

UROP Report: Impacts of the Deepwater Horizon Spill on Intertidal Invertebrate Communities in the Northern Gulf of Mexico

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Abstract

The Gulf of Mexico coastal region is an economically and biologically productive and important habitat in the United States. On April 20, 2010 the Deepwater Horizon oil rig exploded and sank, releasing five million barrels of oil over a three month period and affecting 650 miles of Gulf of Mexico coastline. The goal of this project was to examine the effects of the oil spill at eight sites along the Gulf of Mexico beginning six months after the spill. Samples were collected from each site and the composition of infaunal communities and the sediment characteristics were assessed. Previous studies have shown that oil spills cause an increase in abundance of polychaete and oligochaete worms, while causing a decrease in sensitive species such as amphipods. These effects should lead to a reduction in diversity, as measured by Shannon's Index. The results found in this study were not statistically significant, but trends were observed in oiled sites that suggest: (1) oiled sites have an increased proportion of annelid worms making up the community, (2) oiled sites have proportionally fewer sensitive species (amphipods), and (3) the diversity in oiled sites is lower than in the most pristine site. Although these effects are not contributable directly to the Deepwater Horizon oil spill, this study may serve as background for future studies and provide information on coastal benthic invertebrate communities in habitats that have not been well studied in the Gulf of Mexico previously.

Introduction

The coastal region of the Gulf of Mexico provides an important natural resource. The benthic infauna of these coastal areas provide a food source for both economically and recreationally important species, including brown shrimp (*Penaeus aztecus*; McTigue and Zimmerman 1998), gulf flounder (*Paralichthys albigutta*), spot croaker (*Leiostomas xanthurus*; Gloeckner and Luczkovich 2008), and the blue crab (*Callinectes sapidus*; Hsueh et al. 1992). The same fauna also provides a food source for migratory shore birds which stop over on the Gulf of Mexico during their spring and fall migrations.

The coastal Gulf of Mexico suffered a significant pollution event beginning on April 20, 2010 with the explosion and eventual sinking of the Deepwater Horizon oil rig. The well was capped on July 15, 2010, but not before releasing five million barrels of crude oil (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011). The oil affected 650 miles of Gulf of Mexico coastal habitat (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011). The impact of the Deepwater Horizon oil spill on the benthic invertebrate communities has yet to be determined, but in other regions these communities are a useful indicator for pollution.

The analysis of oil spill effects on benthic invertebrate communities has been the subject of many studies of both large and small-scale oil spills including the Amoco Cadiz (Dauvin 1982, Dauvin 1998, Dauvin 2000), the Exxon Valdez (Jewett et al. 1999), the 'Tsesis' oil spill (Elmgren et al. 1983, Linden et al. 1979), and several other smaller spills (Bonsdorff 1981, Smith and Simpson 1998, Smith and

Simpson 1995, Gestiera and Dauvin 2000). Although varying effects on benthic invertebrate communities were found, some generalizations can be made about the effects observed: 1) an initial mortality of sensitive species (crustaceans, specifically amphipods), 2) a proliferation of opportunistic species (most importantly polychaete worms), 3) the effects are variable depending on the initial community, 4) effects in long-term studies are usually seen for 10 or more years. These effects taken together would lead to an expected increase in abundance and decrease in diversity at sites impacted by an oil spill.

Another factor that must be taken into account when examining communities across habitats is the environmental characteristics and their effects on determining species distributions. When studying the Exxon Valdez oil spill, Jewett et al. (1999) found that subtle differences in environmental characteristics had a large effect in determining community structure. Dauvin (1982, 2000) showed that communities with fewer sensitive species, oil spill effects are minimal. Therefore, environmental characteristics are important in determining the effects of an oil spill and some habitats may show an increased susceptibility to oil spills. Unfortunately little work has been done in the Northern Gulf of Mexico describing the distribution of species based on environmental characteristics. Studies elsewhere examining benthic communities and environmental characteristics show that sediment characteristics such as median grain size, organic content, and particle diversity are important in determining the community structure of benthic organisms (Gray 1974, Whitlatch 1981, De Graer et al. 2008).

