

HYDROMEDUSA SEASONALITY AND DIVERSITY IN GALVESTON BAY

A Thesis

by

SARAH KATHLEEN PRUSKI

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Chair of Committee,
Committee Members,

Intercollegiate Faculty Chair,

Maria Pia Miglietta
Anja Schulze
Antonieta Quigg
Anna Armitage

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ABSTRACT

Hydrozoa (phylum Cnidaria) is one of the most diverse and widespread classes of gelatinous zooplankton. They are understudied because they are often inconspicuous and overlooked in many planktonic studies. Due to their complex life cycle, they undergo blooms and seasonal fluctuations. However, the factors that cause their fluctuations and blooms are unknown. Hydromedusae are top predators and are in direct competition with fish for resources. They can thus significantly impact the marine ecosystem during their seasonal blooms. Therefore, it is important to understand their seasonality, both in diversity and abundance, to better understand marine food webs and manage fishing grounds such as Galveston Bay and the Gulf of Mexico. To enhance our taxonomic knowledge of Hydrozoa in Galveston Bay and understand their seasonality, plankton samples were collected locally four times a week over thirteen months. These samples were examined for both abundance and species diversity to understand how the Hydrozoa population fluctuates in response to seasonal abiotic factors such as temperature, salinity, dissolved oxygen, and chlorophyll a. Twenty-five different species were found in Galveston Bay with strong seasonality in overall abundance and species richness. Dominant species included *Blackfordia virginica*, *Liriope tetraphylla*, *Clytia gracilis*, *Malagazzia carolinae*, *Nemopsis bachei* and the genus *Obelia*. Temperature alone had strong correlation with overall medusa abundance and the majority of the dominant species. This study provides a first assessment of the composition of hydromedusa in Galveston Bay and their seasonal response to environmental factors.

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All other work conducted for the thesis was completed by the student independently.

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1. INTRODUCTION

The term jellyfish usually refers to the Cnidarian classes of Scyphozoa, Hydrozoa, and Cubozoa and the phylum Ctenophora. However, the medusozoans (Scyphozoa, Hydrozoa, and Cubozoa) make up the majority of gelatinous zooplankton (Collins, 2002; Mills, 2001). These Cnidarian classes have different life cycles. Cubozoa have planulae which settle and metamorphose into sessile solitary polyps. Each polyp then metamorphoses into a sexual medusa (Werner et al., 1971). Scyphozoa planulae also settle and metamorphose into sessile solitary polyps. These polyps reproduce asexually to form more solitary polyps (Collins, 2002) and then undergo strobilation, a process which produces juvenile scyphomedusa (ephyrae) through transverse fission at the oral ends of the polyp. Ephyrae mature into full sexual medusae (Collins, 2002). Hydrozoans also have planulae and asexual sessile polyps; however, the polyps are mostly colonial and the medusa (or jellyfish) is produced by asexual budding from the polyps instead of by strobilation (Boero & Bouillon, 1993). Hydrozoa have the greatest life cycle variation of all the classes with some species lacking the polyp or medusa stage all together. Also, while Scyphozoa and Cubozoa have 200 and 20 species respectively, hydrozoans have about 3,800 nominal species and thus represent the most abundant and diverse class of the Phylum Cnidaria (Bouillon et al., 2004). All the medusozoans exhibit some form of seasonal population fluctuation.

Jellyfish are top predators in the plankton, they feed on other zooplankton such as the planktonic larvae of many organisms as well as small fish and crustaceans. This is

often the same food source as larval or juvenile fishes manifesting a clear competition between economically important fish and the jellyfish (Mills, 2001). This interference with fishery populations has brought jellyfish to the attention of marine scientists in recent years (Brotz, 2012; Ghermandi, 2015; Mills, 2001; Quiñones, 2015; Richardson et al., 2009). Moreover, as marine ecosystems are perturbed by human activities and top predators are heavily removed through overfishing, there are more opportunities for gelatinous zooplankton to outcompete juvenile fishes and dominate the food web through predation and competition (Richardson et al., 2009).

Jellyfish fluctuate seasonally and undergo massive blooms, which are unpredictable and hard to study (Coma et al., 2000; Richardson et al., 2009). These fluctuations have significant impact on fish populations and marine ecosystems in general. Moreover, there is controversial evidence that these blooms may be increasing in frequency and range. Localized increases of jellyfish have been recorded in many areas of the globe (Brotz, 2012; Ghermandi, 2015; Mills, 2001; Richardson et al., 2009). Theorized to be driven by climate and anthropological effects such as eutrophication, overfishing, climate change, and biological invasions due to ballast water, these blooms can be enormous and have a detrimental impact on marine communities (Richardson et al., 2009). Some ecosystems, once rich fisheries grounds, are now dominated by gelatinous zooplankton (Brotz, 2012; Ghermandi, 2015; Mills, 2001). For example, the North Namibian Benguela has seen a dramatic shift from a previously fish abundant ecosystem to an ecosystem overwhelming dominated by jellyfish. After severe overfishing and fishery collapses in the 1960s, several jellyfish species have invaded the

North Benguela and are hindering the recovery of fish stocks (Lynam et al., 2006). Similar examples of jellyfish interference have been found in Israel, the Black Sea, and throughout the Norwegian Sea (Ghermandi, 2015). In the Black Sea, the invasion of the ctenophore *Mnemiopsis leidyi* dropped the anchovy landings by 65% in two years due to its predatory behavior on fish larvae and its competition with adults (Shiganova, 1998). These collapses have exposed jellyfish as significant taxon of study for the sustainability of ecosystems (Ghermandi, 2015). Jellyfish blooms have also caused deleterious effects on various human activities, as they can burst fishing nets, block alluvial sediment suction in diamond mining operations, contaminate commercial catches, and interfere with fish assessments. During their blooms, jellyfish are also responsible for losses in tourist revenue through beach closures as their stings can be extremely painful and in some cases dangerous (Richardson et al., 2009).

Despite accounts of a recent local increase of jellyfish, there is not consensus in the scientific community that the jellyfish populations are increasing globally or that their increase is due to climate-driven effects. In fact, recent studies have shown that the global jellyfish population undergoes oscillations approximately every 20 years (Condon, 2013). The most recent oscillation produced an increase of jellyfish in the 1990s. It is theorized this oscillation has fed the belief that there is a continual worldwide increase (Condon, 2013). Whether jellyfish have a natural oscillation to their populations or they are indeed increasing due to human impacts and a changing environment, they remain an important component of ocean ecosystems and marine food webs (Quiñones, 2015).

1.1 Hydrozoa Life Cycle and Seasonality

Within the Cnidaria, the class Hydrozoa is the most diverse, widespread, and the least studied of the Cnidarian classes. Hydrozoan medusae are often overlooked in planktonic studies because of their generally petite size (bell size varies between 1 to 50 mm), difficulty to identify at genus or species level, and diverse and complex life cycles (Boero and Bouillon, 1993; Miglietta et al., 2008). Hydrozoans have a benthic and planktonic phase. The benthic polyps reproduce asexually to form polyp colonies that can bud the medusa. Medusae are released seasonally into the water column (Boero and Bouillon, 1993). The sexual medusa spawn in the water column, and the fertilization is external. The fertilized eggs develop into planula larvae. Planulae settle onto suitable substrate and metamorphoses into a new polyp (Bouillon et al., 2006). Both polyp colonies and medusae are characterized by strong seasonality (Boero and Bouillon, 1993). Benthic polyps have been observed to only produce medusa during certain months of the year (Coma et al., 2000). Polyps may also be able to persist in the environment as inactive stolons during unfavorable conditions (Tökölyi, 2016). The period of polyp activity and medusa production varies greatly among individual species as particular species respond differently to environmental cues (Boero and Bouillon, 1993). The cues triggering medusa production in most Hydrozoa species are unknown. The lack of knowledge on the environmental factors that trigger medusa production by the benthic polyps makes it impossible to predict when and where blooms will happen.

Studies on medusa production have been narrow and very species specific. Circannual rhythms, temperature, salinity, and moon phases have all been proposed as

possible cues, but have only been tested on individual species (Brock, 1975; Genzano and Kubota, 2003; Ma & Purcell, 2005; Stefani, 1956; Werner, 1954; Werner, 1961), and no general patterns in hydromedusae production have been identified. Available studies on single species point to a combination of temperature, salinity, dissolved oxygen, and water turbidity as possible factors in hydromedusae blooms (Ma & Purcell, 2005; Nowaczyk et al., 2016; Wintzer et al., 2013).

Upwelling, often correlated with high phytoplankton productivity, has also been correlated to hydromedusae blooms in tropical waters (Miglietta et al., 2008). The specific relationship between phytoplankton blooms and jellyfish blooms has not been studied on a broad scale, however, phytoplankton blooms often results in a corresponding zooplankton population increase (Raymont, 2014). This increase in prey is hypothesized to have some effect on jellyfish populations, however, recent studies have not found a strong correlation between jellyfish outbreaks and phytoplankton blooms (Xu, 2013).

1.2 Challenges of Correctly Identifying Hydroids

The lack of knowledge on Hydrozoa general biology and ecology is mainly due to the many challenges faced while studying and identifying them. With approximately 3,800 characterized species and their complex life stages, their taxonomic identification is challenging (Zheng et al., 2014). Morphological identification of Hydrozoa is hindered by their limited features, small size, phenotypic plasticity, and the presence of cryptic species (Calder, 2009; Zheng et al., 2014). Historically, it has been challenging to also match the planktonic (medusa) and the benthic stage (polyp) of the same species

as they are morphologically very different and inhabit ecologically different environments. Many juvenile or new born medusae belonging to different taxonomic groups look remarkably similar which makes many species only able to be identified in their adult morph (Calder, 2009). Insufficient morphological data makes it difficult to differentiate cryptic species (Calder, 2009; Govindarajan et al., 2005; Miglietta et al., 2009; Zheng et al., 2014). Hydrozoa can also show extreme plasticity with species looking remarkably different in different environments (Moura et al., 2011). Polyps of the same species may express different phenotypic characteristics dependent on environmental conditions and/or substrate. Also, medusae from the same species may show different morphological characters in different locations within their geographic range (Miglietta & Lessios, 2009). This has led to significant taxonomic confusion as morphotypes of the same species have been described as different species (Miglietta et al., 2009).

Because morphological identification has been so challenging within Hydrozoa, genetic analysis and especially DNA barcoding techniques have become important tools to study the diversity of this group. The 5' region of mitochondrial cytochrome c oxidase subunit I (COI) is the standard barcoding marker for most animals (Moura et al., 2011). Although there has been some success using COI to DNA barcode Hydrozoa (Bucklin et al., 2011; Govindarajan et al., 2005), the large ribosomal subunit of the mitochondrial RNA (lsu-rRNA, 16S), has been found to be easier to amplify and an excellent low-cost tool to identify species boundaries in Hydrozoa (Miglietta et al., 2009; Zheng et al., 2014). The mitochondrial 16S has been used in a wide range of

studies for accurate determination of species diversity and revision of taxonomic levels within the Hydrozoa (Govindarajan et al., 2005; Miglietta et al., 2009; Zheng et al., 2014) and it is widely considered the barcoding molecule for Hydrozoa.

1.3 The Study Site: Galveston Bay

The turbid and high nutrient waters of Galveston Bay provide a home to many economically important species and are a nursery for larval and juvenile fish such as the red drum, *Sciaenops ocellatus*. Red drum spawn during early fall, and the planktonic larvae get swept into Galveston Bay where they settle to grow into juvenile fishes (Stunz, 2002). Hydromedusae are generally carnivores, feeding on a wide variety of zooplankton and larvae of vertebrates and invertebrates (Wintzer et al., 2013). Hydromedusae have been reported to alter zooplankton populations, ichthyoplankton, and protistan community dynamics due to their predation on those communities (Yilmaz, 2015). They are thus in direct competition with larval and juvenile fish for prey (Richardson et al., 2009). The larval stage of red drum and most fishes is the most vulnerable with high mortality rates, due to predation, starvation, and environmental processes (Perez & Fuiman, 2015). A hydromedusa jellyfish population bloom could, therefore, cause harm to the fish population within Galveston Bay by depleting their prey (Richardson, et al., 2009). For this reason, it is an important undertaking to study the abundance, diversity, and seasonality of hydromedusae in Galveston Bay to understand and manage the ecosystem.

The most recent study conducted on Hydrozoa in Galveston Bay was by Defenbaugh and Hopkins (1973). It focused strictly on the polyp stage with 210 samples

(total) taken from a variety of nearshore sites throughout Galveston Bay from June 1968 to September 1969. Of these samples, 26 nominal species were morphologically identified. This survey, conducted over 45 years ago, was the first study of its kind within Galveston Bay providing the only check list of Galveston Bay Hydrozoa to date (Defenbaugh & Hopkins, 1973). It has yet to be updated, and it lacks any information on the medusa stage, as well as any morphological identification keys or species description. My thesis represents a first attempt to assess the diversity of the Galveston Bay medusae of the class Hydrozoa, using morphological and molecular tools. It is also the first attempt to characterize their seasonality and their blooms. This is important because, understanding which hydromedusae species are currently present in Galveston Bay will allow for a better understanding of the local biodiversity, and understanding the seasonality and blooms of the medusa and the abiotic factors that regulate them represents a crucial step toward predicting future blooms and assessing their impact on the marine ecosystem, food chain, and commercial fisheries.

1.4 Research Aims

This research aimed to:

1. Assess the biodiversity of Hydrozoa medusae in the Galveston Bay using a morphological and molecular approach.

Twenty-six species of Hydrozoa have been recorded in the study area (Defenbaugh and Hopkins, 1973). Of these, 15 species (belonging to 9 genera and 7 families) produce medusa. With this study we aim to more accurately account for Hydrozoa biodiversity in the Galveston Bay using molecular tools and test for the presence of cryptic species.

2. Monitor medusae abundance and seasonality during a 12-month period, assess the effect of temperature, salinity, dissolved oxygen, and phytoplankton biovolume (as a proxy for local productivity) on medusae densities and blooms.

Recent studies by Nowaczyk et al. (2016) and Wintzer et al. (2013) found that warmer temperatures led to higher medusa abundance of their hydrozoan study species. Thus, if temperature is a factor that induces medusa budding, seasonal fluctuation of hydromedusae with peaks of abundance in Spring and Summer is expected. If productivity (i.e. phytoplankton biovolume) is a factor that induces medusa budding (as indicated by Miglietta et al., 2008), a correlation between medusae peaks of abundance and periods of high productivity is expected.

2. METHODS

2.1 Medusa Collection

Planktonic samples were collected using a 100-micron net, 90 cm long, with a 30-cm mouth. The small mesh size and the collecting bottle attached to the net prevented damage to any delicate hydromedusae that were collected. Plankton tows were conducted within the boat basin at Texas A&M University Galveston on Pelican Island (29°18'47.0"N 94°48'59.8"W). The basin receives unfiltered seawater from Galveston Bay through the ship channel. Two tows per day were conducted three to four times a week from September 2015 to September 2016. The samples were collected during the morning by towing the net 6 times along the side of the dock by walking back and forth at a constant rate for a total of 156 m. The net was kept completely submerged in the water during the tow, which will ensure that approximately the same amount of water was filtered for each sample. The plankton collected during the two consecutive tows were combined and considered as a single daily sample. The plankton was examined in the laboratory under a Leica M80 Stereomicroscope and the hydromedusae were isolated from other planktonic organisms using a pipette. Individual medusae were photographed using a Leica M80 Stereomicroscope connected to a Leica MC170 HD camera. Medusae were morphologically identified to the lowest possible taxonomic level using appropriate taxonomic keys (e. g. Bouillon et al., 2006) and preserved in ethanol for molecular analysis. The number of species and total hydromedusae abundance of each sample was recorded. The long-term goal is to make this an online resource

available to scientists and the public that will depict the seasonal biodiversity of jellyfish in Galveston Bay. Links will also be provided for this website to existing databases for Galveston Bay, such as, <http://txmarspecies.tamug.edu/> which at the moment includes few Cnidaria.

2.2 Molecular Analysis and Phylogenetics

Species identification was confirmed using the hydrozoan barcoding molecule (a ~600bp fragment of the large ribosomal subunit of the mitochondrial RNA (lsu-rRNA, 16S)). Genomic DNA was extracted using a protocol modified from Zietara et al. (2000). The lsu-rRNA 16S was amplified using PCR as follows: Primers SHA (5' ACGGAATGAACTCAAATCATG T-3') and SHB (5'-TCGACTGTTTACCAAAAACA TA-3') (Cunningham and Buss, 1993) was used and the following PCR conditions were implemented for amplification: 1 min at 94°C, 35 cycles of 94°C for 15 s, 50°C for 1:30 min and 72°C for 2:30 min, and a final extension at 72°C for 5 min. PCR products were purified using exoSAP-it following manufacturer protocol. The purified PCR product was run on a 1% agarose gel stained with Sybrsafe at 100 Watt for 20min to determine presence/absence of DNA. Confirmed PCR products were sent to the Genomics Core Lab at Texas A&M University Corpus Christi for sequencing analysis.

All sequence data were edited in Geneious 10.0.5, aligned using Geneious alignment tools, and realigned using MUSCLE alignment tools. Sequences from each species were run through the National Center for Biotechnology Information (NCBI) Basic Local Alignment Search Tool (BLAST) for species identification. For each

sequence and its most significant BLAST hit, identity scores and e-values were evaluated. For each species, morphological analyses and barcoding data was compared for correct species identification. For species with multiple sequences, Maximum Likelihood (ML) and Bayesian analyses were performed using TOPALi v2 (Mline et al., 2008). This analysis aims to analyze sequences belonging to the same species but collected on different days, and test for the presence of cryptic species. All phylogenetic trees were created using the best model for each dataset, as calculated in TOPALi v2. Trees were then edited using Figtree v 1.4.3 and midpoint rooted.

