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Title

The distribution of gelatinous plankton and zooplankton in the region of the North Equatorial Front (NEF) and its implications for the trans-oceanic migration of western-Pacific leatherback sea turtles (*Dermochelys coriacea*)

Abstract

Given the concern over the endangered status of the Pacific Leatherback Sea Turtle (*Dermochelys coriacea*), attention has been brought to the threats they face during nesting periods on shore, but less effort has been made to reduce the risks leatherbacks face during their pelagic migrations – namely by-catch by long-line fisheries. Satellite images of turtles tagged in Monterey, CA have revealed that they repeatedly travel along the North Equatorial Front (NEF)— the boundary between the North Pacific Central Water (NPCW) and North Pacific Equatorial Water (NPEW) masses— during their trans-Pacific migrations. We hypothesize that leatherback turtles are attracted back to this region in order to feed on the gelatinous plankton that aggregates along frontal boundaries. To test this hypothesis, neuston and meter tows were performed along a portion of the North Pacific Equatorial Front along which a tagged leatherback was migrating. The tows revealed that the density of gelatinous organisms was much higher at the front than in the colder, oligotrophic waters to the north. It was concluded that the leatherback was using this frontal boundary during its migration to balance its need to feed on gelatinous plankton with its metabolic need to stay in cooler waters. Because leatherback turtles exhibit such high fidelity for this stretch of the pelagic Pacific, we recommend the establishment of a "corridor" of protection for these animals.

Introduction

The leatherback turtle, *Dermochelys coriacea*, which appeared on earth over 100 million years ago and, according to the fossil record, has not changed significantly over the past 65 million years (Dutton et al 1999), is currently severely threatened. The Pacific ocean has two populations of leatherbacks (west and east) both of which are currently considered endangered. The Eastern Pacific Ocean, once considered a major leatherback sea turtle stronghold, has undergone a documented decline of over 80% in nesting turtles over the past 25 years (Spotila et al. 2000). The biggest threat to leatherback turtles in this region is longline fisheries which, in the year 2000 alone, were responsible for the by-catch of roughly 63% of the juvenile turtle population (20,000 individuals) (Spotila 2004). In addition, destruction of nesting habitat has contributed to the overall population decline.

Except for the brief time leatherbacks spend on beaches as eggs, hatchlings, or nesting, this species spends most of its time at sea moving from temperate to tropical waters (James et al 2005) spending 55-80% of their time submerged (Southwood et al 1999).

Leatherbacks are diving reptiles that have been recorded to dive up to 1,500 m with the majority of their dives < 200 m particularly at night when it appears their time is spent feeding on gelatinous plankton in the Deep Scattering Layer (DSL) (Shillinger et. al in prep TOPP 2007) (*Figure 1*). Gelatinous organisms are the preferred prey of the leatherback sea turtle which will follow schools of jellyfish, siphonophores, tunicates, and salps drifting with the ocean's currents for its food source (Spotila 2005). Studies have shown that in the juvenile stage, leatherback turtles eat the equivalent of their body weight in jellyfish each day (EPA 2006). Leatherbacks are thought to mature between the ages of 13 and 14 years with adult females attaining a body mass of 275.6 - 562.7 kg (post oviposition), (Georges and Fossette, 2006) and carapace length of up to 257 cm (Price et. al 2006).

Due to their large size, leatherbacks utilize a "suite of physiological adaptations including low metabolic rate, large thermal inertia, blood flow adjustments, and peripheral insulation" collectively known as *gigantothermy* to maintain an elevated body temperature across the gradient of temperatures they experience in both their long, migratory, horizontal and daily, vertical migrations (Wallace et. al 2005). However, because they are reptiles their hearts are not as tolerant to the increase in pressure that occurs when temperature is increased which may be why they dive so frequently and are found in cooler waters. (Bleakney, 1965). Although swimming is more energetically efficient than other forms of locomotion, adult leatherback turtles continue to consume large quantities of gelatinous organisms after they reach maturity to sustain their metabolic demands (Lushi et al 2003).

Even though there continues to be a documented decline in the Pacific leatherback population each year (NACAP 2005), relatively little is known about the life strategies and diet of this animal over its trans-oceanic migrations.

As far as we know, leatherbacks appear to be generalists that forage on a variety of gelatinous organisms which leads us to believe that an abundance of gelatinous plankton versus the diversity of the community may be play a more important role in attracting a leatherback turtle to an area. However, little is known about the life histories of gelatinous organisms— some may bloom seasonally, others with an increase in nutrient level or a change in temperature. Without this knowledge it is difficult to say conclusively one way or another what factor is a better indicator of potential leatherback presence. The capacity for the presence of gelatinous plankton, and by association, leatherback sea turtles may be correlated with the amount of surrounding photosynthesizing phytoplankton (detectable via satellite imaging of chlorophyll-a) because, depending on the size of the gelatinous creature, these phytoplankton are either consumed directly by or eaten by something else (another gelatinous organism or zooplankton) that is then consumed by it. The density of zooplankton in an area is taken into account both as another method of determining the level of productivity of a water mass, and as other drifting organisms, what the community response of these organisms is to the varying physical, oceanographic characteristics of the North Equatorial Front (NEF) region.

Previous research has suggested that on their long migrations, leatherbacks are opportunistic foragers (Eckert et al 2005) and that they locate biological "hot spots," such as eddies (Markman Schwartz 2005), which enable them to increase their foraging efficiency. It has also been shown that upwelling in the North Pacific Equatorial Water (NPEW) mass in a region known as the "equatorial cold tongue" (roughly 4ºN - 4ºS of the equator) leads to increased primary productivity which is indicated through satellite imagery via chlorophyll-a fluorescence (*Figure 2*). This southerly water is propagated latitudinally by Tropical Instability Waves (TIWs) most noticeable as fluctuations in SST (Fielder et. al, 2006) originating at the equator. The saw-toothed pattern apparent on the chlorophyll-a satellite image is formed by shear between the westward flowing South Equatorial Current (SEC), eastward flowing North Equatorial Counter Current (NECC), and westward flowing North Equatorial Current (NEC) as well as by anticyclonic Tropical Instability Vortices (TIVs) which are a train of wind-driven eddies formed off the Yucatan peninsula. Although these interactions occur south of the North Equatorial Front (NEF), the "signature" of these forces is clearly visible along the NEF which marks the boundary between the NPEW and North Pacific Central Water (NPCW) masses (Willett et. al. 2006).

By studying the physical oceanographic and biological features that define the migration route of turtles tagged by the TOPP program off the coast of Monterey, CA (*Figure 3*) across the transient region of the North Equatorial Front (NEF), we hope to provide information useful in determining the likelihood of leatherback turtle presence in the Pacific Ocean. We hope the information gathered in this study will be used to establish of a “corridor of protection” for leatherbacks based on the the identification of physical oceanographic characteristics that determine where planktonic organisms and therefore, where the turtles themselves are most likely to be located at any given time of year.

Methods

Sea surface temperature (SST), fluorescence (V), zooplankton density (mL/m^3) , and gelatinous density (mL/m^3) data was collected at four stations along the cruise track. These stations will be subsequently referred to (from north to south) as: “Filament, North Pacific Central Water (NPCW), North Equatorial Front (NEF), and North Pacific Equatorial Water (NPEW) (*Figure 5)*.

The location of each station was determined by a combination of sea-surface temperature and fluorescence measurements of surface water which were constantly collected by a flow-through fluorometer. The direction and strength of surface currents were constantly measured by the ship's ADCP. These *in situ* measurements, in combination with satellite images of chlorophyll-a and sea surface temperature (*Figure 2, 5*) enabled the very precise positioning of each station location.

A 2-meter (diameter) net with a mesh size of 500 µm, a neuston net (area =1 m^2) with a mesh size is 330 µm, and CTD-HC were deployed at night between the hours of 2015 to 0420 with a moon phase between 1-4%, at each station. (Deployments were consistently at the same time of day to avoid complications from the diel vertical migrations of planktonic organisms). A target depth of 50 meters was chosen for the 2-meter net because previous studies suggest that, at nighttime, leatherback turtles dive most frequently to depths of 50 meters or less (Schillinger et al. in prep, TOPP) (*Figure 1*).

Variation in tow length (distance in meters) and depth (m) between stations can be attributed to slight differences in wire angle, speed of the sailing-research vessel, and weather conditions. The 2-meter net was towed at depth for 30 minutes and the neuston was deployed along the surface for 30 minutes. A flowmeter was attached to each net to accurately determine the exact distance the nets traveled through the water. The CTD/HC was programmed to take measurements every second and was sent down to 423-480m to record vertical temperature (ºC) and fluorescence (V) profiles in the water column. Analysis of the tows was consistent at each of the four stations. "Hundred-counts" (the identification of 100 organisms from a random sample of biomass from a net deployment) were completed for every 2-meter and neuston tow. Zooplankton and gelatinous biomass (mL) were measured via volume displacement, and these values were then normalized for variance in tow length/ volume into zooplankton and gelatinous density (mL/m^3 for the 2-meter net, mL/m^2 for the neuston which is not fully submerged). Gelatinous organisms were identified when possible and recorded. Shannon-Weiner index values were assigned to each of the samples as an indication of species diversity for the sample. This procedure of collection and analysis was followed at each of the four stations.

At the "Filament" station located at 14º 30.4' N x 156º 30.5'W was sampled at 2215 during a moon phase of 3%. The CTD-hydrocast had a maximum depth of 488 meters (*Table I*). The 2-meter (diameter) was deployed and towed at a resulting depth of 44 meters for a distance of 1792 meters. The neuston net was deployed and remained at the surface for 1852 meters.

The next station, "North Pacific Central Water (NPCW)", was located at 12º 19.1' N x 156º 32.9' W at 0420 during a moon phase of 1%. The hydrocast was lowered to a depth of 423 meters. The 2-meter net was towed at a depth of 55 meters for 2162 meters. The length of the neuston deployment was 2162 meters.

The third station, North Equatorial Front (NEF), was located at 10º 46.7' N x 156º 35.3' W. At 2312 with a moon phase of 3%, the CTD-HC was lowered to a resulting depth of 470 meters. The 2-meter reached a maximum depth of 37 meters and was towed for an overall length of 1532 meters. The neuston net deployment covered 1819 linear meters of ocean surface.

At the final station, North Pacific Equatorial Water, located at 8º 18.5' N x 156º 28.3' W, sampling took place at 2310 with a moon phase of 4%. The maximum depth of the CTD-hydrocast was 480 meters, the 2-meter net was towed at a depth of 41 meters over a total deployment distance of 2220 meters. The neuston net was deployed for a total of 1160 meters.

This consistency prevented confounding data from different phases of diel vertical migrations of zooplankton and gelatinous organisms.

Results

Temperature

Sea surface temperature (ºC) is detectable via satellite. The comparison between in situ measurements for SST and satellite values reveal the low margin of error of 0.1ºC for this remote sensing tool. The shape and location of the NEF is readily distinguishable on the image (*Figure 4*). The North Pacific Equatorial Water (NPEW) station registered the highest SST at 27.25ºC. The lowest temperature of the fours stations was 25.8ºC which was recorded at the North Pacific Central Water (NPCW) station. The Filament and North Equatorial Front (NEF) stations, although separated by 4º13.3' of latitude maintained a similar SST; 26.78ºC and 26.43ºC respectively (*Table 2*). Temperature profiles taken through the water column show the deepest thermocline (depth = 125.02 m) at the NPCW station and highest thermocline (85.01 m) at the Filament station (*Figure 6*).

