sea temperatures.

- Introduction -

Cephalopoda form one of the largest classes of the phylum Mollusca. They are exclusively marine and have been around for 500 million years (Nixon & Young 2003). They are considerably diverse and are grouped into two different subclasses: Coleoidea and Nautiloidea. A nautilus is part of the latter subclass and is the most primitive with an external shell. The Coleoidea class has not been around as long as the Nautiloidea but includes the rest of the cephalopods: the octopus, cuttlefish, vampire squid, and squid. Cephalopods are organisms that play important roles in the marine ecosystem (Clarke 1996). From shelled nautiluses to the giant squid, the class cephalopoda is composed of a variety of macroinvertebrates that share a predatory lifestyle (Rodhouse & Nigmatullin 1996). In turn, they are major food items in the diets of marine mammals, pelagic birds, and large fishes (Clarke 1996). They are also used as food for human consumption. Because of their highly developed brain and sensory organs, they are important experimental animals in biomedical research (Nixon & Young 2003). As an entirely coastal and generally limited to very shallow water species, the squid in the Loliginidae family are easily attainable to marine scientists for research. Taking into consideration studies from 1964 to 2002, this study will compare squid distribution and abundance in the eastern Gulf of Mexico and Tampa Bay and use physical factors to examine possible correlations. On a broader scale, it will examine and compare the biology of different species of squid found.

The eastern Gulf of Mexico

The Gulf of Mexico has a characteristic location. It is a partially land-locked, between-continent, marginal sea that is very different from the adjacent Atlantic Ocean. The total surface area of the Gulf of Mexico is 1.5 million square kilometers (Gore 1992). Submerged shallow and intertidal areas that are less than 20 meters deep make up the largest component of the Gulf of

Mexico (Moretzsohn et al. 2013). The continental shelf is between 20-180 meters deep, followed by continental slopes and abyssal or deep-sea basins (Figure 1).

The Loop current is essentially driven by wind and the incoming oceanic currents of the Atlantic Ocean and the Caribbean Sea (Moretzsohn et al. 2013). In the Gulf, seawater originates from the Caribbean Sea, enters through the Yucatàn Channel then circulates as the Loop Current, and finally exits through the Straits of Florida. It is common for the Loop Current to divide throughout the year, affecting regional current patterns. Drainage of water from the Mississippi River and other large rivers affect direction and flow of the current.

Sea surface temperatures fluctuate depending on the season. During the summer, the average surface temperature is 29°C. During the winter, the more southern portion of the Gulf has an average of 24°C while the northern portion has an average of 19°C (Gore 1992). Salinity levels in the Gulf of Mexico vary depending on location and season. Salinity values are usually from 24 to 37 parts per thousand (ppt).

Tampa Bay

Tampa Bay is located on the eastern central region of the Gulf of Mexico with a surface area of approximately 1000 square kilometers (Schmidt et al. 2004). It extends approximately 53 km inland from the Gulf of Mexico and receives freshwater from a 6,583 km^2 watershed. There are four sub-basins: Old Tampa Bay (OTB), Hillsborough Bay (HB), Middle Tampa Bay (MTB), and Lower Tampa Bay (LTB) (Figure 2). It has an average depth of 4.0 meters with a 10.0 meter deep shipping channel running from the mouth to HB (Chen 2006).

Circulation of Tampa Bay is driven by buoyancy, tides, and winds (Weisberg & Zheng 2006). Since Tampa Bay is an estuary, fresh water from adjacent rivers must travel to the Gulf of

Mexico. More than 100 tributaries and more than 40 brackish creeks and coastal streams flow into the bay, including the Alafia River and the Hillsborough River. Salinity levels in Tampa Bay vary by location ranging from the high teens to the mid-thirties. Salinity at the mouth of Tampa Bay ranges between 31-36 ppt (Schmidt et al. 2004).

Cephalopods

Cephalopoda form one of the three largest classes of the phylum Mollusca, arising approximately 500 million years ago (Nixon & Young 2003). Characteristics such as a closed circulatory system, a complex nervous system, a highly modified true coelom and a predatory lifestyle help define and distinguish cephalopods from other molluscs (Brusca & Brusca 2003). There are two major subclasses of Cephalapoda. Subclass Nautiloidea includes *nautilus*. Subclass Coleoidia includes all other cephalopods: squid, cuttlefish, and octopods (Figure 3).

Cephalopods are exclusively found in marine habitats of the world: both pelagic and benthic in bays, seas and the open ocean. Depth of distribution ranges from the surface to over 5000 m (Roper 1984). Approximately 50% of cephalopod genera are found in the open ocean suspended at all levels of the water column (Ruppert et al 2004). Cephalopod diversity is higher at the bottom of both shallow and deep seas (Clarke 1996).

Squids are found in all marine habitats of the world. Adult squids range in size from less than 10 mm dorsal mantle length (DML) to over 2 m DML depending on the species (Jereb & Roper 2005). They are soft-bodied, bilaterally symmetrical animals with a developed head and body that is made up of a muscular mantle, the mantle cavity, and the external fins. The head bears a crown of 8 arms and 2 tentacles that have suckers and/or hooks. The mouth has a beak and radula. The coleoids have short life spans, varying from less than 1 year to 5 years (Nixon &

Young 2003). For example, some live only one to three years, dying after a single spawn (Ruppert et al. 2004).

There are two suborders of squid: Oegopsina and Myopsina (Nixon & Young 2003). A thin transparent cornea covers the eyes of members of the suborder Myopsina. Pickfordiateuthidae and Loliginidae are the two families of Myopsina that are found in coastal waters. Loliginids live on the shelf and upper slope areas of the ocean in tropical and temperate waters. The family Loliginidae includes the genus *Doryteuthis* and *Lolliguncula*. *Doryteuthis plei (D. plei), Doryteuthis roperi (D. roperi),* and *Doryteuthis pealeii (D. pealeii)* are found in the continental shelf an upper slope waters (figures 4-6). *Lolliguncula spp.* are found in warm, shallow inshore waters. *Lolliguncula brevis (L. brevis)* occurs primarily in bays and in near shore waters to depths of 20 m (Figure 7). It is a small sized squid that tolerates low salinities (Jereb & Roper 2005).

As predatory carnivores, squid feed on a wide range of prey to achieve high growth rates and maintain a fast metabolism. The functional mouth of cephalopods is the brachial crown which captures, envelopes, and immobilizes prey (Rodhouse & Nigmatullin 1996). All cephalopods have a radula for rasping or drilling their prey. Some inject a neurotoxin to prevent struggle from the often larger prey (Brusca & Brusca 2003). Their diet, however, depends on their habitat. Pelagic squid feed on fish, crustaceans and other squids. Cuttlefish feed on epibenthic invertebrates, for example shrimp and crabs. Both cuttlefish and squid tear prey with their beak. Some octopods feed on clams, snails, and crustaceans, injecting them with a poison. Other octopods are suspension feeders. Nautilus feed on benthic crustaceans (Ruppert et al 2004). Newly hatched cephalopods feed on plankton (Rodhouse & Nigmatullin 1996).

Sexes are separate in all cephalopods. Adults can vary in size; depending on the species some males are larger than the female and vice versa (Nixon & Young, 2003). One or more of the arms of the male, called the hectocotylus, is modified upon maturity for exchanging sperm to the female. The modification varies but typically involves modification of the tip of an arm to pick up and transfer spermatophores (Ruppert et al. 2004). During copulation, the hectocotylus is inserted into the female's mantle cavity. Coleoids breed only once before dying, while *Nautilus* can breed annually for a number of years (Ruppert et al 2004).

