Munidopsis density relating to a shift in community composition between time periods 2009–2012 versus 2014–2017

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Abstract

Deep-sea ecosystems are vital in global carbon cycling. Shallow water phytoplankton make up the base trophic level of oceanic ecosystems. Climate change influences surface processes, which has downstream impacts on deep-sea communities within the benthopelagic and abyssal zones. Since 1989, carbon input, demand, and changes in seafloor communities have been studied at Station M, located 220 km off the coast of central California at a depth of approximately 4000 meters (m). A remotely-operated vehicle study of sea-floor communities depicted a change in the local deep-sea community composition in 2011 as particulate organic carbon (POC) flux increased with changing surface conditions. *Munidopsis* (squat lobsters) is an important member of the benthic community as a mobile detritus-feeding consumer, and prey to grenadiers. Squat lobster density over time may be an indicator of a local community's long-term health and composition. Here we conducted an inter-period analysis of Station M time-lapse imagery over the two time periods, 2009–2012 and 2014–2017, in 12-hour intervals to answer the question, "Is there a change in *Munidopsis* density between the time period leading up to and post community reconfiguration?" Average size was also analyzed for correlation with density. We hypothesized a significant difference in *Munidopsis* density between two time periods: 2009–2012 and 2014–2017. These time periods were selected for image quality and coverage of the prior established community transition and post community shift. Annotated *Munidopsis* were analyzed statistically for changes in density and size with qualitative inter-/intra-species interaction discussion. Understanding how the density of species, like *Munidopsis,* changes over time during community shifts will impart greater understanding of deep-sea abyssopelagic community dynamics.

Introduction

Researching deep-sea trophic dynamics, specifically the benthopelagic and abyssal zone that cover 75% of seafloor area, is necessary to understand changing oceanic aspects and global energy cycle redistribution processes (Ramirez-Llodra et al., 2011; Kuhnz et al., 2014). Production of particulate organic carbon (POC), originating in surface waters, sinks as "marine snow" and sustains species from the epipelagic zone to the abyssopelagic zone. Particulate matter is composed mainly of biogenic and fecal pellets, including deceased micro/macrofauna such as gelatinous zooplankton. This detritus sinks through the water column at varying rates depending on composition, density and form (ex. 850-1500 m/day avg. for jelly-POC) where it decays or is consumed by numerous organisms (Lebrato et al, 2013). Unconsumed detritus settles to the sea floor and is the primary source of nutrition for a community of suspension/mobile detritivous macrofauna and meiofauna (Smith et al., 2018).

Increasing atmospheric CO_2 concentrations have a direct impact on global climate change and natural systems (Parmesan, Yohe. 2003). This has led to the warming and acidification of ocean waters which has significant detrimental effects on marine communities. Such effects include coral bleaching and death that lead to weakened and collapsed ecosystems (Parmesan,

Yohe. 2003; Pandolfi et al., 2011). Increased surface water temperatures have influenced phytoplankton productivity resulting in a downstream impact throughout oceanic zones into the abyssopelagic zone. Increasing phytodetritus fall from increased productivity is having an effect on deep-sea communities, but to what extent is unknown (Kuhnz et al., 2014; Smith et al., 2018). During 1989, an abyssal time-series project was established by Scripps Institution of Oceanography and later maintained by the Monterey Bay Aquarium Research Institute (MBARI) to study correlations between climate conditions and seafloor processes. Remotely operated vehicle data from between 2006 and 2012 revealed a reconfiguration of the local benthos from a sessile to predominately mobile community in 2011, possibly due to an increase of POC flux events (Kuhnz et al. 2014). Squat lobsters were consistently observed prior and post the community composition shift.