The goal of this study was to elucidate the effects of the Deepwater Horizon oil spill on coastal benthic macroinvertebrate communities beginning six months after the oil spill. I hypothesize that 1) oiled areas will have increased overall abundance, especially of opportunistic species, 2) oiled sites will have lower diversity relative to non-oiled sites, 3) oiled sites will contain a relatively lower proportion of sensitive species (e.g., amphipods), 4) environmental characteristics will be important in determining community structure.

Methods

Study Sites

Samples were collected from nine sites along the Northern Gulf of Mexico from October 2010 to April 2011 (Table 1). The sites contained four habitat types: mudflats, back bays, sandy beaches, and remnant wetlands.

Sampling Methods

Two adjacent sediment cores were collected using a PVC corer with a 10cm diameter and a 5cm depth ($3.9 \times 10^{-4} \text{ m}^3$). The sample was taken from an area where shorebirds were seen actively foraging. The cores were placed in glass mason jars for transport to the lab. One core for sediment analysis was kept frozen, while the other core was sieved through a 500-micrometer mesh sieve. The material that remained on the mesh was preserved in 95% ethanol. The second core was kept frozen until it was needed for sediment analysis.

Laboratory Analysis

The sieved samples were sorted for invertebrates using a dissecting scope and compound microscope. Most invertebrates were identified to the family level, although some were identified only to higher taxa. Meiofauna were excluded due to the likely loss of individuals from using a 500-micrometer sieve. Each sample was sorted twice to insure that a minimal amount of invertebrates were missed during sorting. After identification, sorted invertebrates were placed in a vial of 95% ethanol.

Grain size, organic content, and grain size variability were measured using the duplicate samples. Median grain size and grain size variability were determined using a Beckman Coulter LS laser diffractometer after the sediments had been treated with hydrogen peroxide and sodium hexametaphosphate. Organic content of the sediment was determined using the Loss on Ignition method (LOI). Samples were dried to a constant weight, placed into the oven at 500°C for 6 hours and reweighed. Oiling level for each site was determined using SCAT data from the National Oceanic and Atmospheric Administration.

Results

The average abundances per site show no clear trend with the oiling level (Figure 1). Cameron was found to have the highest abundance per sample, followed by Ocean Springs and Waveland. The remaining sites were in order: Wisner back bay, St. Marks, Dauphin Island, Isles Dernieres, Wisner remnant wetland, and Perdido. The top three average abundances were calculated including samples that had a very large amount of a single taxon present in the sample. One Cameron sample contained 775 bivalves, one Waveland sample contained 116 amphipods in the family Haustoriidae, and one Ocean Springs sample contained 129 members of Tanaidaceae. If the samples that contained these large amounts of individuals are removed the order of sites based on average abundance of individuals is: Cameron, Wisner back bay, St. Marks, Dauphin Island, Ocean Springs, Waveland, Isles Dernieres, Wisner remnant wetland, and Perdido. After removing the samples that had high abundances of single taxa, there is still no clear relationship between oiling level and abundance.

The average number of polychaete and oligochaete worms found at each site and the percentage of those worms making up the total abundance at each site also showed no clear relationship with oiling level, although some oiled sites have abundances made up of a large percentage of polychaete and oligochaete worms (Figure 2, Figure 3). All of the oiled sites, excepting Isles Dernieres and excluding samples with large amounts of a single taxon, show polychaete and oligochaete worms making up at least 60% of the community. The invertebrate community of Cameron, although not oiled directly by the Deepwater Horizon oil spill, was dominated by polychaete worms (91% excluding the sample with 775 bivalves). Ocean Springs, after removing the sample with 129 tanaids, and Wisner back bay were dominated by polychaetes and oligochaetes at 90% and 94% respectively.