2.3 Medusa Abundance and Correlation with Abiotic Factors

Daily temperature (°C), salinity (ppt), dissolved oxygen (mg/L) (DO), and chlorophyll a (µg/L) data of the Galveston Bay were made available by the Phytoplankton Dynamics Laboratory at Texas A&M University at Galveston. These abiotic factors were analyzed together with the daily jellyfish abundance and species diversity in the Galveston Bay. Temperature, salinity and DO were measured each morning at the same time as the plankton tows occurred; therefore, they perfectly reflect the water conditions at the time of sampling. Chlorophyll a data is available from January 2016 to the end of the sampling period only, so correlation between chlorophyll and medusa abundance was analyzed from January 2016-September 2016.

Relative abundance was plotted against the date of collection to try and identify any blooms. A “bloom” was defined as any day with an abundance at least 1 standard deviation from the mean daily abundance (Miglietta et al., 2008). Species richness for each day was plotted against each month to track seasonal diversity. The data was also

compartmentalized into seasons as follows based on the calendar in the Northern Hemisphere: Fall: October, November, December; Winter: January, February, March; Spring: April, May, June; Summer: July, August, September. Abiotic factors (temperature, salinity, DO) and productivity (chlorophyll a) were analyzed with a series of six multivariate ordinary least squares (OLS) regressions using SAS University Edition. The dependent variable was daily medusa abundance and the independent variables were abundance, temperature, salinity, DO. Models 1-3 were run without fixed time effects. Models 4-6 were run with fixed time effects using calendar quarter dummies. Models 2, 3, 5, and 6 were run with squared temperature to test for the possibility of a non-linear relationship. The variable chlorophyll a was included in models 3 & 6. The species dominance index was calculated using equation 1 (Wang et al., 2016):

$$Y = \frac{n_i}{N} f_i \quad (1)$$

where n is the number of individual species i; f is frequency of species i throughout the sampling period; N is the total number of individuals. Species with a dominance index more than 0.02 were taken as dominant species.

Shannon-Weaver Index was calculated using equation 2:

$$H' = - \sum_{i=1}^R p_i \ln p_i \quad (2)$$

where H' is Shannon-Weaver Index; the p_i is the proportion of population density of species i relative to the total number of population density; R is the total number of species.

Five dominant species (*Liriope tetraphylla*, *Blackfordia virginica*, *Malagazzia carolinae*, *Clytia gracilis*, and *Nemopsis bachei*) and the dominant genus *Obelia* were further investigated to analyze their seasonality. SAS University Edition was used to create regression models for each of the prevalent jellyfish species abundance to determine any correlation with abiotic factors.

3. RESULTS

3.1 Seasonality of Hydromedusa Abundance and Diversity

A total of 1321 individual medusae were collected over 191 sampling days over a span of 13 months (September 2015 to September 2016). Samples were collected an average of 14.7 days per month. Figure 1 represents the total medusa abundance for each sampling day. The daily average for the sampling period was 7 individuals. 19 blooms were recorded over the 13 sampling months, the minimum abundance for a bloom was 19 medusae and is represented in Figure 1 by a dashed line. 5 blooms occurred during the summer, 6 blooms occurred during the winter, and 8 blooms occurred during the spring. The maximum daily abundance was 104 individuals on April 11, 2016.

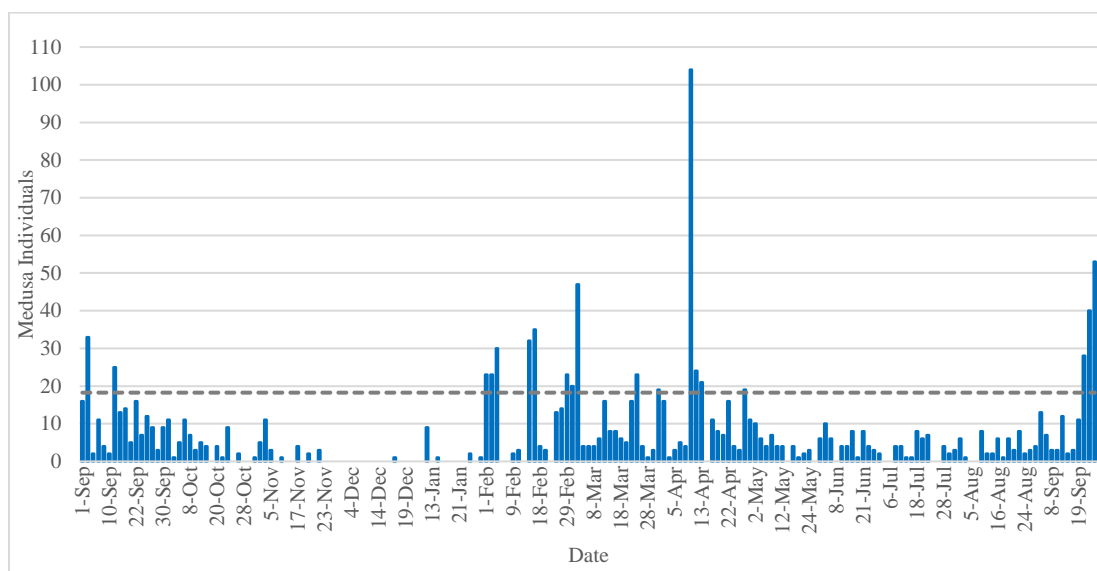


Figure 1: Medusa abundance per sampling day. The dashed line represents one standard deviation above the mean abundance; any abundance above the dashed line is considered a bloom.

Figure 2 represents the diversity and medusa abundance for each month of the sampling period. September 2015, February 2016, and April 2016 had the highest abundance numbers with 182, 218, and 248 individuals respectively. December 2015 had the lowest abundance with only one individual medusa. March 2016 had the highest species richness with a total of 14 species, followed by September 2016 with 11 species. December 2015 and January 2016 both only had one species.

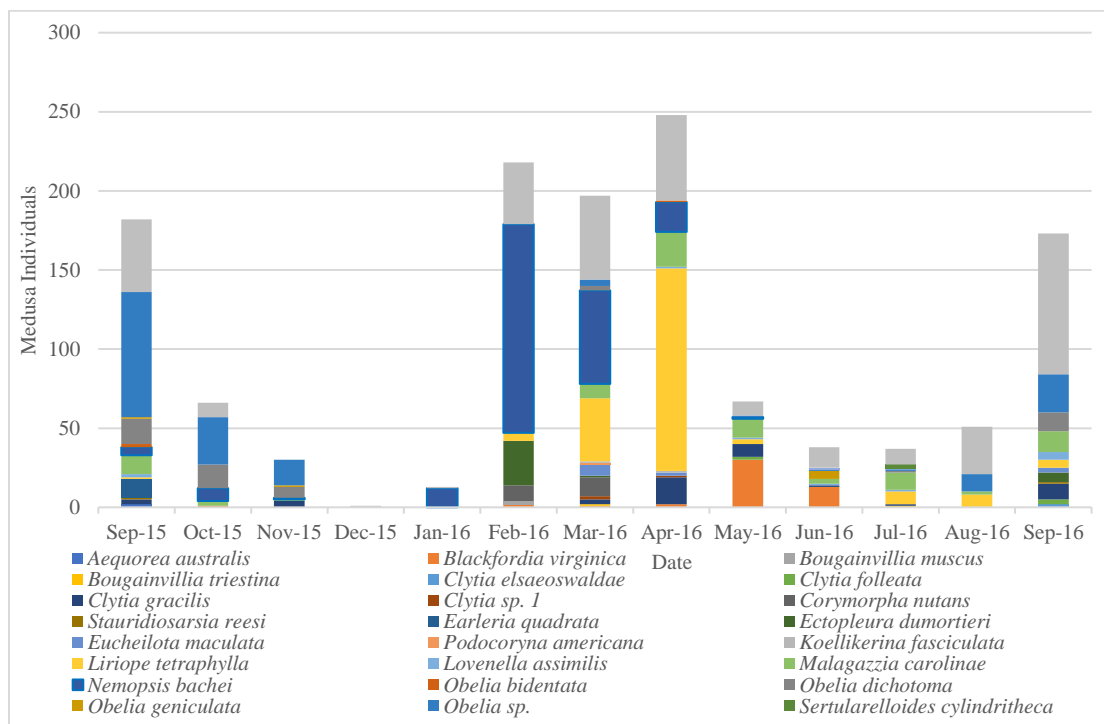


Figure 2: Monthly medusa abundance and species richness

Table 1 shows the Shannon Weaver Index for each month. The month of December was removed from these calculations due to the fact that only one medusa was found during that month. Shannon Weaver indicated variation in diversity between

the months of this study. The months with the highest diversity were March, July, and September 2016. The months with the lowest diversity were January, February, and August of 2016.

Table 1: Shannon Weaver Index. The higher the Shannon Weaver index, the more diversity. The three lowest diversities are colored blue, and the three highest are in grey.

| Month | Shannon Weaver |
|--------|----------------|
| Sep-15 | 1.68 |
| Oct-15 | 1.43 |
| Nov-15 | 1.28 |
| Jan-16 | 0.27 |
| Feb-16 | 1.19 |
| Mar-16 | 1.86 |
| Apr-16 | 1.44 |
| May-16 | 1.62 |
| Jun-16 | 1.58 |
| Jul-16 | 1.74 |
| Aug-16 | 1.06 |
| Sep-16 | 1.7 |

3.2 Relations Between Hydromedusa and Environmental Factors

The relationship between abundance, temperature, salinity, and dissolved oxygen for each sampling day was plotted in Figure 3 for a visual representation. The strong salinity drop in May 2016 was due to a large amount of rain during that time.

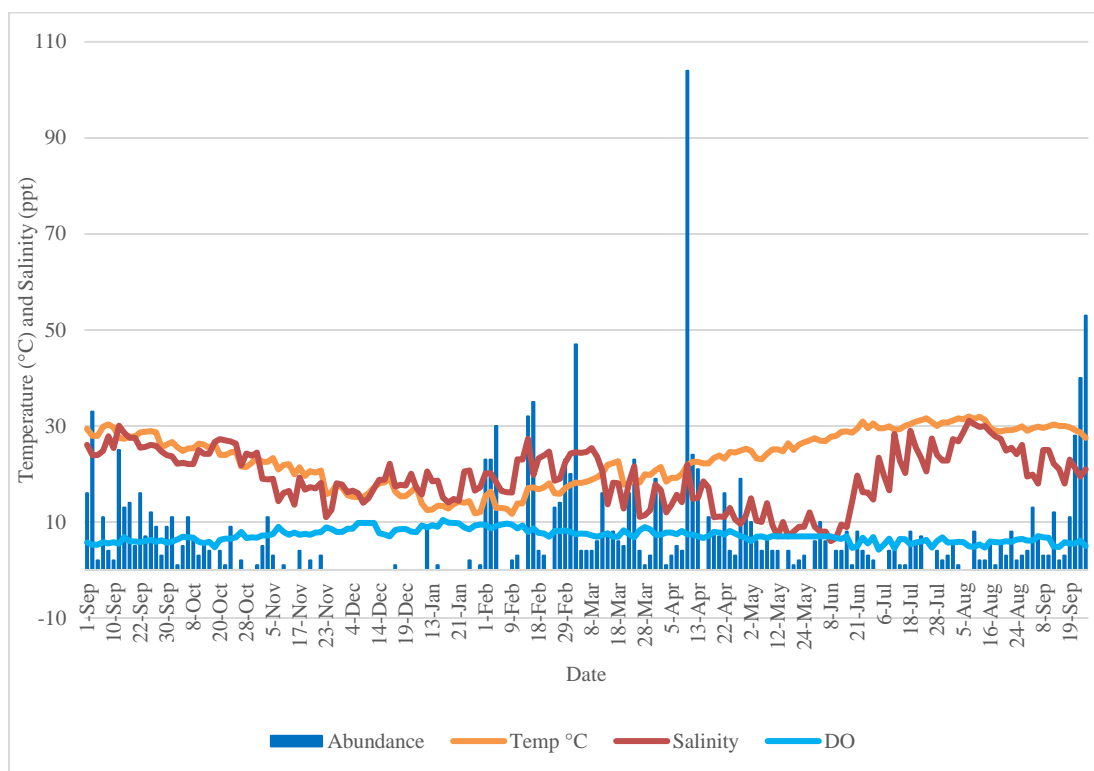


Figure 3: Daily temperature (°C), salinity (ppt), and dissolved oxygen (DO) (mg/L) against the daily medusa abundance.

The relationship between productivity and hydromedusa abundance was evaluated using chlorophyll a data from The Phytoplankton Dynamics Lab at Texas A&M University. The abundance of hydromedusa was plotted against the amount of chlorophyll a ($\mu\text{g/L}$) measured for each sampling day from January 2016-September 2016 (Figure 4).

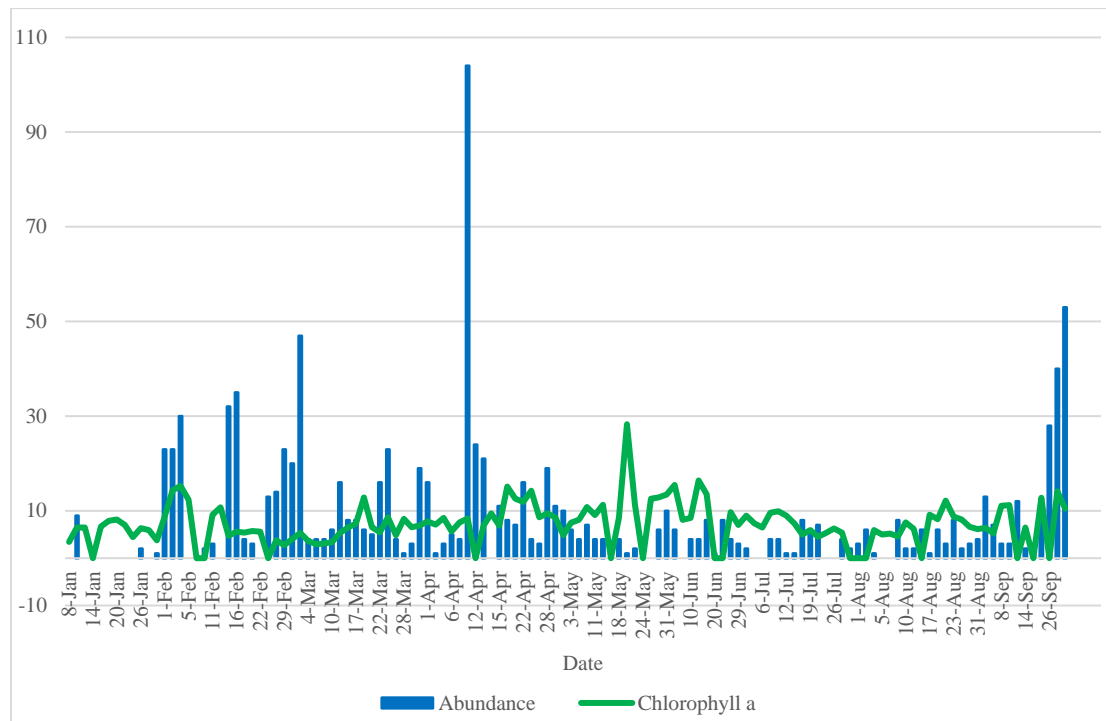


Figure 4: Daily medusa abundance against daily chlorophyll a ($\mu\text{g/L}$) measurements

In order to understand the effect of environmental factors on medusa abundance, multivariate ordinary least squares (OLS) regressions were run. The dependent variable was daily medusa abundance and the independent variables were abundance, temperature, salinity, DO, and chlorophyll a. (see Table 2). Figure 3 suggests that medusa abundance is seasonal. To account for this seasonality, which cannot be explained by the independent variable, regression models were estimated including time fixed effects. These fixed effects were estimated with the inclusion of calendar quarter dummies.

Table 3 presents the results from six regression models showing the process to find the most robust model. Some regression models include Squared Temperature to account for the possibility that the relationship between medusa abundance and temperature is non-linear. Models 3 and 6 include the chlorophyll a data which was only available for January 2016 to September 2016 reducing the number of observations in the model. Chlorophyll a was not statistically correlated at an $\alpha=0.05$ value for either of these regression models. While the impact of salinity is significant only in models without time fixed effects (Model 1-3), temperature is strongly significant in models that also account for time fixed effects (Model 4-6). Model 5, for instance, shows temperature having a very significant correlation with medusa abundance at $\alpha=0.05$. Model 5 was chosen as the best-fit model as it has the highest R-squared without sacrificing the number of observations.

The quadratic term for temperature is necessary to appreciate the impact of temperature on abundance. The linear term alone may generate wrong conclusions on temperatures impact on abundance, such that temperature has a linear negative effect on abundance, when really the quadratic term shows us that there is a peak temperature correlated with a large portion of the medusa. We can determine this temperature with equation three:

$$\text{Peak Temperature} = \frac{B_1}{|2B_2|} \quad (3)$$

where B_1 is the Temperature coefficient and B_2 is the Temperature² coefficient. We find that approximately 21.3 °C is peak temperature. This means that as the temperatures fall too far above or below 21.3 °C that there is a reduction in medusa abundance.

Table 2: Statistical description of the variables.

| | Mean | Median | StdDev | Q1 | Q3 |
|---------------|-------------|---------------|---------------|-----------|-----------|
| Abundance | 7.3385 | 4 | 11.5101 | 0 | 9 |
| DO | 7.534 | 7 | 6.7007 | 6 | 7.92 |
| Salinity | 19.5429 | 19.73 | 5.8589 | 15.71 | 24.17 |
| Temperature | 23.2723 | 24.21 | 5.7794 | 18.17 | 28.85 |
| Chlorophyll a | 4.9739 | 5 | 2.7256 | 2 | 7 |

Table 3: Multiple regression models run to find the relationship between abundance and environmental factors. Fixed time effects were fixed by season. P-values are presented in parenthesis underneath their corresponding coefficients. Values significant at alpha=0.05 are highlighted in bold.