Squat lobsters of the diversified *Galatheoidea* superfamily inhabit all oceanic zones throughout the Pacific (Palero et al. 2017; Drazen et al. 2008). *Munidopsis* commonly found on the abyssal planes are ecologically important in their trophic roles as prey and generalist benthic consumers (Drazen et al. 2008). Squat lobster communities range from massive pelagic swarms of *Munida* to our observed seclusive behavior of *Munidopsis* inhabiting the abyssal benthic planes (Diez et al. 2012). *Munidopsis* species observed on the abyssal planes at Station M do not exhibit the same community swarm behaviors or density as other related species. *Munidopsis* wide distribution and relatively high caloric content makes them excellent prey for juvenile macrourids, which contribute up to 38% of their diet (Drazen et al. 2008) Quantitative analysis of *Munidopsis* populations at Station M over time may be useful for identifying changes to mid-trophic level communities relating to the benthos shift observed during 2011 (Kuhnz et al. 2014). In part of assessing the benthos at Station M we asked the question, "Is there a change in *Munidopsis* density relating to a shift in community composition between the time periods 2009–2012 versus 2014–2017?" It is important to determine if squat lobster densities have changed as a result of increasing POC flux and if they contribute to benthopelagic trophic stability. Due to the low stability and shift of Station M's community, our null hypothesis is, **there is no significant change in *Munidopsis* population density relating to a shift in community composition between time periods 2009-2012 verses 2014-2017.** If unsupported our alternative hypothesis is, **there is a significant change in *Munidopsis* population density relating to a shift in community composition between time periods 2009-2012 versus 2014-2017.**

Methods

All data collected used images taken *in situ* at Station M (Figure 1). The location contains a suite of instruments located off the coast of central California (34°50'N, 123°00'W) at a depth of approximately 4000 m (Smith et al., 2017). The suite consists of an autonomous benthic rover, a satellite communications capable surface wave glider and three moorings (Figure 1). Two of the three moorings have time-lapse cameras at their base. These "near" and "far" field cameras are equipped with high-intensity (400 W-s) strobes to illuminate the seafloor while taking hourly images. Time-lapse photographs were taken every hour recording an area of approximately 20 m^2 by the far-field camera and 2 m^2 by the near-field camera (Smith et al. 2017). Time-lapse far-field images were visually scanned and annotated utilizing MBARI Video Annotation and Reference System (VARS) software in 12 hr intervals (noon and midnight local time) (Schlining Stout, 2006). Image quality and lighting varied between deployments. Each image was visually analyzed for the presence of *Munidopsis*. All specimens were identified to genus due to the

constraints in image resolution. *Munidopsis* observed at Station M include *M. albatrossae* and *M. kensmithi*. The standard of identification and annotation of squat lobsters consisted of positive identification of a unique morphological aspect (ex. chelipeds). The widest points of an individual's carapace were measured for approximation of overall size. Due to image quality, or the squat-lobster's angle observed, not every specimen was measured. Because little is known about the behavior of abyssal plain *Munidopsis*, residency times and distance between individuals were recorded for qualitative analysis. Imagery prior and post 12-hour annotated images were scanned for the continued presence of the specimen. The number of frames in which an individual was seen was recorded as a proxy for residence time. Substrate on which *Munidopsis* was observed was also noted. Frames where multiple specimens were seen was noted, distance between individuals (DBI) was measured, and identification numbers were assigned as required. All distances were computed into measurements of cm for carapace width and DBI, and m^2 for density. Density was calculated by dividing the number of squat-lobsters counted by the camera specific field of view. All calculations utilized VARS data querying and a Canadian Grid that accounted for the variables of camera type, field of view and inclination (Wakefield and Genin, 1987).

Annotated data from VARS were exported to Microsoft Excel (2016) and RStudio (ver. 3.5.1) where density over time was calculated and graphed. Data sets were empirically and statistically tested for normality utilizing Q-Q plots, shapiro-wilk and wilcoxon rank sum with continuity correction tests. We compared density data of the two time periods to test our null hypothesis and answer our question whether there was a significant change in *Munidopsis* population density relating to the community shift of 2011 (Kuhnz et al. 2014). Results were graphed via RStudio depicting average, standard deviation and outliers. Individual residency patterns (ex. time spent on a sponge) and distance between individuals within the same time-lapse photo frame were recorded for future *Munidopsis* behavioral research.