The amphipod abundance and the proportion of amphipods in the community were also variable (Figure 4, Figure 5). No amphipods were found at Perdido, Dauphin Island, or Wisner remnant wetlands. Among the remaining sites the highest amphipod abundance per sample was 39 individuals at Waveland, although this average is skewed due to the presence of 116 Haustorid amphipods in one

sample. The next highest average abundance of amphipods was found at Isles Dernieres, Ocean Springs, and St. Marks. The remaining sites had average abundances of one or less. The percentage of the abundance composed of amphipods at each site also followed a similar trend with amphipods making up 85% of the abundance at Isles Dernieres, 82% at Waveland, 10% at St. Marks, 8% at Ocean Springs. The remaining sites had less than 3% of their total abundance made up of amphipods.

Shannon's Diversity index showed that the sites not affected directly by the Deepwater Horizon oil spill had both the highest diversity (St. Marks, 2.1) and the lowest diversity (Cameron, .58; Figure 6). Perdido, because the site was made up of only one sample with one organism, had a diversity of 0. All of the sites except St. Marks fit into two main categories. One category consists of sites with a Shannon's diversity between .58 and .75. The sites in this category were Cameron, Cameron without the sample with 775 bivalves, Waveland, and Isles Dernieres. The other category consists of sites with a Shannon's diversity from 1.2 to 1.5 and included: Wisner back bay, Wisner remnant wetland, Ocean Springs (with and without the sample with 129 tanaids), Dauphin Island, and Waveland with the sample having 116 *Haustorid* amphipods removed. St. Marks stood out from the other sites with the highest Shannon's diversity.

The cluster dendrogram created from the environmental data shows three main groups (Figure 7). One group consisted of all of the samples from Dauphin Island and Perdido and one sample from Ocean Springs. This group was characterized by large mean grain size, low organic content, and a low variation in sediment grain size. Another group consisted of samples from Wisner back bay and remnant wetlands, one sample from St. Marks, one sample from Ocean Springs, and all but one of the samples from Cameron. This cluster was characterized by low mean grain size, high organic content, and high variation in sediment grain size. The remaining samples fell into a third cluster that was intermediate between the two other clusters in mean grain size, organic content, and sediment grain size variation. The cluster dendrogram created from the community composition data did not show any clear relationships with the environmental characteristics (Figure 8). Some samples that clustered together in the environmental analysis did also cluster together in the community analysis, but the majority of the clusters created in the community analysis mixed different environmental clusters. Three of the Dauphin Island samples (DI007, DI009, DI0012) clustered together in both the environmental dendrogram and the community dendrogram. Six samples from St. Marks, Wisner, and Ocean Springs (W005, W027, StMarks001, W010, OS006, and W025) that clustered together in the environmental dendrogram also clustered in the community dendrogram. The remaining samples did not show distinct relationships between the environmental characteristics and the community characteristics.

Discussion

One trend that can be seen in the results is the high abundances of polychaetes and low abundances of amphipods found in the oiled sites. Although these differences are not significant they do show the effects that previous studies predict for oil spills (Dauvin 1982, Dauvin 1998, Dauvin 2000, Smith and Simpson 1995, Jewett et al. 1999). At Wisner and Dauphin Island the proportion of the community made up by annelid worms was fairly high while the proportion of the community made up of amphipods was low. The proportion of the community made up by annelid at St. Marks was lower

while the proportion of the abundance made up by amphipods was higher. These differences in proportions of the community made up by annelid worms and amphipods could be a possible effect of the oil spill, but it could also be due to other factors. Dauvin (2000) showed that the pre-spill communities are important in determining the impact of an oil spill. If sensitive species are not present in the community before the spill, then the oil spill may show little impact on the community. It is possible that there were few amphipods present before the Deepwater Horizon oil spill affected these areas. This shows the importance of having baseline data and a large enough sample size to detect organisms that are present in low abundances.