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|---------------------------------|------------------------------|
| Temperature | -0.01163 (0.929) | 3.926646 (0.0048) | -0.27855 (0.1447) | -0.030937 (0.9302) | 5.769446 (<.0001) | 6.836276 (0.0007) |
| Temperature^2 | | -0.088435 (0.0056) | | | -0.135678 (<.0001) | -0.169093 (0.0012) |
| Salinity | 0.286182 (0.0095) | 0.412761 (0.0023) | 0.301374 (0.0354) | 0.767459 (0.0667) | 0.72675 (0.0712) | 0.785605 (0.1579) |
| DO | -0.08606 (0.0011) | -0.031346 (0.155) | -0.12514 (0.0014) | -0.079636 (0.0112) | -0.035964 (0.2155) | -0.01208 (0.6941) |
| Chlorophyll a | | | -0.2171 (0.6926) | | | -0.364258 (0.4594) |
| Fixed Time Effects | No | No | No | Yes | Yes | Yes |
| Number of Observations | 191 | 191 | 113 | 191 | 191 | 113 |
| R-Square | 0.02459 | 0.06898 | 0.03507 | 0.1054 | 0.1739 | 0.2077 |

3.3 Species Identification

All individual medusa went through the PCR process, but only 470 mitochondrial 16S rRNA gene sequences were sequenced successfully due to small

amount of tissue found in medusa. A total of 24 Hydrozoa species were identified during the study period (see Appendix I for species names, identity, query-cover, and e-values calculated in BLAST). Morphological identification of planktonic hydromedusae is difficult because of their small size, the high number of species and the fact that new-born medusae and adult medusae (with mature gonads) may appear very different in size and morphological characters. We thus identified the species using both morphology (using the pictures taken soon after collection as aids) and using BLAST results. We acknowledge that this is not a perfect method, however given the nature of the study animal and the frequency of our sampling, it represents what we believe to be a satisfactory compromise. Appendix I represents the 470 individual medusa that were successfully sequenced and their BLAST results.

There is no accepted standard for species acceptance for hydrozoa based off of BLAST results as there are still unresolved taxonomic relationships throughout Hydrozoa (Zheng et al., 2014). Therefore, the following interpretation of our BLAST results, although arbitrary, are based on both morphological data and barcoding data and represent a functional interpretation of the data, BLAST species identity value of 98% or more were considered a near good match and species identification was considered acceptable. This category represents approximately 34% of our results. A BLAST species identity value between 95% and 97.9% species identification was considered satisfactory. This category made up 47% of our results. The final 19% of the sequences had a BLAST species identity range from 87% to 94.9% and we treated these results as

ambiguous. These most likely represent species whose sequence is not present in Genbank and their identification through BLAST is therefore inaccurate.

3.4.1 Phylogenetic Trees

Phylogenetic trees were generated for each species that had multiple individual sequences. The trees were built to observe the interspecies diversity and test for the possibility of cryptic species. Both Maximum Likelihood and Bayesian model analysis were conducted on the sequence alignments and the best fit models are presented in Table 3. The results of the Bayesian and Maximum Likelihood trees were congruent in all instances and Figures 5-12 show the Bayesian phylogenetic trees for all analyzed species. All trees are midpoint rooted. Taxa have been color coded according to season. Taxa that were collected in the Fall (October-December) are colored maroon. Winter (January-March) is colored blue. Spring taxa (April-June) are colored pink, and Summer (July-September) are colored tan. Numbers at the tips of the trees represent the date and unique number associated with each medusa and their sequence.

Table 4: Best fit phylogenetic models for each species with multiple sequence alignments.

| Species | Model |
|------------------------------|---------|
| <i>Clytia gracilis</i> | GTR+G |
| <i>Ectopleura dumortieri</i> | HKY+G |
| <i>Eucheilota maculata</i> | HKY+I+G |
| <i>Liriope tetraphylla</i> | HKY+G |
| <i>Lovenella assimilis</i> | HKY+G |
| <i>Malagazzia carolinae</i> | HKY |
| <i>Nemopsis bachei</i> | HKY+G |
| <i>Obelia dichotoma</i> | HKY+G |
| <i>Obelia geniculata</i> | F81+G |

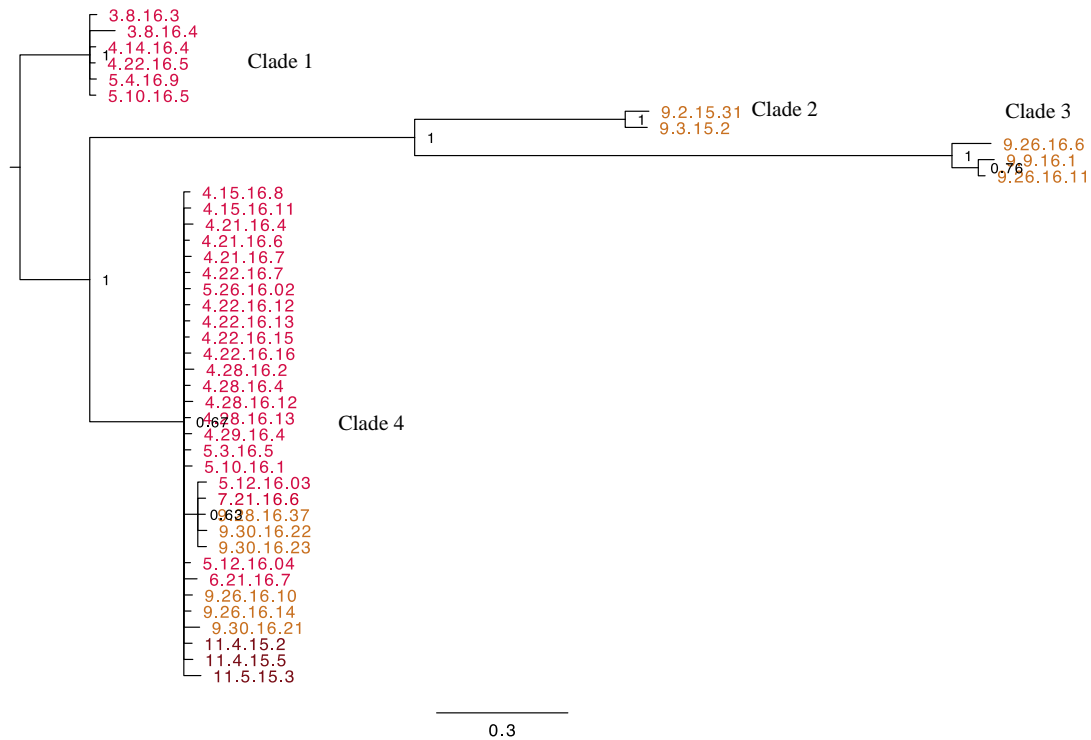


Figure 5: Bayesian phylogenetic hypothesis, calculated using MrBayes derived from mitochondrial 16S rRNA gene sequences of *Clytia gracilis*. Numbers near the nodes indicate values of posterior probability. The branch length indicator represents 0.3 substitutions per site.

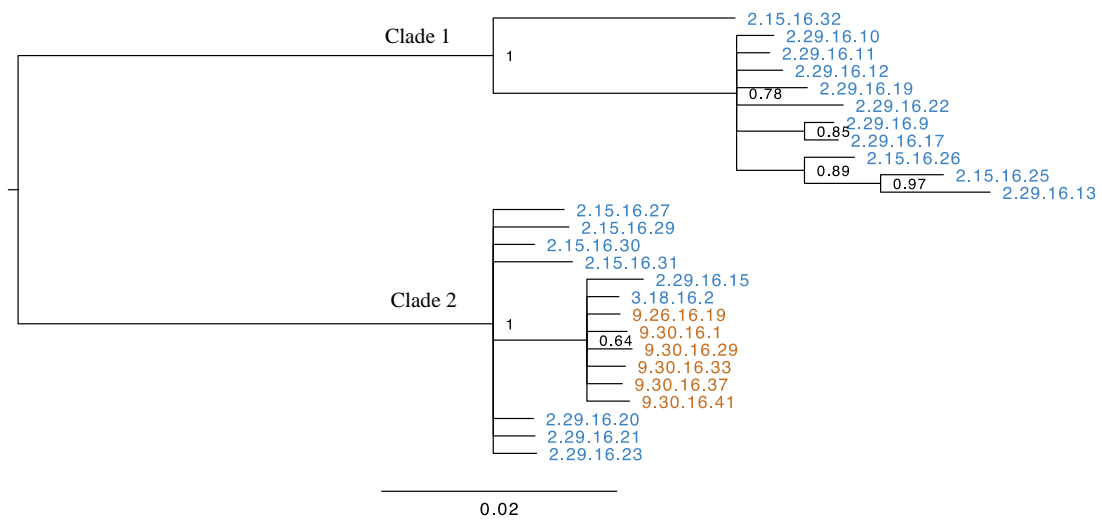


Figure 6: Bayesian phylogenetic hypothesis, calculated using MrBayes derived from mitochondrial 16S rRNA gene sequences of *Ectopleura dumortieri*. Numbers near the nodes indicate values of posterior probability. The branch length indicator represents 0.02 substitutions per site.

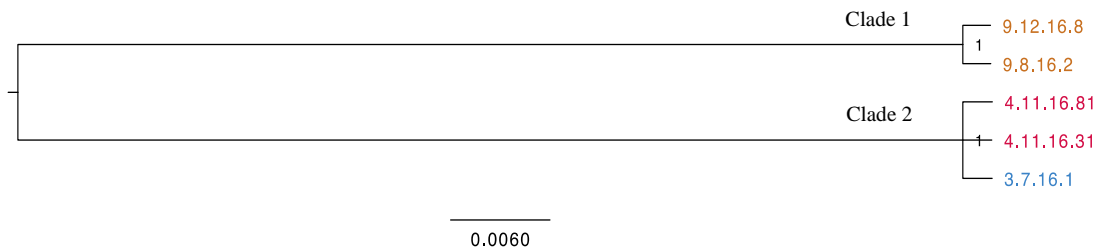


Figure 7: Bayesian phylogenetic hypothesis, calculated using MrBayes derived from mitochondrial 16S rRNA gene sequences of *Eucheilota maculata*. Numbers near the nodes indicate values of posterior probability. The branch length indicator represents 0.0060 substitutions per site.

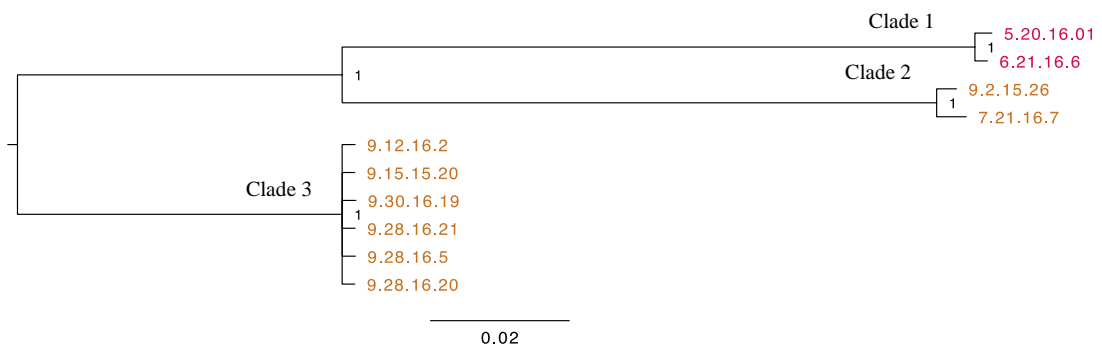


Figure 8: Bayesian phylogenetic hypothesis, calculated using MrBayes derived from mitochondrial 16S rRNA gene sequences of *Lovenella assimilis*. Numbers near the nodes indicate values of posterior probability. The branch length indicator represents 0.02 substitutions per site.

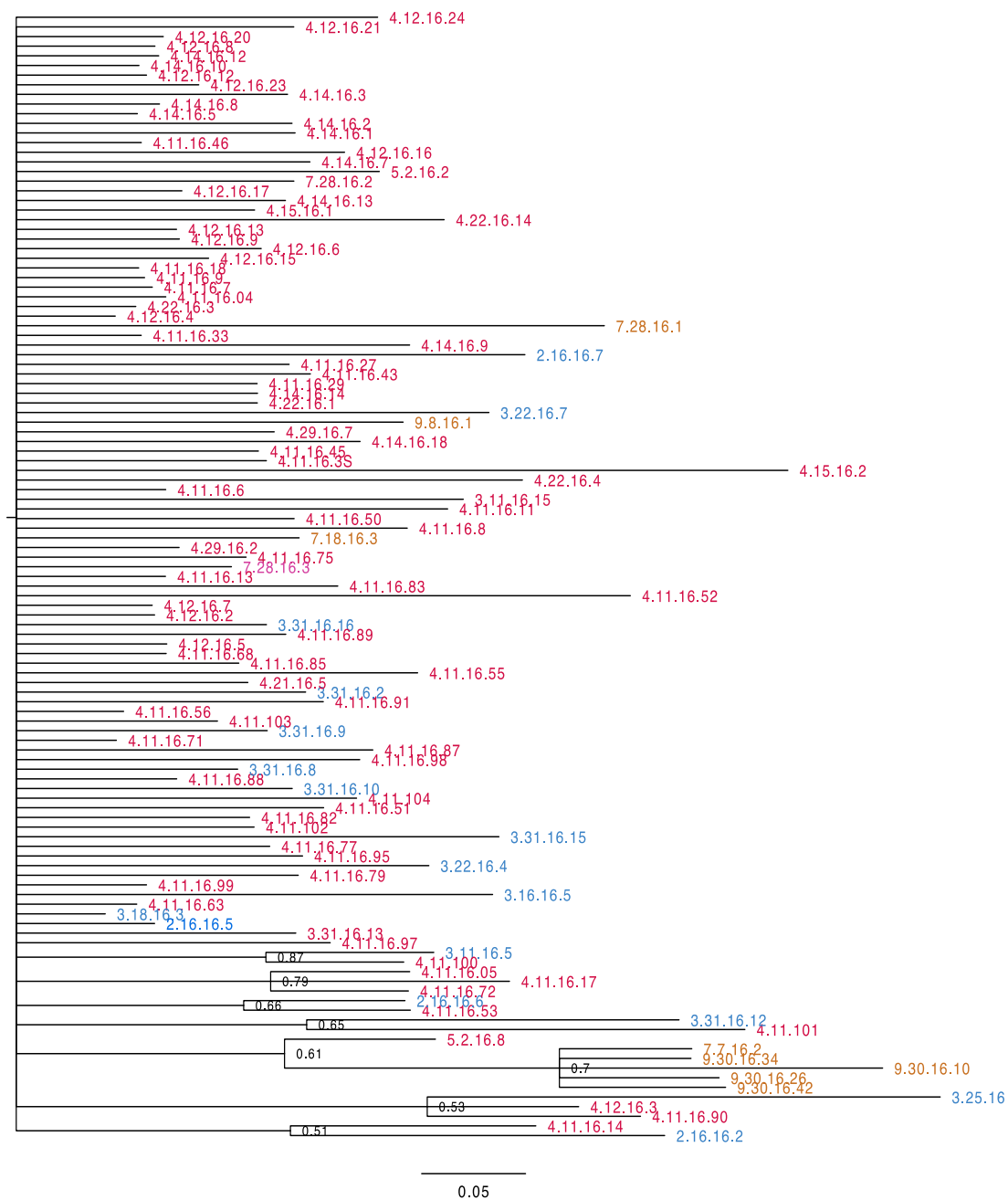


Figure 9: Bayesian phylogenetic hypothesis, calculated using MrBayes derived from mitochondrial 16S rRNA gene sequences of *Liriope tetraphylla*. Numbers near the nodes indicate values of posterior probability. The branch length indicator represents 0.05 substitutions per site.

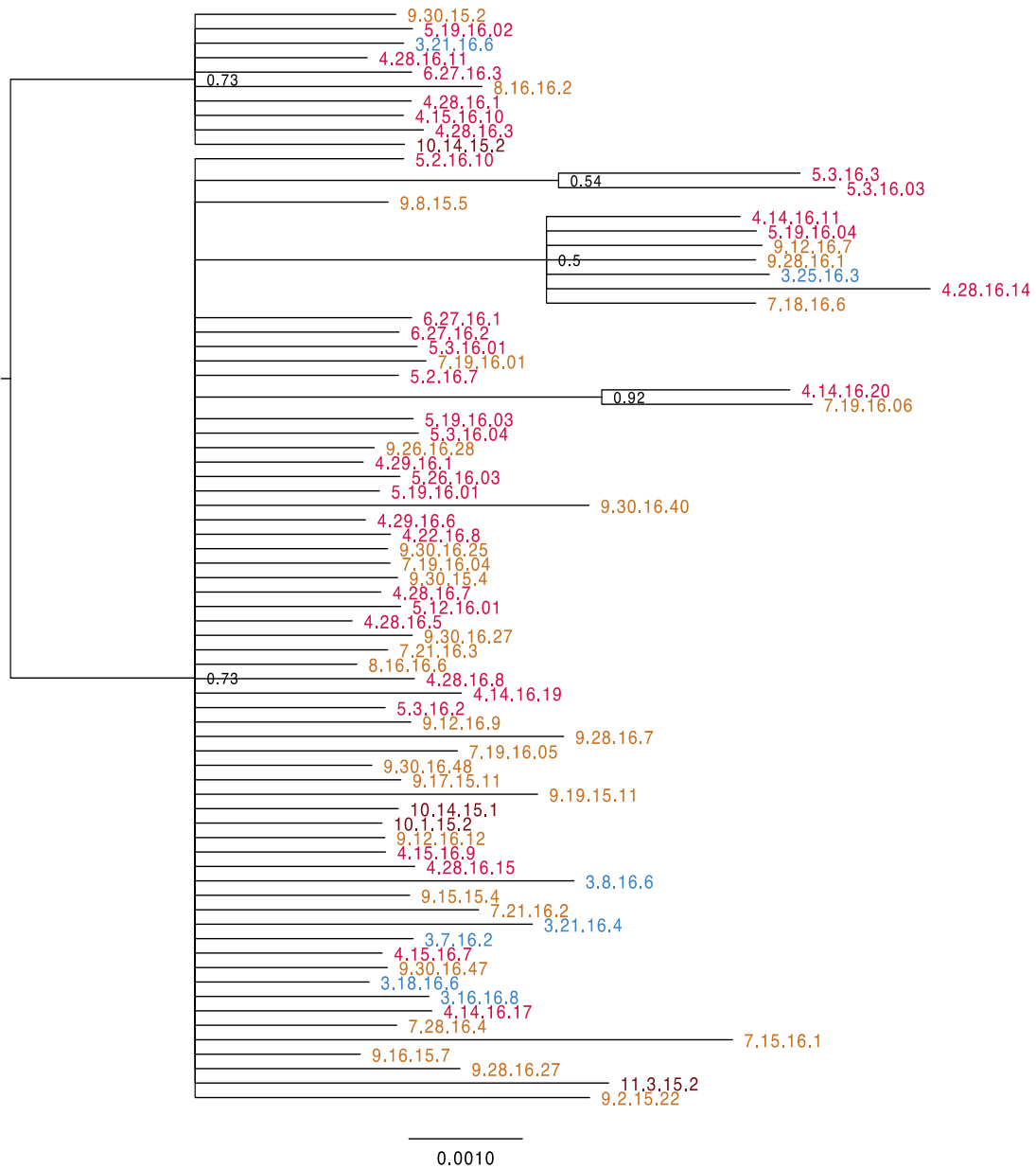


Figure 10: Bayesian phylogenetic hypothesis, calculated using MrBayes derived from mitochondrial 16S rRNA gene sequences of *Malagazzia carolinae*. Numbers near the nodes indicate values of posterior probability. The branch length indicator represents 0.0010 substitutions per site.