Results

Comparing Density and Width during Two Four-Year Periods: 2009–2012 and 2014–2017. *Munidopsis* density was significantly ($p<0.001$) different between the two analyzed time-series periods. 2009–2012 had a density average of 1.75E-3 ±4.19E-2 count/m^2 compared to 2014–2017 average of 2.26E-3 ±4.83E-2 count/m^2 (Table 1). A Q-Q Plot of density (Figure 2) and applied shapiro-wilk normality test result revealed data were abnormal (W = 0.20594, p-value < 2.2e-16). A wilcoxon rank sum test was applied resulting in rejection of our null hypothesis (W = 1612400, p-value < 3.14e-12) that there is no significant change in *Munidopsis* population density relating to POC flux events between time periods 2009–2012 to 2014–2017, for the alternative with a 95% confidence interval. *Munidopsis* width was also significantly different ($p<0.05$) between the two periods. 2009–2012 had an average width of 2.9 cm compared to 2014–2017 average of 2.4 cm with standard deviations of 0.8 cm and 0.7 cm respectively (Table 1). Normality was the result when width data were applied to a Q-Q Plot (Figure 4). A two-tail t-Test was used to calculate a significant p-value of 0.0138.

Residency and Distance between Individuals over Eight-Year Time Series: 2009-2012, 2014-2017. Additional behavioral observations were collected and measured in addition to testing our hypothesis. 90 individual *Munidopsis* specimens were annotated over two or more frames, for a total of 1868 hrs. Squat lobsters observed in more than one frame were noted with

number of consecutive frames required. Of this group, the data collected consisted of a minimum of 2 hrs, maximum of 362 hrs, and an average of $12.0\overline{6}$ hrs with a standard deviation of 39.16 hrs (Table 2). During this data set, 6 individuals were observed residing on sponge for an average of $75.8\overline{3}$ hrs. *Munidopsis* observed in a single one hour frame consisted of 1309 individuals all residing on mud. Distance between 65 individual *Munidopsis* measured an average of 169.83 cm, 11.59 cm minimum, 472.84 maximum with a standard deviation of 132.88 cm (Table 2).

Discussion and Conclusion

The benthic community restructuring at Station M, beginning in 2011 which corresponded with an increase in POC flux events, had a significant impact on the local benthopelagic zone (Kuhnz et al. 2014; Smith et al. 2018). Our analysis depicted an increase in density between the two time periods 2009–2012 versus 2014–2017 (Table 1, Figure 1). These two time periods were selected due to the community shift in 2011 from a sessile suspension feeding community to motile dominate. The first time period, 2009–2012, covers the years leading up to and including the start of the community restructuring. Period 2, 2014–2017, spanned an equal amount of time post community shift after the new community makeup had been fully established. Comparing the two time periods statistically, we verified the community shift corresponded with changes in the density and width of squat lobsters inhabiting the area at Station M. For many deep-sea decapods, reproduction and growth is influenced by food availability (Rosa and Nunes, 2003). Major flux events were recorded at Station M during 2011, 2012 and 2015-2017 resulting in an abundance of food supply (Smith et al., 2017). The large detrital aggregates available in 2011 and beyond may have increased the carrying capacity of local *Munidopsis* along with other mobile organisms advantaged by the ample clumped food supply (Kuhnz et al. 2014; Smith et al. 2018). When comparing the calculated *Munidopsis* average carapace width decrease of 0.5 cm between of the two periods to the increase in density it suggests a growing new generation of squat-lobsters which is not solely attributable to migration (Table 1, Figure 1 and 2).

Potential future research may test whether juvenile macrourids, predators of *Munidopsis*, may have benefited from the increased density resulting in a cascading multi-tropic energy transfer effect corresponding with the community composition shift (Drazen, 2008; Kuhnz et al. 2014). Macrourid eggs hatch in shallow water (~300- m), and begin descending while feeding. Macrourids do not reach abyssal depths until maturity, but may still hunt shallow waters for food (D'Onghia, 1999). *Munidopsis* density and the abyssal community composition may have a direct influence on shallow water communities and local fisheries.