Fluorescence (in situ)

Surface fluorescence, as a proxy for productivity, was a primary factor used in determining tow locations. An *increase* from an average surface fluorescence of 0.12-0.2 V (not shown) to 0.509 V supported by both the flow-through fluorometer and the chlorophyll-a satellite image prompted deployment at the "Filament" station. A 75% difference in the level of surface fluorescence exists between the highest recorded value at the NPEW station (0.600 V) and the lowest recorded value (0.151 V), at the NPCW station. The fluorescence at other stations within the North Pacific Equatorial Water mass is roughly 85-86% of that at the NPEW station— but is still relatively high (*Table 3*). Fluorescence vs. depth profiles for the four stations indicate a deep chlorophyll maximum layer for the NPCW station at 135m with a peak in fluorescence from the surface down to 45-55m for the remaining three stations (*Figure 7*). Sea Surface Temperature and fluorescence appear to be correlated across the four sample sites (*Figure 8*) (R^2= 0.84) .

Currents

An ADCP was used to analyze current direction and speed at locations running from north to south along the North Equatorial Front. At the Filament station (14º30.4'N x 156º30.5' W) the current was Eastward flowing with a stronger signature at 25m and 50m depths. The NPCW station showed currents moving to the North, but no distinguishable trend with depth was observed. The NEF and NPEW stations registered westward flow associated with the North Equatorial Current (NEC). (*Table 4*)

Gelatinous Density

In both the 2-meter and neuston net deployments, the lowest relative gelatinous density was recorded at the NPCW station. Where the highest relative density was found differed between the two nets— the 2-meter net recording its highest density (0.072 mL/m^3) at the NPEW station, and the neuston had the highest gelatinous density at the Filament station (0.0069 mL/m^3). In both nets, there was a decrease in density at the NPCW station. In the 2-meter net, after the original drop in density from "Filament" to "NPCW" density steadily increased as latitude decreased. In the neuston net, the NEF registered a greater relative density of gelatinous organisms than both the NPCW and the NPEW. (*Table 5, Figures 9-10*). Large pyrosomes were found in the warmer, more southernly waters. Pyrosomes are a colonial, pelagic tunicate, and therefore are included in the "gelatinous" category. The impact of a few of these pyrosomes on the total density of gelatinous organisms can be seen in Figure 11. It is important to note that some cube jellies with ~20 cm diameter medusae were observed off the side of the boat at the time of deployment at the NEF station, but none were picked up by the nets. The highest numbers of pyrosomes were found in the Filament and NPEW stations but the highest density was recorded in the NEF and NPEW samples (*Figure 11*).

Zooplankton Density

Zooplankton density in the 2-meter net was relatively the highest at the NEF station (0.07580 mL/m^3) and lowest at the NPCW station (0.01950 mL/m^3). In the neuston net, the lowest relative density was also at the NPCW station (0.001 mL/m^2), but the highest relative density was found at the NPEW station (0.034 mL/m^2). Overall trends in the nets differ in that the NPEW is higher than the NEF for the neuston and lower than the NEF in the 2-meter net. (*Table 6*, *Figures 9, 10*). Total density of planktonic organisms have identical patterns in both net types with less of a difference shows less between the two southern-most stations associated with the North Pacific Equatorial Water mass and a more striking contrast between these stations and the one located in the North Pacific Central Water mass (*Figure 18a, b)*.

Number and Relative Diversity of Gelatinous Organisms

The most abundant gelatinous species at the Filament station was the salp (96 distinguishable individuals) while gelatinous plankton at the NPCW station was dominated by ctenophores (42 individuals). At the NEF and NPEW stations siphonophores were the most abundant gelatinous organism (235 and 121 individuals, respectively). Overall diversity was highest at the Filament station (0.42 on the Shannon-Weiner Index). The NEF had two times the number of gelatinous planktonic organisms of the Filament (284 vs. 132 individuals), and registered at 0.28 on the Shannon-Weiner Index which is close to the value for the NPCW (0.27) where only 52 individuals were found. (*Table 7, Figure 12*).

Percent Composition of Zooplankton

Hundred counts representative of the zooplankton in each net deployment showed the following trends for the 2-meter net: a 63-75% copepod composition for the Filament, NEF, and NPEW stations with a dip to 31% in the NPCW where euphausids dominated at 56% of total zooplankton organisms. The Shannon-Weiner Index did not vary much across the four stations— staying in a range of 0.37-0.46 with relative “high” diversity in the NPCW (0.46). In the neuston net, copepods were the most dominant organism at every site ranging from 59% at the NEF to 83% at *both* the Filament and NPCW stations. Diversity fluctuated more relative to the 2-meter net deployments indicated by a Shannon-Weiner index range of 0.27 at the NPCW station to 0.58 at the NPEW station (*Figures 13, 14*).

Discussion

There are a variety of factors at play influencing why a leatherback turtle, tagged in Monterey, CA traverses the boundary between the northern-most edge of the North Equatorial Current (NEC) and North Pacific Common Water— the North Equatorial Front (NEF). Because this zone has increased primary productivity at the surface, it may also have a higher density of consumers that feed on photosynthesizing organisms which include gelatinous organisms and zooplankton. Although exact relationships between phytoplankton, zooplankton, and gelatinous plankton is are extremely complex and vary on a species-by-species basis, the presence of phytoplankton at some level is necessary for the presence of both gelatinous organisms and zooplankton. Both types of plankton are taken into account, even though leatherback turtles only feed on gelatinous species, as an indication of the relative capacity of an area to support planktonic life. Relative fluctuations in the composition of these planktonic communities can then be analyzed against other conditions to determine what factors may be influencing these changes. However, in this study, there are not enough replicate samples per station to run a statistical analysis on the findings to attribute any significance to the observed trends. The physical characteristics of the open ocean play a role in community composition. Since gelatinous organisms are not strong swimmers, they may "bloom" in areas of nutrient upwelling but may have distribution patterns dependent on the interaction of the currents they come into contact with which may carry them away until they drift into something (like a front) that stops their spread and accumulates them.

The high thermocline indicated for the NPEW station is expected for an area of nutrient upwelling where the cold water is closest to the surface. Likewise, we observed what we expected to find in the NPCW temperature profile which revealed a depressed thermocline indicative of the lower, weaker level of density-driven mixing attributed to oligotrophic water masses. (*Figure 6*) Less mixing appears to contribute a trend in low overall fluorescence and plankton density.

Fluorescence profiles, Figure 7, indicate that the stations in the North Pacific Equatorial Waters, or those originating from this water mass (Filament, NEF, and NPEW) all had high surface fluorescence while the NPCW station had low surface fluorescence with a deep, low, chlorophyll-maximum layer characteristic of an oligotrophic area. This is also associated with low mixing to the surface which drives nutrient limited phytoplankton to the lower limit of the euphotic zone.

Temperature and fluorescence in this region are correlated which suggests that upwelled water at the at the equator is warmed and then cooled as it moves north, but origin plays a role as indicated by the "Filament" station (*Table 2*) which maintains the higher temperature (and fluorescence) signature of the equatorial waters even though it is at a higher latitude than the NPCW station to the south. The density of gelatinous plankton found in the neuston net deployments followed a trend similar to that of surface fluorescence with both showing values for the NPCW station at roughly 25% of those for the NPEW station. Although there is no way to measure the significance of this finding, the trend appears to suggest that in oligotrophic waters, fluorescence may be an accurate indicator of gelatinous density (*Figure 10, Table 3*).

Currents in the region showed an unexpected, strong, eastward flow at the "Filament." The current direction anticipated at 14º30' N would be a weak northerly signature influenced primarily by winds or a distinct westward flow if the NEC had shifted to the north. Chlorophyll-a and SST satellite telemetry, suggest that the “filament” was a piece of the productive water from the NEC that had been rotated and sheared by geostrophic current interaction further south and then spread up to the by tropic instability waves (TIWs). Consistent with the findings for the southerly North Pacific Equatorial Water stations, this “filament” has high fluorescence, a shallow thermocline, and increased gelatinous density (relative to the oligotrophic “control” site in the North Pacific Central Water mass). This supports the hypothesis that this water originated in the north Pacific equatorial region. The westward flow of the NEC which spans south of 10º50’ at the time of this study, may reveal an energetic benefit for leatherbacks on the westward leg of their trans-Pacific migrations (*Figures 15, 16, 17*). The retention of an elevated temperature, fluorescence, and planktonic density relative to the cool, oligotrophic latitudes it has been thrust into suggests the physics of a region plays a large role in shaping the biological boundaries between regions of the pelagic oceanic environment.

Relative densities for gelatinous plankton and zooplankton were high in the equatorial frontal waters (of which the “filament” is an extension) and low in the oligotrophic NPCW mass. Although the significance of these densities cannot be determined without further studies (due to a lack of replicates), this trend supports the hypothesis that there is an accumulation of organisms in the North Equatorial Front which may be attracting leatherbacks to feed in this area. There is no clear trend in species diversity in either gelatinous or zooplankton at this time, but the filament, which gave the highest Shannon-Weiner index value for gelatinous plankton gives (relatively speaking) the lowest values for zooplankton which, if studied further, may reveal top-down control by gelatinous organisms on zooplankton. (*Figures 13, 14*). If there was any indication of a current or temperature shift during the year this may influence the presence of plankton blooms. If an area has many species, it is more likely to have at least one of them presence in abundance at all times of the year than an area with fewer species. An area of high diversity may indicate a high level of disturbance as well. Therefore, one would expect higher Shannon-Weiner values for areas such as the "filament." This is observed for gelatinous plankton which has its highest value at 0.42 at the filament and its lowest (0.28) in the relatively less dynamic (in terms of currents) NPCW region. The moon cycle may also play a role, but since measurements were done under similar lighting conditions in order to remain consistent there is no way of analyzing this variable. Because there is no known preference of leatherback turtles for one species of gelatinous plankton over another there is no way to tell how the composition of gelatinous organisms at a given site influences the presence of leatherbacks (*Figure 12*). As large animals that appear to be gelatinous plankton generalists, abundance vs. diversity probably plays a higher role in whether or not the turtles will be found in a given region.

Conclusions

Findings strongly indicate that leatherback turtles tagged in Monterey, CA are opportunistically foraging in an area of higher gelatinous density, by migrating along the North Equatorial Front. Even though the more southernly waters of the North Pacific Equatorial Water mass have an even higher level of gelatinous plankton density, it is very likely that the elevated temperature of this region makes it an undesirable place for these gigantothermic turtles to forage. Therefore, the original hypothesis that leatherbacks are using the NEF to opportunistically feed is supported to the extent that they cannot travel any further south where foraging would be more "optimal" because the negative impact of higher ocean temperature on their cardio-vascular system would outweigh the slight increase gelatinous plankton abundance. This suggests that instead of optimizing for one variable— the presence of food, leatherbacks are balancing the need to consume large quantities of gelatinous plankton with their energetic demands which limit them to cooler waters. Because the "corridors" between productive waters, where gelatinous plankton have been shown to be more abundant, and oligotrophic zone are so accurately visualized via satellite in terms of SST and chlorophyll-a (as tested in our methods) this powerful tool may be used with increased confidence to establish areas of protection for the endangered Pacific Leatherback Sea turtle. Further research suggested includes continued sampling of the region to determine the significance of relative density differences and species compositions as well as to determine whether there is any direct linkage between gelatinous and zooplankton abundance. There is still a big gap in our understanding of the distribution of gelatinous organisms and zooplankton in the North Equatorial Pacific which we hope will also soon be resolved to a level of statistical significance through higher sample replication.