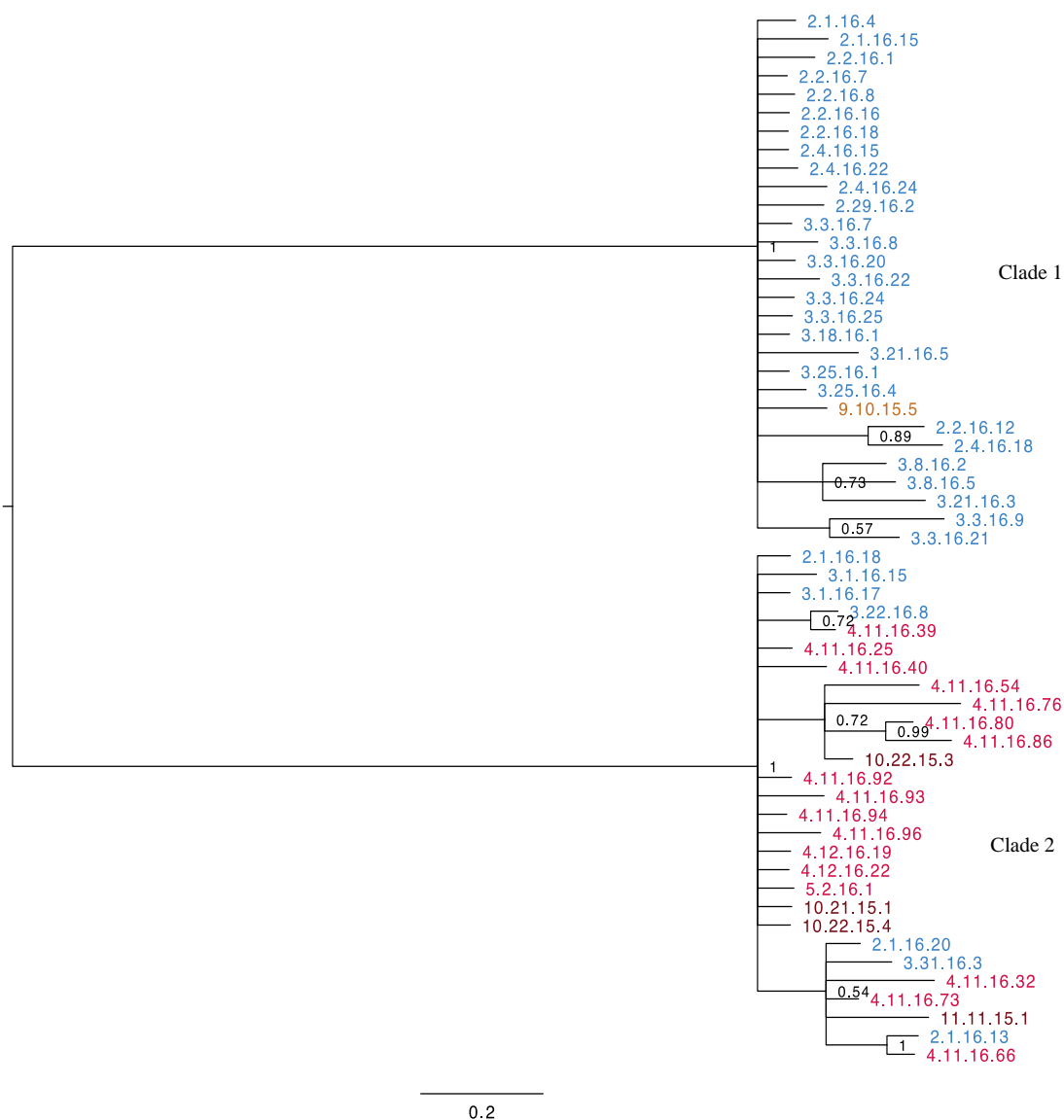


Figure 11: Bayesian phylogenetic hypothesis, calculated using MrBayes derived from mitochondrial 16S rRNA gene sequences of *Nemopsis bachei*. Numbers near the nodes indicate values of posterior probability. The branch length indicator represents 0.2 substitutions per site.

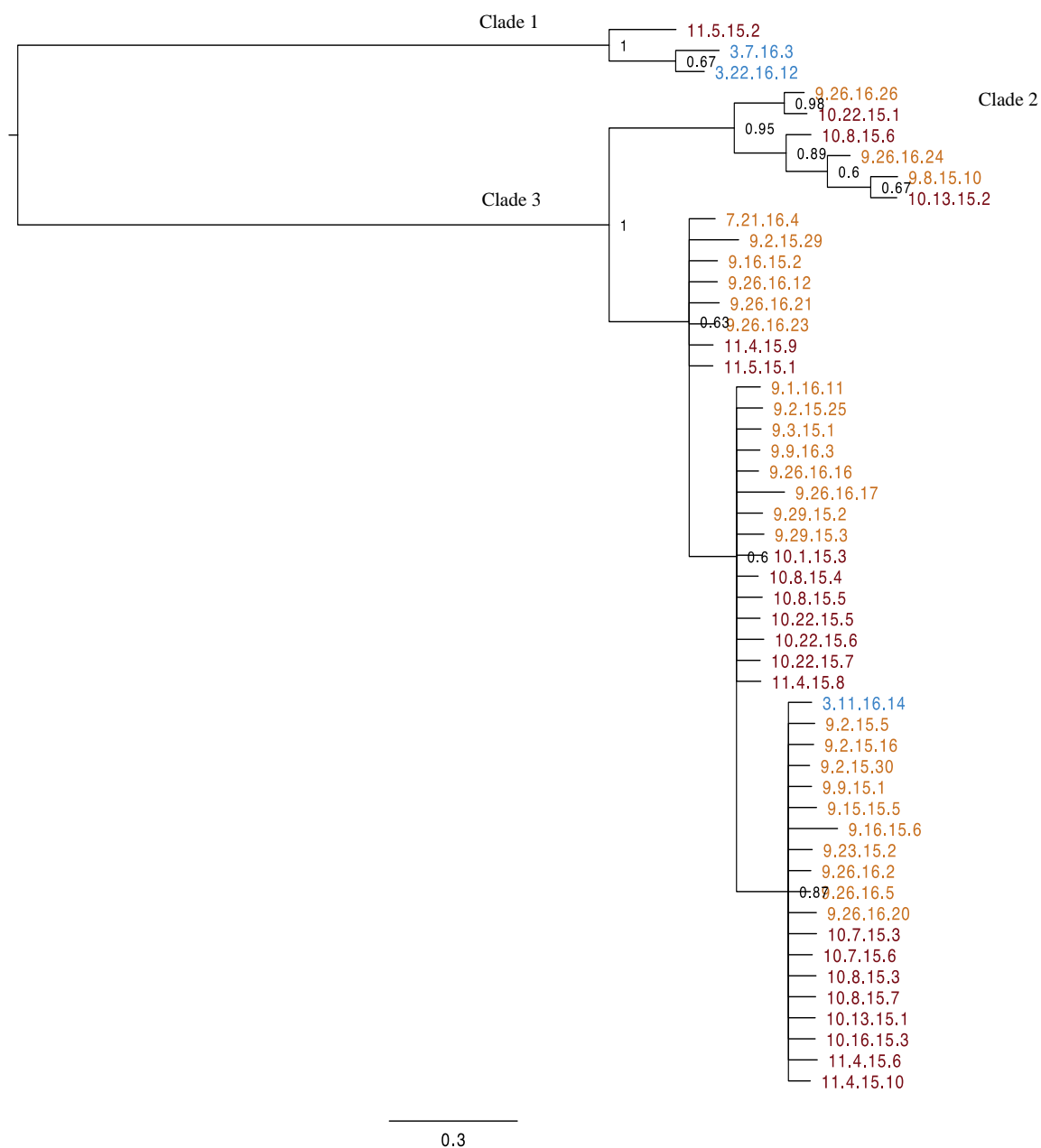


Figure 12: Bayesian phylogenetic hypothesis, calculated using MrBayes derived from mitochondrial 16S rRNA gene sequences of *Obelia dichotoma*. Numbers near the nodes indicate values of posterior probability. The branch length indicator represents 0.3 substitutions per site.

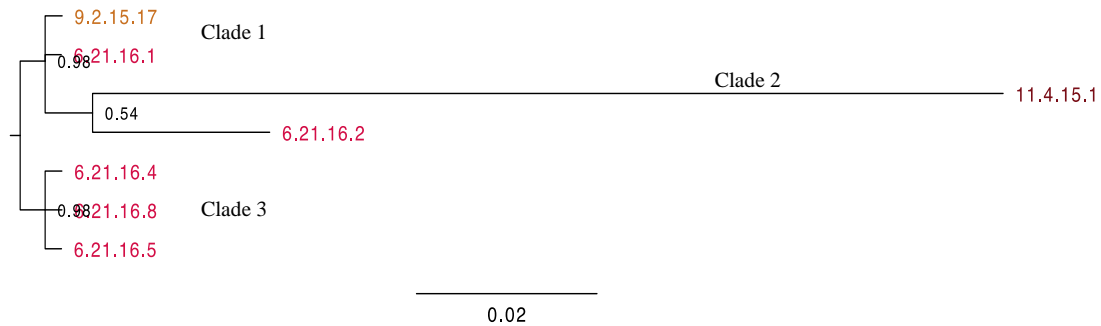


Figure 13: Bayesian phylogenetic hypothesis, calculated using MrBayes derived from mitochondrial 16S rRNA gene sequences of *Obelia geniculata*. Numbers near the nodes indicate values of posterior probability. The branch length indicator represents 0.02 substitutions per site.

3.4 The Community Composition and Seasonality of Dominant Species of Hydromedusa

Table 4 shows the 25 species and the month when they were collected.

Malagazzia carolinae was the most common species and found in 10 out of the 13 months sampled. Several species including *Aequorea australis*, *Bougainvillia muscus*, *Clytia elsaeoswaldae*, and *Turritopsis dohrnii* were rare and only found once during the sampling period. The species *Clytia* sp. and *Obelia* sp. represent medusa that we could identify to the genus level but not the species level. Table 5 shows the dominant species for each month. Only one medusa was found during December 2015 and could not be identified to species, so it is not included in the dominance analysis. The genus *Obelia* dominated the months September 2015-November 2015 and August 2016-September 2016. *Nemopsis bachei* was the most dominant species January 2016-March 2016. *Liriope tetraphylla* was the most dominant species in April 2016. The most dominant species in May 2016 was *Blackfordia virginica*. *Malagazzia carolinae* dominated June 2016-July 2016.

Table 5: Species list and presence per month of sampling period

| Species | Sep-15 | Oct-15 | Nov-15 | Dec-15 | Jan-16 | Feb-16 | Mar-16 | Apr-16 | May-16 | Jun-16 | Jul-16 | Aug-16 | Sep-16 |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| <i>Aequorea australis</i> | X | | | | | | | | | | | | |
| <i>Blackfordia virginica</i> | | X | | | | X | X | X | X | X | | | |
| <i>Bougainvillia muscus</i> | | | | | | X | | | | | | | |
| <i>Bougainvillia triestina</i> | | | | | | | X | | | | X | | |
| <i>Clytia elsaeswaldae*</i> | | | | | | | | | | | | | X |
| <i>Clytia folleata</i> | | | | | | | | | X | | | | X |
| <i>Clytia gracilis</i> | X | | X | | | | X | X | X | X | X | | X |
| <i>Clytia</i> sp. 1 | | | | | | | X | X | | | | | |
| <i>Corymorpha nutans</i> | | | | | | | X | | | | | | |
| <i>Stauridiosarsia reesi</i> | X | | | | | | | | | | | | X |
| <i>Earleria quadrata*</i> | X | | | | | | | | | | | | |
| <i>Ectopleura dumortieri</i> | | | | | | X | X | | | | | | X |
| <i>Eucheilota maculata*</i> | | | | | | | X | X | | | | | X |
| <i>Podocoryna americana</i> | | | | | | | X | | | | | | |
| <i>Koellikerina fasciculata*</i> | | | | | | | X | X | | | | | |
| <i>Liriope tetraphylla</i> | X | | | | | | X | X | X | | X | X | X |
| <i>Lovenella assimilis*</i> | X | | | | | | | X | X | X | X | | X |
| <i>Malagazzia carolinae</i> | X | X | | | | | X | X | X | X | X | | X |
| <i>Nemopsis bachei</i> | X | X | X | | | X | X | X | X | | | | |
| <i>Obelia bidentata</i> | X | | | | | | | X | | | | | |
| <i>Obelia dichotoma</i> | X | X | X | | | | X | | | | X | | X |
| <i>Obelia geniculata*</i> | X | X | X | | | | | | | X | | | |
| <i>Obelia</i> sp. | X | X | X | | | | X | | X | X | X | X | X |
| <i>Sertularelloides cylindricus*</i> | | | | | | | | | | | | | |
| <i>Turritopsis dohrnii</i> | | | | | | | | | | X | | | |

*These species did not have BLAST results higher than a 95% ident value

Table 6: Dominant species for each month of sampling period

| Month | Species | Dominance |
|--------|------------------------------|-------------|
| Sep-15 | <i>Malagazzia carolinae</i> | 0.050718512 |
| | <i>Obelia dichotoma</i> | 0.04057481 |
| | <i>Obelia</i> sp. | 0.300507185 |
| Oct-15 | <i>Malagazzia carolinae</i> | 0.034965035 |
| | <i>Nemopsis bachei</i> | 0.074592075 |
| | <i>Obelia dichotoma</i> | 0.104895105 |
| | <i>Obelia</i> sp. | 0.314685315 |
| Nov-15 | <i>Malagazzia carolinae</i> | 0.025641026 |
| | <i>Nemopsis bachei</i> | 0.020512821 |
| | <i>Obelia dichotoma</i> | 0.107692308 |
| | <i>Obelia</i> sp. | 0.369230769 |
| Jan-16 | <i>Nemopsis bachei</i> | 0.568047337 |
| Feb-16 | <i>Ectopleura dumortieri</i> | 0.029640085 |
| | <i>Nemopsis bachei</i> | 0.372618207 |
| Mar-16 | <i>Liriope tetraphylla</i> | 0.124951191 |
| | <i>Malagazzia carolinae</i> | 0.035142522 |
| | <i>Nemopsis bachei</i> | 0.184303007 |
| Apr-16 | <i>Clytia gracilis</i> | 0.042183623 |
| | <i>Liriope tetraphylla</i> | 0.317617866 |
| | <i>Malagazzia carolinae</i> | 0.068238213 |
| | <i>Nemopsis bachei</i> | 0.047146402 |
| May-16 | <i>Blackfordia virginica</i> | 0.206659013 |
| | <i>Clytia gracilis</i> | 0.07347876 |
| | <i>Liriope tetraphylla</i> | 0.027554535 |
| | <i>Malagazzia carolinae</i> | 0.137772675 |
| Jun-16 | <i>Malagazzia carolinae</i> | 0.060728745 |
| | <i>Obelia geniculata</i> | 0.030364372 |
| Jul-16 | <i>Liriope tetraphylla</i> | 0.133056133 |
| | <i>Malagazzia carolinae</i> | 0.228690229 |
| Aug-16 | <i>Liriope tetraphylla</i> | 0.09653092 |
| | <i>Malagazzia carolinae</i> | 0.030165913 |
| | <i>Obelia</i> sp. | 0.149321267 |
| Sep-16 | <i>Clytia gracilis</i> | 0.035571365 |
| | <i>Malagazzia carolinae</i> | 0.057803468 |
| | <i>Obelia dichotoma</i> | 0.032014229 |
| | <i>Obelia</i> sp. | 0.096042686 |

3.5 Relationship between Dominant Species and Environmental Factors

Regression models following Model 5 in Section 3.2 were run for the five most dominant species: *Blackfordia virginica*, *Clytia gracilis*, *Liriope tetraphylla*, *Malagazzia carolinae*, *Nemopsis bachei*, and the most dominant genus *Obelia* to determine their species-specific relationships with environmental factors. The species-specific models were run using medusa abundance as the dependent variable, temperature (linear and non-linear), salinity, and dissolved oxygen as the independent variables, and time fixed effects classified by season (Table 7). Figures 15-20 show the plots of each species abundance with temperature, salinity, and DO and suggest that each species has a distinct seasonality.

Table 7: Best-fit regression models run to find the relationship between dominant species and environmental factors. P-values are presented in parenthesis underneath their corresponding coefficients. Values significant at alpha=0.05 are highlighted in bold.

| | <i>Blackfordia virginica</i> | <i>Clytia gracilis</i> | <i>Liriope tetraphylla</i> | <i>Malagazzia carolinae</i> | <i>Nemopsis bachei</i> | <i>Obelia</i> |
|------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|
| Temperature | -0.085091 (0.4929) | 0.2967857 (0.0007) | 1.335539 (0.0216) | 0.3557258 (0.0268) | 0.2277842 (0.7171) | 1.265557 (0.0005) |
| Temperature^2 | 0.0029645 (0.3956) | -0.007051 (0.0012) | -0.037724 (0.0301) | -0.0081399 (0.0514) | -0.008364 (0.5319) | -0.02835 (0.0019) |
| Salinity | -0.0248638 (0.1388) | -0.017753 (0.1768) | 0.389765 (0.1904) | -0.012308 (0.6265) | 0.2161154 (0.0069) | 0.061861 (0.1464) |
| DO | -0.0016194 (0.0551) | -0.000859 (0.5489) | 0.016066 (0.4022) | -0.002049 (0.4096) | -0.035907 (0.0123) | 0.007388 (0.1842) |
| Fixed Time Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Number of Observations | 191 | 191 | 191 | 191 | 191 | 191 |
| R-Square | 0.1266 | 0.1197 | 0.1247 | 0.1039 | 0.2288 | 0.178 |

Blackfordia virginica did not have a significant correlation with any of the environmental factors. *Clytia gracilis*, *Liriope tetraphylla*, *Malagazzia carolinae*, and

Obelia had a significant ($\alpha=0.05$) relationship with temperature only. *Nemopsis bachei* did not have significant correlation with temperature, but correlation with both salinity and DO showed significance at $\alpha=0.05$.

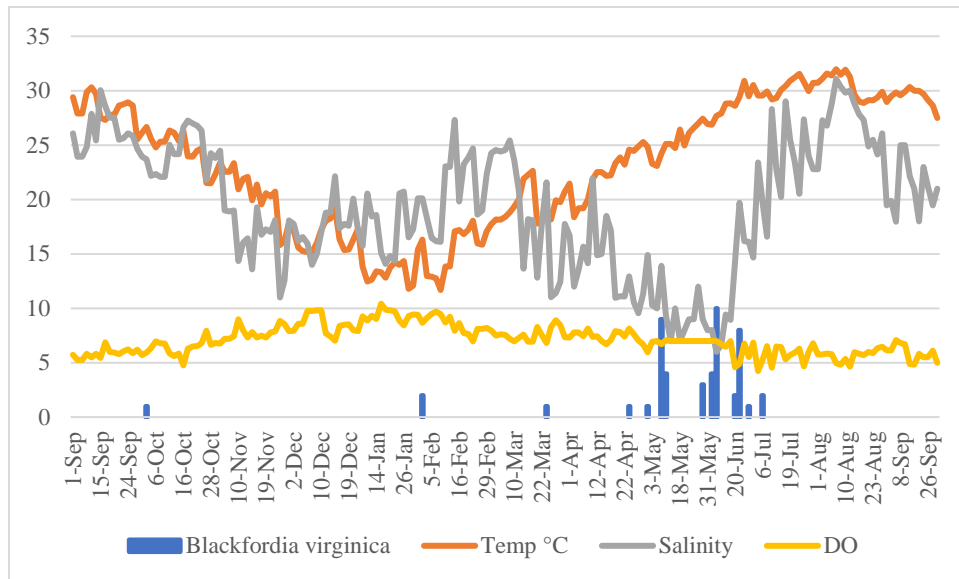


Figure 14: Relationship of *Blackfordia virginica* abundance with temperature (°C), salinity (ppt), and DO (mg/L).

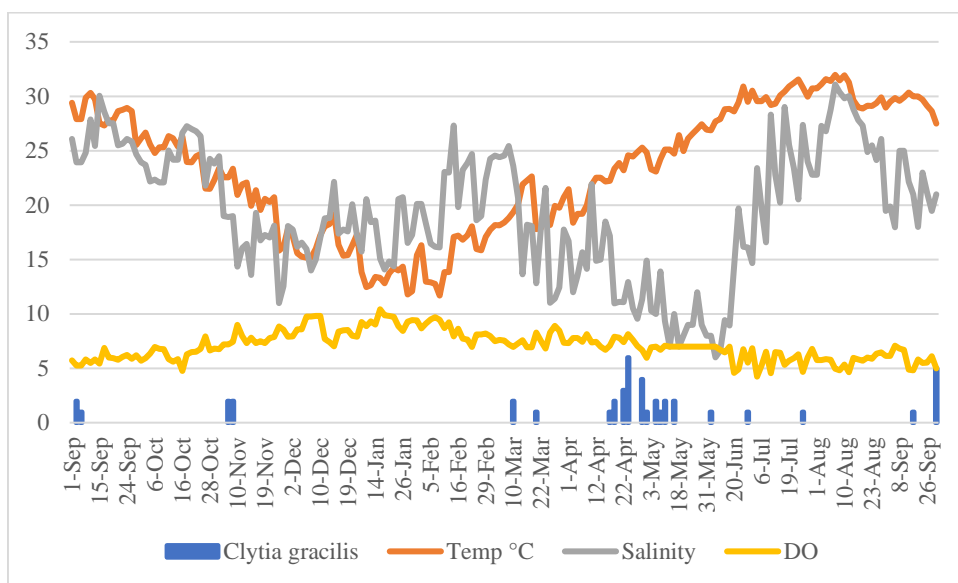


Figure 15: Relationship of *Clytia gracilis* abundance with temperature (°C), salinity (ppt), and DO (mg/L).

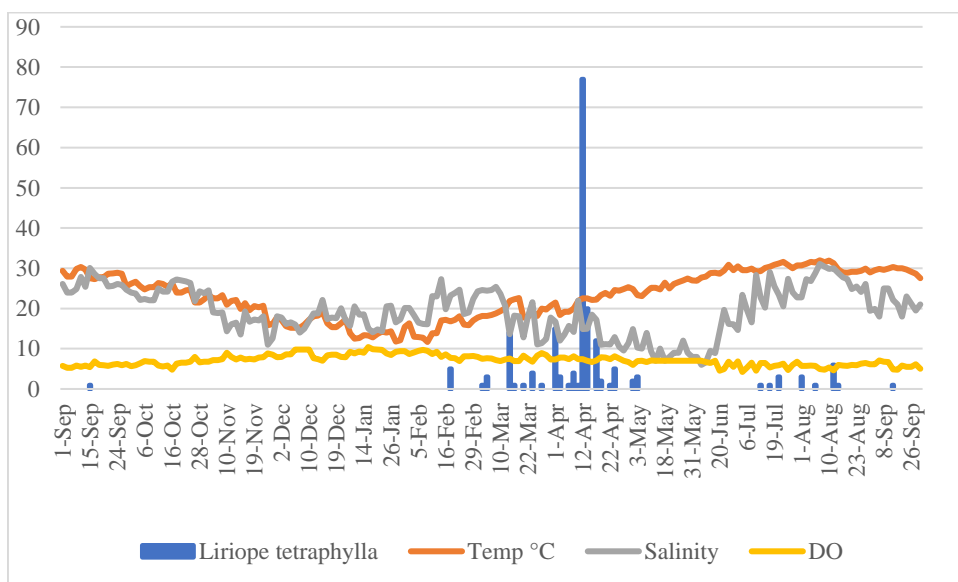


Figure 16: Relationship of *Liriope tetraphylla* abundance with temperature (°C), salinity (ppt), and DO (mg/L).

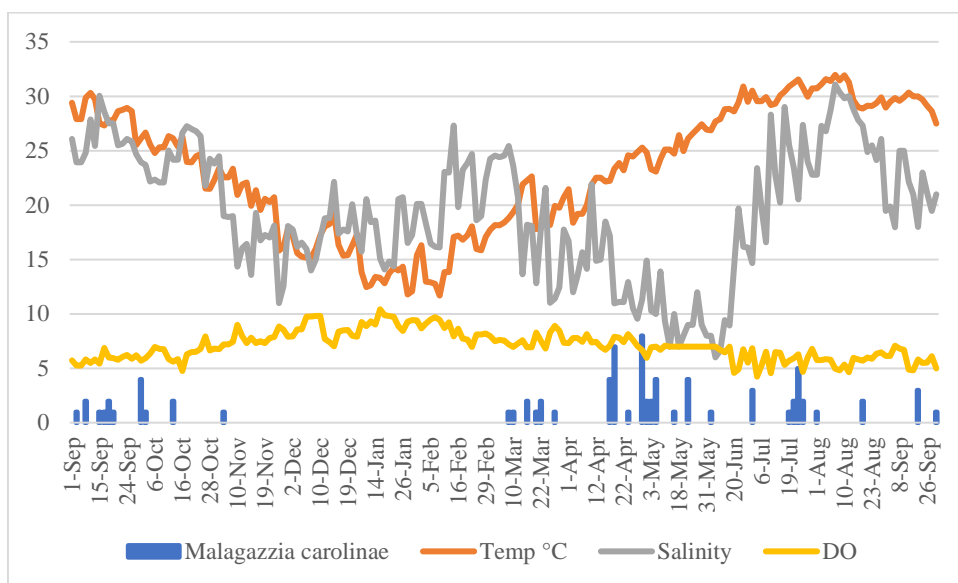


Figure 17: Relationship of *Malagazzia carolinae* abundance with temperature (°C), salinity (ppt), and DO (mg/L).

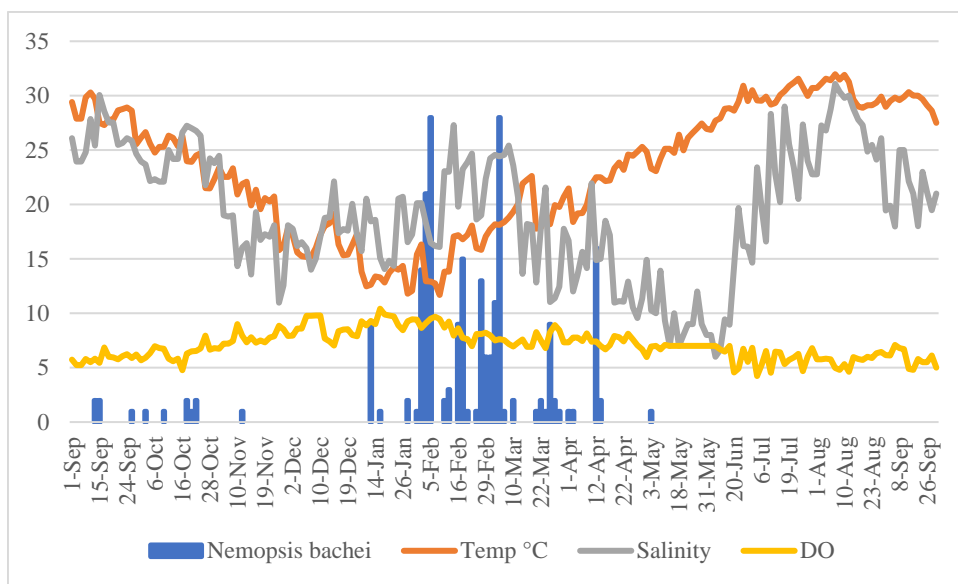


Figure 18: Relationship of *Nemopsis bachei* abundance with temperature (°C), salinity (ppt), and DO (mg/L).

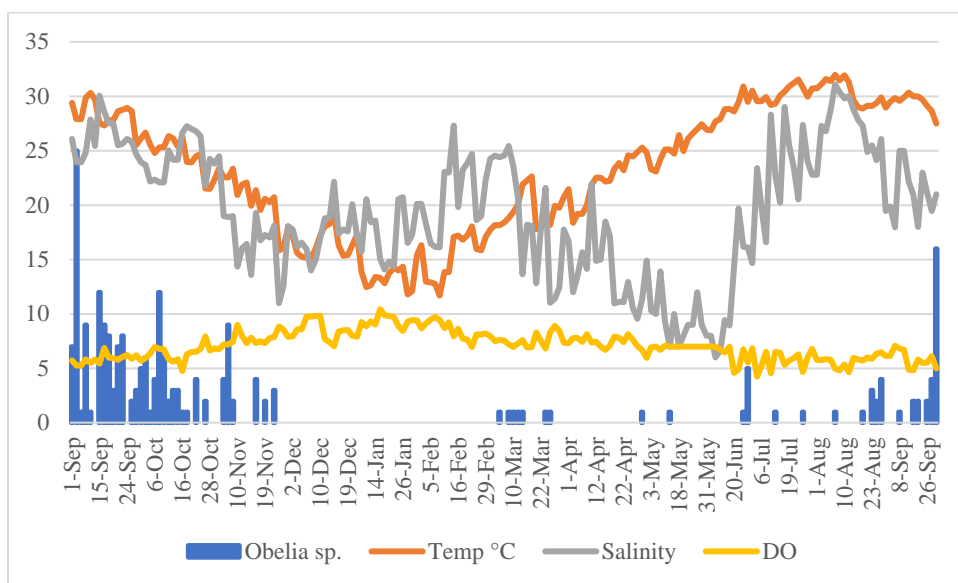


Figure 19: Relationship of *Obelia* abundance with temperature (°C), salinity (ppt), and DO (mg/L).

4. DISCUSSION

The jellyfish abundance varied seasonally with blooms occurring only in the summer, winter, and spring. The taxonomic composition of hydromedusa community also varied dramatically over the sampling period with different species dominating each month and season.

4.1 Species Composition

The phylogenetic trees created offered a look into the intraspecies genetic diversity of the common species found during this study. The species *Blackfordia virginica*, *Earleria quadrata*, and *Clytia folleata* had multiple sequences with very little intraspecific diversity, and therefore the phylogenetic trees for these species were not included. The common species *Clytia gracilis* (Figure 5) is composed by 4 very divergent clades all with 100 posterior probability. This indicates that *C. gracilis* may be composed by several cryptic species and confirms previously published data on *C. gracilis* in other basins such as the China Sea (He et al., 2015). The different clades appear in different months: clade one is found in winter and spring (March, April, and May). Clades 2 and 3 in September only and clade 4 found in spring and summer (April, May, June, July, September) and in fall (November). *Ectopleura dumortieri* also showed multiple lineages (Figure 6). Clade 1 comprises specimens collected in winter (February), clade 2 comprises specimens collected in winter and summer (February, March and September). Within Clade 1, one specimen collected on 2/15/2016 has a noticeable long branch indicating that it may be a representative of an additional lineage within *E. dumortieri*. The species *Eucheilota maculata* (Figure 7) also shows two well

supported reciprocally monophyletic clades, one found only in September and one found in March/April. *Lovenella assimilis* (Figure 8) shows three distinct and well supported lineages, one found in April/May (Clade 1), one in July and September (Clade 2) and one (Clade 3) in September only. *Liriope tetraphylla* was present in all four seasons and did not present distinct clades, instead it showed a large amount of intraspecific diversity (Figure 9). Similarly, *Malagazzia carolinae* was found in spring, fall, and summer and has interspecies variation, but no obvious seasonality or well supported clades (Figure 10). *Nemopsis bachei* sequences clustered in two distinct and well supported clades: Clade 1 was collected in February and March while Clade 2 had a strong presence in April, but was also found in February, March, and October. The very common species *Obelia dichotoma* presented several clades: Clade 1 was present in March and November, Clade 2 found in September and August, and Clade 3 found abundantly in July, September, October, November. All these clades show some degree of intra clade diversity.

The results of this phylogenetic analyses show that some of the most common and abundant species found in Galveston Bay may be composed by multiple cryptic species with very distinct seasonality. This suggests that these putative cryptic species produce medusae in response to different environmental triggers

4.2 Environmental Variables

Temperature and salinity went through large fluctuations throughout the sampling period while DO was comparatively more stable. Temperature shows a strong correlation for both total jellyfish abundance and the abundance of many of the dominant

species (Tables 3 & 7). This is consistent with previous studies conducted on individual hydromedusa species (Ma & Purcell, 2005; Nowaczyk et al., 2016; Wintzer et al., 2013). Salinity was not significantly correlated with total medusa abundance in the best fit model, but *Nemopsis bachei* specifically showed distinct seasonality and had a significant relationship with salinity (Figure 18). This is consistent with previous studies on this species which have shown a correlation with salinity and not temperature (Nowaczyk et al., 2016). *Blackfordia virginica* was also a dominant species in the spring but was not statistically correlated with any of the tested environmental factors (Table 7). The individual species analysis supports the concept that individual species produce medusa in response to different trigger(s). Our data show that temperature has a non-linear relationship with total medusa abundance (Table 3). Using the temperature coefficients generated through the regression model (Table 3), we can determine the temperature of approximately 21.5 °C was correlated with the highest jellyfish abundance in Galveston Bay. Deviation from this temperature value seems to be correlated with a decline in total number of jellyfish. An extended study would need to be conducted to verify this data, but should it be supported, this relationship to temperature could be used to predict moments of high hydromedusa abundance in Galveston Bay.

4.3 Galveston Bay Species Richness

The most recent species list of Hydrozoa for the Gulf of Mexico was compiled by Calder & Cairns in 2009 and listed 214 species. Only 7 of species recorded in this study were on the Calder & Cairns checklist. An additional 7 species found in this study

had already been reported in the Gulf of Mexico in other studies (See Table 6). 9 of the species found in this study have not been recorded in the Gulf of Mexico. The most recent study on Hydrozoa in Galveston Bay was conducted by Defenbaugh & Hopkins in 1970. They surveyed only polyps and found 25 species in the bay. Only 4 of the species found in this study were previously described in Galveston Bay. 19 of the species found in this study have never before been described in Galveston Bay (Table 6).

Galveston Bay has a large amount of ship traffic exposing it to potential species invasion through ballast water, so monitoring of the planktonic medusa could prevent ecological disturbances (Steichen et al., 2012). The majority of the dominant species in Galveston Bay are widely distributed throughout the Gulf of Mexico. *Malagazzia carolinae*, however, was present 10 out of the 13 months, and has not been recorded in the Gulf of Mexico since its discovery. *Malagazzia carolinae* was first described in 1900 by Mayer in Tortugas, Florida, an island at the edge of the Gulf of Mexico. Since its discovery, it has not been described in the Gulf of Mexico and is generally found on the coasts of New Zealand and China (Bouillon, 1995; Du et al., 2011). Due to the lack of previous hydromedusa studies in the Gulf of Mexico, more surveys will be required before we can know the extent of the distribution of *Malagazzia carolinae* in the Gulf of Mexico.