The Shannon's diversity index shows that St. Marks has the highest diversity of the sites that were measured. The other sites where oil had been reported by SCAT data all had a lower diversity. This may be a product of oil spill impact, although moderately oiled sites would be expected to have an intermediate diversity, which is not the case. Cameron was unaffected by the Deepwater Horizon oil spill, but had a low diversity score. This may be due to habitat differences between Cameron and other sites, or may also be due to unmeasured background pollution. The Shannon's diversity values are lower in oiled sites but there is no clear trend between oiled sites.

Another aspect of studying the effects of an oil spill on a community is the recovery of the community over time. Long-term studies have shown that the recovery process can take 10 or more years (Dauvin 1998, Dauvin 2000, Jewett et al. 1999). The small amount of amphipods found at Wisner back bay may be a sign of recovery. One amphipod of the family Ampeliscidae was found at Wisner back bay and this family was used by Gestiera and Dauvin (2000) as a group sensitive to oil contamination. Although the presence of amphipods in low levels may be a sign of recovery, because there is no baseline data we cannot know whether the pre-spill community naturally had low levels of amphipods. Future monitoring of this site may show that the abundance of amphipods will increase over time.

The cluster dendrogram from the sediment characteristics also was not able to explain the communities that were found in the sampling. Studies have found that the characteristics of the sediment are important in determining what benthic organisms are able to inhabit an area (De Graer et al. 2008, Whitlatch 1981, Gray 1974). The lack of findings in this aspect of the experiment is also likely due to the high variability of community composition and of sediment characteristics in the samples. The benthic coastal communities of the Gulf of Mexico have not been well-studied and future work on the community structure benthic infauna and how that structure relates to sediment characteristics may help in being able to predict what organisms occur where. This information would be useful for studies examining the effects of pollution and environmental degradation.

Oil spill cleanup efforts may also have been a factor in some of the communities. The cleanup following the Exxon Valdez spill caused damage to the infaunal community (Jewett et al. 1999). The Wisner remnant wetland may show the effects of some cleanup following the Deepwater Horizon oil spill. The remnant wetland is found on the Gulf of Mexico side of the Wisner property and was more accessible to cleanup than was the back bay (K. Coblenz, personal observation). This was due to the inability of large equipment to reach the back bay because of muddy conditions. The remnant wetland showed low abundances, while the back bay showed high abundances, especially of polychaetes.

Although this may be simply due to environmental characteristics, the cleanup involved moving large amounts of oiled sediment from the beach and this likely would lead to a removal of many of the invertebrates. The small abundance found could be due to the slow recolonization of the area following the cleanup. Observations such as this at other sites and knowledge of the exact cleanup policies that were implemented may help to show the impact of the oil spill cleanup efforts.

Natural variability in the benthic community and low sample size at each site hampered our ability to find conclusive results. With a low sample size drawn from across seasons the natural variability of benthic communities was further increased. Another issue was a lack of pre-oil spill data. This has been an issue in many previous oil spill studies and masks some of the possible changes that may have occurred at the sites. To make comparisons between sites, two non-oiled reference sites were chosen, St. Marks and Cameron. St. Marks appears to be the most pristine of the sites, but there is evidence that Cameron may be continually oiled by a large amount of boat traffic and oil refineries in the vicinity. If this were true, Cameron could then be used as chronically oiled reference site, but because SCAT data was used to develop the oiling categories, tests would need to be done to determine the presence and levels of oil at Cameron. Although all of these issues are present, there are still some trends that exist that may show some effects of the oil spill on coastal benthic invertebrates.

Although the findings of this study were not significant, there are trends that did occur that a better designed study may be able to examine. This study also attests to the variability of coastal infaunal communities and the need to account for that variability in the study design. The lack of correlation between the sediment characteristics and the community structures was also largely due to the variability of the communities and may also have been affected by inherent differences between sites in environmental characteristics that were not measured such as salinity. Future work should examine accounting for what characteristics are important in determining the range of benthic species in coastal areas of the northern Gulf of Mexico and also examine sites such as Wisner for signs of recovery from possible impacts. This may be a way in which the impact of an oil spill may be able to be detected. Overall this work provides some background and ideas that may lead to future analysis of the coastal benthic communities of the northern Gulf of Mexico.