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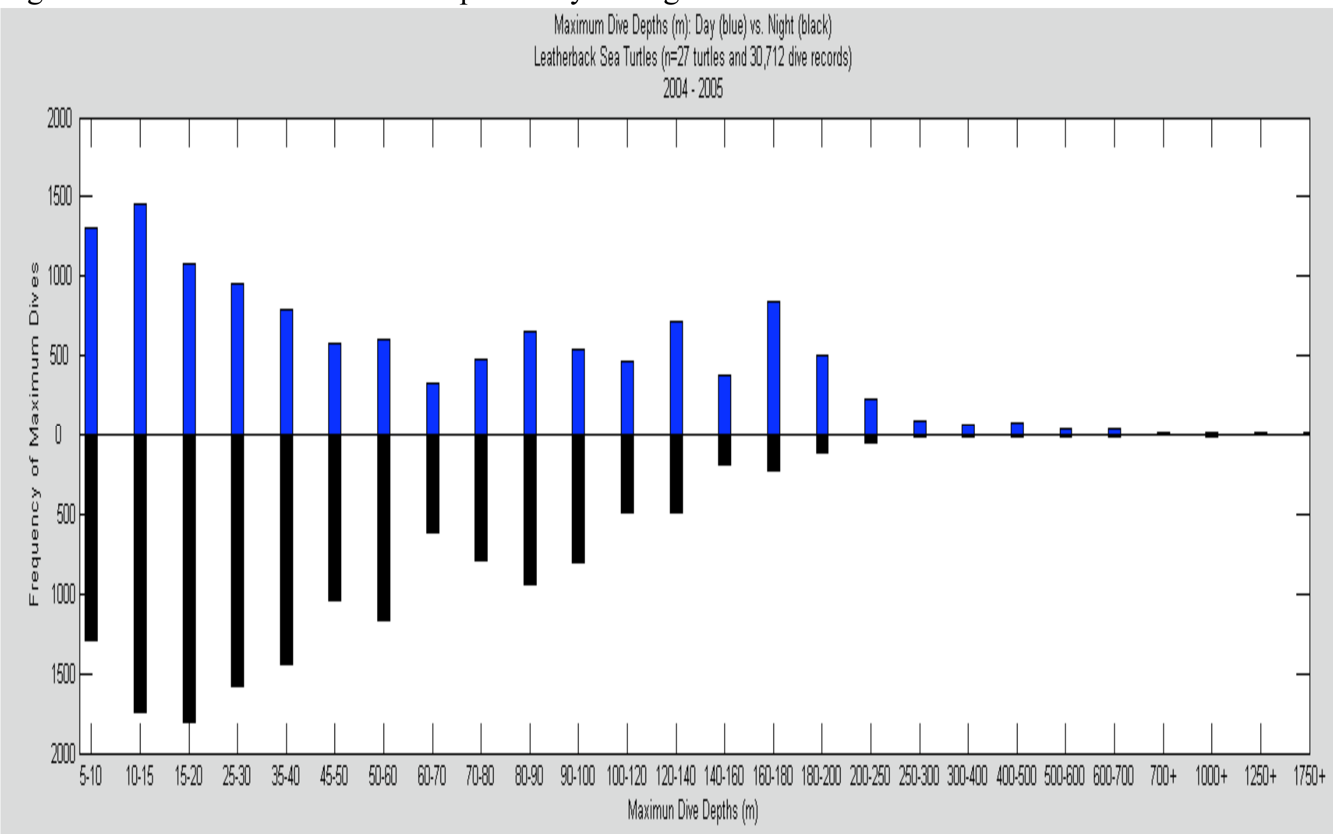
Figures and Tables

Figure 1: Leatherback turtle dive depths - day vs. night



Y-axis = frequency, X-axis= maximum dive depth (m). Day= blue, Night= black.

Figure 2: Chlorophyll-a Satellite Image

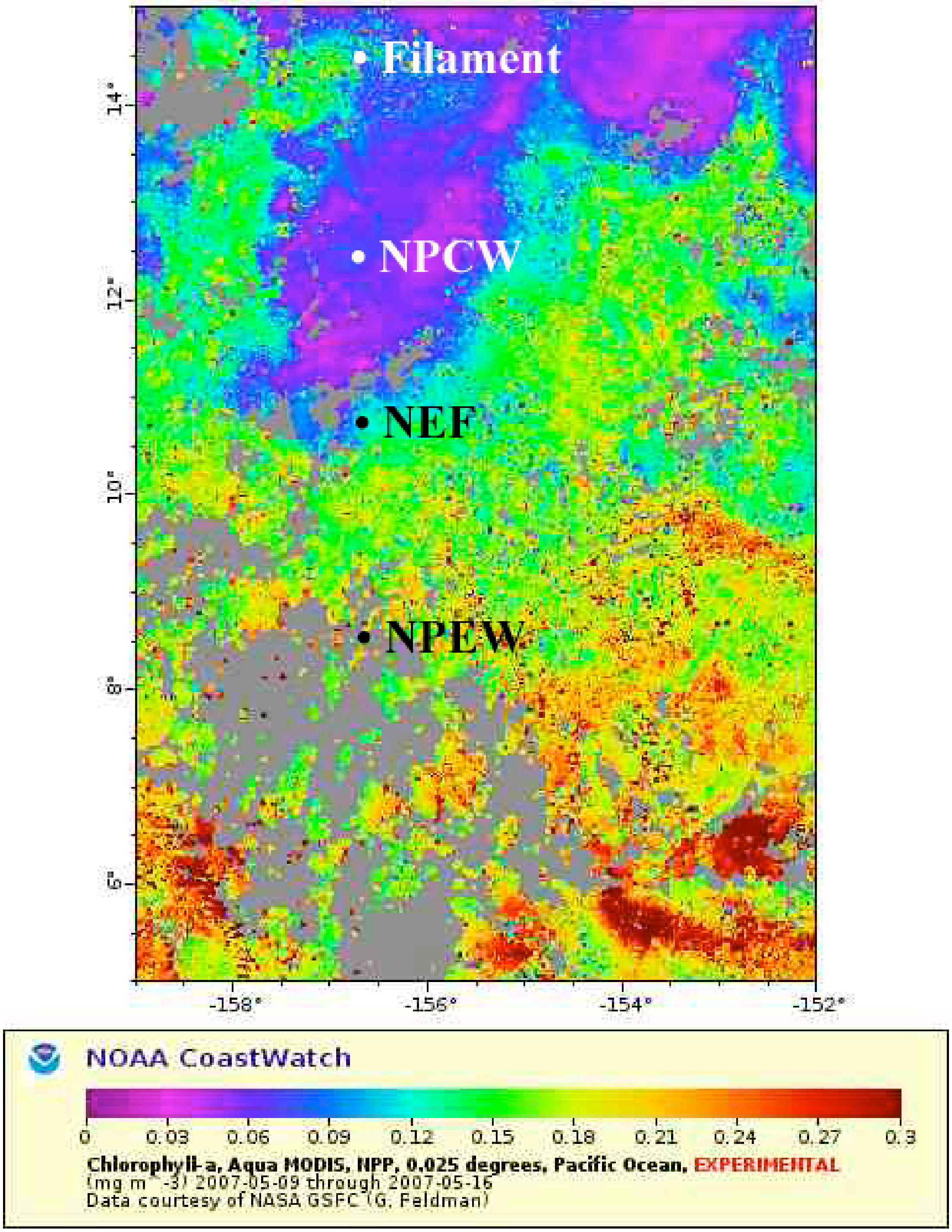
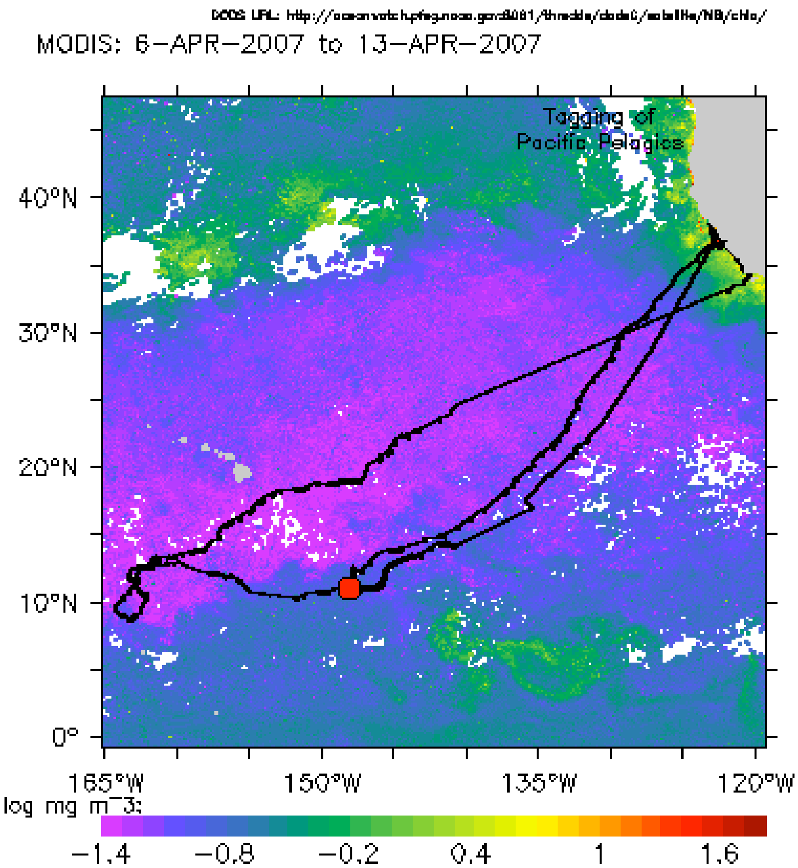
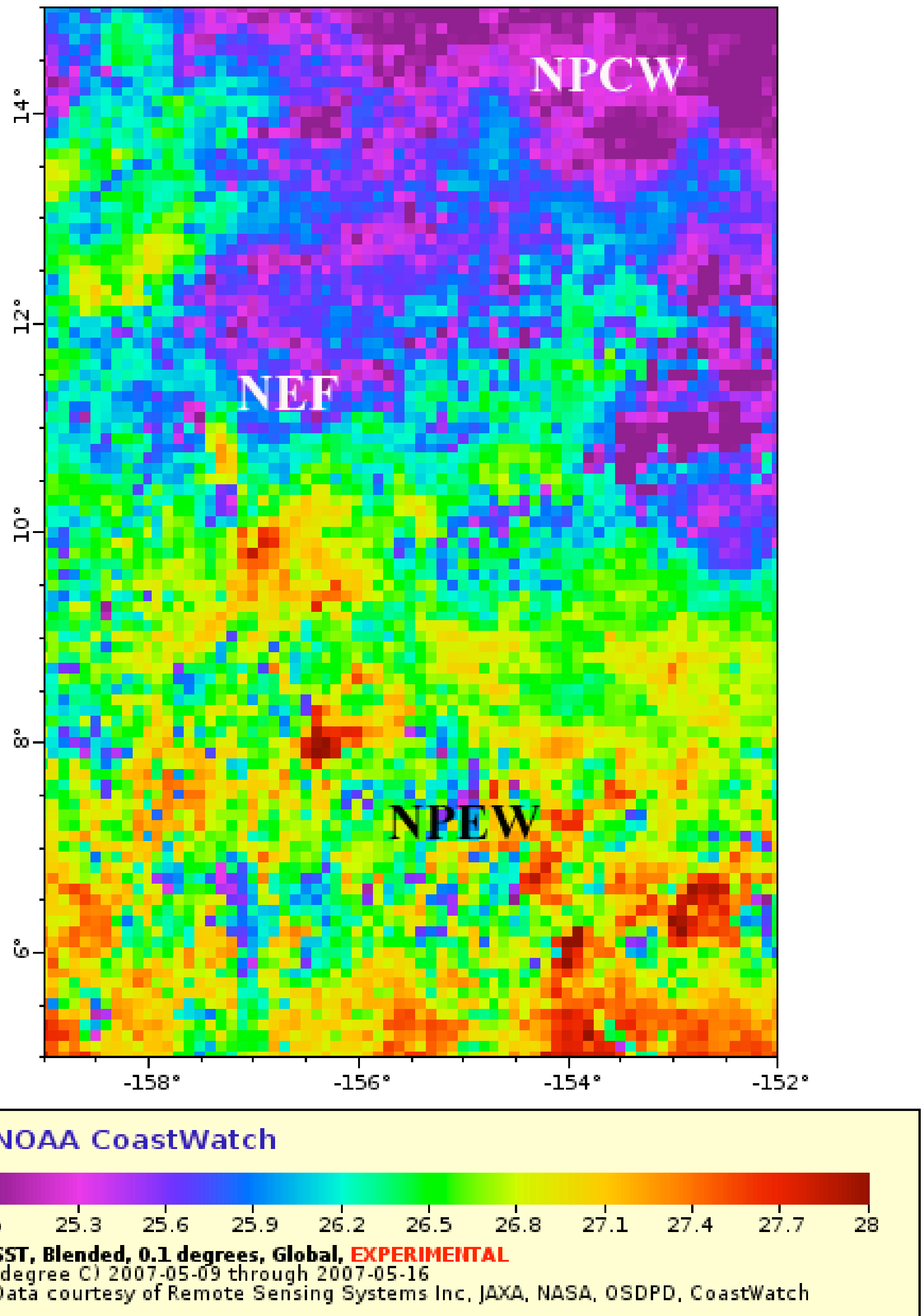