Aequorea australis, *Bougainvillia muscus*, *Stauridiosarsia reesi*, and *Turritopsis dohrnii* have not been previously described in the Gulf of Mexico. All of these species had strong BLAST identity results above 95% (Appendix 1), but had sample sizes lower than 5 individuals. Future monitoring will indicate whether these species have a lasting

presence in the Gulf of Mexico. *Clytia elsaeoswaldae*, *Earleria quadrata*, *Eucheilota maculata*, *Lovenella assimilis*, and *Sertularelloides cylindritheca* have also not been previously described in the Gulf of Mexico, however, the BLAST identity results for these species were all below 95% (Appendix 1). Therefore, no valid conclusions at this time can be drawn for these species as more morphological identification needs to be conducted to determine whether this species identification is correct.

This study was the first year in a continuing study for the Miglietta Lab at Texas A&M University at Galveston. Multiple years of sampling will provide a stronger representation of the seasonality and hydrozoa species present in Galveston Bay.

Table 8: References for species found in Gulf of Mexico and Galveston Bay

| Species | Galveston Bay | Gulf of Mexico | Reference |
|-------------------------------------|---------------|----------------|--|
| <i>Aequorea australis</i> | | | |
| <i>Blackfordia virginica</i> | | X | Cairns & Fautin, 2009. |
| <i>Bougainvillia muscus</i> | | X | Cairns & Fautin, 2009. |
| <i>Bougainvillia triestina</i> | | | |
| <i>Clytia elsaeswaldae</i> * | | | |
| <i>Clytia folleata</i> | | X | Cairns & Fautin, 2009. |
| <i>Clytia gracilis</i> | X | X | Defenbaugh & Hopkins, 1973; Calder & Cairns, 2009. |
| <i>Clytia</i> sp. 1 | | | |
| <i>Corymorpha nutans</i> | | X | Cairns & Fautin, 2009. |
| <i>Stauridiosarsia reesi</i> | | | |
| <i>Earleria quadrata</i> * | | | |
| <i>Ectopleura dumortieri</i> | | X | Calder & Cairns, 2009. |
| <i>Eucheilota maculata</i> * | | | |
| <i>Podocoryna americana</i> | | X | Calder & Cairns, 2009. |
| <i>Koellikerina fasciculata</i> * | | X | Martell-Hernandez et al., 2014. |
| <i>Liriope tetraphylla</i> | | X | Cairns & Fautin, 2009. |
| <i>Lovenella assimilis</i> * | | | |
| <i>Malagazzia carolinae</i> | | X | Mayer, 1900. |
| <i>Nemopsis bachei</i> | | X | Cairns & Fautin, 2009. |
| <i>Obelia bidentata</i> | X | X | Defenbaugh & Hopkins, 1973; Calder & Cairns, 2009. |
| <i>Obelia dichotoma</i> | X | X | Defenbaugh & Hopkins, 1973; Calder & Cairns, 2009. |
| <i>Obelia geniculata</i> * | X | X | Defenbaugh & Hopkins, 1973; Calder & Cairns, 2009. |
| <i>Obelia</i> sp. | | | |
| <i>Sertularella cylindritheca</i> * | | | |
| <i>Turritopsis dohrnii</i> | | | |

*These species did not have BLAST results higher than a 95% ident value

5. CONCLUSION

The hydromedusa of Galveston Bay were collected and identified through morphological and molecular techniques over a 13 month period to assess the species richness and abundance. 25 total species were found and only 4 had previously been described in Galveston Bay. All of the species with multiple sequences were analyzed using both ML and Bayesian analyses, and Bayesian phylogenetic trees were created to represent the intraspecific differences. Our results suggest that most of the common and abundant species in Galveston Bay may be composed of multiple cryptic species that respond to different environmental triggers.

The hydromedusa abundance was also compared to the environmental factors temperature, salinity, DO, and chlorophyll a through multiple multivariate OLS regression models. The models suggest that temperature has a non-linear relationship with medusa abundance and is statistically correlated. Although productivity (chlorophyll a) was predicted to have a strong correlation, it did not present significant correlation in these models. Our results suggest that there is seasonal fluctuation in the abundance and diversity of hydromedusa in Galveston Bay that could be partially driven by temperature.

This study represents the first look into the hydromedusa community in Galveston Bay which play a large part in the ecosystem as top predators of the food web. Further studies and long-term monitoring are necessary to confirm the results found in this introductory 13-month study and to continue to understand the seasonality and diversity of hydromedusa in Galveston Bay.

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APPENDIX I

Blast results for all completed sequences

| Date | BLAST Species | Ident | Query | E-value |
|-------------|------------------------------|-------|-------|---------|
| 09.02.15.05 | <i>Obelia dichotoma</i> | 99.8 | 100 | 0 |
| 09.02.15.09 | <i>Aequorea australis</i> | 99.6 | 88.74 | 0 |
| 09.02.15.16 | <i>Obelia dichotoma</i> | 99.7 | 98.22 | 0 |
| 09.02.15.17 | <i>Obelia geniculata</i> | 93 | 100 | 0 |
| 09.02.15.22 | <i>Malagazzia carolinae</i> | 92.59 | 96.1 | 0 |
| 09.02.15.25 | <i>Obelia dichotoma</i> | 100 | 100 | 0 |
| 09.02.15.27 | <i>Stauridiosarsia reesi</i> | 95.7 | 100 | 0 |
| 09.02.15.29 | <i>Obelia dichotoma</i> | 99.7 | 100 | 0 |
| 09.02.15.30 | <i>Obelia dichotoma</i> | 99.7 | 99.84 | 0 |
| 09.02.15.31 | <i>Clytia gracilis</i> | 93.1 | 98.3 | 0 |
| 09.03.15.01 | <i>Obelia dichotoma</i> | 99.04 | 99.8 | 0 |
| 09.03.15.02 | <i>Clytia gracilis</i> | 93.5 | 98.06 | 0 |
| 09.08.15.05 | <i>Malagazzia carolinae</i> | 96.4 | 87.09 | 0 |
| 09.08.15.10 | <i>Obelia dichotoma</i> | 99.6 | 99.82 | 0 |
| 09.09.15.01 | <i>Obelia dichotoma</i> | 99.6 | 98.43 | 0 |
| 09.10.15.05 | <i>Nemopsis bachei</i> | 90.5 | 87.01 | 0 |
| 09.15.15.04 | <i>Malagazzia carolinae</i> | 95 | 99 | 0 |
| 09.15.15.05 | <i>Obelia dichotoma</i> | 99.5 | 100 | 0 |
| 09.15.15.09 | <i>Obelia bidentata</i> | 99.6 | 98.43 | 0 |
| 09.16.15.02 | <i>Obelia dichotoma</i> | 99 | 98 | 0 |
| 09.16.15.05 | <i>Aequorea australis</i> | 99.4 | 84.44 | 0 |
| 09.16.15.06 | <i>Obelia dichotoma</i> | 99 | 98 | 0 |
| 09.16.15.07 | <i>Malagazzia carolinae</i> | 96 | 92 | 0 |
| 09.17.15.11 | <i>Malagazzia carolinae</i> | 96 | 99 | 0 |
| 09.22.15.01 | <i>Earleria quadrata</i> | 87 | 98.25 | 0 |
| 09.22.15.06 | <i>Earleria quadrata</i> | 87.3 | 98 | 0 |
| 09.22.15.12 | <i>Earleria quadrata</i> | 87.4 | 98.42 | 0 |
| 09.23.15.02 | <i>Obelia dichotoma</i> | 99 | 8 | 0 |
| 09.24.15.04 | <i>Earleria quadrata</i> | 87 | 100 | 0 |
| 09.24.15.10 | <i>Earleria quadrata</i> | 87.5 | 98.95 | 0 |
| 09.25.15.03 | <i>Nemopsis bachei</i> | 91 | 92 | 0 |
| 09.25.15.06 | <i>Earleria quadrata</i> | 87.5 | 96.71 | 0 |
| 09.25.15.08 | <i>Earleria quadrata</i> | 87 | 98 | 0 |
| 09.29.15.02 | <i>Obelia dichotoma</i> | 99 | 100 | 0 |
| 09.29.15.03 | <i>Obelia dichotoma</i> | 100 | 100 | 0 |
| 09.30.15.02 | <i>Malagazzia carolinae</i> | 96.3 | 85.83 | 0 |

| | | | | |
|-------------|------------------------------|------|-------|---|
| 09.30.15.04 | <i>Malagazzia carolinae</i> | 96.6 | 85.46 | 0 |
| 10.01.15.02 | <i>Malagazzia carolinae</i> | 95.9 | 94.4 | 0 |
| 10.01.15.03 | <i>Obelia dichotoma</i> | 99.6 | 99.6 | 0 |
| 10.07.15.03 | <i>Obelia dichotoma</i> | 99.3 | 91.91 | 0 |
| 10.07.15.06 | <i>Obelia dichotoma</i> | 99 | 97 | 0 |
| 10.08.15.03 | <i>Obelia dichotoma</i> | 99.5 | 97.93 | 0 |
| 10.08.15.04 | <i>Obelia dichotoma</i> | 99.8 | 99.8 | 0 |
| 10.08.15.05 | <i>Obelia dichotoma</i> | 99.8 | 97 | 0 |
| 10.08.15.06 | <i>Obelia dichotoma</i> | 99 | 97.8 | 0 |
| 10.08.15.07 | <i>Obelia dichotoma</i> | 99.3 | 97.93 | 0 |
| 10.1.15.6 | <i>Blackfordia virginica</i> | 93.1 | 97.23 | 0 |
| 10.13.15.01 | <i>Obelia dichotoma</i> | 99 | 99 | 0 |
| 10.13.15.02 | <i>Obelia dichotoma</i> | 98 | 100 | 0 |
| 10.14.15.01 | <i>Malagazzia carolinae</i> | 96 | 94 | 0 |
| 10.14.15.02 | <i>Malagazzia carolinae</i> | 95.7 | 92.9 | 0 |
| 10.16.15.03 | <i>Obelia dichotoma</i> | 99.6 | 98.06 | 0 |
| 10.21.15.1 | <i>Nemopsis bachei</i> | 90.4 | 92.2 | 0 |
| 10.22.15.01 | <i>Obelia dichotoma</i> | 99 | 99 | 0 |
| 10.22.15.04 | <i>Nemopsis bachei</i> | 90.7 | 94.87 | 0 |
| 10.22.15.05 | <i>Obelia dichotoma</i> | 99 | 92.83 | 0 |
| 10.22.15.06 | <i>Obelia dichotoma</i> | 100 | 100 | 0 |
| 10.22.15.07 | <i>Obelia dichotoma</i> | 99.6 | 93.65 | 0 |
| 10.22.15.3 | <i>Nemopsis bachei</i> | 90.2 | 92.37 | 0 |
| 11.03.15.02 | <i>Malagazzia carolinae</i> | 96 | 100 | 0 |
| 11.04.15.02 | <i>Clytia gracilis</i> | 98.2 | 100 | 0 |
| 11.04.15.05 | <i>Clytia gracilis</i> | 98.1 | 100 | 0 |
| 11.04.15.06 | <i>Obelia dichotoma</i> | 99 | 97 | 0 |
| 11.04.15.08 | <i>Obelia dichotoma</i> | 99 | 100 | 0 |
| 11.04.15.09 | <i>Obelia dichotoma</i> | 99.6 | 92.8 | 0 |
| 11.04.15.10 | <i>Obelia dichotoma</i> | 99.6 | 99.12 | 0 |
| 11.05.15.01 | <i>Obelia dichotoma</i> | 99.6 | 97.9 | 0 |
| 11.05.15.02 | <i>Obelia dichotoma</i> | 99.6 | 100 | 0 |
| 11.05.15.03 | <i>Clytia gracilis</i> | 98.1 | 99.65 | 0 |
| 11.11.15.01 | <i>Nemopsis bachei</i> | 91 | 90 | 0 |
| 11.4.15.1 | <i>Obelia geniculata</i> | 94.7 | 97.57 | 0 |
| 2.01.16.04 | <i>Nemopsis bachei</i> | 99.6 | 84.06 | 0 |
| 2.01.16.06 | <i>Bougainvillea muscus</i> | 96.8 | 96.39 | 0 |
| 2.01.16.13 | <i>Nemopsis bachei</i> | 90.4 | 82.76 | 0 |
| 2.01.16.15 | <i>Nemopsis bachei</i> | 99.2 | 85.36 | 0 |
| 2.01.16.18 | <i>Nemopsis bachei</i> | 90.6 | 91.27 | 0 |
| 2.01.16.19 | <i>Nemopsis bachei</i> | 90.6 | 91.27 | 0 |
| 2.01.16.20 | <i>Nemopsis bachei</i> | 90.6 | 91.27 | 0 |

| | | | | |
|------------|------------------------------|------|-------|---|
| 2.01.16.21 | <i>Blackfordia virginica</i> | 99.7 | 100 | 0 |
| 2.01.16.22 | <i>Bougainvillia muscus</i> | 95.9 | 98.42 | 0 |
| 2.01.16.23 | <i>Blackfordia virginica</i> | 100 | 81.41 | 0 |
| 2.02.16.01 | <i>Nemopsis bachei</i> | 99.2 | 92.19 | 0 |
| 2.02.16.07 | <i>Nemopsis bachei</i> | 99.4 | 92.37 | 0 |
| 2.02.16.08 | <i>Nemopsis bachei</i> | 98.9 | 92.21 | 0 |
| 2.02.16.12 | <i>Nemopsis bachei</i> | 99.2 | 83.82 | 0 |
| 2.02.16.16 | <i>Nemopsis bachei</i> | 99.4 | 83.16 | 0 |
| 2.02.16.18 | <i>Nemopsis bachei</i> | 99.6 | 83.48 | 0 |
| 2.15.16.25 | <i>Ectopleura dumortieri</i> | 95.4 | 99.82 | 0 |
| 2.15.16.26 | <i>Ectopleura dumortieri</i> | 94.7 | 100 | 0 |
| 2.15.16.27 | <i>Ectopleura dumortieri</i> | 95.4 | 100 | 0 |
| 2.15.16.29 | <i>Ectopleura dumortieri</i> | 95.2 | 99.47 | 0 |
| 2.15.16.30 | <i>Ectopleura dumortieri</i> | 95.2 | 99.47 | 0 |
| 2.15.16.31 | <i>Ectopleura dumortieri</i> | 95.1 | 100 | 0 |
| 2.15.16.32 | <i>Ectopleura dumortieri</i> | 95.3 | 100 | 0 |
| 2.16.16.02 | <i>Liriope tetraphylla</i> | 96.4 | 85.64 | 0 |
| 2.16.16.05 | <i>Liriope tetraphylla</i> | 95.6 | 97.69 | 0 |
| 2.16.16.06 | <i>Liriope tetraphylla</i> | 96.7 | 85.88 | 0 |
| 2.16.16.07 | <i>Liriope tetraphylla</i> | 96.5 | 87.84 | 0 |
| 2.29.16.02 | <i>Nemopsis bachei</i> | 99.2 | 85.99 | 0 |
| 2.29.16.09 | <i>Ectopluera dumortieri</i> | 95.7 | 100 | 0 |
| 2.29.16.10 | <i>Ectopluera dumortieri</i> | 95.7 | 100 | 0 |
| 2.29.16.11 | <i>Ectopluera dumortieri</i> | 95.9 | 100 | 0 |
| 2.29.16.12 | <i>Ectopluera dumortieri</i> | 95.6 | 100 | 0 |
| 2.29.16.13 | <i>Ectopluera dumortieri</i> | 95 | 100 | 0 |
| 2.29.16.15 | <i>Ectopluera dumortieri</i> | 94.7 | 100 | 0 |
| 2.29.16.17 | <i>Ectopluera dumortieri</i> | 95.3 | 100 | 0 |
| 2.29.16.19 | <i>Ectopleura dumortieri</i> | 95.5 | 100 | 0 |
| 2.29.16.20 | <i>Ectopleura dumortieri</i> | 95.5 | 100 | 0 |
| 2.29.16.21 | <i>Ectopleura dumortieri</i> | 95.5 | 100 | 0 |
| 2.29.16.22 | <i>Ectopleura dumortieri</i> | 95.3 | 100 | 0 |
| 2.29.16.23 | <i>Ectopleura dumortieri</i> | 95.5 | 100 | 0 |
| 2.4.16.15 | <i>Nemopsis bachei</i> | 99.6 | 84.02 | 0 |
| 2.4.16.18 | <i>Nemopsis bachei</i> | 99.3 | 93.4 | 0 |
| 2.4.16.22 | <i>Nemopsis bachei</i> | 99.6 | 91.24 | 0 |
| 2.4.16.24 | <i>Nemopsis bachei</i> | 99.4 | 92.21 | 0 |
| 3.01.16.15 | <i>Nemopsis bachei</i> | 90.2 | 83.45 | 0 |
| 3.01.16.17 | <i>Nemopsis bachei</i> | 90.8 | 83.77 | 0 |
| 3.01.16.19 | <i>Clytia sp. 1</i> | 91.3 | 96.66 | 0 |
| 3.03.16.07 | <i>Nemopsis bachei</i> | 98.6 | 96.27 | 0 |
| 3.03.16.08 | <i>Nemopsis bachei</i> | 99.4 | 85.79 | 0 |