Additionally, squat lobster behavioral observations were recorded involving individual's residency patterns (ex. time spent on a sponge) and distance between individuals within the same time-lapse photo frame. These were recorded for future *Munidopsis* behavioral research and qualitative analysis. Unlike deep-sea *Munidopsis* species inhabiting densely populated areas such as hydrothermal vents, the behavior of those observed at Station M were relatively passive and seclusive. Considering the zero-sum dynamics at Station M and the average recorded distance between individuals, the lack of observed agonistic-behavior may be correlated with the need to reduce energy expenditure from aggressive behavior during low flux conditions prior to 2009 (Ruhl et al, 2014; Smith et al, 2018). Behavior observed between species also appeared passive, although one event included a squat lobster engaged in interference competition with

Scotopanes. With an increased density post community shift, we ask the questions, will behavior change occur which further impacts the community, and will it extend *Munidopsis* potential range? Additional behavior observed included residency patterns of individuals. Notably, a potential mutualistic relationship was observed between *Munidopsis kensmithi* and various sponges. Squat-lobsters recorded over two or more consecutive frames averaged 76 hrs spent on sponges compared to an average 7 hrs on sediment (Table 2). Subsequent *Munidopsis* within the vicinity did not challenge the existing resident squat lobster for sponge occupancy, nor inhabit upon vacancy for a similar amount of time. We speculate this could be the result of squat lobsters utilizing sponges as a food source, clearing detrital particles too large for the sponge to digest and benefitting the sponge by clearing collar cells blockage. With the abundant food deposited on sediment after the community shift we ask if this may affect the sponge dynamics as well.

From 1989 to 2009, Station M flux events were stable compared to patterns recorded from 2010 to 2017 (Smith et al. 2018). For future studies, we hypothesize that *Munidopsis* density would reflect this stability. If this is supported through analysis, then *Munidopsis* might be utilized as an indicator of abyssal plane benthic community condition. This correlation between increased shallow water productivity supplying food and benthic community composition supports the correlation between climate change and the abyssal plains. Since so little is known about abyssal communities, the role of squat lobsters and their connections to other organisms, we feel this is an area that warrants future observation and analysis both at Station M and other abyssal benthic plane locations.

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Acknowledgments:

Measurement	2009–2012	2014–2017
Density Average	1.75E-3	2.26E-3
Density STDEV	4.19E-2	4.83E-2
Width Average	2.9 cm	2.4 cm
Width STDEV	0.8 cm	0.7 cm

Table 1: Calculated averages and densities for two four year time periods leading up to and post 2011 benthic community restructuring (Kuhnz et al., 2014).

Measurement	Residency	DBI
Average (mud,sponge)	12 hrs (7,76 hrs)	169.8 cm
STDEV (mud,sponge)	39.16 hrs (11,142 hrs)	132.9 cm
Min,Max	2,362 hrs	11.6,472.8 cm

Table 2: Measurements of recorded residency in hours (*Munidopsis* present in ≥2 frames) and distance between individuals (DBI) in centimeters.
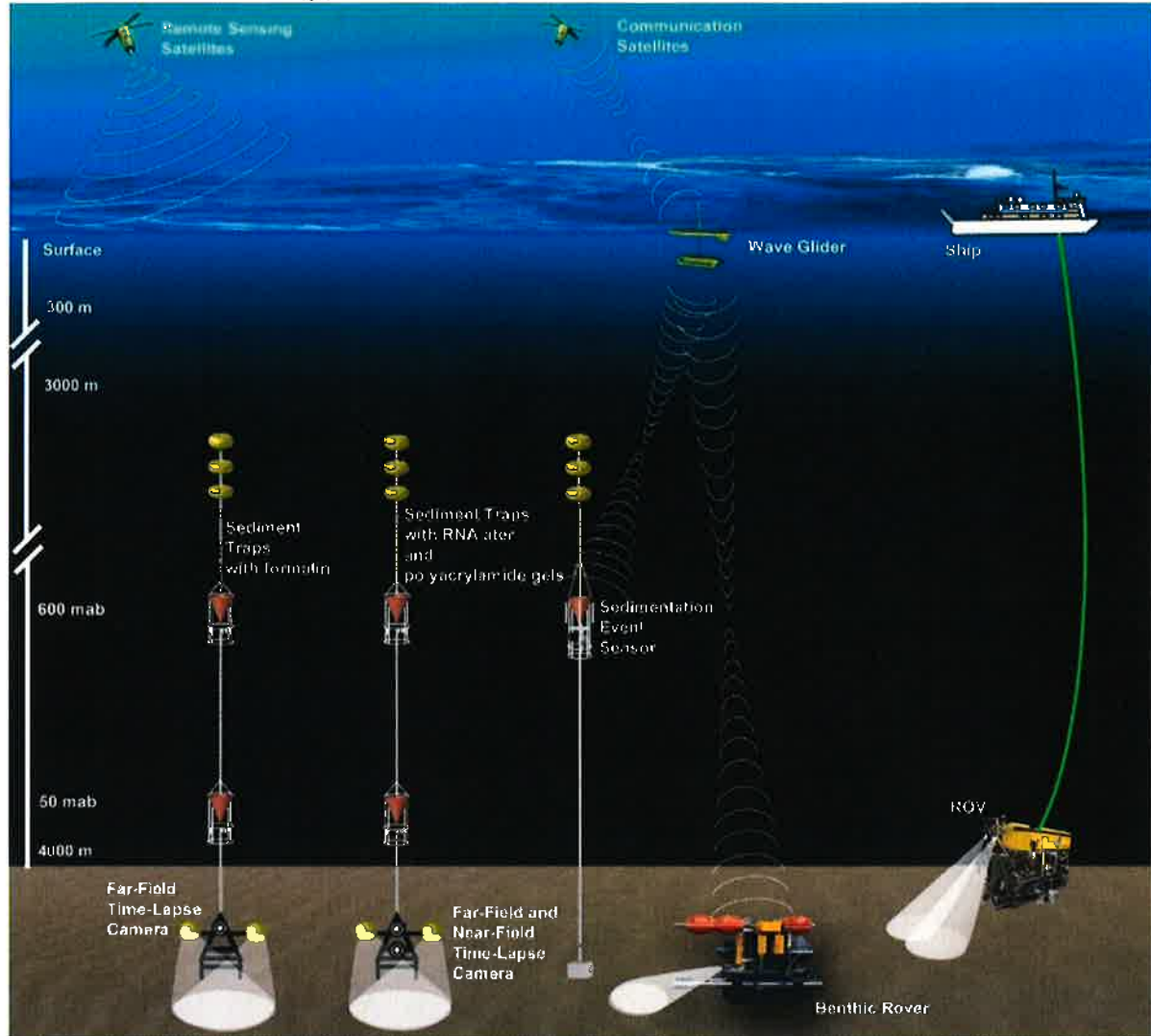
Figure 1: Station M instrument suite (Smith et al., 2017).
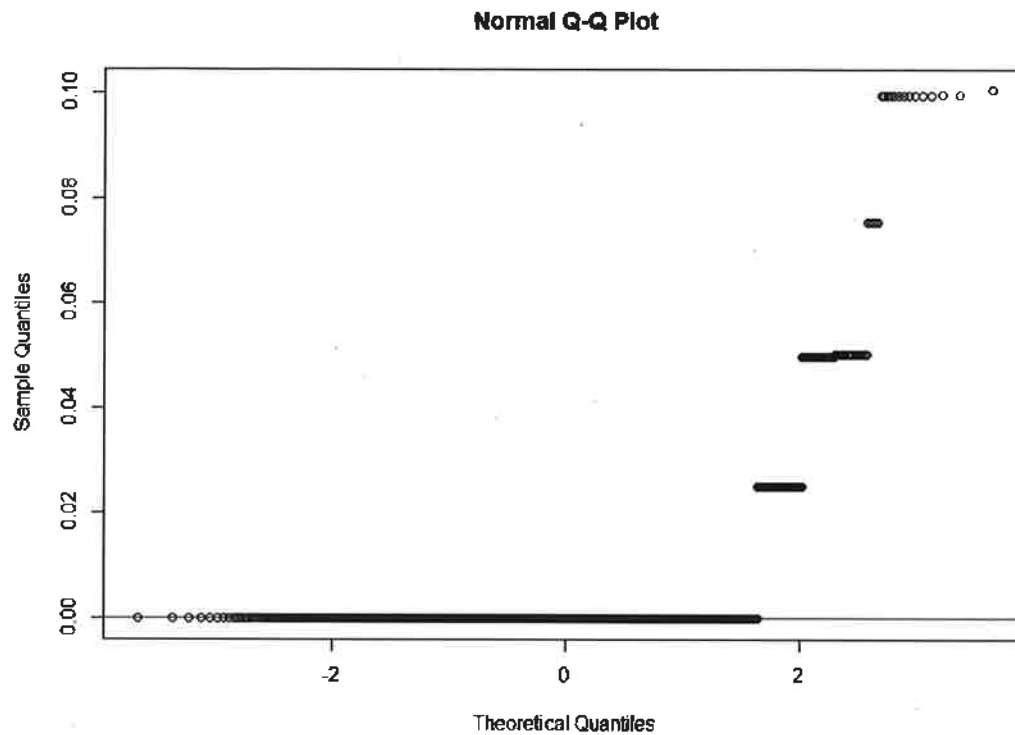
Normal Q-Q Plot