Figure 3: Two-year Argo track of male leatherback turtle overlaid on satellite chlorophyll-a image



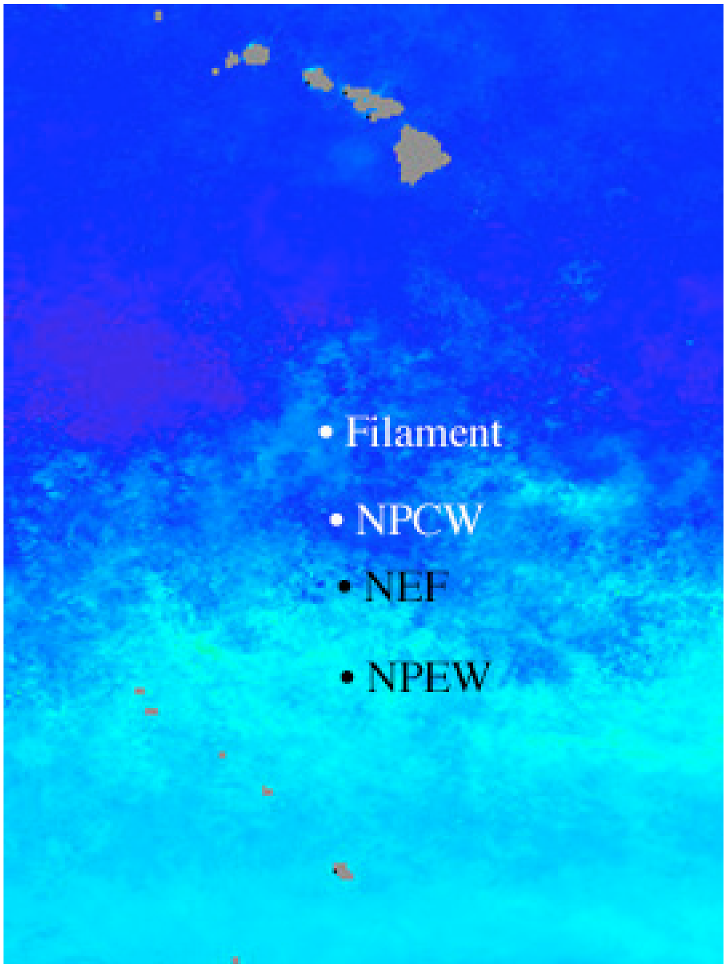
The boundary between the North Pacific Central Water (NPCW) and North Pacific Equatorial Water (NPEW) indicated by the purple region and blue area to the south respectively, is the North Equatorial Front (NEF). It is evident through this satellite composite that the leatherback turtle returns to this front on its trans-Pacific migrations.

Figure 4: Satellite Sea Surface Temperature (ºC)



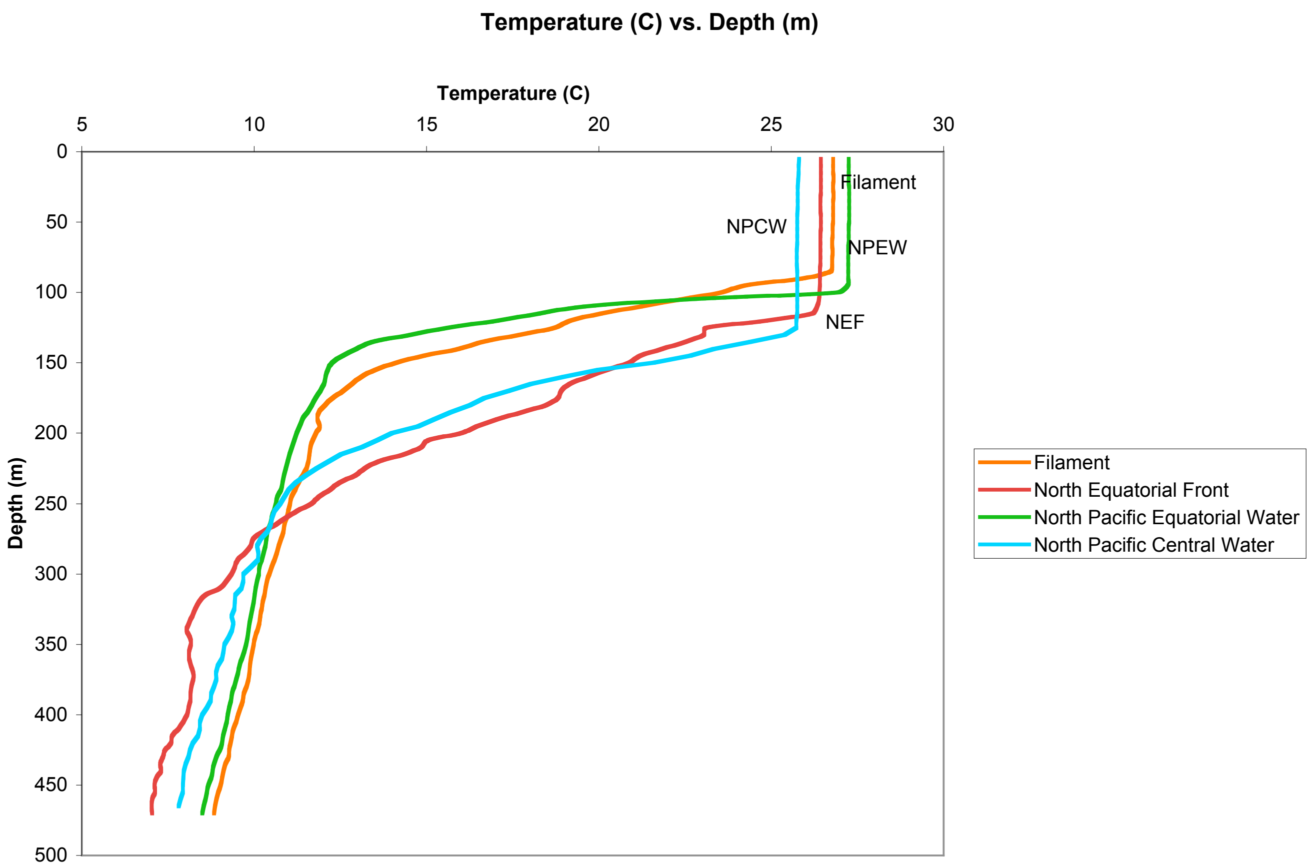
The contrast between the warm NPEW and NPCW (purple) masses can be seen clearly via SST imaging. The boundary between the two is the region of the North Equatorial Front (NEF).

Figure 5: Relative position of station locations



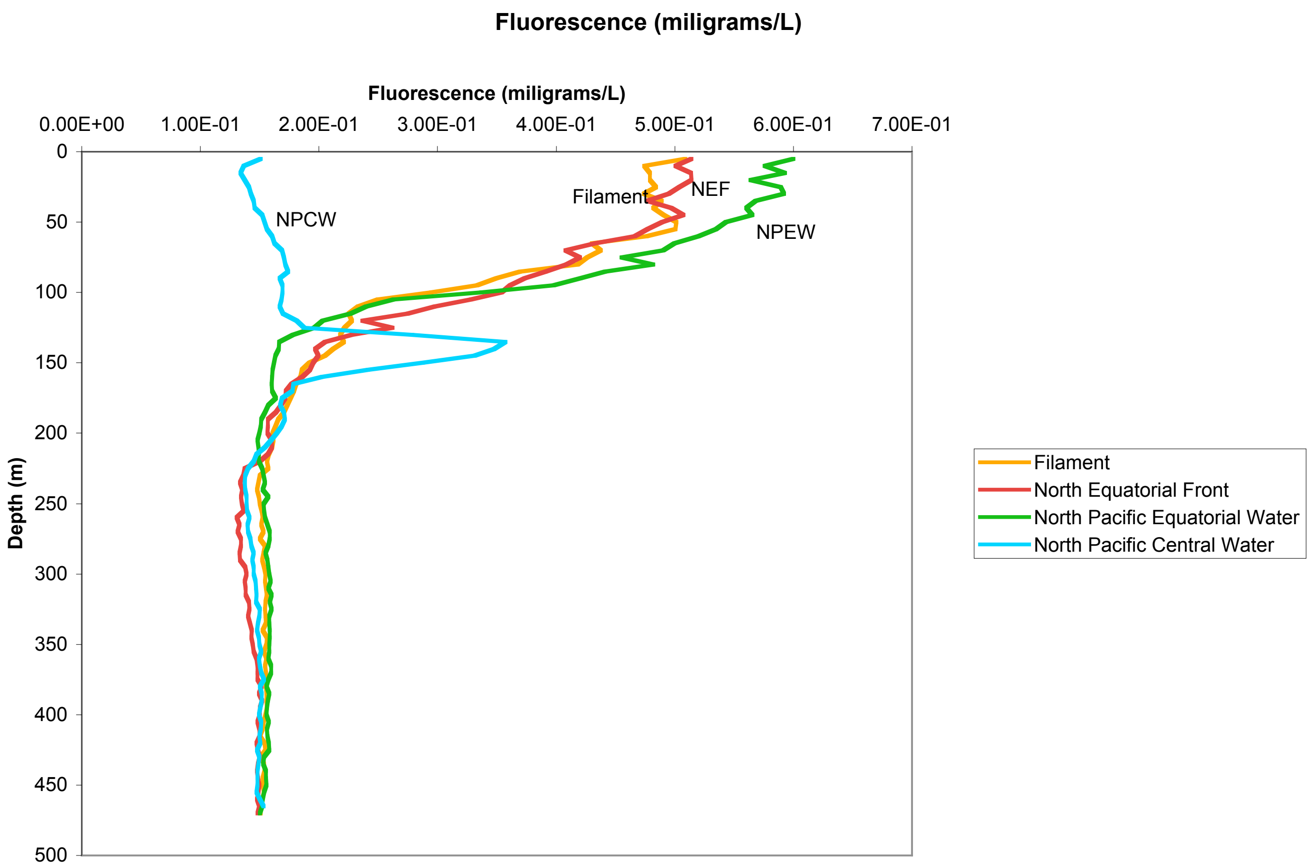
Filament: 14º30'N, NPCW (North Pacific Common Water): 12º19'N, NEF (North Equatorial Filament): 10º47'N, NPEW (North Pacific Equatorial Water): 8º18'.

Figure 6



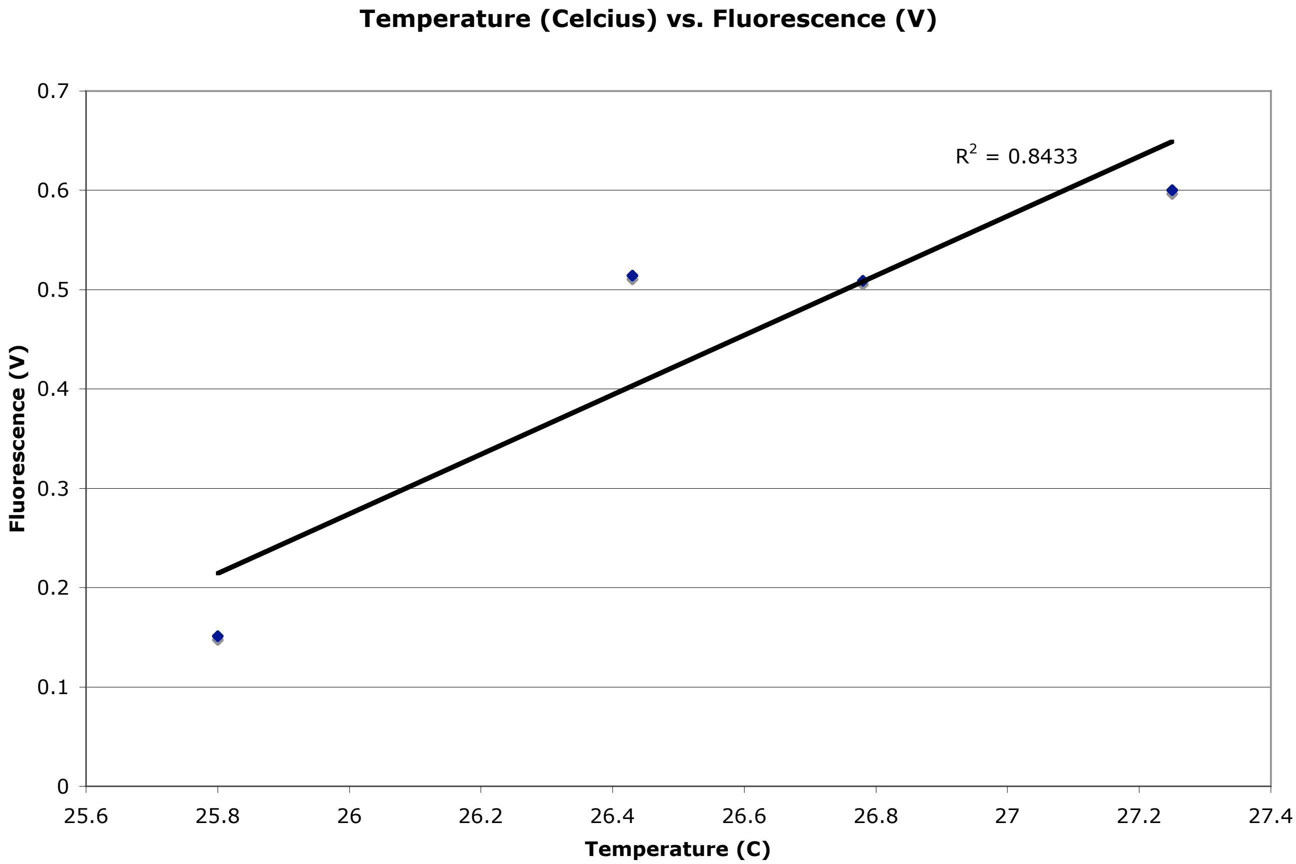
Upwelling is indicated in the filament and NPEW stations by a relatively shallow thermocline where cooler water is closer to the surface driving density-dependent mixing.

Figure 7



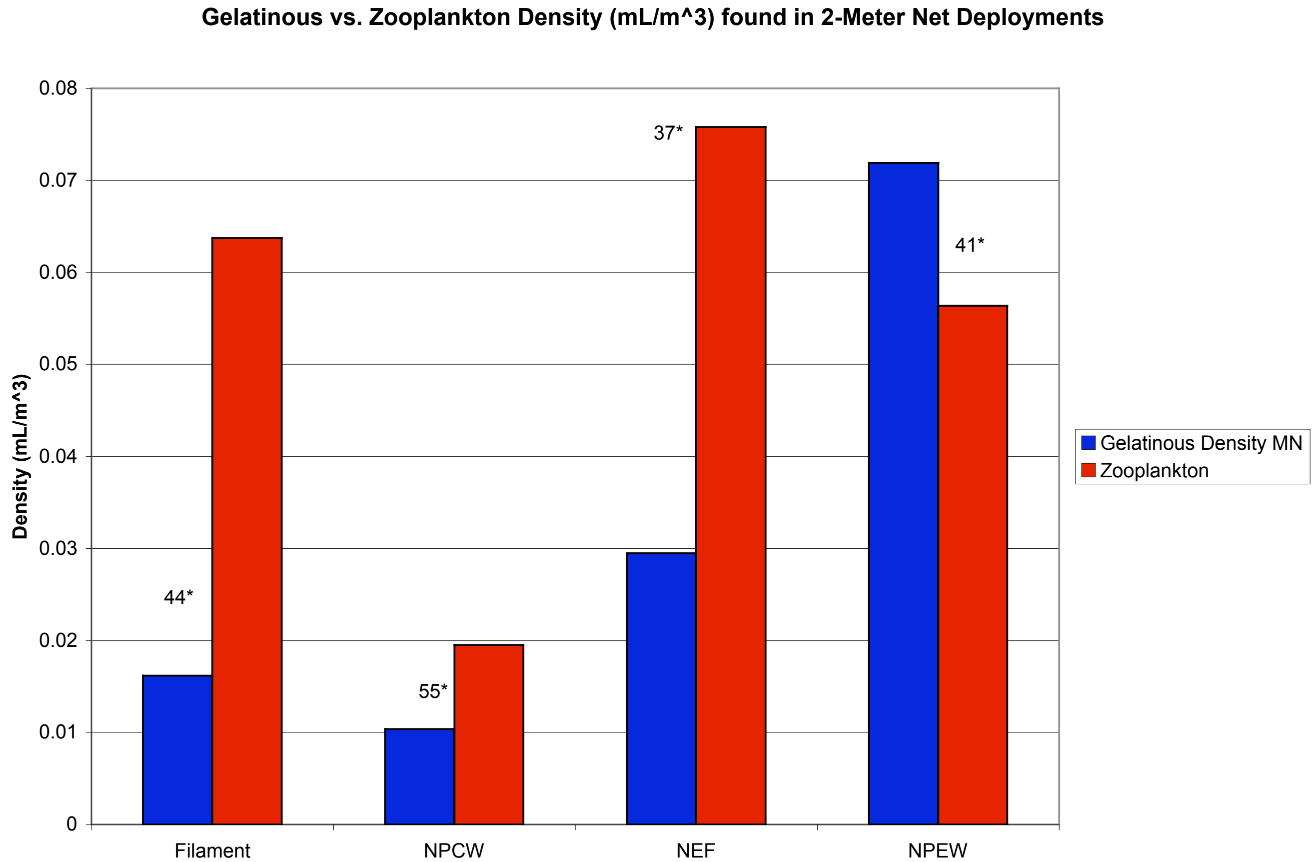
The NPCW station, with a low, deep chlorophyll maximum, has a fluorescence signature characteristic of oligotrophic water whereas the stations located in the frontal region show the high surface fluorescence associated with highly productive waters.

Figure 8



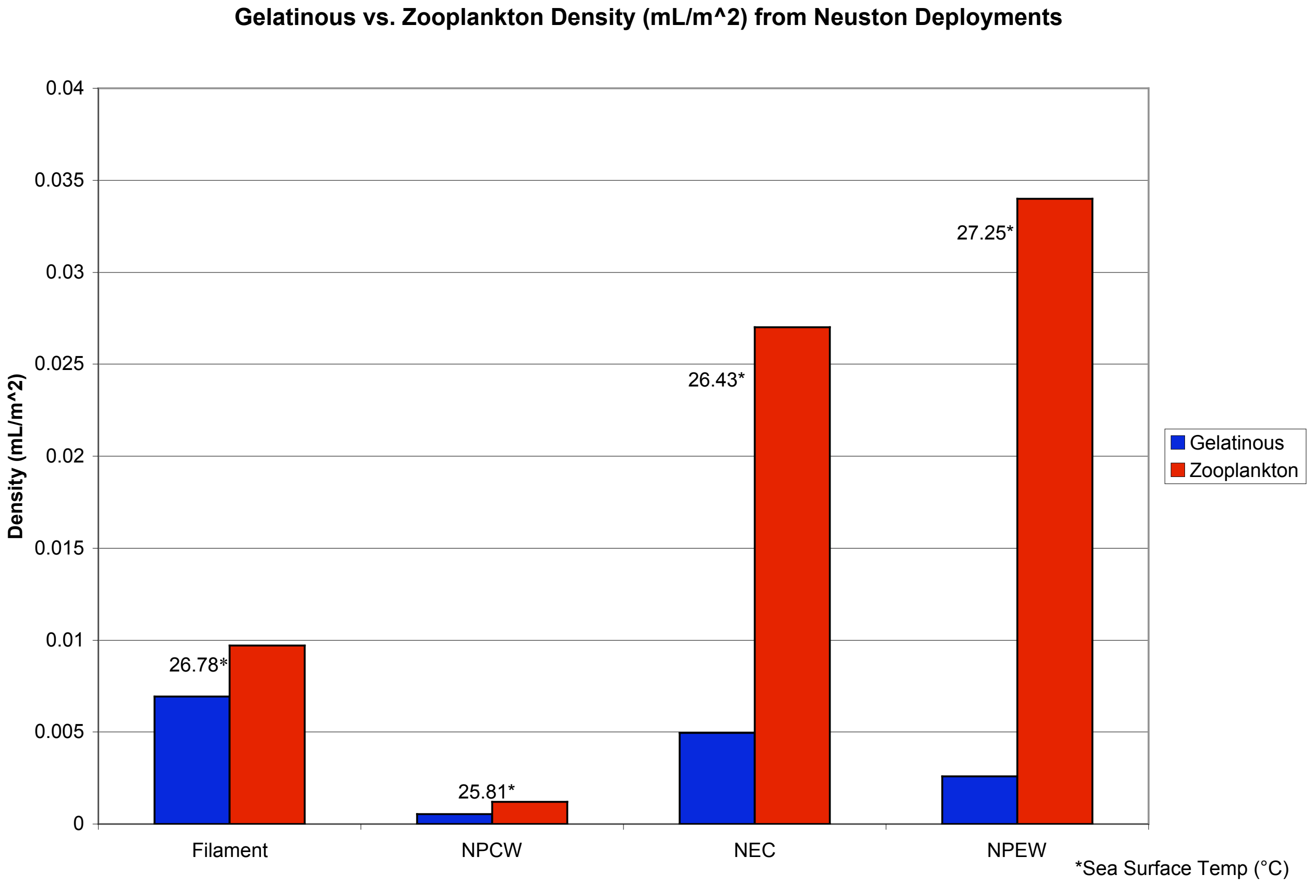
Temperature and Fluorescence appear to be correlated along the four sample sites.