Distribution of the major groups differs between coastal areas and the oceans and seas. The squid family Loliginidae is typically limited to coastal regions of the shelf that is less than 200 meters deep (Boyle & vonBoletzky. 1996). The bottom dwellers Sepiida, Sepiolida, and Octopodinae and the nektonic Myopsina squids are found in coastal waters. Families of the teuthins squids and Spirulida, Vampryromorpha, Cirroctopoda, and Octopoda generally dominate the oceans and seas (Nixon & Young 2003).

On the shelf, cephalopods are outnumbered by similar-sized fish. In oceanic waters, they are structurally diverse and play a greater role in trophic dynamics than in shallow seas (Clarke 1996). There are a higher number of species living on the western margins of the ocean compared to the eastern margins. The most abundant cephalopod fauna is found along the coastlines of the western Pacific (Nixon & Young, 2003).

Cephalopods are important as predators and as food of top predators in and above the sea. Upon hatching, paralarvae and juvenile squids feed on small fish, crustaceans and other small organisms their size. Both muscular and non-muscular squid feed on paralarvae and juveniles. Oceanic birds such as petrels prey on larval and juvenile squid. Billfish, broadbills, marine mammals, and tunas feed on muscular squids such as ommastrphids, loliginids and non-muscular squids (Clarke 1996).

Research Goals

1. To compare the squid distribution and abundance to other studies in a similar environment and use physical factors (temperature, salinity) to examine possible correlations
2. To examine and compare the biology of different species of squid found in the eastern Gulf of Mexico and Tampa Bay

- Materials and Methods -

Sampling

A total of 170 squid were collected from the eastern Gulf of Mexico and Tampa Bay in 2007 and 2012 during research cruises by the Florida Fish and Wildlife Conservation Commission (FWC). The two sets of cruises (2007 and 2012) are not related. The study area extended from 26-28°N and 81-84ºE. In 2007, the samples were collected throughout the months of May-August from seasonal baitfish cruises in the Gulf of Mexico. Collections were made with 6.1 m otter trawls with 38-mm stretch mesh and 3-mm mesh liner. In 2012, the samples were collected throughout the month of April in the eastern Gulf of Mexico as part of the Fisheries-Independent Monitoring program that conducts stratified-random sampling to estimate fish abundance and population trends. Each tow lasted five to ten minutes. In depths less than 1.5 m, a 21.3 m bay seine technique was used. Squid that were captured were immediately put into sea water for preservation. Samples were initially preserved in seawater but upon returning to the lab after the cruise, they were put in a 50:50 formalin/seawater mixture. Water temperature, salinity, and depth data were available for the 2007 cruises. Water quality parameters such as depth, temperature, dissolved oxygen, conductivity, pH, salinity, and secchi disc measurements were taken at the trawl start position of the cruises in 2012. All values were put into an excel program for statistical analysis.

Laboratory Analyses

Each organism was identified to the lowest possible taxonomic level, in most cases to the species level with identification guides (Nesis 1987; Vecchione & Young 2010a, b, c, d; Jereb & Roper 2005). The sex was determined if possible. A dissecting microscope was used to identify small features and sex. Dorsal mantle length was measured with Vernier calipers (±.05 mm). Each specimen's mass was recorded on a digital scale (±0.005 g). These characteristics were recorded in excel for further analysis. After the specimens were analyzed, they were transferred from the 50/50 formalin/seawater mixture to a 50/50 isopropyl/water mixture for storage. Distribution maps were created with ArcView 9.2 for each representative species.

Statistical Analyses

The mantle length data were analyzed using an independent one-sample t-test for significance with $\alpha = 0.05$ in excel. The null hypothesis was that there is no significant difference in mantle length between the species being compared. Pearson's product-moment correlation coefficient was measured in excel between dorsal mantle length and salinity, depth, temperature, latitude, and longitude. A strong correlation was considered for $1 > r > 0.5$ or $-0.5 > r > -1$; a medium correlation for $0.5 > r > 0.3$ or $-0.3 > r > -0.5$; a weak correlation for $0.3 > r > 0.1$ or $-0.1 > r > -0.3$. A value of $r = 0$ meant that there was no correlation.

- Results -

Distribution and abundance

A distribution map was created for all squid collected (Figure 8). Distribution maps for each of the four squid species found within the eastern Gulf of Mexico and Tampa Bay were created (Figures 9-12). Four squid species were identified. *L. brevis* was exclusively found in Tampa Bay and neighboring tributaries (Figure 9)). *D. plei*, *D. pealeii*, and *D. roperi* were found on the continental shelf of the eastern Gulf of Mexico (Figures 10-12). The most frequent squid caught was *D. plei* with a frequency of 112. Next was *L. brevis* with a frequency of 43. *D. roperi* had a frequency of 2 and *D. paeleii* was the least frequent with a frequency of 1.

A number of factors were analyzed using all of the data to see what kind of result Pearson's correlation coefficient would yield. Depth and salinity, and temperature and DML were strongly correlated. Latitude and DML, and latitude and species have a medium correlation. Latitude and sex, longitude and sex, and depth and DML have a weak correlation. Longitude and DML were not correlated. Table 1 shows the correlation coefficient values for the factors analyzed.

D. plei was found at an average temperature of 19.15°C (±14 SD). *D. roperi* was found at an average of 20.98°C (±1 SD). *D. pealeii* was found at an average temperature of 20.7°C (±0 SD). *L. brevis* was found at an average temperature of 27.63°C (±1 SD). The *Doryteuthis spp.* were found at a similar average temperature, and *L. brevis* was found at a higher average temperature than the others (Figure 13).

D. plei was found at an average salinity of 36.29 ppt (±.66 SD). *D. roperi* was found at an average of 36.86 ppt (±.16 SD). *D. pealeii* was found at an average of 36.59 ppt (±0 SD). *L.*

brevis was found at an average salinity of 29.91 ppt (±2 SD). The *Doyteuthis spp*. were found at a similar average salinity, and *L. brevis* was found at a lower average salinity than the others (Figure 14).

D. plei was found at an average depth of 14.57 m (±7 SD). *D. roperi* was found at an average of 18.3 m (±8 SD). *D. pealeii* was found at an average of 25.62 m (±0 SD). *L. brevis* was found at the lowest average depth of 5.15 m (±3 SD) (Figure 15).

Biology

A total of 29 males and 122 females were identified. For the remaining 19, sex could not be determined because of the poor quality of the specimen. The sex ratio was 4.2 f: 1 m (Figure 16). Of the 29 males found, 22 were *D. plei*, 4 were *L. brevis*, 1 was *D. roperi*, and 1 was *D. pealeii*. Of the 122 females, 83 were *D. plei*, 33 were *L. brevis*, and 1 was *D. roperi* (Figure 17).

The range in DML for all squid captured was 7.5 mm to 243.7 mm (Figure 18). The average DML for *D. plei* was 83.7 mm (±39 SD), for *D. roperi* was 48.2 mm (±.4 SD), for *D. pealeii* was 45.6 mm (± 0 SD), and for *L. brevis* was 18.1 mm (±11 SD). T-tests were performed for DML between species to determine if the differences are statistically significant. They all yielded values of $p < 0.05$. Thus, the null hypothesis is rejected and the dorsal mantle lengths among species are significantly different.

- Discussion -

Distribution and Abundance

There were 4 squid species from 1 family examined in the present study. This number is smaller than that found in earlier larger studies (Dragovich & Kelly 1967; Passarella 1990;

Judkins 2009) in the same area. This study examined unidentified specimens from select research cruises conducted by FWC.

All squid found were in coastal environments—along the continental shelf, in bays, and in tributaries (Figure 8). All squid were in the family Loliginidae, dwellers of shelf areas of the world's oceans (Nixon and Young 2003). The abundance of organisms varied between species, with *Doryteuthis plei* (n=105), *Lolliguncula brevis* (n=37), *Doryteuthis roperi* (n=2), and *Doryteuthis pealeii* (n=1). *D. plei* was the most numerous in the eastern Gulf of Mexico, while *L. brevis* was most numerous in Tampa Bay and neighboring tributaries.