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Figures:

Table 1. Location and site characteristics of the six study sites.

Site	Coordinates	Habitats	Oiling Level
Wisner Beach, LA	29.06479N 90.10448W	Back Bay Remnant Wetland	Heavy
Cameron, LA	29.45475N 93.20268W	Mudflat	None
Isles Dernieres, LA	29.35596N 90.39315W	Sandy Beach	Heavy
St. Marks National Wildlife Refuge, FL	30.062463N 84.060746W	Back Bay	None
Perdido Beach, FL	30.172721N 87.274902W	Sandy Beach	None
Ocean Springs, MS	30.235454N 88.490121W	Remnant Wetland	Moderate
Dauphin Island, AL	30.145588N 88.113057W	Sandy Beach	Heavy
Waveland Beach, MS	30.172489N 89.194664W	Sandy Beach	Moderate

Figure 1:

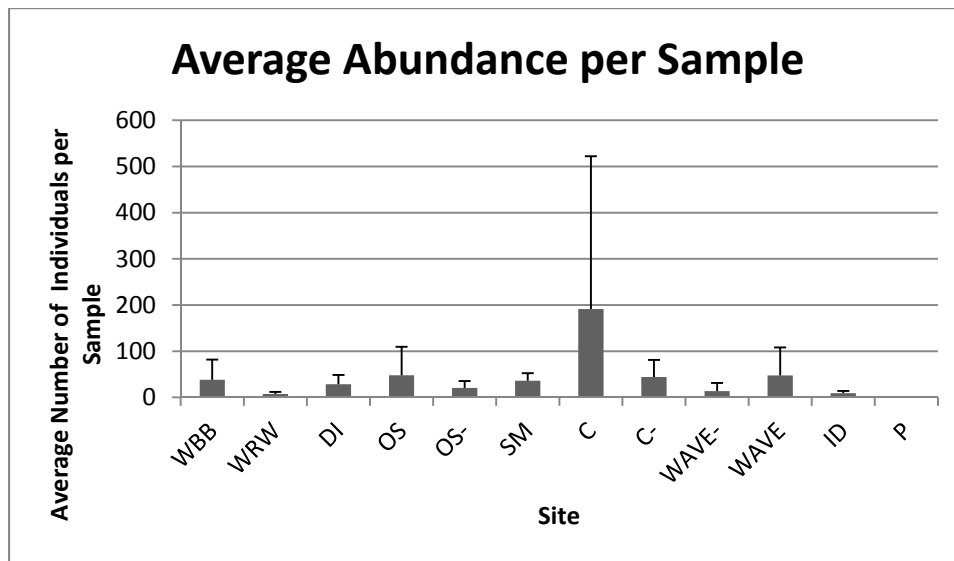


Figure 2:

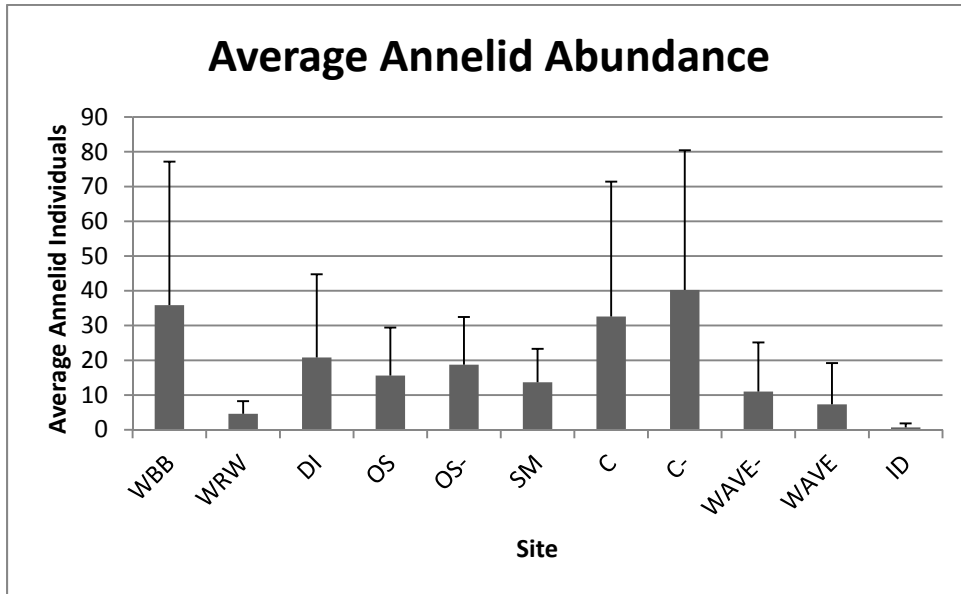


Figure 3:

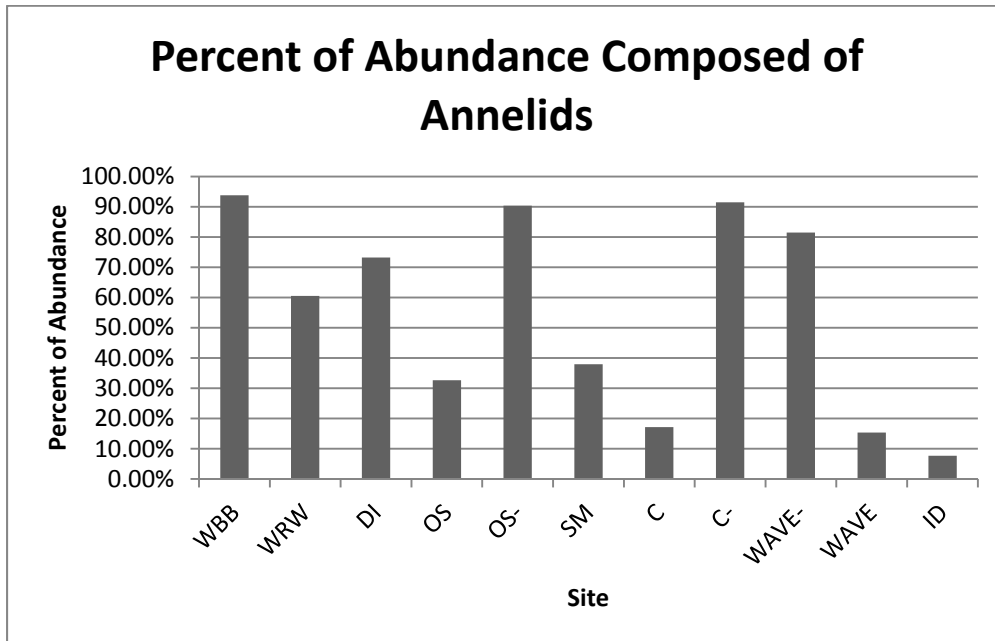


Figure 4:

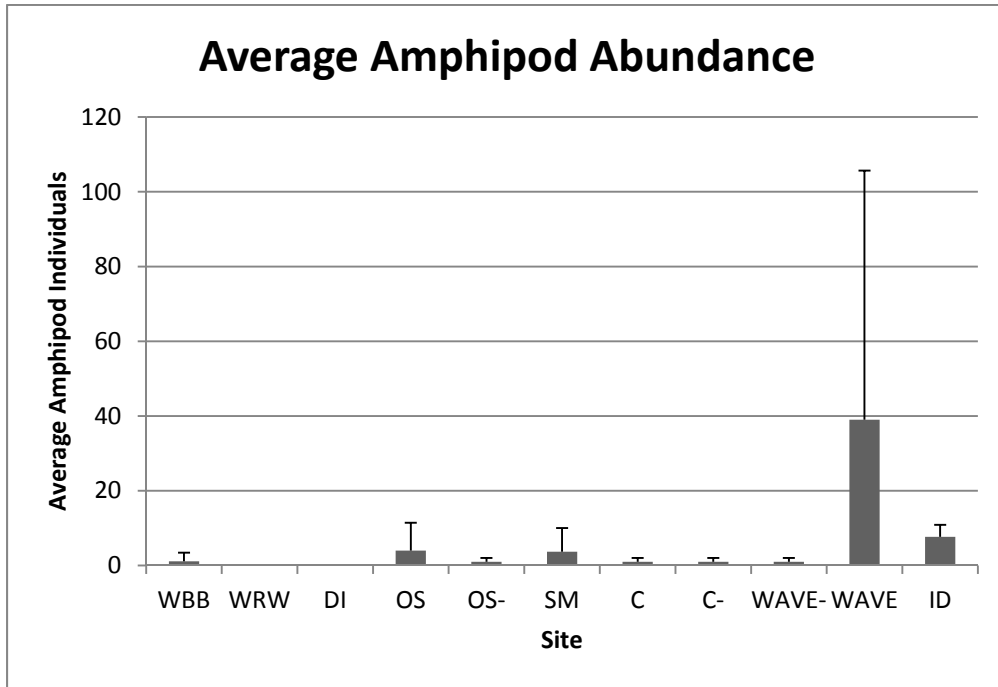


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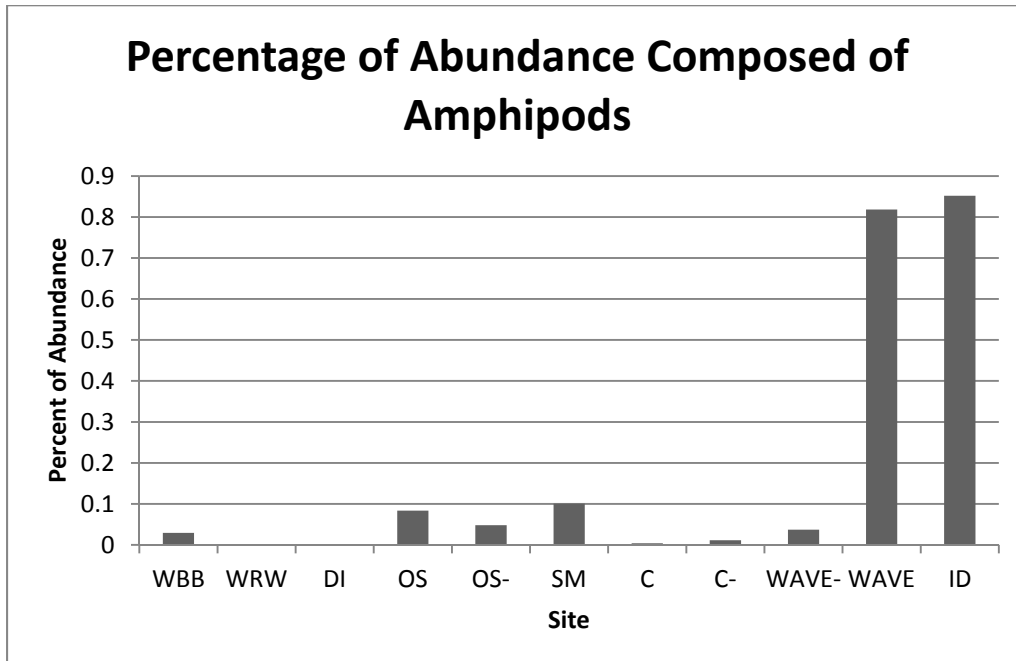


Figure 6:

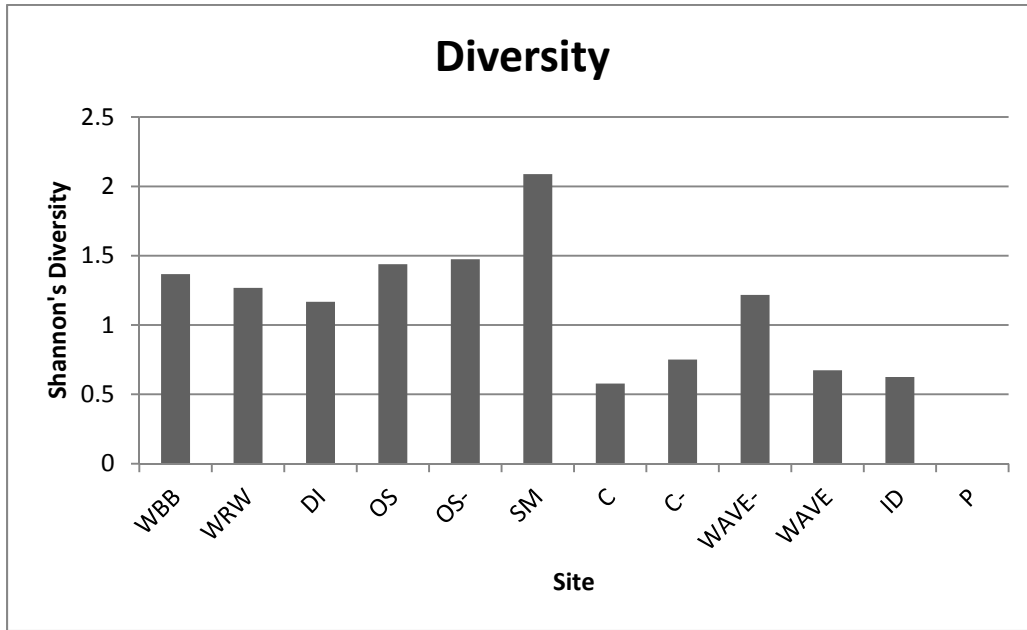


Figure 7:

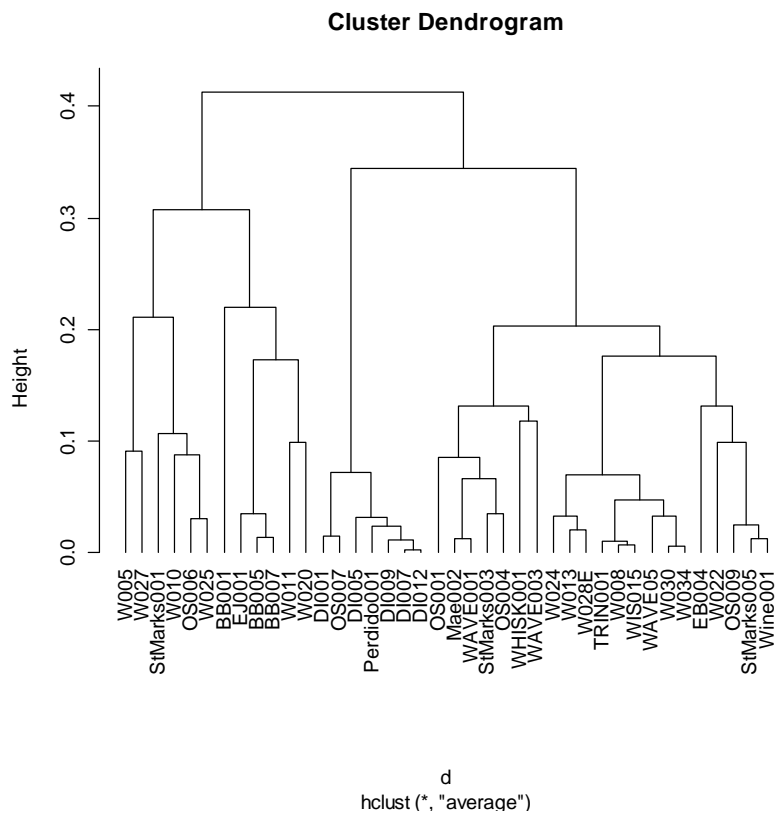


Figure 8:

