Size, Quantity and Pigment of "Decapod Crustaceans" Through the Water Column

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Introduction

The open ocean is devoid of shelter, making vision critical for both predation and predator avoidance (Domanski 1986). Animals within this environment must consequently use visibility (or invisibility) in order to survive. In response to these unique pelagic conditions, organisms have developed complex adaptations to enhance their survival. A number of these adaptations include transparency, counter shading, counter illumination, mirrored body surfaces and in the deep-sea, changes in external pigment (Gagnon 2007). All of these adaptations are strategies to minimize visual predation by decreasing intense light reflections. Many zooplankton use both transparency and alteration in their external pigment as their form of camouflage (Domanski 1986). The latter strategy is primarily used in the deep-sea, where many decapod crustaceans have been observed exhibiting either bright red or red-orange pigments. Since these wavelengths of light do not penetrate to the deep-sea, the crustaceans are invisible at depth (Gagnon 2007). However, decapod crustacean species collected in surface waters appear transparent, which results in a refractive index similar to water, causing relatively little light to be backscattered (Hacker 1991).

In addition to pigmentation patterns throughout the water column, abundance and size trends have also been observed within decapod crustacean fauna. At two abyssal sites in the Northeast Atlantic Ocean, decapod crustacean abundance decreased exponentially with depth. However, the size of the organisms increased with depth in the water column (Domanski 1986). Off the coast of Japan, the same abundance and size trend was also observed in decapod crustaceans (Omori 1981). This decrease in abundance of crustaceans with depth may be attributed to a decrease in dissolved organic matter and reduction in ATP produced by bacteria, consequently lessening the overall available biomass for consumption by individual organisms (Gagnon 2007). This decrease in food within the deep-sea may be an impetus for increased scavenging. Scavenging amphipods and decapod crustaceans that live in both deep pelagic and benthic environs actually exhibit gigantism, appearing much larger than typical crustaceans (Omori 1981 and Rex et. al. 2006). These organisms are extremely mobile, and are adapted to quickly locate and consume large deadfalls (Gagnon 2007 and Rex et. al. 2006). Consequently, the increase in crustacean size with depth may be in response to a currently unknown set of evolutionary selective pressures compared to their sedentary counterparts, as a result of scavenging (Rex et. al. 2006). Thus, the present study examines if the size, quantity and pigment of decapod crustaceans change with depth in the water column in the deep-sea at Southwest Reef, Bahamas.

Methods

Pelagic decapod crustaceans were sampled from discrete depth ranges throughout the water column from the surface to 900 meters using an nine-net Multiple Opening Closing Net Environmental Sampling System (MOCNESS) towed at an average speed of 2 knots. Each net had a 1 m^2 mouth opening with a 130 um mesh that was opened and closed independently from the ship at eight discrete sampling depths, except for one net representing the integrated sample. Nets were deployed to collect samples within the following depth strata: 750-900m, 650-750m, 550-650m, 450-550m, 350-450m, 250-350m, 150-250m and 0-150m. Sampling periods lasted approximately 3.5 hours. A total of two identical MOCNESS hauls were conducted during mid-day, in the manner described above, on 5/15/08 and 5/21/08 at Southwest Reef in the Bahamas (N 24°52'.9795; W 77°32'.3854) during a cruise aboard the R/V Seward Johnson of Harbor Branch Oceanographic Institution. However, during the MOCNESS haul on 5/15/08 there was no surface tow from 0-150m due to a lost cod end.

All macrozooplankton from each cod end were sorted under a dissecting scope and all decapod crustaceans were subsequently sorted and counted. Due to the dearth of amphipods and plethora of copepods found in each MOCNESS sample, only the "shrimp-like" organisms were considered in this study and will be referred to as shrimp throughout the paper. Shrimp from each depth stratum were sorted, subsequently counted under a dissecting scope and placed into respective scintillation vials categorized by depth at which they were found. For samples greater than 500 individual shrimp, the sample was split 1:4 and then counted. Abundance was subsequently extrapolated to the entire sample. Each individual shrimp was then measured from the anterior to posterior end (excluding the antennae) via the use of calipers. For samples greater than 500 individual shrimp, the sample was split 1:4, as described above, and measurements of the shrimp were taken 1:10 in that subset.

Due to time and instrument constraints on the ship, a qualitative method was used to measure pigment in each shrimp. Each individual from every MOCNESS depth stratum was observed and grouped based on similarities between three qualitative variables: pigment coloration, pigment patterns and significant morphological features. A representative of each group from each depth stratum was subsequently chosen and photographed. After all representative photographs were taken, each photo was used to analyze the extent of pigment coverage over the entire surface area of the shrimp via observation. This method was utilized to qualitatively assess the percent pigment of each category of shrimp found at each depth stratum throughout the water column.

Results

Overall, average size of the shrimp increased as depth increased for each MOCNESS haul (Figure 1 and Figure 2). However, there was a large increase in average size at 350m followed by a large decrease in average size at 450m during the second MOCNESS on 5/21/08 (Figure 1). This was due to an excessively large, red-pigmented shrimp that was found at 350m depth, which consequently increased the average size for that depth (Figure 1). If this shrimp is taken out of the analysis, the increase in size at 350m depth is not as large (Figure 2).

The quantity of shrimp showed an overall decrease with increased depth for each MOCNESS haul (Figure 3). However, there was an increase in the amount of shrimp found at 450m depth (Figure 3 and Figure 4). Due to the fact that there was no surface tow for the MOCNESS haul on 5/15/08, the quantity of shrimp found in the surface waters from 0m to 150m is absent from Figure 3 and Figure 4 for this specific MOCNESS. Nevertheless, the MOCNESS haul on 5/21/08 included a surface tow and consequently there was a large increase in the quantity of shrimp found in the surface waters from 0m to 150m depth compared to the other depth strata (Figure 3). If this surface tow is taken out of the analysis, then the MOCNESS haul on 5/21/08 shows a similar trend to that of the MOCNESS haul on 5/15/08: an overall decrease in quantity of shrimp with an increase in depth (Figure 4).

The percent pigment of shrimp increased with depth for each MOCNESS haul (Figure 5 and Figure 6). In general, shrimp found at 150m depth had 3% pigmentation (Figure 7), shrimp found at 450m had 50% pigmentation (Figure 8) and shrimp found at 900m had 100% pigmentation (Figure 9). However, there were a few slight decreases in percent pigment at some midwater depth strata (Figure 5 and Figure 6). There was also an inordinate increase in percent pigment at 350m depth, which was again due to the excessively large, red-pigmented shrimp that was found at 350m depth during the MOCNESS on 5/21/08, which consequently increased the average percent pigment for that depth (Figure 5). If this shrimp is taken out of the analysis, there is a large decrease in percent pigment at 350m depth and slightly similar trends are seen for each MOCNESS haul: an overall increase in percent pigment with an increase in depth (Figure 6).

Discussion

This present study supports the idea that shrimp may show a decrease in abundance and an increase in size and percent pigment as one goes deeper in the water column (Figures 1-6). Off Japan, observations made by camera from a submersible at shelf depths (less than 300m) have shown maximum concentrations of pelagic shrimp *Sergia lucens,* however, concentrations decreased with depth, and no individuals were observed 1.4m from the bottom (Omori 1981). Additionally, off the coast of Cape Point, South Africa decreases in concentrations of deep-sea decapod crustacea have been observed (Kensley 1968). This may be a direct result of decreases in available dissolved organic matter and nutrient input lessening the ability for a large standing stock of crustaceans to exist at depth, due to the increased distance from coastal and sunlit waters (Rex et. al. 2006). In the present study, this may have been the case. However, this study did not take into account the possibilities of vertical migrations of pelagic shrimp. Shrimp have been known to vertically migrate up into shallower waters during the night to feed and down into deeper waters during the day (Kilkuchi 1985). Thus, during the day, there should be a higher abundance of shrimp at depth than at the surface. Since this study observed the opposite trend during the day, it may be possible to assume that vertical migration was not a factor and rather a result of decreased availability of dissolved organic matter (Pearre 1979).

Additionally, the size of the shrimp increased with depth (Figure 1 and Figure 2). Certain pelagic species of shrimp have been known to double and even triple in size within the deep-sea (Omori 1981). This may be a direct result of decreased food availability, such as nutrients and dissolved organic matter within deep-sea environs, which creates an impetus for crustaceans to scavenge (Rex et. al. 2006). Decapod crustaceans found at abyssal depths off the coast of Japan, exhibit gigantism, appearing much larger than typical crustaceans (Domanski 1986 and Omori 1981). This observed increase in crustacean size may be the response to currently unknown evolutionary selective pressures, as a consequence of scavenging (Rex et. al. 2006).

Overall, there was an observed increase in percent pigment of shrimp found in deeper waters (Figure 5 and Figure 6). This is most likely due to the changing light levels within the ocean as one goes deeper (Karuppsamy 2006). Since the pelagic is devoid of shelter, vision is now critical for both predation and predator avoidance (Domanski 1986). Consequently, shrimp must camouflage their bodies to become invisible within this environment in order to minimize visual predation. A significant adaptation that has been observed within deep-sea decapod crustaceans is changes in external pigment (Gagnon 2007). Shrimp that are found in shallower waters are subjected to a sunlit environment, so they use transparency as their form of camouflage (Karuppasamy 2006). This is effective because many transparent species of shrimp have refractive indices close to water and thus little light is backscattered, making them appear invisible (Gagnon 2007). As one goes deeper into the sea, certain wavelengths of light get absorbed. Higher energy wavelengths, such as the colors black and red get absorbed first; whereas lower energy wavelengths, like the color blue, get absorbed farther down in the ocean (Karuppasamy 2006). Additionally, light intensity decreases exponentially with depth, and the spectrum of light narrows, becoming increasingly blue. Consequently, shrimp found in deeper waters are subjected to environments with little or no light penetration. Thus, they have adapted external red pigments to camouflage their bodies in an environment where red light does not exist (Gagnon 2007).

Due to the lack of a sufficient quantitative analysis for measuring shrimp pigmentation, these conclusions are merely speculations. Therefore, it would be interesting to develop a quantitative protocol for analyzing percent pigmentation of the shrimp found at each depth so that a definitive trend could be analyzed. Additionally, the deployment of the MOCNESS at more sample sites would help increase sample size to see if similar trends are found in quantity, size and pigmentation of shrimp through the water column.

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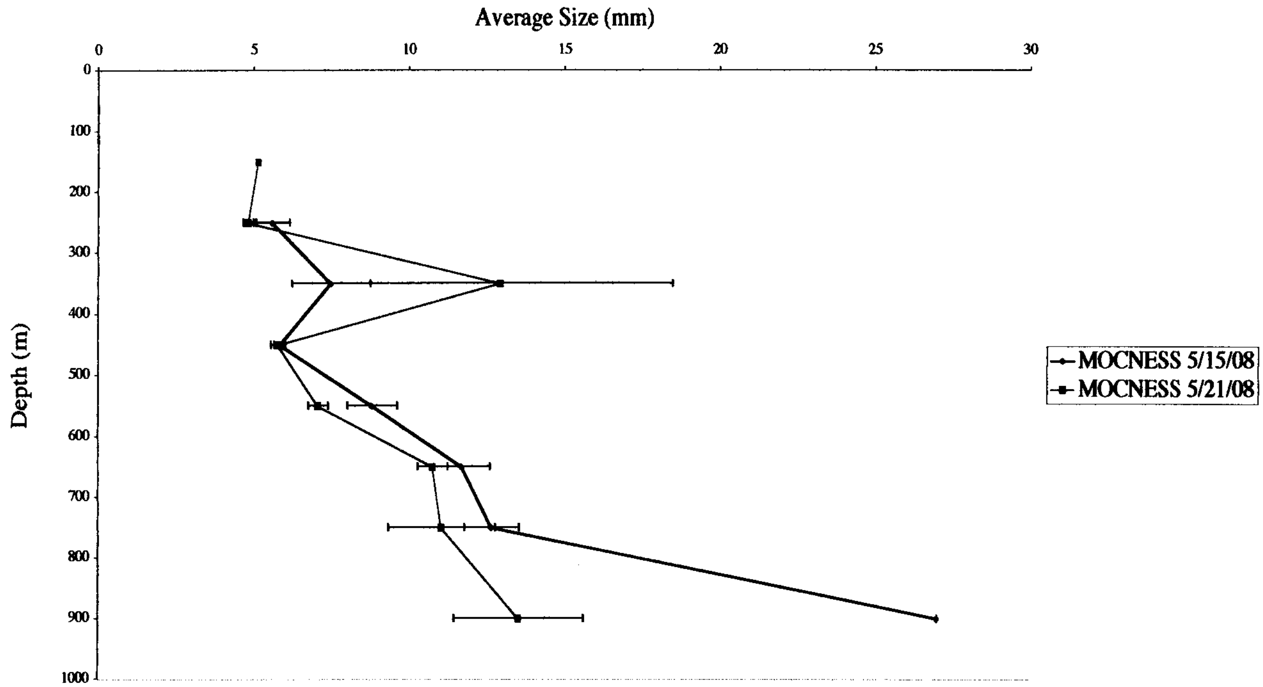

Figure 1. Average size of shrimp found at different depths in the water column, including the measurement of an excessively large shrimp found at 350m. All bars represent standard error.

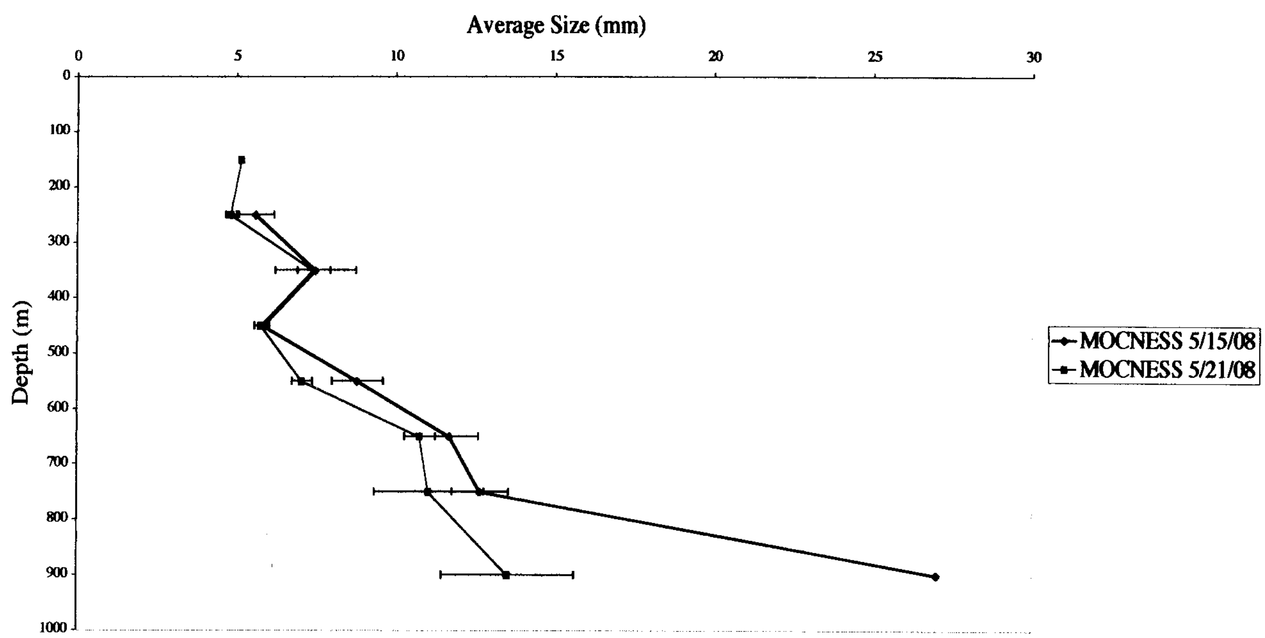

Figure 2. Average size of shrimp found at different depths in the water column, excluding the measurement of an excessively large shrimp found at 350m. All bars represent standard error.

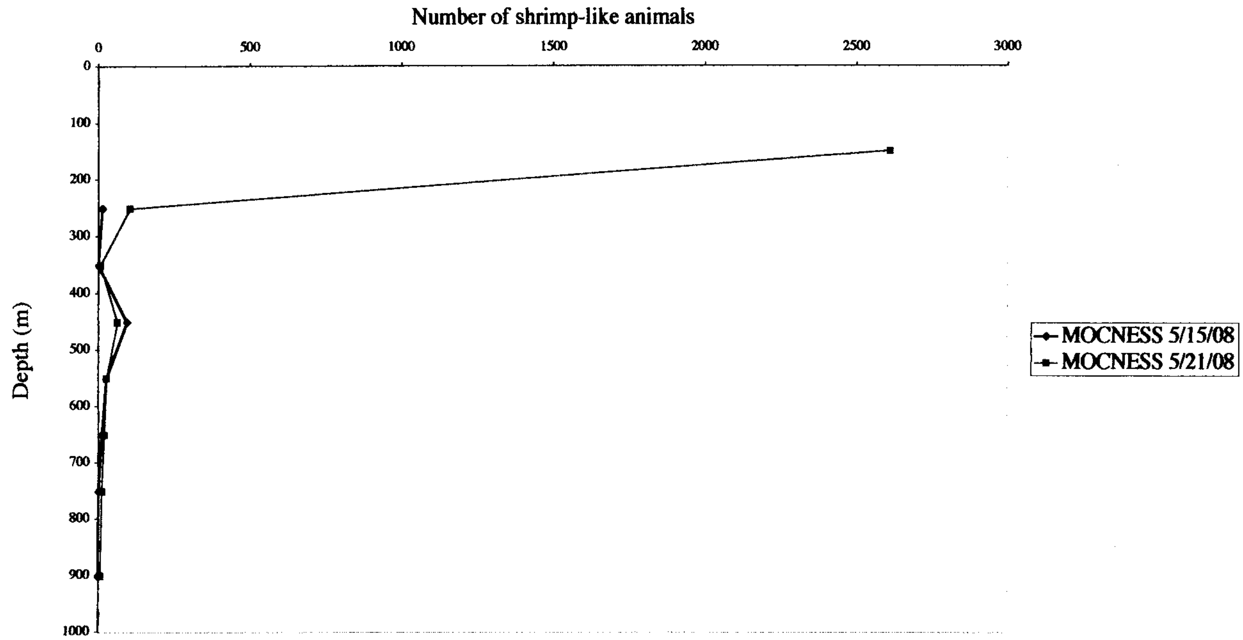

Figure 3. Number of shrimp found at different depths in the water column including the surface tow from the MOCNESS haul on 5/21/08.

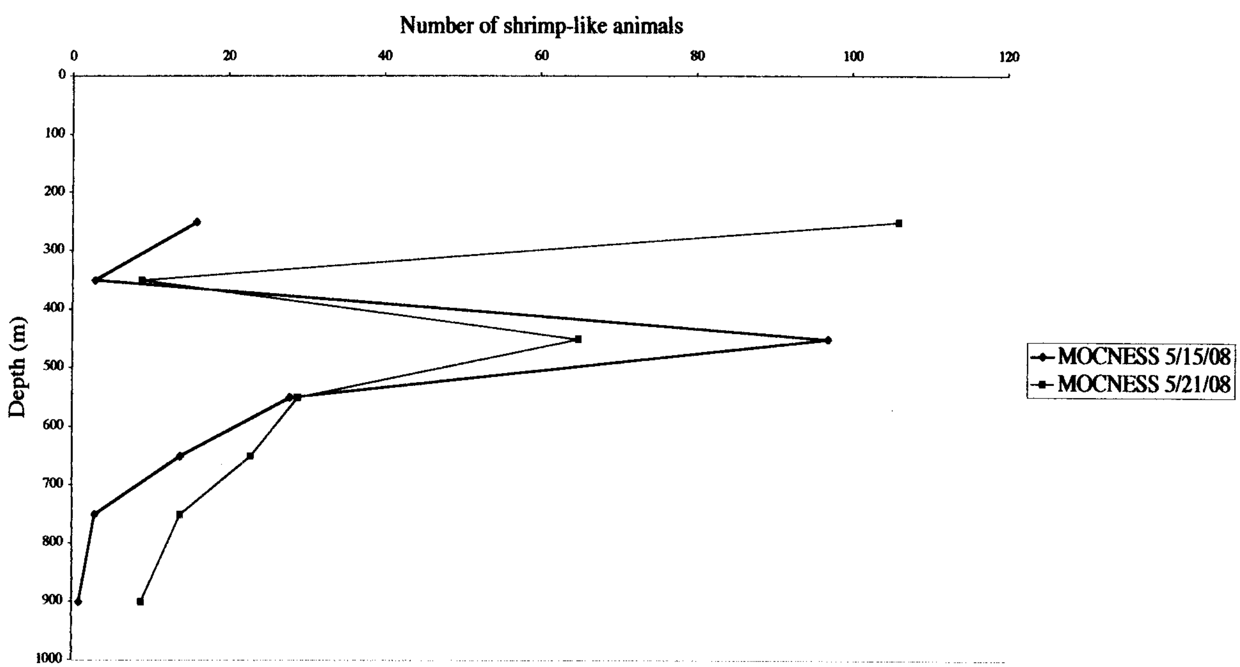

Figure 4. Number of shrimp found at different depths in the water column excluding the surface tow from the MOCNESS haul on 5/21/08.