In a macro-invertebrate count study of Tampa Bay, *L. Brevis* was the second most abundant invertebrate found and was the only squid found (Dragovich & Kelly 1964). Old Tampa Bay, the upper portion of Tampa Bay and Hillsborough Bay, were the most abundant areas for this species (Dragovich & Kelly 1964). Similarly, this current study found that most *L. brevis* were collected around Old Tampa Bay and Hillsborough Bay. However, the most abundant area for this species was in a neighboring tributary of Hillsborough Bay, Alafia River (Figure 9). *L. brevis* is often caught in tributaries such as this because of salt influx from the neighboring bay. Bartol et al. (2002) focused on *L. brevis* distribution in Chesapeake Bay over 4 years, finding squid in both the bay and tributaries. However, in each year the proportion of *L. brevis* squid in the mainstem were higher than in the tributaries (Bartol et al. 2002). Since the current study sampled each site only once, multiple sampling may have possibly yielded similar results to the Chesapeake Bay study.

D. plei, *D. roperi*, and *D. pealeii* were found off the continental shelf of the eastern Gulf of Mexico (Figures 10-12). Similarly, in a past study of cephalopod biogeography in the Broad

Caribbean, *D. plei, D. roperi*, and *D. pealeii* were found throughout the Gulf of Mexico (Judkins 2009). *D. plei* was the most abundant squid (Judkins 2009). These results are concordant with the current findings, as *D. plei* was most abundant (n=105). Judkins (2009) found *D. pealeii* to be the second most numerous squid. In contrast, *D. roperi* was second most numerous (n=2) in the current study. This could be attributed to low sampling of the area and/or the season of collection.

In a macro-invertebrate count of Tampa Bay, *L. brevis* were located in a salinity range from 17.32 to 35.66 ppt (Dragovich & Kelly 1964). A few years later, a similar study found the squid in a more narrow range of 18.19 to 31.15 ppt (Dragovich & Kelly 1967). Both studies were over a 12 month period (Dragovich & Kelly 1964, 1967). Large ranges in salinity indicate that *L. brevis* tolerate brackish to saline waters (Nixon & Young, 2003). Under laboratory conditions, it was found that *L. brevis* can tolerate a salinity range from 17.5 to 36 ppt (Hendrix et al. 1981). Deaths occurred anywhere above or below this range (Hendrix et. al 1981). In the current study, *L. brevis* was found in brackish to saline waters with a salinity range of 24 to 31.8 ppt. These ranges can be attributed to collections in the near the mouth of the bay to in tributaries. The observed ranges in salinity can be attributed to the seasons during May to August of the squid collection. According to Dragovich and Kelly (1964) more frequent catches of *L. brevis* were made in late spring and summer. Seasonal salinity changes of Tampa Bay are associated with rainfall and land run-off (Dragovich & Kelly 1964).

An eight year study of distributions of *Lolliguncula brevis* was conducted in the Apalachicola estuary in North Florida. Migration of *L. brevis* is influenced by both temperature and salinity (Laughlin & Livingston 1982). When there were low squid numbers, there were low salinities (Laughlin & Livingston 1982). Similarly, in Chesapeake Bay the probability of catching *L. brevis* increased in higher salinities and water temperatures, and was much greater in normoxic than hypoxic waters. They were found at depths between 10 and 15 m. In this current study, *L. brevis* was captured between depths of 0.1 to 7.6 m. The low depths of capture can be attributed to the low average depth of Tampa Bay at 4.0 m.

Biology

L. brevis females have a maximum dorsal mantle length of 110 mm, while males have a maximum of 85 cm (Vecchione & Young 2010). *L. brevis* males generally mature at approximately 40 mm DML regardless of age; females do not mature before about 60 mm DML (Jackson et al. 1997). Applying Jackson et al's (1997) conclusions to the current study, all of the male and female *L. brevis* collected in this study were immature. Dragovich and Kelly (1963) concluded that sexually mature individuals are present in Tampa Bay at all times and thus breeding occurs throughout the year. However, this is contrary to what was found in the current study. It is important to take into consideration that not all areas of Tampa Bay were examined in the current study and thus there may have been sexually mature individuals at other sites in the bay. Further research at multiple sites throughout the bay is needed to form any firm conclusions.

The dorsal mantle length (DML) of *D. plei* males is up to 350 mm, and females is up to 220 mm (Vecchione & Young 2010b). This is concordant with what was found in the current study. All females have a dorsal mantle length of less than 220 mm and all males are less than 350 mm. *D. plei* mature over a broad range of sizes depending on season and locality (Vecchione & Young 2010b). The dorsal mantle length of *D. roperi* is up to 70 mm and maturity is attained as 40 mm (Vecchione & Young 2010c). Thus, both *D. roperi* collected in this study were mature. *D. pealeii* has a maximum dorsal mantle length of 470 mm, with males growing larger than the females (Vecchione & Young 2010a). According to the FAO Species Catalogue for Fishery Purposes No. 4, Vol. 2 (2005), the minimum mantle length of mature males and females are 61 and 73 mm, respectively. Thus, the *D. pealeii* collected was immature with a dorsal mantle length of 45.6 mm.

A squid's development can be attributed to factors such as water temperature. A number of studies show that cephalopods have different growth/maturation rates in response to different seasons or temperatures (Forsythe & Hanlon 1988, 1989; Bizikov 1991; Jackson 1993). The t-test conducted between *D. plei* and *L. brevis* DML in this current study shows that the measurements between species are statistically different. *D. plei* specimens have a larger mean DML than *L. brevis.* This difference in size can be attributed to a factor such as water temperature. *L. brevis* was found at a higher mean temperature than *D. plei*. This suggests a smaller dorsal mantle length like that found in *L. brevis* can be attributed to higher water temperatures. According to Pearson's correlation coefficient, DML and water temperature have a strong correlation (Table 1). A trend that can be made from this is as temperature increases, dorsal mantle length decreases. Oesterwind et al (2010) studied biology patterns of North Sea cephalopods, finding that size and growth are strongly correlated. Squid collected in winter had a higher mean dorsal mantle length than those collected in summer (Oesterwind et al. 2010). Additional t-tests were conducted between *D. plei* and *D. roperi*, and *L. brevis* and *D. roperi* yielding similar results. However, there were a limited number of *D. roperi* (n=2) collected. Thus, the power of the statistics is not strong enough to draw any firm conclusions.

Conclusion

The first portion of this study focused on squid distribution and abundance in the eastern Gulf of Mexico and Tampa Bay region. Species such as *Doryteuthis plei, Doryteuthis pealeii*, and *Doryteuthis roperi* found on the continental shelf were concordant with previous studies in the area. The frequent appearance of *Lolliguncula brevis* in tributaries of Tampa Bay was unexpected. This finding further suggests *Lolliguncula brevis* tolerates low salinities, high temperatures, and shallow water. Further records of squid distribution and abundance are needed at different times of the year to strengthen the compiled data. Additionally, research into the physiology of these inshore species may further both evolutionary and ecological understanding.

The second objective of this study focused on the biology of different species of squid found in the eastern Gulf of Mexico and Tampa Bay. A correlation was made between dorsal mantle length and water temperature. This suggests that environmental factors play a role in physical attributes of squid species according to the data. This is important because in light of global climate change and ocean warming, there may be a reduction in DML that may impact species fitness. However, the power of the statistics is not strong enough to draw any concrete conclusions. The relationship between dorsal mantle length and temperature could be looked at in future studies to see if ocean warming is indeed influencing the anatomy of different squid species. The findings of this report emphasize the importance for the need of more detailed information on major squid species in coastal waters, particularly in light of rising sea temperatures

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- Figures -

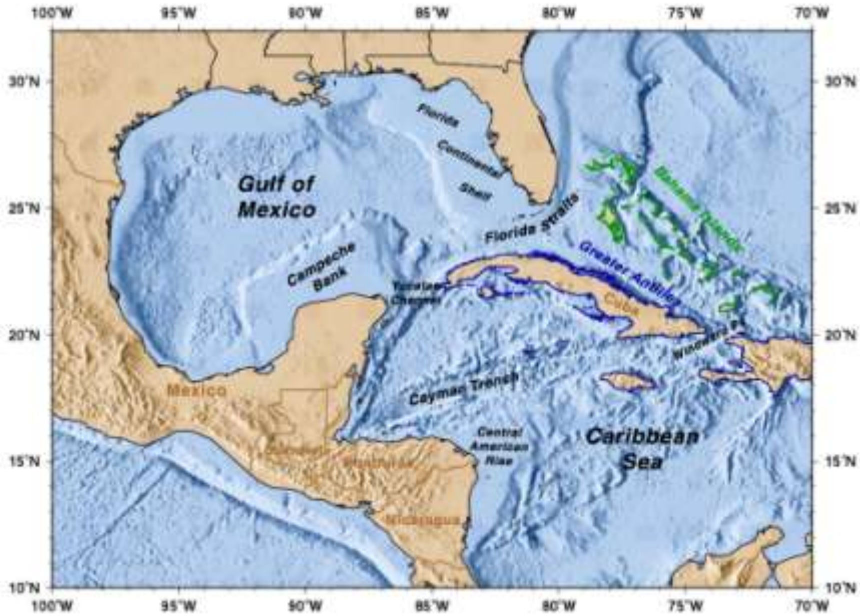

Figure 1. Gulf of Mexico. This figure illustrates the shelves of the Gulf of Mexico: study site 1 (Ryan 2001).

Figure 2. Bay Segments of Tampa Bay. This figure illustrates the sub-basins of Tampa Bay: study site 2 (Southwest Florida Water Management District).

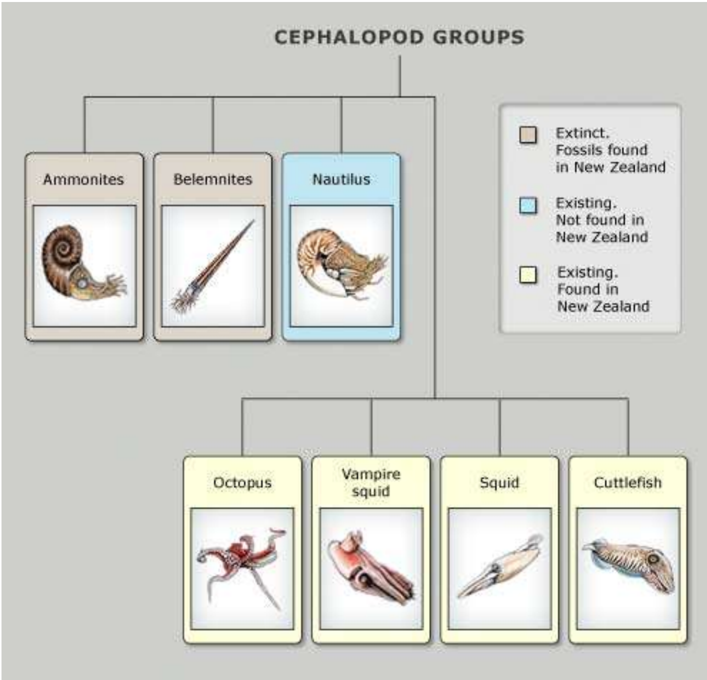

Figure 3. Cephalopod groups. This image shows extinct and existing cephalopods (Wassilieff & O'Shea 2012).

Figure 4. *Doryteuthis plei* live specimen (Hanlon 2005)

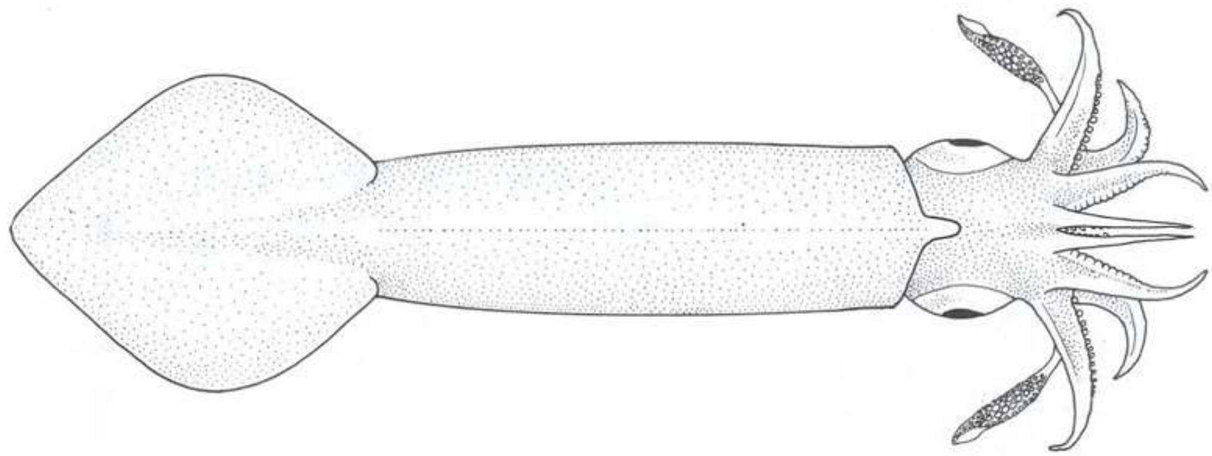

Figure 5. *Doryteuthis roperi* sketch (Vecchione 2003).

Figure 6. *Doryteuthis pealeii* live specimen (Vecchione & Young 2010a).

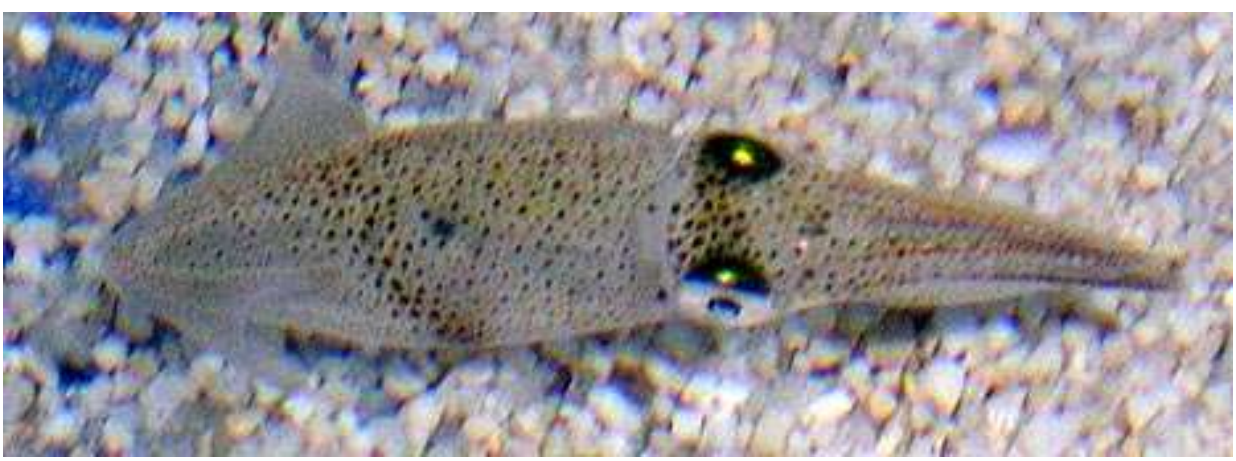

Figure 7. *Lolliguncula brevis* live specimen (Stewart 2007).

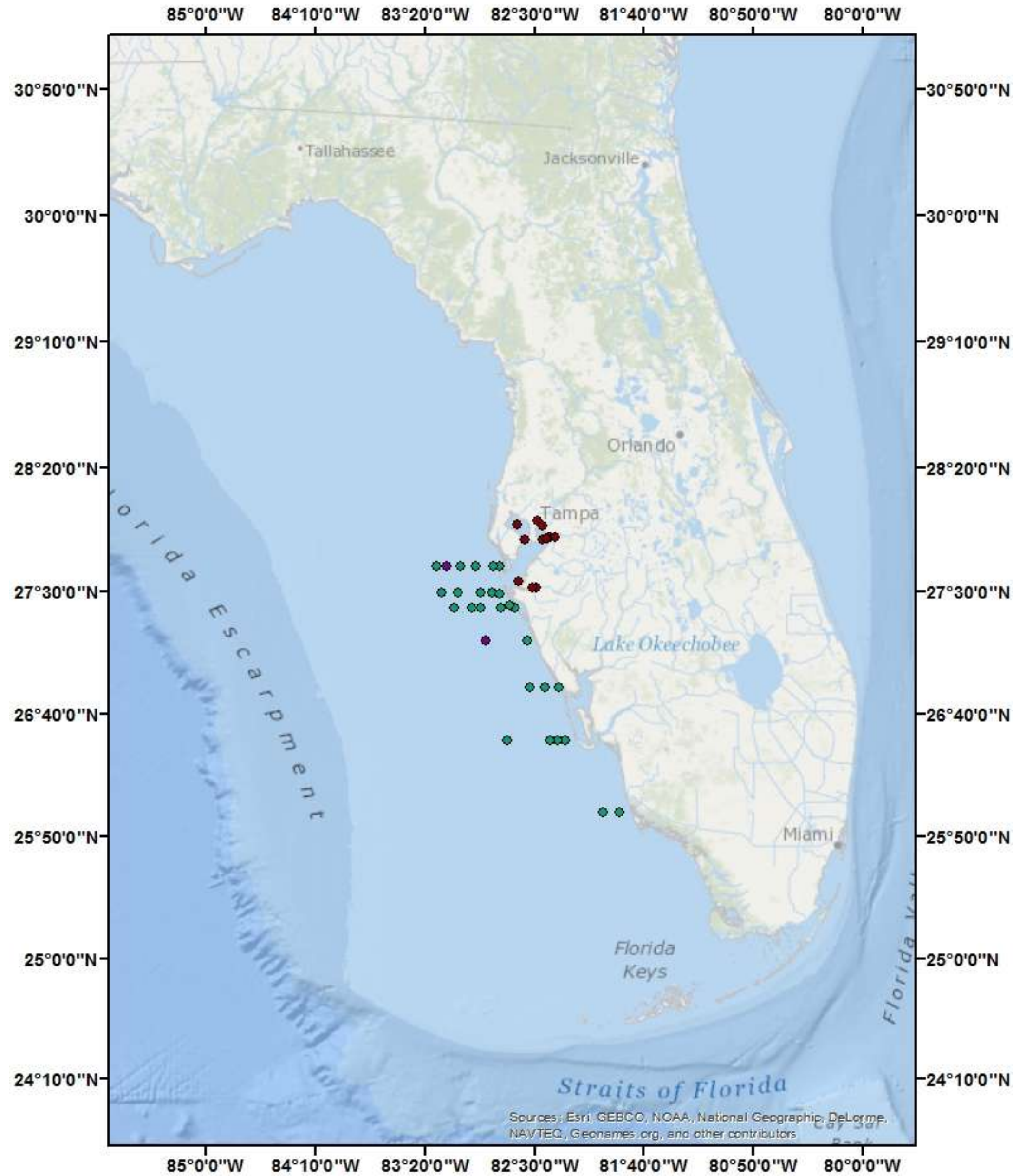

Figure 8. Distribution of all squid species.

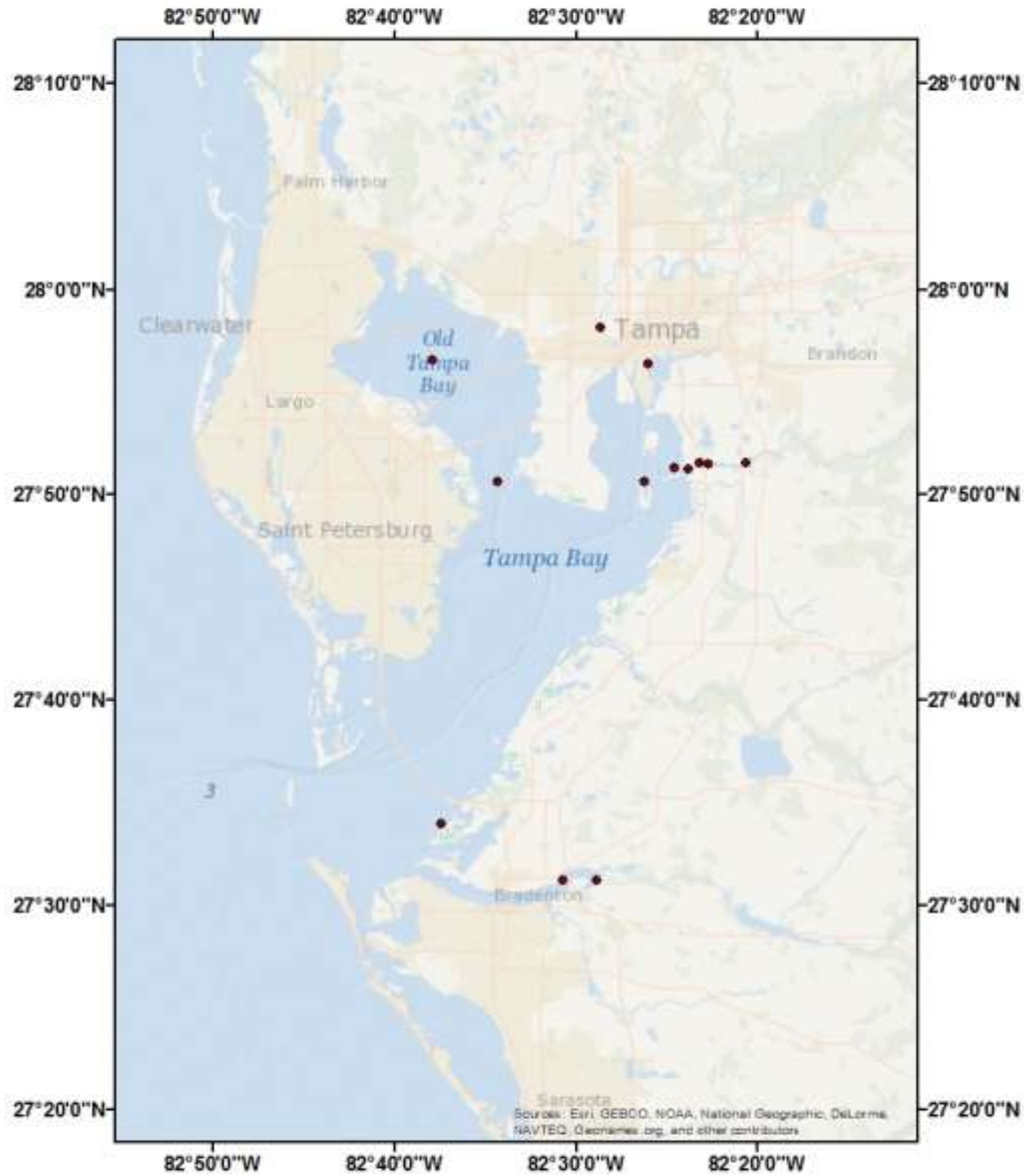

Figure 9. Distribution of *Lolliguncula brevis*.