Figure 9



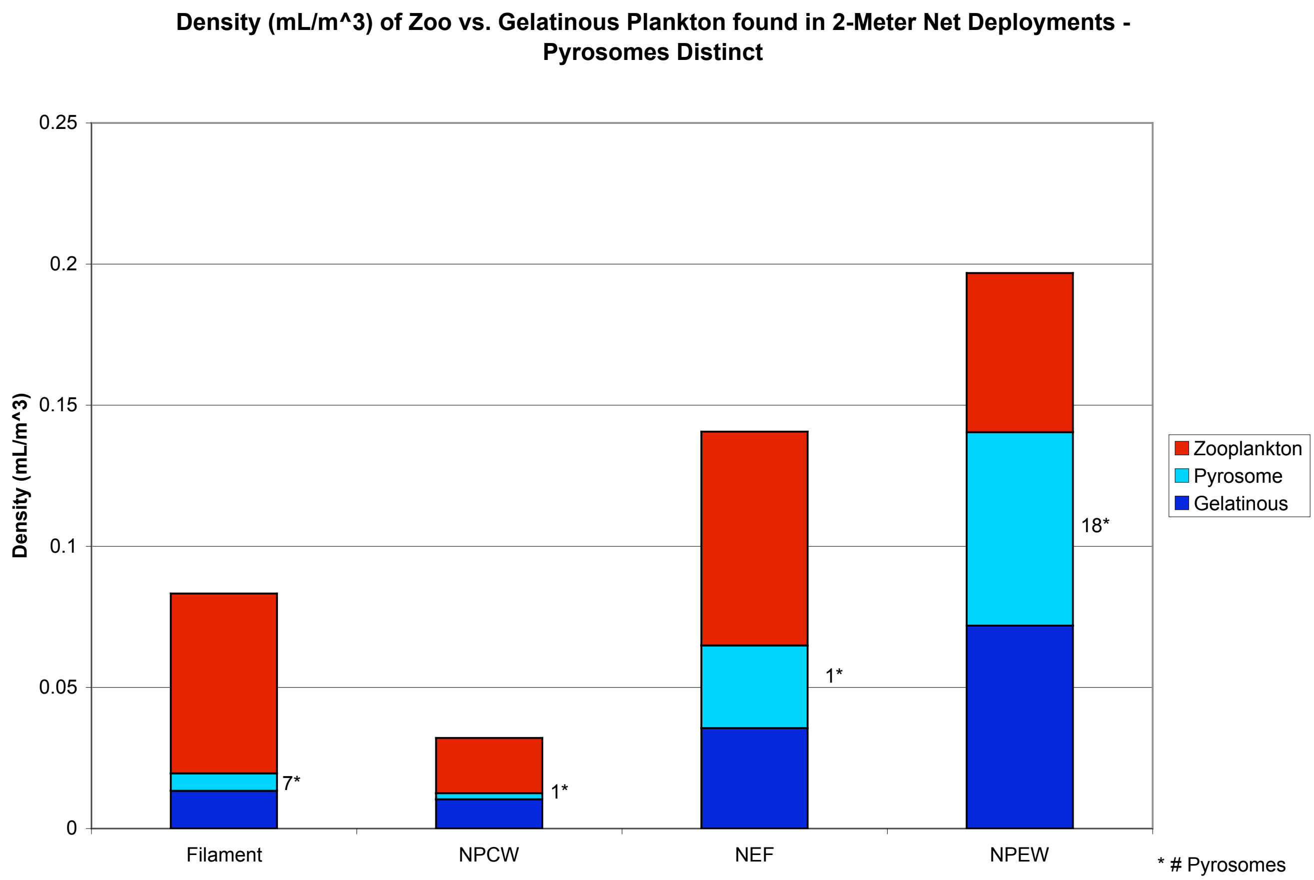
There is higher zooplankton and gelatinous density in waters of equatorial origin (those that spread from the North Pacific Equatorial Water mass).

Figure 10



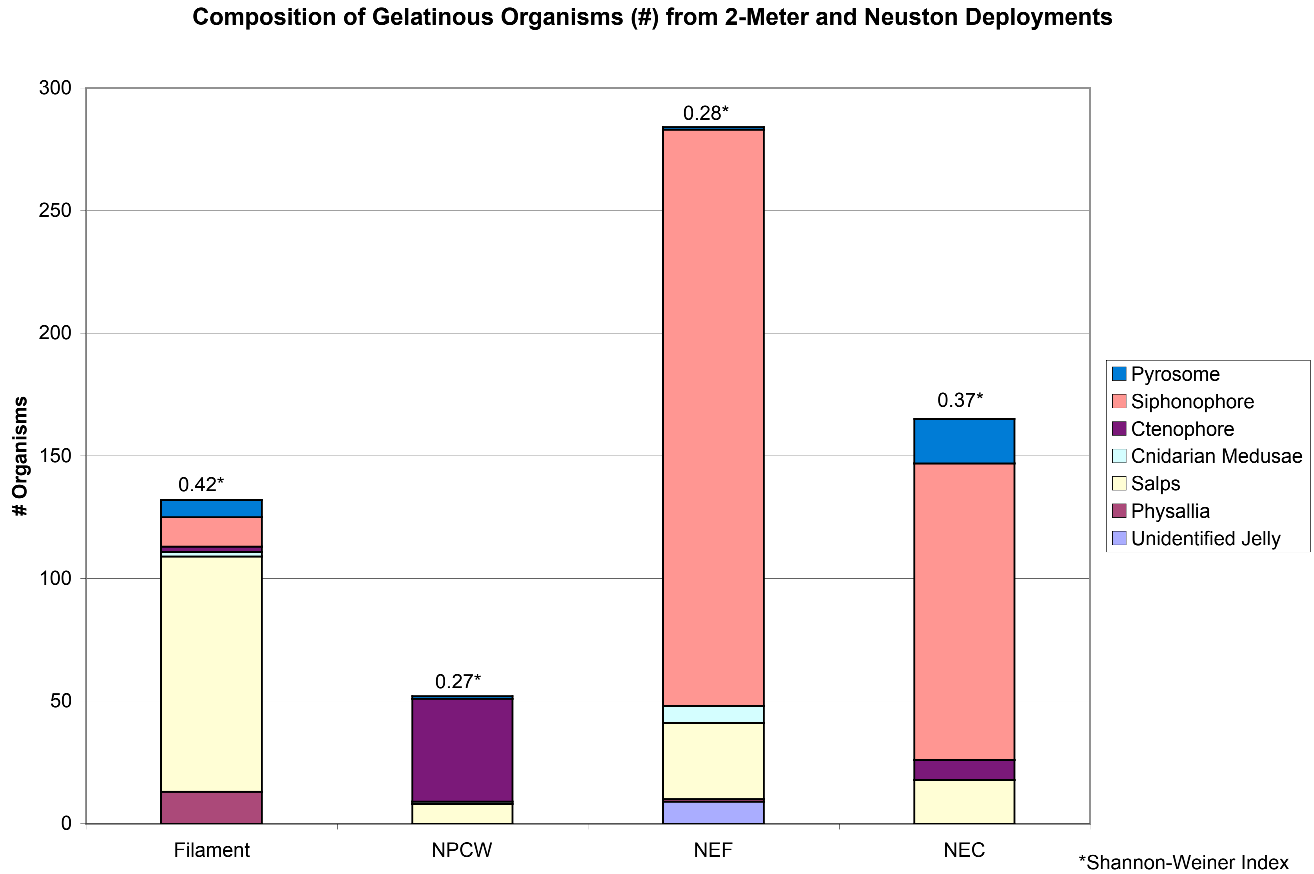
Density is higher for the frontal regions than for the station located in the North Pacific Central Water mass.

Figure 11



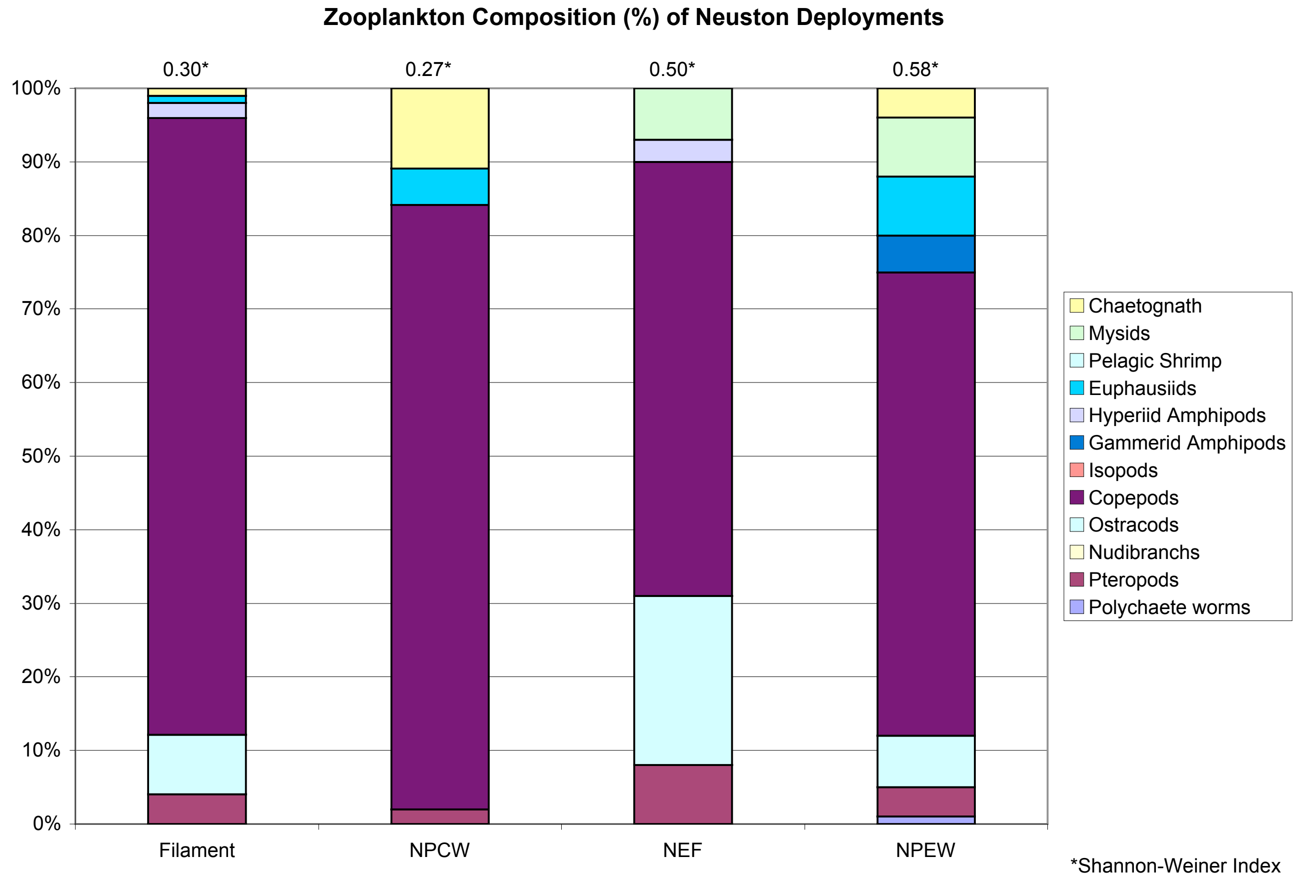
Pyrosomes accounts for nearly half of the gelatinous density at the NPEW station. Pyrosomes have a large size range as indicated by the difference in density between the 7 individuals found at the Filament and single individual found at the NEF site.