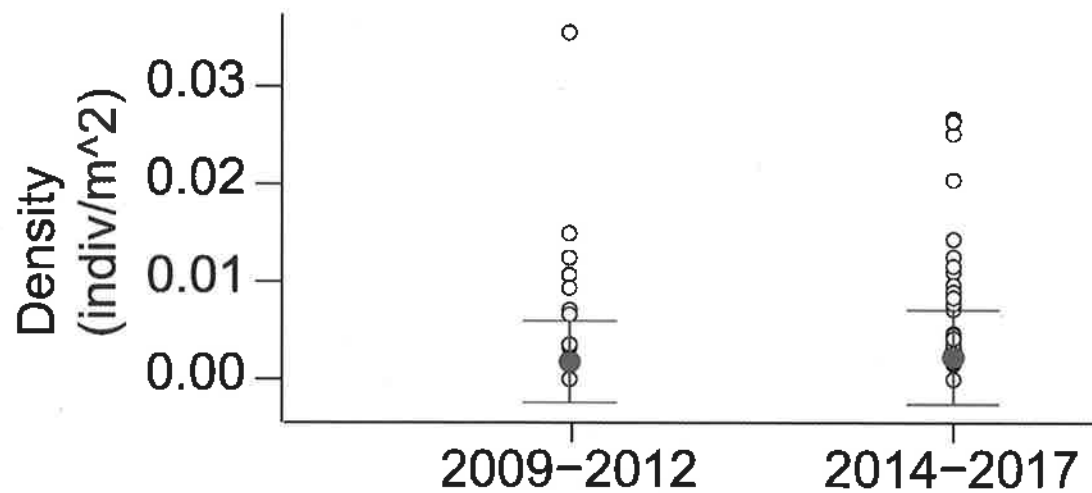

Figure 2: Abnormal density data depicted on a Q-Q Plot with normal line.