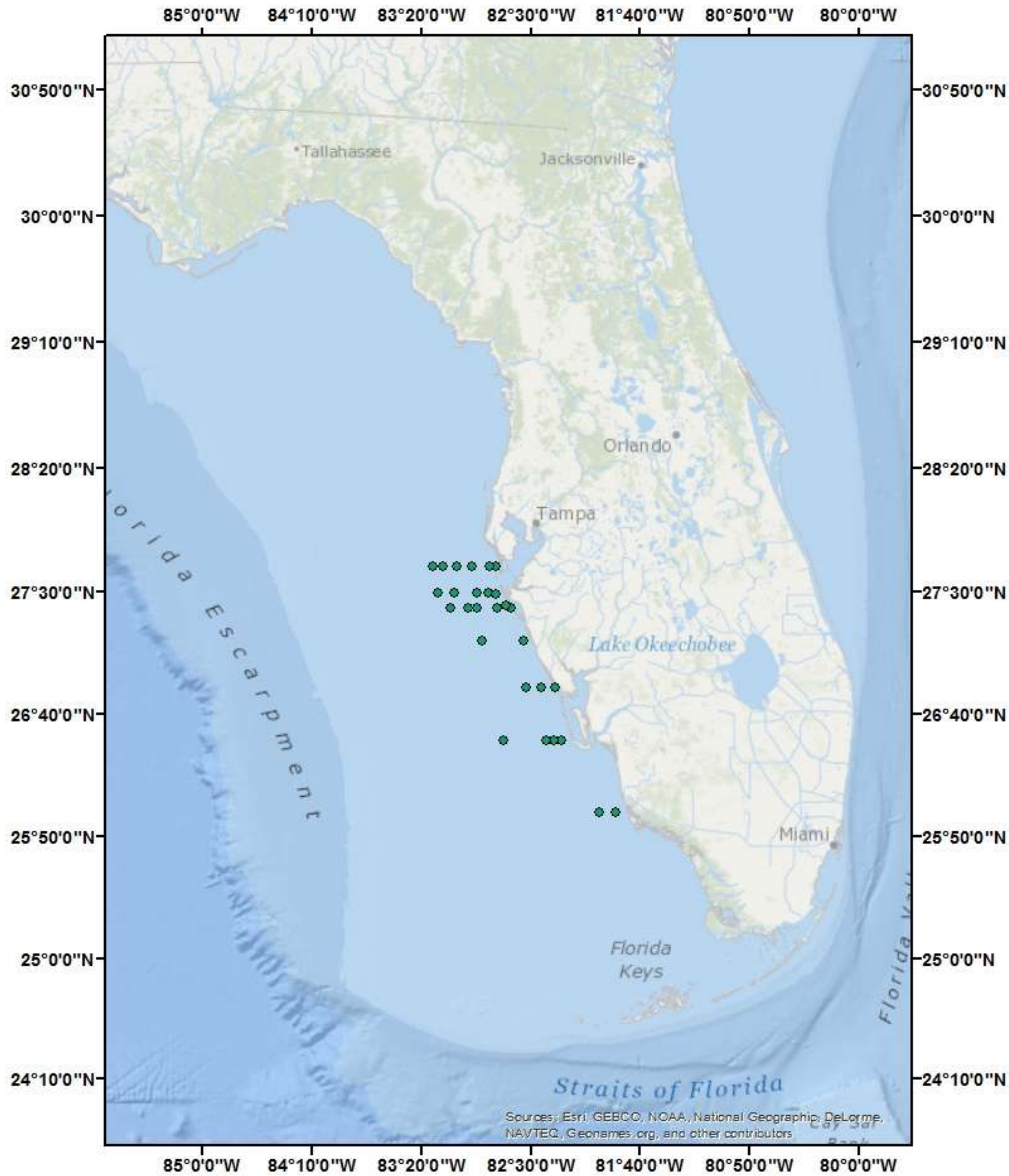

Figure 10. Distribution of *Doryteuthis plei*.

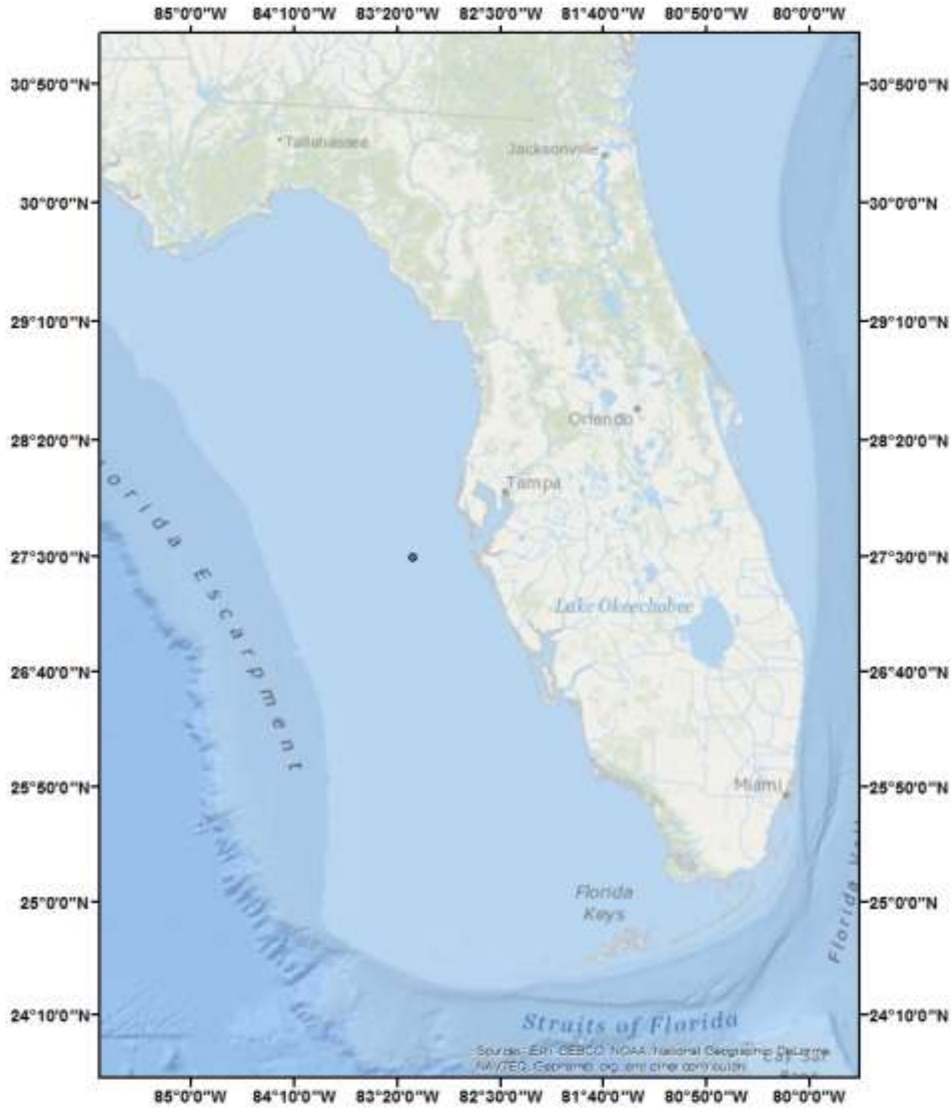

Figure 11. Distribution of *Doryteuthis pealeii*.

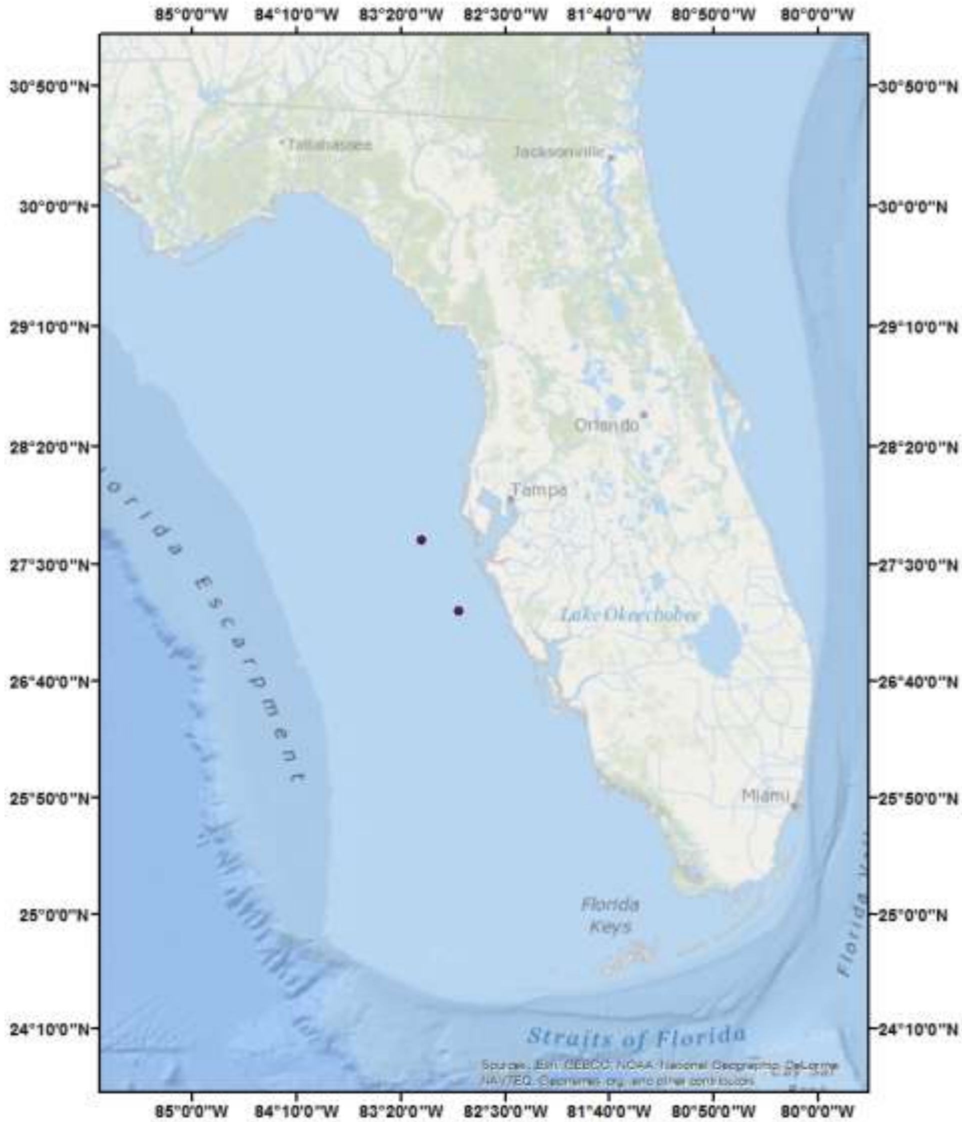

Figure 12. Distribution of *Doryteuthis roperi*.

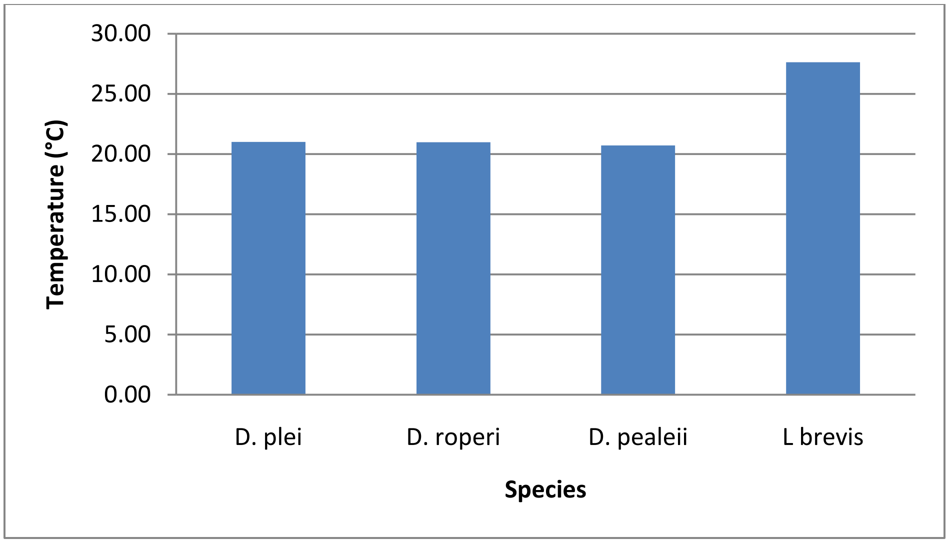

Figure 13. Average water temperature each species was found.

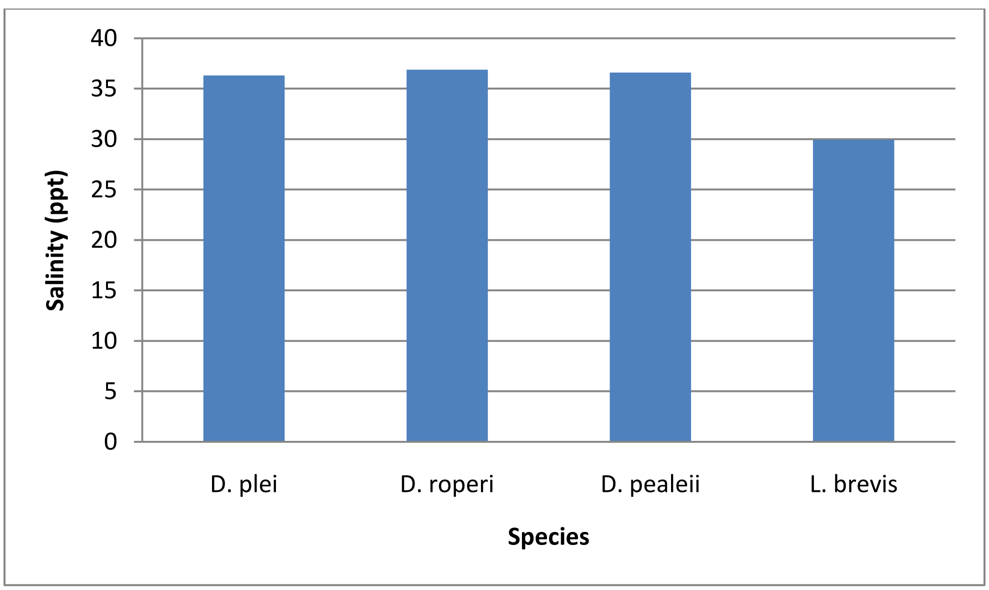

Figure 14. Average salinity each species was found.

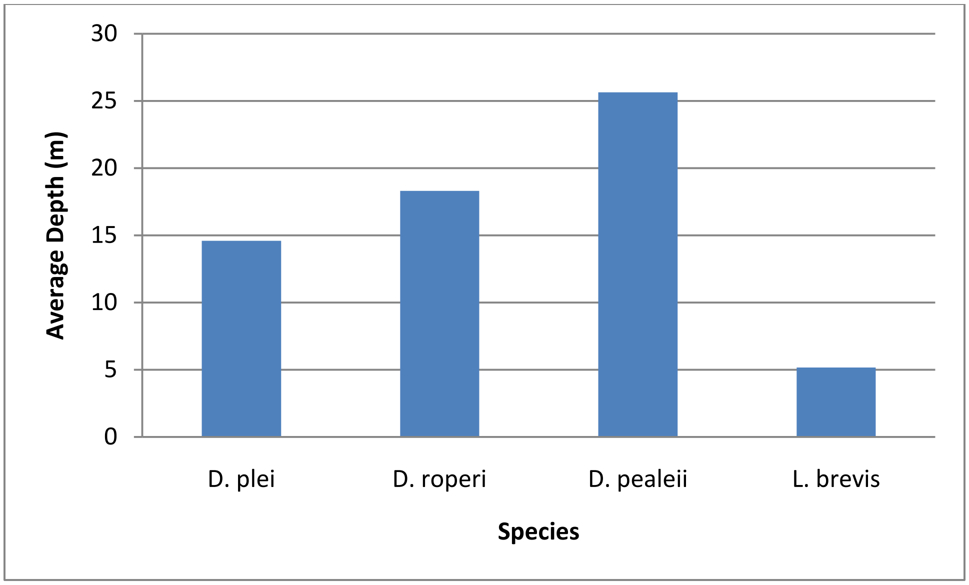

Figure 15. Average depth of each species found.

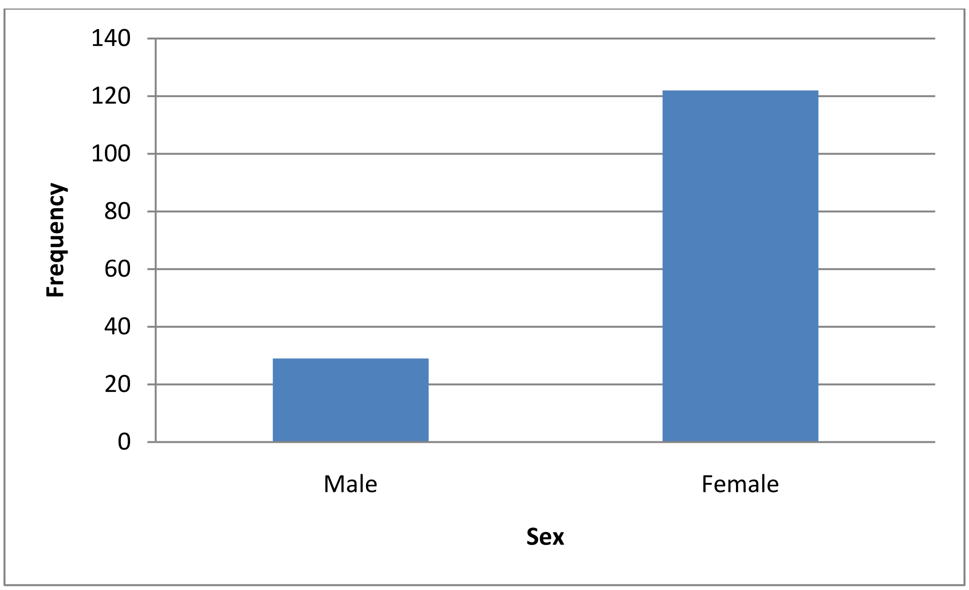

Figure 16. Sex ratio of squid captured.

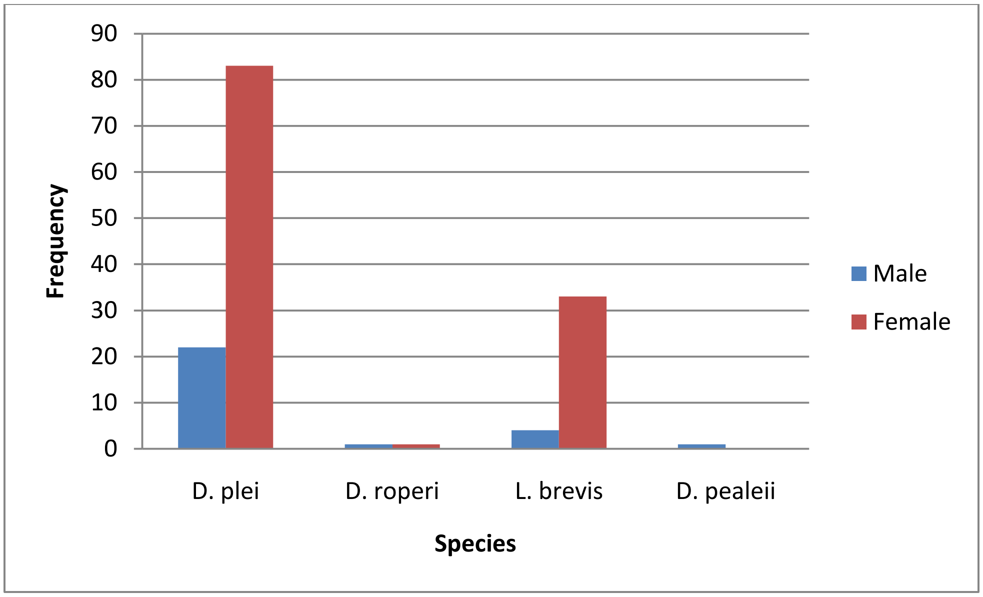

Figure 17. Sex ratio of squid by species.

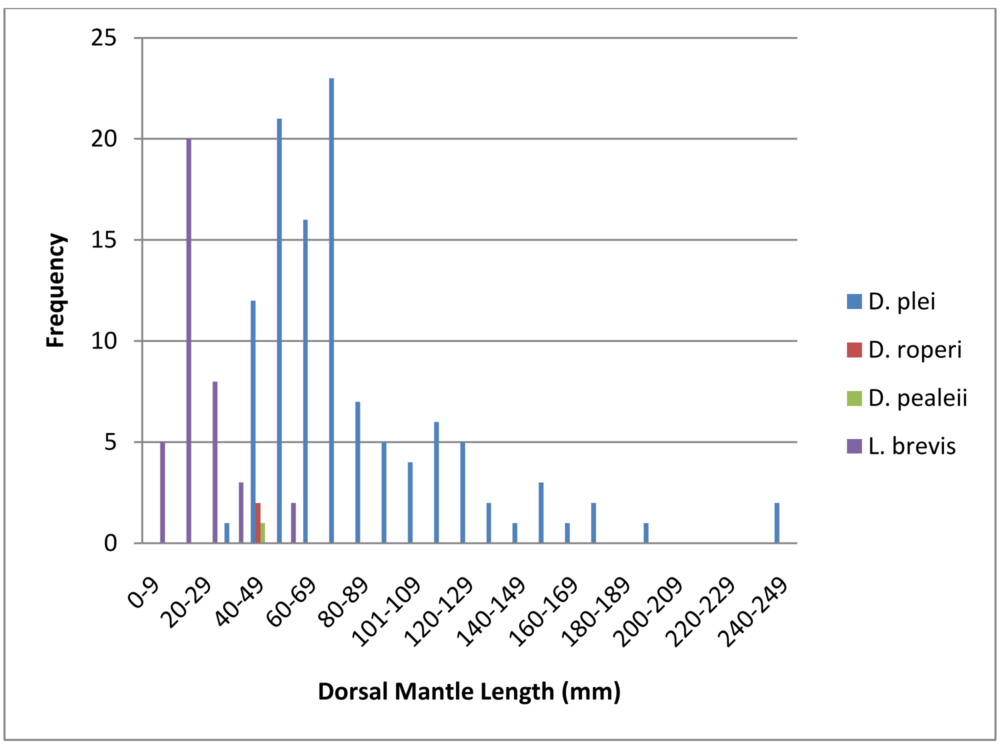

Figure 18. Frequency of dorsal mantle length ranges of each species.

- Tables -

Table 1: Calculated values of Pearson's correlation coefficient.

Factors	Pearson's Correlation Coefficient (r)
Latitude v DML	-0.444933204
Longitude v DML	-0.087289887
Depth v DML	0.21823928
Temperature v DML	-.554786016