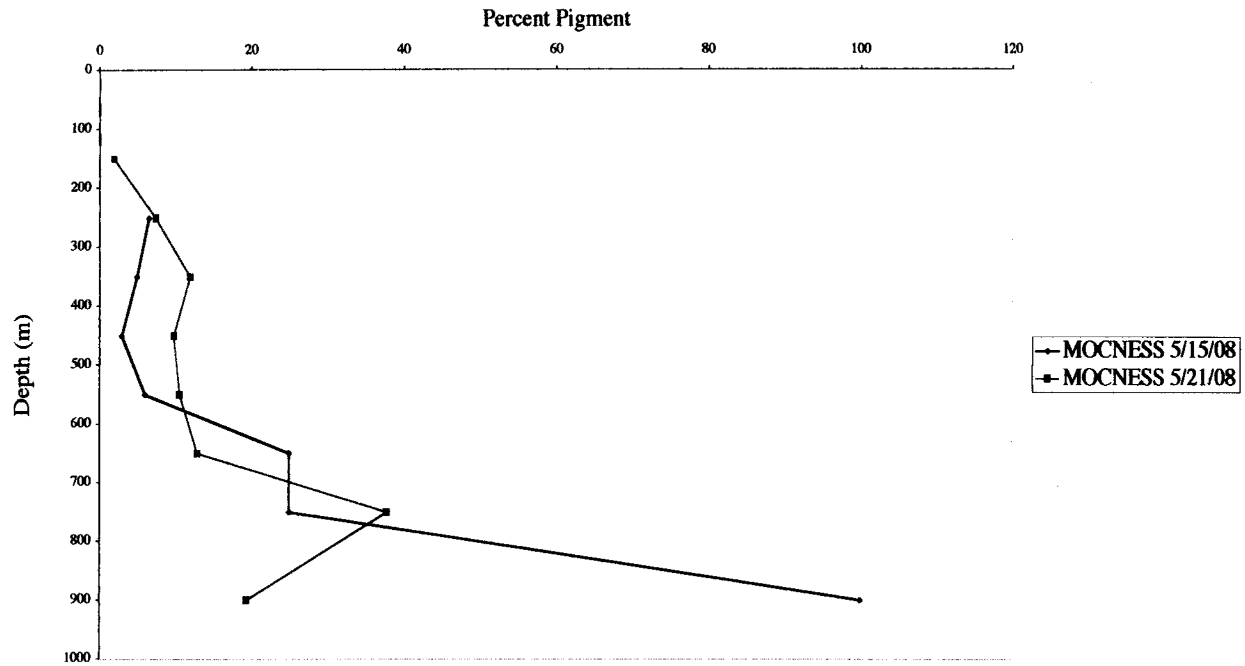

Figure 5. Percent pigment of shrimp found at different depths in the water column including the excessively red-pigmented shrimp found at 350m.

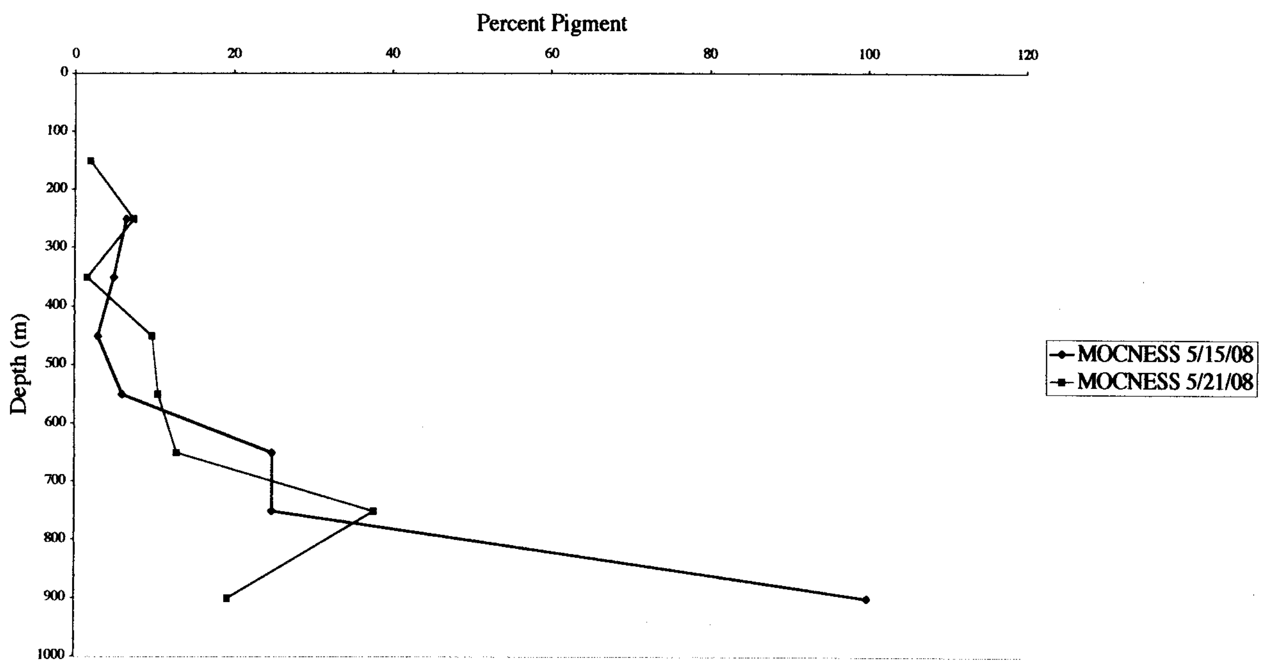

Figure 6. Percent pigment of shrimp found at different depths in the water column excluding the excessively red-pigmented shrimp found at 350m.