Figure 3: Depicting the average density and standard deviation of the two time periods when compared to each other.
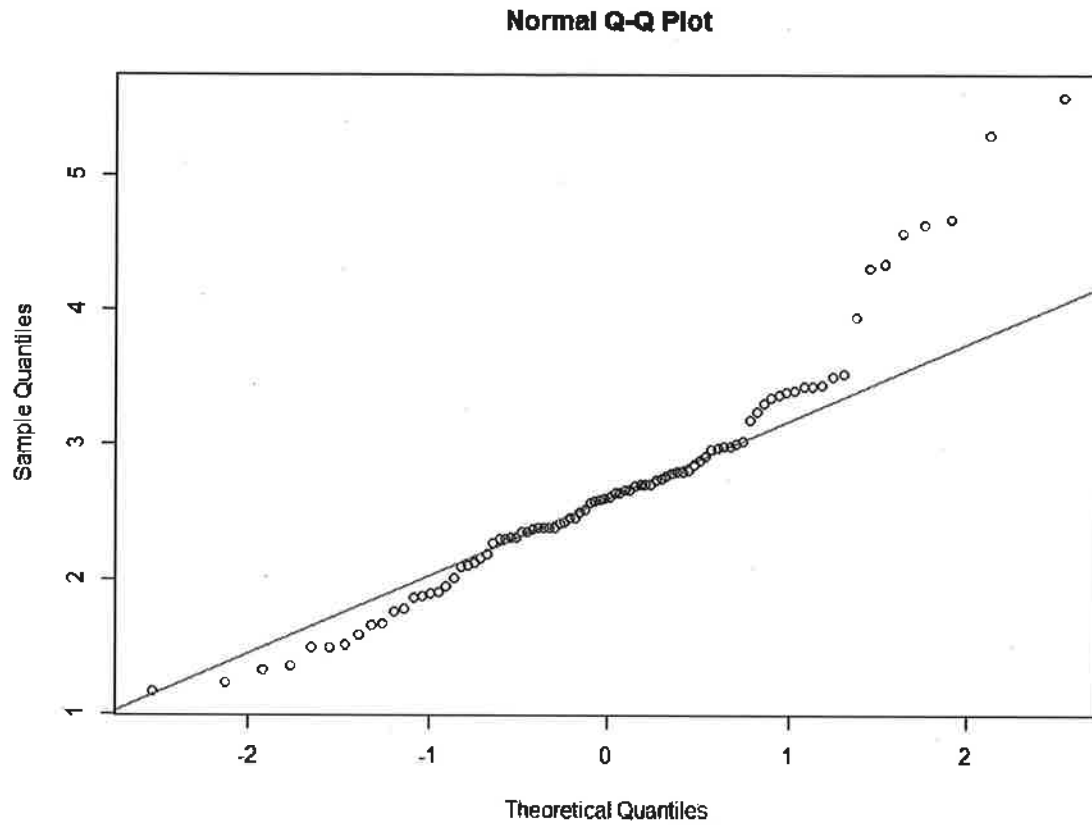
Normal Q-Q Plot

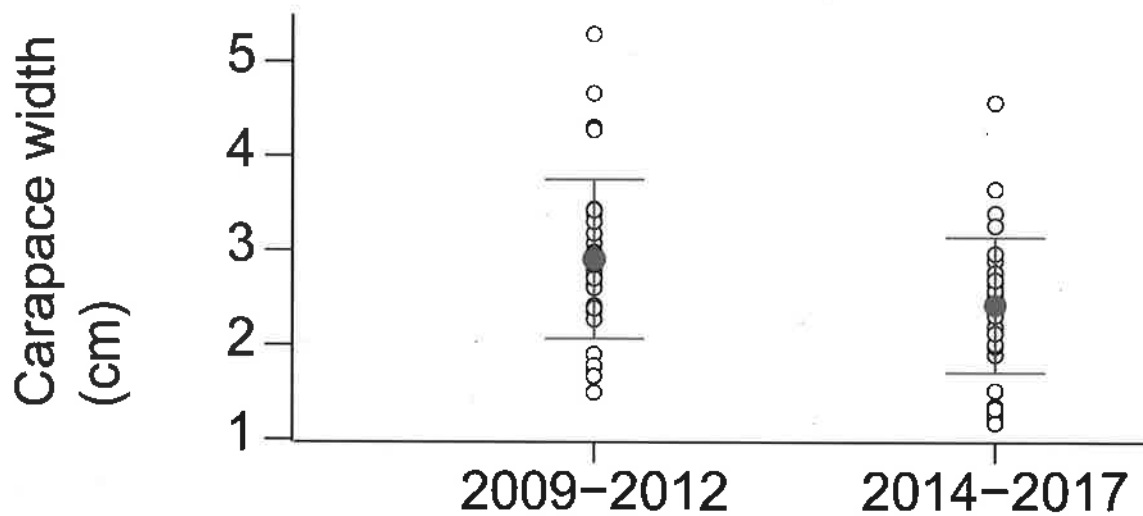Figure 4: Normal width data depicted on a Q-Q Plot with normal line.

Figure 5: Depicting the average *Munidopsis* carapace width and standard deviation of the two time periods when compared to each other.