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|------------|---------------------------------|------|-------|------|
| 3.03.16.09 | <i>Nemopsis bachei</i> | 98.7 | 85.34 | 0 |
| 3.03.16.20 | <i>Nemopsis bachei</i> | 99.4 | 85.79 | 0 |
| 3.03.16.21 | <i>Nemopsis bachei</i> | 98.8 | 86.19 | 0 |
| 3.03.16.22 | <i>Nemopsis bachei</i> | 99.2 | 85.64 | 0 |
| 3.03.16.24 | <i>Nemopsis bachei</i> | 99.6 | 85.64 | 0 |
| 3.03.16.25 | <i>Nemopsis bachei</i> | 99.6 | 85.64 | 0 |
| 3.04.16.03 | <i>Corymorpha nutans</i> | 88.9 | 96.47 | 0 |
| 3.07.16.01 | <i>Eucheilota maculata</i> | 93.2 | 99.65 | 0 |
| 3.07.16.02 | <i>Malgazzia carolinae</i> | 96.1 | 92.23 | 0 |
| 3.07.16.03 | <i>Obelia dichotoma</i> | 99.6 | 98.93 | 0 |
| 3.07.16.04 | <i>Hydractinia americana</i> | 97 | 100 | 0 |
| 3.08.16.02 | <i>Nemopsis bachei</i> | 99.2 | 92.17 | 0 |
| 3.08.16.03 | <i>Clytia gracilis</i> | 100 | 99.65 | 0 |
| 3.08.16.04 | <i>Clytia gracilis</i> | 99.8 | 100 | 0 |
| 3.08.16.05 | <i>Nemopsis bachei</i> | 98.9 | 91.21 | 0 |
| 3.08.16.06 | <i>Malagazzia carolinae</i> | 95.9 | 92.4 | 0 |
| 3.11.16.05 | <i>Liriope tetraphylla</i> | 96.8 | 85.71 | 0 |
| 3.11.16.14 | <i>Obelia dichotoma</i> | 99.8 | 99 | 0 |
| 3.11.16.15 | <i>Liriope tetraphylla</i> | 96.4 | 97.64 | 0 |
| 3.16.16.05 | <i>Liriope tetraphylla</i> | 96.5 | 100 | 0 |
| 3.16.16.08 | <i>Malagazzia carolinae</i> | 96.1 | 100 | 0 |
| 3.18.16.01 | <i>Nemopsis bachei</i> | 99.2 | 92.03 | 0 |
| 3.18.16.02 | <i>Ectopleura dumortieri</i> | 95.6 | 98.74 | 0 |
| 3.18.16.03 | <i>Liriope tetraphylla</i> | 96.7 | 91.36 | 0 |
| 3.18.16.04 | <i>Clytia gracilis</i> | 96.6 | 99.48 | 0 |
| 3.18.16.06 | <i>Malagazzia carolinae</i> | 96.1 | 93.21 | 0 |
| 3.21.16.03 | <i>Nemopsis bachei</i> | 99.1 | 92.16 | 0 |
| 3.21.16.04 | <i>Malagazzia carolinae</i> | 96.1 | 92.39 | 0 |
| 3.21.16.05 | <i>Nemopsis bachei</i> | 99.4 | 93.46 | 0 |
| 3.21.16.6 | <i>Malagazzia carolinae</i> | 95.9 | 95 | 0 |
| 3.22.16.02 | <i>Blackfordia virginica</i> | 100 | 91.21 | 0 |
| 3.22.16.03 | <i>Koellikerina fasciculata</i> | 89.6 | 100 | 0 |
| 3.22.16.04 | <i>Liriope tetraphylla</i> | 96.6 | 79.86 | 0 |
| 3.22.16.07 | <i>Liriope tetraphylla</i> | 96.8 | 100 | 0 |
| 3.22.16.08 | <i>Nemopsis bachei</i> | 91 | 84.5 | 0 |
| 3.22.16.12 | <i>Obelia dichotoma</i> | 100 | 0 | 99.8 |
| 3.22.16.14 | <i>Bougainvillia triestina</i> | 95.5 | 99.6 | 0 |
| 3.25.16.01 | <i>Nemopsis bachei</i> | 99.4 | 91.25 | 0 |
| 3.25.16.02 | <i>Liriope tetraphylla</i> | 96.7 | 92.29 | 0 |
| 3.25.16.03 | <i>Malagazzia carolinae</i> | 96.1 | 93.54 | 0 |
| 3.25.16.04 | <i>Nemopsis bachei</i> | 99.4 | 90.77 | 0 |
| 3.31.16.02 | <i>Liriope tetraphylla</i> | 96.7 | 92.29 | 0 |

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|-------------|----------------------------|------|-------|---|
| 3.31.16.03 | <i>Nemopsis bachei</i> | 90 | 91.39 | 0 |
| 3.31.16.08 | <i>Liriope tetraphylla</i> | 96.7 | 92.45 | 0 |
| 3.31.16.09 | <i>Liriope tetraphylla</i> | 96.6 | 100 | 0 |
| 3.31.16.10 | <i>Liriope tetraphylla</i> | 96.5 | 92.31 | 0 |
| 3.31.16.12 | <i>Liriope tetraphylla</i> | 95.9 | 100 | 0 |
| 3.31.16.13 | <i>Liriope tetraphylla</i> | 96.8 | 100 | 0 |
| 3.31.16.15 | <i>Liriope tetraphylla</i> | 96 | 99.8 | 0 |
| 3.31.16.16 | <i>Liriope tetraphylla</i> | 96.2 | 99.31 | 0 |
| 4.11.16.03 | <i>Liriope tetraphylla</i> | 96.7 | 92.93 | 0 |
| 4.11.16.04 | <i>Liriope tetraphylla</i> | 96.7 | 92.77 | 0 |
| 4.11.16.05 | <i>Liriope tetraphylla</i> | 96.7 | 98.3 | 0 |
| 4.11.16.06 | <i>Liriope tetraphylla</i> | 97 | 92.45 | 0 |
| 4.11.16.07 | <i>Liriope tetraphylla</i> | 96.8 | 92.77 | 0 |
| 4.11.16.08 | <i>Liriope tetraphylla</i> | 96.8 | 93.25 | 0 |
| 4.11.16.09 | <i>Liriope tetraphylla</i> | 96.8 | 92.61 | 0 |
| 4.11.16.100 | <i>Liriope tetraphylla</i> | 96.6 | 100 | 0 |
| 4.11.16.101 | <i>Liriope tetraphylla</i> | 96.9 | 100 | 0 |
| 4.11.16.102 | <i>Liriope tetraphylla</i> | 96.9 | 100 | 0 |
| 4.11.16.103 | <i>Liriope tetraphylla</i> | 96.6 | 97.33 | 0 |
| 4.11.16.104 | <i>Liriope tetraphylla</i> | 96.9 | 100 | 0 |
| 4.11.16.11 | <i>Liriope tetraphylla</i> | 96.7 | 92.61 | 0 |
| 4.11.16.13 | <i>Liriope tetraphylla</i> | 96 | 100 | 0 |
| 4.11.16.14 | <i>Liriope tetraphylla</i> | 96.6 | 100 | 0 |
| 4.11.16.17 | <i>Liriope tetraphylla</i> | 96.2 | 100 | 0 |
| 4.11.16.18 | <i>Liriope tetraphylla</i> | 96.2 | 100 | 0 |
| 4.11.16.25 | <i>Nemopsis bachei</i> | 88.7 | 99.35 | 0 |
| 4.11.16.27 | <i>Liriope tetraphylla</i> | 96.3 | 99.8 | 0 |
| 4.11.16.29 | <i>Liriope tetraphylla</i> | 96.7 | 92.61 | 0 |
| 4.11.16.31 | <i>Eucheilota maculata</i> | 93.2 | 99.83 | 0 |
| 4.11.16.32 | <i>Nemopsis bachei</i> | 90.9 | 91.41 | 0 |
| 4.11.16.33 | <i>Liriope tetraphylla</i> | 96.8 | 92.45 | 0 |
| 4.11.16.39 | <i>Nemopsis bachei</i> | 91 | 88.85 | 0 |
| 4.11.16.40 | <i>Nemopsis bachei</i> | 90.8 | 88.95 | 0 |
| 4.11.16.43 | <i>Liriope tetraphylla</i> | 96.7 | 92.45 | 0 |
| 4.11.16.45 | <i>Liriope tetraphylla</i> | 96.5 | 92.77 | 0 |
| 4.11.16.46 | <i>Liriope tetraphylla</i> | 96.2 | 100 | 0 |
| 4.11.16.50 | <i>Liriope tetraphylla</i> | 96.4 | 100 | 0 |
| 4.11.16.51 | <i>Liriope tetraphylla</i> | 96.3 | 92.62 | 0 |
| 4.11.16.52 | <i>Liriope tetraphylla</i> | 96.3 | 93.25 | 0 |
| 4.11.16.53 | <i>Liriope tetraphylla</i> | 96.5 | 92.61 | 0 |
| 4.11.16.54 | <i>Nemopsis bachei</i> | 89.5 | 92.9 | 0 |
| 4.11.16.55 | <i>Liriope tetraphylla</i> | 96.3 | 92.78 | 0 |

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|------------|----------------------------|------|-------|---|
| 4.11.16.56 | <i>Liriope tetraphylla</i> | 96.9 | 92.78 | 0 |
| 4.11.16.60 | <i>Clytia sp. 1</i> | 89.4 | 100 | 0 |
| 4.11.16.63 | <i>Liriope tetraphylla</i> | 96.7 | 92.62 | 0 |
| 4.11.16.64 | <i>Lovenella assimilis</i> | 90.5 | 96.47 | 0 |
| 4.11.16.66 | <i>Nemopsis bachei</i> | 90.4 | 92.9 | 0 |
| 4.11.16.68 | <i>Liriope tetraphylla</i> | 96.5 | 92.78 | 0 |
| 4.11.16.71 | <i>Liriope tetraphylla</i> | 96.5 | 92.78 | 0 |
| 4.11.16.72 | <i>Liriope tetraphylla</i> | 96.5 | 92.15 | 0 |
| 4.11.16.73 | <i>Nemopsis bachei</i> | 90.4 | 93.1 | 0 |
| 4.11.16.75 | <i>Liriope tetraphylla</i> | 97 | 92.61 | 0 |
| 4.11.16.76 | <i>Nemopsis bachei</i> | 89.8 | 96.5 | 0 |
| 4.11.16.77 | <i>Liriope tetraphylla</i> | 96.9 | 92.78 | 0 |
| 4.11.16.79 | <i>Liriope tetraphylla</i> | 96.5 | 92.78 | 0 |
| 4.11.16.80 | <i>Nemopsis bachei</i> | 90 | 92.48 | 0 |
| 4.11.16.81 | <i>Eucheilota maculata</i> | 92.8 | 99.82 | 0 |
| 4.11.16.82 | <i>Liriope tetraphylla</i> | 95 | 100 | 0 |
| 4.11.16.83 | <i>Liriope tetraphylla</i> | 96.7 | 92.62 | 0 |
| 4.11.16.85 | <i>Liriope tetraphylla</i> | 97 | 92.31 | 0 |
| 4.11.16.86 | <i>Nemopsis bachei</i> | 89.8 | 90 | 0 |
| 4.11.16.87 | <i>Liriope tetraphylla</i> | 96.8 | 96.57 | 0 |
| 4.11.16.88 | <i>Liriope tetraphylla</i> | 96.7 | 97.97 | 0 |
| 4.11.16.89 | <i>Liriope tetraphylla</i> | 96.8 | 97.33 | 0 |
| 4.11.16.90 | <i>Liriope tetraphylla</i> | 96.8 | 98.57 | 0 |
| 4.11.16.91 | <i>Liriope tetraphylla</i> | 96.6 | 97.33 | 0 |
| 4.11.16.92 | <i>Nemopsis bachei</i> | 90.6 | 92.37 | 0 |
| 4.11.16.93 | <i>Nemopsis bachei</i> | 90.6 | 90.6 | 0 |
| 4.11.16.94 | <i>Nemopsis bachei</i> | 90.6 | 89.9 | 0 |
| 4.11.16.95 | <i>Liriope tetraphylla</i> | 96.9 | 100 | 0 |
| 4.11.16.96 | <i>Nemopsis bachei</i> | 90.4 | 92.99 | 0 |
| 4.11.16.97 | <i>Liriope tetraphylla</i> | 96.8 | 100 | 0 |
| 4.11.16.98 | <i>Liriope tetraphylla</i> | 96.5 | 100 | 0 |
| 4.11.16.99 | <i>Liriope tetraphylla</i> | 97.1 | 100 | 0 |
| 4.12.16.02 | <i>Liriope tetraphylla</i> | 96.8 | 84.09 | 0 |
| 4.12.16.03 | <i>Liriope tetraphylla</i> | 96.6 | 100 | 0 |
| 4.12.16.04 | <i>Liriope tetraphylla</i> | 96.6 | 100 | 0 |
| 4.12.16.05 | <i>Liriope tetraphylla</i> | 96.8 | 100 | 0 |
| 4.12.16.06 | <i>Liriope tetraphylla</i> | 96.6 | 100 | 0 |
| 4.12.16.07 | <i>Liriope tetraphylla</i> | 96.8 | 100 | 0 |
| 4.12.16.08 | <i>Liriope tetraphylla</i> | 96.8 | 100 | 0 |
| 4.12.16.09 | <i>Liriope tetraphylla</i> | 96.7 | 96.8 | 0 |
| 4.12.16.12 | <i>Liriope tetraphylla</i> | 96.6 | 100 | 0 |
| 4.12.16.13 | <i>Liriope tetraphylla</i> | 96.8 | 92.77 | 0 |

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|------------|---------------------------------|------|--------|---|
| 4.12.16.15 | <i>Liriope tetraphylla</i> | 96.7 | 92.29 | 0 |
| 4.12.16.16 | <i>Liriope tetraphylla</i> | 96.7 | 92.29 | 0 |
| 4.12.16.17 | <i>Liriope tetraphylla</i> | 97 | 92.29 | 0 |
| 4.12.16.18 | <i>Koellikerina fasciculata</i> | 89.3 | 96.5 | 0 |
| 4.12.16.19 | <i>Nemopsis bachei</i> | 91 | 84.25 | 0 |
| 4.12.16.20 | <i>Liriope tetraphylla</i> | 97 | 97.98 | 0 |
| 4.12.16.21 | <i>Liriope tetraphylla</i> | 96.2 | 97.98 | 0 |
| 4.12.16.22 | <i>Nemopsis bachei</i> | 91 | 84.25 | 0 |
| 4.12.16.23 | <i>Liriope tetraphylla</i> | 96.7 | 97.98 | 0 |
| 4.12.16.24 | <i>Liriope tetraphylla</i> | 96.6 | 97.48 | 0 |
| 4.14.16.01 | <i>Liriope tetraphylla</i> | 96.7 | 92.94 | 0 |
| 4.14.16.02 | <i>Liriope tetraphylla</i> | 90 | 100 | 0 |
| 4.14.16.03 | <i>Liriope tetraphylla</i> | 96.5 | 91.97 | 0 |
| 4.14.16.04 | <i>Clytia gracilis</i> | 100 | 100 | 0 |
| 4.14.16.05 | <i>Liriope tetraphylla</i> | 96.4 | 87.36 | 0 |
| 4.14.16.07 | <i>Liriope tetraphylla</i> | 95.9 | 91.35 | 0 |
| 4.14.16.08 | <i>Liriope tetraphylla</i> | 96.3 | 92.28 | 0 |
| 4.14.16.09 | <i>Liriope tetraphylla</i> | 96.3 | 93.54 | 0 |
| 4.14.16.10 | <i>Liriope tetraphylla</i> | 96.7 | 97.98 | 0 |
| 4.14.16.11 | <i>Malagazzia carolinae</i> | 96.4 | 87.3 | 0 |
| 4.14.16.12 | <i>Liriope tetraphylla</i> | 96.7 | 97.98 | 0 |
| 4.14.16.13 | <i>Liriope tetraphylla</i> | 97 | 97.48 | 0 |
| 4.14.16.14 | <i>Liriope tetraphylla</i> | 97 | 92.94 | 0 |
| 4.14.16.17 | <i>Malagazzia carolinae</i> | 96.5 | 92.72 | 0 |
| 4.14.16.18 | <i>Liriope tetraphylla</i> | 96.2 | 100 | 0 |
| 4.14.16.19 | <i>Malagazzia carolinae</i> | 95.8 | 86.75 | 0 |
| 4.14.16.20 | <i>Malagazzia carolinae</i> | 95.8 | 87.11 | 0 |
| 4.15.16.01 | <i>Liriope tetraphylla</i> | 95.7 | 91.97 | 0 |
| 4.15.16.02 | <i>Liriope tetraphylla</i> | 96.3 | 92.44 | 0 |
| 4.15.16.07 | <i>Malagazzia carolinae</i> | 95.7 | 86.37 | 0 |
| 4.15.16.08 | <i>Clytia gracilis</i> | 98.5 | 99.8 | 0 |
| 4.15.16.10 | <i>Malagazzia carolinae</i> | 96 | 86.84 | 0 |
| 4.15.16.11 | <i>Clytia gracilis</i> | 98.1 | 99.8 | 0 |
| 4.15.16.9 | <i>Malagazzia carolinae</i> | 96.1 | 91 | 0 |
| 4.21.16.05 | <i>Liriope tetraphylla</i> | 89.8 | 96.55 | 0 |
| 4.21.16.4 | <i>Clytia gracilis</i> | 98.4 | 100 | 0 |
| 4.21.16.6 | <i>Clytia gracilis</i> | 98.1 | 100 | 0 |
| 4.21.16.7 | <i>Clytia gracilis</i> | 98.1 | 100 | 0 |
| 4.22.16.01 | <i>Liriope tetraphylla</i> | 90.6 | 92.367 | 0 |
| 4.22.16.03 | <i>Liriope tetraphylla</i> | 90.4 | 89.9 | 0 |
| 4.22.16.04 | <i>Liriope tetraphylla</i> | 90.4 | 92.99 | 0 |
| 4.22.16.05 | <i>Clytia gracilis</i> | 100 | 98.06 | 0 |

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|------------|------------------------------|------|-------|---|
| 4.22.16.06 | <i>Blackfordia virginica</i> | 100 | 83.04 | 0 |
| 4.22.16.07 | <i>Clytia gracilis</i> | 98.3 | 100 | 0 |
| 4.22.16.08 | <i>Malagazzia carolinae</i> | 96.5 | 92.72 | 0 |
| 4.22.16.12 | <i>Clytia gracilis</i> | 98.2 | 100 | 0 |
| 4.22.16.13 | <i>Clytia gracilis</i> | 98.4 | 100 | 0 |
| 4.22.16.15 | <i>Clytia gracilis</i> | 98.2 | 100 | 0 |
| 4.22.16.16 | <i>Clytia gracilis</i> | 98.4 | 100 | 0 |
| 4.28.15.04 | <i>Clytia gracilis</i> | 97.8 | 99.6 | 0 |
| 4.28.16.01 | <i>Malagazzia carolinae</i> | 95.9 | 94.06 | 0 |
| 4.28.16.02 | <i>Clytia gracilis</i> | 98.6 | 100 | 0 |
| 4.28.16.03 | <i>Malagazzia carolinae</i> | 95.7 | 93.96 | 0 |
| 4.28.16.05 | <i>Malagazzia carolinae</i> | 96.3 | 92.44 | 0 |
| 4.28.16.07 | <i>Malagazzia carolinae</i> | 96.1 | 92.44 | 0 |
| 4.28.16.08 | <i>Malagazzia carolinae</i> | 96 | 92.44 | 0 |
| 4.28.16.11 | <i>Malagazzia carolinae</i> | 95.9 | 88.8 | 0 |
| 4.28.16.12 | <i>Clytia gracilis</i> | 99.1 | 100 | 0 |
| 4.28.16.13 | <i>Clytia gracilis</i> | 98.3 | 100 | 0 |
| 4.28.16.14 | <i>Malagazzia carolinae</i> | 96.5 | 91.79 | 0 |
| 4.28.16.15 | <i>Malagazzia carolinae</i> | 95.9 | 92.93 | 0 |
| 4.28.16.16 | <i>Obelia bidentata</i> | 100 | 88.83 | 0 |
| 4.29.16.01 | <i>Malagazzia carolinae</i> | 96.5 | 85.6 | 0 |
| 4.29.16.02 | <i>Liriope tetrapylla</i> | 96.9 | 86.03 | 0 |
| 4.29.16.03 | <i>Blackfordia virginica</i> | 100 | 90.29 | 0 |
| 4.29.16.04 | <i>Clytia gracilis</i> | 99.4 | 100 | 0 |
| 4.29.16.06 | <i>Malagazzia carolinae</i> | 96.3 | 84.2 | 0 |
| 4.29.16.07 | <i>Liriope tetrapylla</i> | 96.7 | 84.88 | 0 |
| 5.10.16.01 | <i>Clytia gracilis</i> | 98.3 | 100 | 0 |
| 5.10.16.02 | <i>Blackfordia virginica</i> | 100 | 89.83 | 0 |
| 5.10.16.03 | <i>Blackfordia virginica</i> | 100 | 91.34 | 0 |
| 5.10.16.04 | <i>Blackfordia virginica</i> | 100 | 91.34 | 0 |
| 5.10.16.05 | <i>Clytia gracilis</i> | 100 | 99.82 | 0 |
| 5.10.16.06 | <i>Clytia folleta</i> | 99.8 | 86.43 | 0 |
| 5.10.16.07 | <i>Blackfordia virginica</i> | 94.4 | 96.01 | 0 |
| 5.10.16.7 | <i>Nemopsis bachei</i> | 94.4 | 96.7 | 0 |
| 5.12.16.01 | <i>Malagazzia carolinae</i> | 96.4 | 91 | 0 |
| 5.12.16.02 | <i>Clytia folleata</i> | 99.8 | 92.26 | 0 |
| 5.12.16.03 | <i>Clytia gracilis</i> | 98.2 | 99.65 | 0 |
| 5.12.16.04 | <i>Clytia gracilis</i> | 98.4 | 99.65 | 0 |
| 5.19.16.01 | <i>Malagazzia carolinae</i> | 96 | 91 | 0 |
| 5.19.16.02 | <i>Malagazzia carolinae</i> | 96 | 91 | 0 |
| 5.19.16.03 | <i>Malagazzia carolinae</i> | 96 | 91 | 0 |
| 5.19.16.04 | <i>Malagazzia carolinae</i> | 96 | 91 | 0 |

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|------------|------------------------------|------|----------|-----------|
| 5.2.16.01 | <i>Nemopsis bachei</i> | 94.7 | 0.00E+00 | 91 |
| 5.2.16.02 | <i>Liriope tetraphylla</i> | 96.4 | 100 | 0 |
| 5.2.16.07 | <i>Malagazzia carolinae</i> | 96.4 | 87.4 | 0 |
| 5.2.16.08 | <i>Liriope tetraphylla</i> | 95.7 | 99.31 | 0 |
| 5.2.16.10 | <i>Malagazzia carolinae</i> | 96 | 91 | 0 |
| 5.20.16.1 | <i>Lovenella assimilis</i> | 93.4 | 92.58 | 0 |
| 5.24.16.02 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.24.16.03 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.26.16.01 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.26.16.02 | <i>Clytia gracilis</i> | 98.3 | 99.83 | 0 |
| 5.26.16.03 | <i>Malagazzia carolinae</i> | 96 | 90 | 0 |
| 5.26.16.04 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.26.16.05 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.26.16.06 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.3.16.01 | <i>Malagazzia carolinae</i> | 96 | 91 | 0 |
| 5.3.16.02 | <i>Malagazzia carolinae</i> | 97 | 92 | 0 |
| 5.3.16.03 | <i>Malagazzia carolinae</i> | 95.9 | 93.99 | 0 |
| 5.3.16.04 | <i>Malagazzia carolinae</i> | 96.6 | 93.99 | 0 |
| 5.3.16.05 | <i>Clytia gracilis</i> | 98.2 | 100 | 0 |
| 5.31.16.10 | <i>Blackfordia virginica</i> | 100 | 81.24 | 0 |
| 5.4.16.01 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.4.16.02 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.4.16.03 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.4.16.04 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.4.16.05 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.4.16.06 | <i>Blackfordia virginica</i> | 100 | 97.77 | 0 |
| 5.4.16.07 | <i>Blackfordia virginica</i> | 99.4 | 90.29 | 0 |
| 5.4.16.08 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 5.4.16.09 | <i>Clytia gracilis</i> | 100 | 100 | 0 |
| 5.4.16.09 | <i>Blackfordia virginica</i> | 99.8 | 100 | 0 |
| 6.14.16.02 | <i>Blackfordia virginica</i> | 100 | 100 | 4.91E-172 |
| 6.14.16.03 | <i>Turritopsis dohrnii</i> | 100 | 100 | 0 |
| 6.15.16.01 | <i>Blackfordia virginica</i> | 99.5 | 100 | 0 |
| 6.15.16.02 | <i>Blackfordia virginica</i> | 99.8 | 100 | 0 |
| 6.15.16.03 | <i>Blackfordia virginica</i> | 98.6 | 100 | 0 |
| 6.15.16.04 | <i>Blackfordia virginica</i> | 99.7 | 99.66 | 0 |
| 6.15.16.05 | <i>Blackfordia virginica</i> | 99.8 | 100 | 0 |
| 6.15.16.06 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 6.15.16.07 | <i>Blackfordia virginica</i> | 99.8 | 98.47 | 0 |
| 6.15.16.08 | <i>Blackfordia virginica</i> | 99.8 | 100 | 0 |
| 6.21.16.01 | <i>Obelia geniculata</i> | 92.9 | 98.76 | 0 |
| 6.21.16.02 | <i>Obelia geniculata</i> | 92.9 | 98.76 | 0 |

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|------------|-----------------------------------|------|-------|---|
| 6.21.16.03 | <i>Blackfordia virginica</i> | 99.8 | 100 | 0 |
| 6.21.16.04 | <i>Obelia geniculata</i> | 92.6 | 98.52 | 0 |
| 6.21.16.05 | <i>Obelia geniculata</i> | 92.6 | 98.52 | 0 |
| 6.21.16.07 | <i>Clytia gracilis</i> | 97.6 | 100 | 0 |
| 6.21.16.08 | <i>Obelia geniculata</i> | 92.6 | 98.52 | 0 |
| 6.21.16.6 | <i>Lovenella assimilis</i> | 93 | 92.58 | 0 |
| 6.27.16.01 | <i>Malagazzia carolinae</i> | 96.1 | 94.53 | 0 |
| 6.27.16.02 | <i>Malagazzia carolinae</i> | 96.1 | 94.53 | 0 |
| 6.27.16.03 | <i>Malagazzia carolinae</i> | 95.9 | 92.76 | 0 |
| 6.30.15.01 | <i>Blackfordia virginica</i> | 98.7 | 98.94 | 0 |
| 6.30.15.02 | <i>Blackfordia virginica</i> | 100 | 100 | 0 |
| 7.15.16.01 | <i>Malagazzia carolinae</i> | 96.5 | 92.9 | 0 |
| 7.18.16.03 | <i>Liriope tetraphylla</i> | 96.6 | 87.65 | 0 |
| 7.18.16.04 | <i>Sertularella cylindritheca</i> | 89.5 | 95.55 | 0 |
| 7.18.16.06 | <i>Malagazzia carolinae</i> | 95.3 | 86.22 | 0 |
| 7.18.16.07 | <i>Sertularella cylindritheca</i> | 89.5 | 95.72 | 0 |
| 7.18.16.08 | <i>Sertularella cylindritheca</i> | 90 | 96.64 | 0 |
| 7.19.16.01 | <i>Malagazzia carolinae</i> | 96.1 | 94.53 | 0 |
| 7.19.16.04 | <i>Malagazzia carolinae</i> | 96.1 | 93.54 | 0 |
| 7.19.16.05 | <i>Malagazzia carolinae</i> | 96.1 | 93.54 | 0 |
| 7.19.16.06 | <i>Malagazzia carolinae</i> | 96.1 | 93.54 | 0 |
| 7.21.16.01 | <i>Bougainvillea triestina</i> | 95.2 | 86.55 | 0 |
| 7.21.16.02 | <i>Malagazzia carolinae</i> | 96.2 | 91.51 | 0 |
| 7.21.16.03 | <i>Malagazzia carolinae</i> | 96.3 | 92.1 | 0 |
| 7.21.16.04 | <i>Obelia dichotoma</i> | 100 | 99.81 | 0 |
| 7.21.16.06 | <i>Clytia gracilis</i> | 98.1 | 100 | 0 |
| 7.21.16.7 | <i>Lovenella assimilis</i> | 89.4 | 97.57 | 0 |
| 7.28.16.01 | <i>Liriope tetraphylla</i> | 96.4 | 99.8 | 0 |
| 7.28.16.02 | <i>Liriope tetraphylla</i> | 96.8 | 87.5 | 0 |
| 7.28.16.03 | <i>Liriope tetraphylla</i> | 96.7 | 87.63 | 0 |
| 7.28.16.04 | <i>Malagazzia carolinae</i> | 95.9 | 85.92 | 0 |
| 7.7.16.02 | <i>Liriope tetraphylla</i> | 97 | 98.29 | 0 |
| 8.16.16.02 | <i>Malagazzia carolinae</i> | 95.9 | 93.08 | 0 |
| 8.16.16.06 | <i>Malgazzia carolinae</i> | 96.3 | 93.24 | 0 |
| 9.01.16.10 | <i>Stauridiosarsia reesi</i> | 95.3 | 100 | 0 |
| 9.01.16.11 | <i>Obelia dichotoma</i> | 99.8 | 99 | 0 |
| 9.12.16.04 | <i>Clytia elsaeswaldae</i> | 93.1 | 95.2 | 0 |
| 9.12.16.06 | <i>Clytia folleata</i> | 98.3 | 95.94 | 0 |
| 9.12.16.07 | <i>Malagazzia carolinae</i> | 96 | 93 | 0 |
| 9.12.16.08 | <i>Eucheilota matulata</i> | 89 | 99 | 0 |
| 9.12.16.09 | <i>Malagazzia carolinae</i> | 97 | 91 | 0 |
| 9.12.16.1 | <i>Eucheilota maculata</i> | 90.9 | 98.07 | 0 |

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|------------|------------------------------|------|-------|----------|
| 9.12.16.12 | <i>Malagazzia carolinae</i> | 95.9 | 86.68 | 0 |
| 9.12.16.2 | <i>Lovenella assimilis</i> | 90.6 | 100 | 0 |
| 9.15.15.20 | <i>Lovenella assimilis</i> | 91.8 | 99.52 | 0 |
| 9.17.15.05 | <i>Earleria quadrata</i> | 87.2 | 98.42 | 0 |
| 9.19.15.11 | <i>Malagazzia carolinae</i> | 95.5 | 96.75 | 0 |
| 9.2.15.26 | <i>Lovenella assimilis</i> | 91 | 89 | 0 |
| 9.2.16.04 | <i>Clytia folleta</i> | 99 | 93 | 0 |
| 9.25.15.05 | <i>Earleria quadrata</i> | 87.5 | 98.07 | 0 |
| 9.26.16.04 | <i>Clytia elsaeoswaldae</i> | 93.1 | 95.22 | 0 |
| 9.26.16.06 | <i>Clytia gracilis</i> | 90.4 | 97.21 | 0 |
| 9.26.16.07 | <i>Clytia gracilis</i> | 92.2 | 97.74 | 0 |
| 9.26.16.10 | <i>Clytia gracilis</i> | 98.2 | 100 | 0 |
| 9.26.16.11 | <i>Clytia gracilis</i> | 88.9 | 99.3 | 0 |
| 9.26.16.12 | <i>Obelia dichotoma</i> | 99.8 | 100 | 0 |
| 9.26.16.14 | <i>Clytia gracilis</i> | 98.2 | 100 | 0 |
| 9.26.16.16 | <i>Obelia dichotoma</i> | 100 | 100 | 0 |
| 9.26.16.17 | <i>Obelia dichotoma</i> | 99.8 | 100 | 0 |
| 9.26.16.19 | <i>Ectopleura dumortieri</i> | 96 | 100 | 0 |
| 9.26.16.2 | <i>Obelia dichotoma</i> | 99.6 | 100 | 0 |
| 9.26.16.20 | <i>Obelia dichotoma</i> | 99.8 | 100 | 0 |
| 9.26.16.21 | <i>Obelia dichotoma</i> | 99.8 | 98.27 | 0 |
| 9.26.16.23 | <i>Obelia dichotoma</i> | 100 | 100 | 0 |
| 9.26.16.24 | <i>Obelia dichotoma</i> | 100 | 0 | 0 |
| 9.26.16.26 | <i>Obelia dichotoma</i> | 99.3 | 100 | 0 |
| 9.26.16.28 | <i>Malagazzia carolinae</i> | 97 | 92 | 0 |
| 9.26.16.5 | <i>Obelia dichotoma</i> | 99.8 | 100 | 0 |
| 9.26.16.7 | <i>Obelia dichotoma</i> | 99.8 | 100 | 0 |
| 9.28.16.01 | <i>Malagazzia carolinae</i> | 96 | 93 | 0 |
| 9.28.16.07 | <i>Malagazzia carolinae</i> | 95.9 | 92.12 | 0 |
| 9.28.16.20 | <i>Lovenella assimilis</i> | 90.7 | 98.78 | 0 |
| 9.28.16.21 | <i>Lovenella assimilis</i> | 90.7 | 99.65 | 0 |
| 9.28.16.27 | <i>Malagazzia carolinae</i> | 96 | 96 | 0 |
| 9.28.16.37 | <i>Clytia gracilis</i> | 98.1 | 100 | 0 |
| 9.28.16.5 | <i>Lovenella assimilis</i> | 90.5 | 97.85 | 0 |
| 9.30.16.01 | <i>Ectopleura dumortieri</i> | 97.9 | 87.27 | 1.42E-13 |
| 9.30.16.10 | <i>Liriope tetraphylla</i> | 96.1 | 100 | 0 |
| 9.30.16.17 | <i>Malagazzia carolinae</i> | 96 | 91 | 0 |
| 9.30.16.19 | <i>Lovenella assimilis</i> | 90.8 | 97.2 | 0 |
| 9.30.16.21 | <i>Clytia gracilis</i> | 96.8 | 100 | 0 |
| 9.30.16.22 | <i>Clytia gracilis</i> | 98 | 100 | 0 |
| 9.30.16.23 | <i>Clytia gracilis</i> | 98 | 100 | 0 |
| 9.30.16.25 | <i>Malagazzia carolinae</i> | 96 | 92 | 0 |

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|------------|------------------------------|------|-------|-----------|
| 9.30.16.26 | <i>Liriope tetraphylla</i> | 96.7 | 100 | 6.46E-171 |
| 9.30.16.27 | <i>Malagazzia carolinae</i> | 96 | 92 | 0 |
| 9.30.16.29 | <i>Ectopleura dumortieri</i> | 95.5 | 99.8 | 0 |
| 9.30.16.33 | <i>Ectopleura dumortieri</i> | 95.9 | 100 | 0 |
| 9.30.16.34 | <i>Liriope tetraphylla</i> | 96.5 | 100 | 0 |
| 9.30.16.37 | <i>Ectopleura dumortieri</i> | 95.9 | 100 | 0 |
| 9.30.16.40 | <i>Malagazzia carolinae</i> | 95.9 | 94.5 | 0 |
| 9.30.16.41 | <i>Ectopleura dumortieri</i> | 95.7 | 100 | 0 |
| 9.30.16.42 | <i>Liriope tetraphylla</i> | 96.8 | 100 | 0 |
| 9.30.16.47 | <i>Malagazzia carolinae</i> | 95.9 | 94.5 | 0 |
| 9.30.16.48 | <i>Malagazzia carolinae</i> | 96.3 | 91.97 | 0 |
| 9.8.16.01 | <i>Liriope tetraphylla</i> | 96 | 99 | 0 |
| 9.8.16.02 | <i>Eucheilota maucrata</i> | 89 | 98 | 0 |
| 9.9.16.01 | <i>Clytia gracilis</i> | 88.9 | 99.3 | 0 |
| 9.9.16.03 | <i>Obelia dichotoma</i> | 99.8 | 100 | 0 |