Figure 12



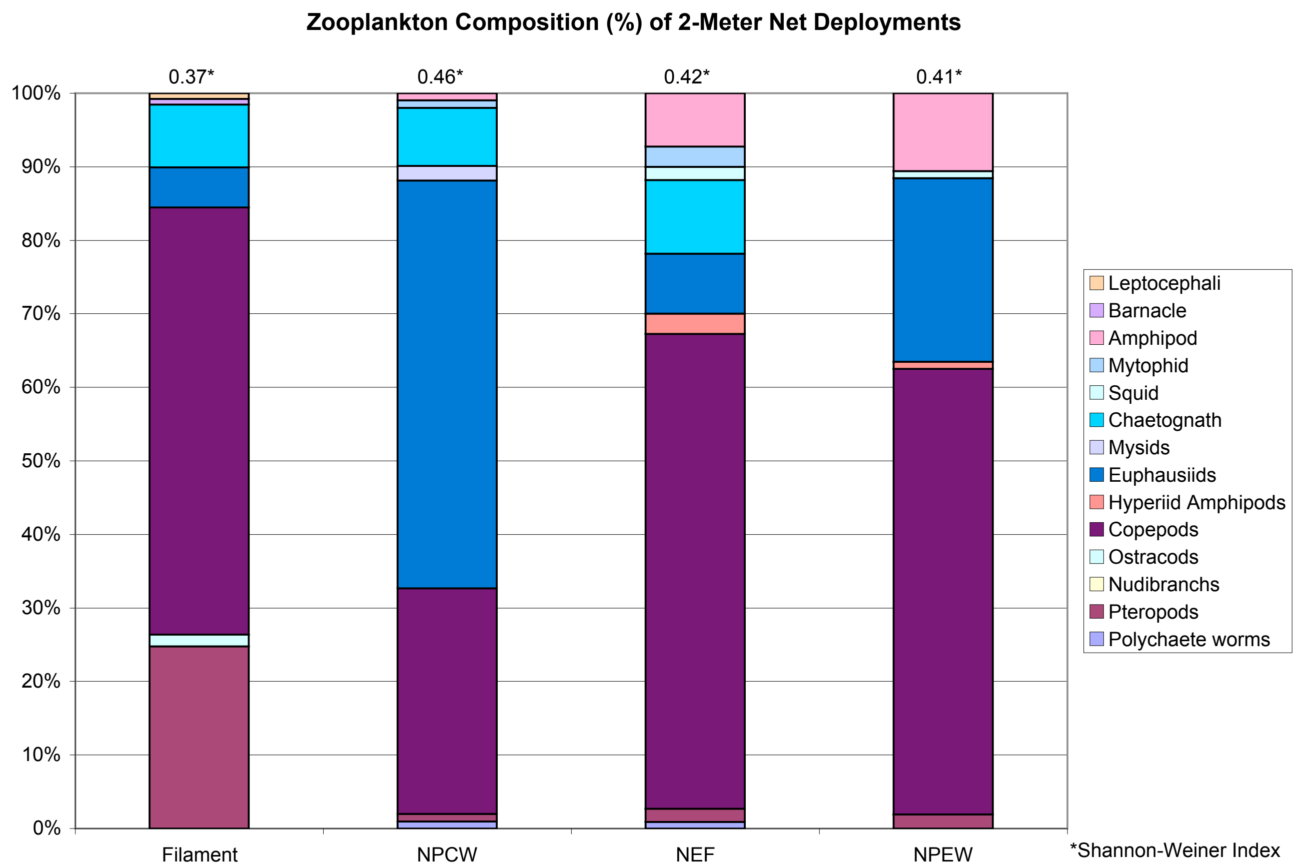
The greatest number of organisms was found at the NEF station, but the highest diversity was recorded at the filament.

Figure 13



Copepods dominated neuston deployments at every station. The highest diversity was found at the station closest to the equator (8º19'N).

Figure 14



Copepods dominated the nets in the region of the front whereas euphausids were more prevalent in the NPCW.

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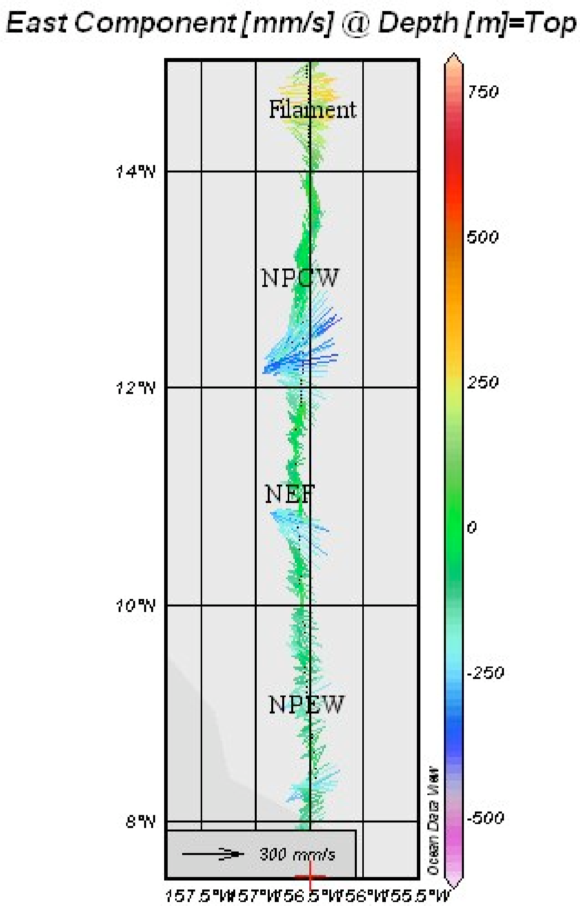
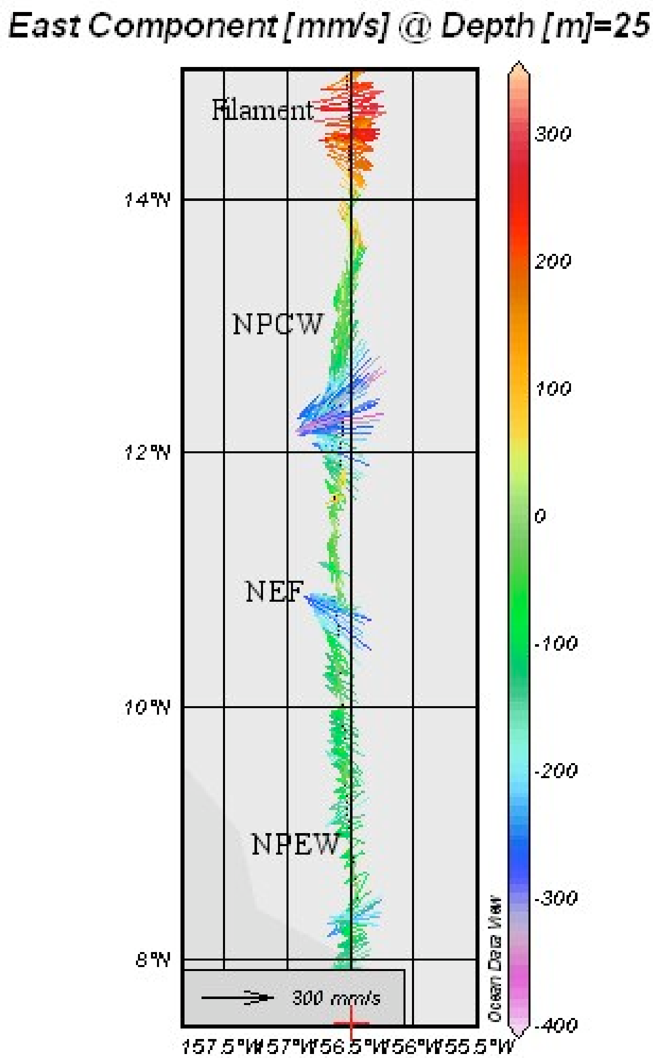
Figure 15



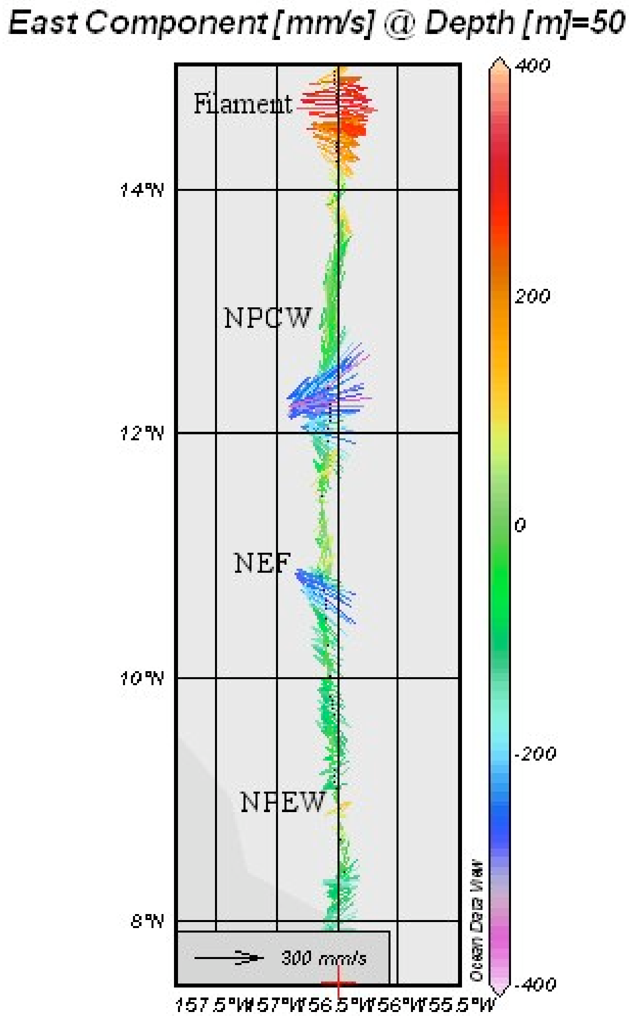
Yellow-Red indicates eastward flow, at the filament a piece of the North Equatorial Current has been sheared of, sending it rotating in the opposite direction of its "parent." Green indicates northward flow. Blue indicates the westward flow of the NEC.

Figure 16



At 25 m, there is an increase in current velocity from that measured at the surface (figure 15).

Figure 17



Between 25 and 50m, current velocity and direction are very similar (see figure 16 for comparison with 25m depth).

Figure 18a

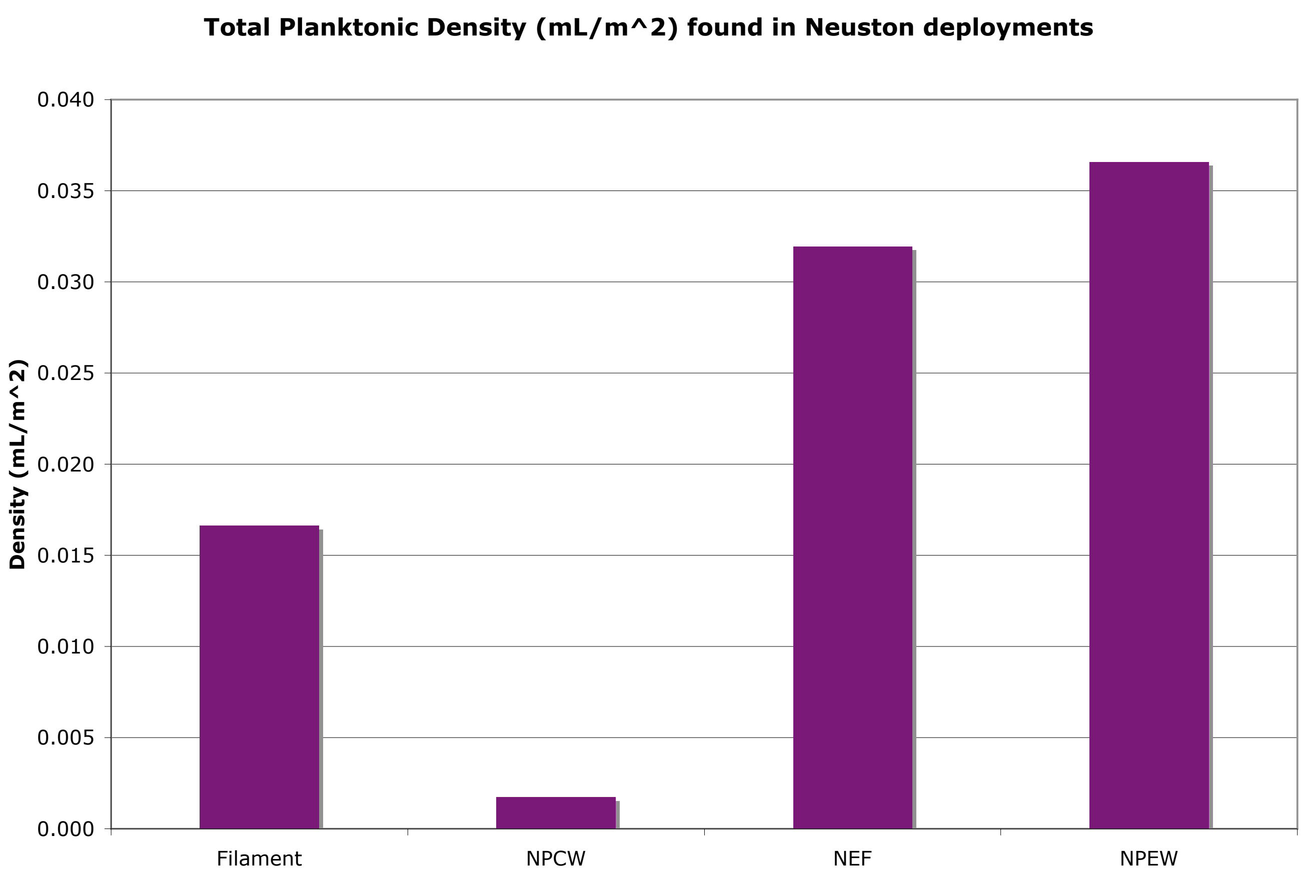

Total Planktonic Density (mL/m^2) found in Neuston deployments
Density (mL/m^2)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Filament
NPCW
NEF
NPEW

Figure 18b

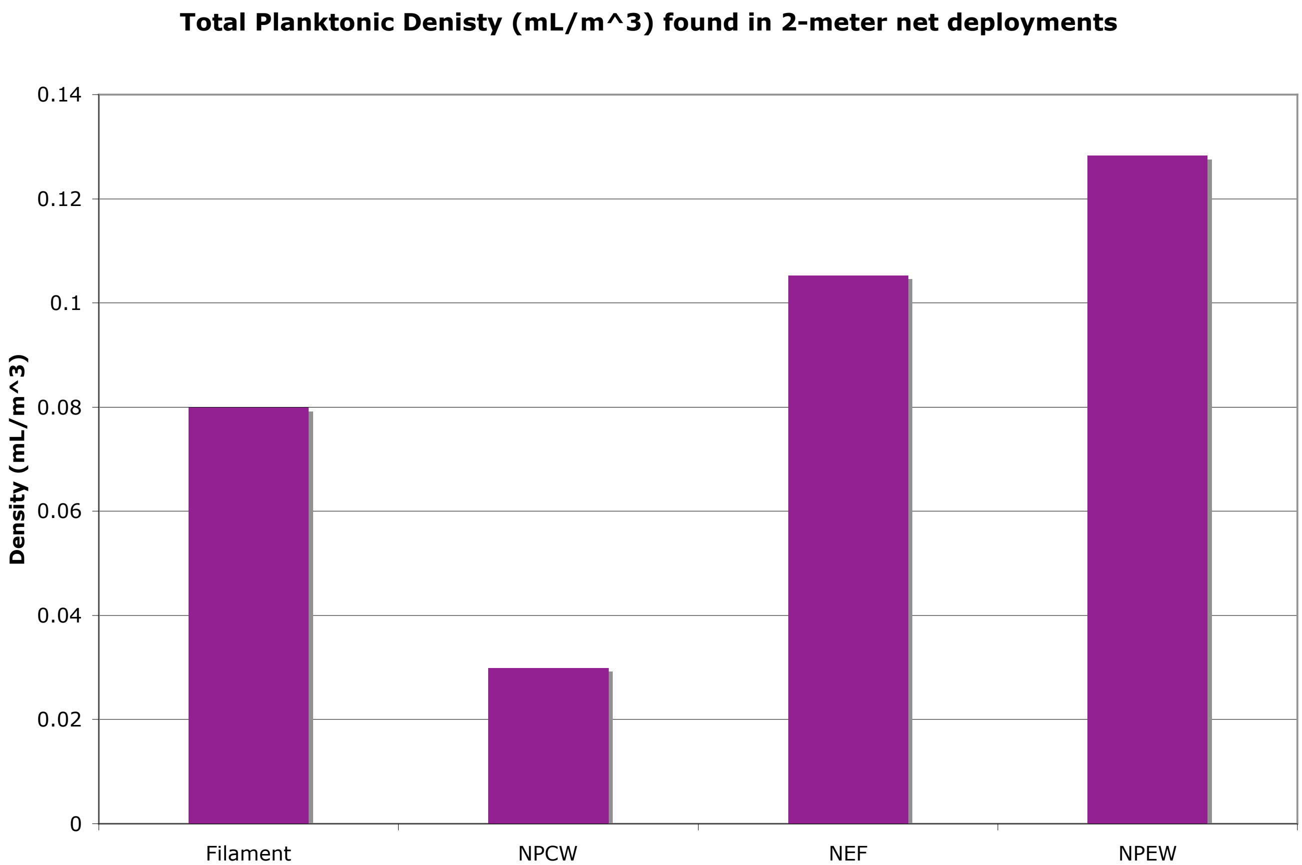


Table I: Location, Time, Moon Phase, Depth, and Length of Deployments

Station	LAT (ºN)	LON (ºW)	Time	Moon Phase	Hydrocast Depth (m)	2-Meter Depth (m)	2-Meter Tow Length (m)	Neuston Tow Length (m)
Filament	14º30.4’	156º30.’	2215	3%	488	44	1792	1852
NPCW	12º19.1’	156º32.9’	0420	1%	423	55	2162	2162
NEF	10º47.7’	156º35.3’	2312	3%	470	37	1532	1819
NPEW	8º18.5’	156º28.3’	2310	4%	480	41	2220	1160
Average			0014	2.75	465.25	44.25	1926.5	1748.25

Table 2: Sea Surface Temperature

Station	Lat./Long.	SST (ºC)	ΔT (ºC)*
Filament	14º30.4'N x 156º30.5' W	26.78	—
NPCW	12º19.1'N x 156º32.9'W	**25.8**	- 0.98
NEF	10˚46.7' N x 156˚35.5' W	26.43	+ 0.77
NPEW	8º18.5' N x 156º28.3' W	**27.25**	+ 0.82

**Change in temperature between successive stations in degrees Celcius (progressing from North to South).*

Table 3: Fluorescence (V)

Station	Lat./Long	Fluorescence (V)	Δ (V)
Filament	14º30.4'N x 156º30.5' W	0.509	+
NPCW	12º19.1'N x 156º32.9'W	**0.151**	- 0.358
NEF	10˚46.7' N x 156˚35.5' W	0.514	+ 0.363
NPEW	8º18.5' N x 156º28.3' W	**0.600**	+ 0.086

**Fluorescence was measured in situ attached to a CTD/HC carousel.*

Table 4: Currents (mm/s of Eastward Component)

Station	Depth (m)	East Component (mm/s)
Filament	0	189
	25	198
	50	204
NPCW	0	-59
	25	-18.4
	50	-36.5
NEF	0	-175
	25	-163
	50	-110
NPEW	0	-104
	25	-71
	50	-57.95

**Positive current values indicate an Eastward flow, negative numbers indicate Westward flow. Low values indicate northerly flow.*

Table 5: Gelatinous Density

Station	2-Meter Net (mL/m^3)	Neuston (mL/m^2)
Filament	0.016174178	**0.00693802**
NPCW	**0.010396009**	**0.000539957**
NEF	0.029460808	0.004948318
NPEW	**0.071877062**	0.002585672

**Red indicates relative highest density for the specified net, blue— the lowest.*

Table 6: Zooplankton Density

Station	2-Meter Net (mL/m3)	Neuston (mL/m^2)
Filament	0.06370	0.010
NPCW	0.01950	0.001
NEF	**0.07580**	0.027
NPEW	0.05640	**0.034**

**Bolded number indicates the relative highest density for that type of net deployment.*

Table 7: Composition of Gelatinous Organisms at each Station (Neuston and 2-Meter Net)

	Filament	NPCW	NEF	NPEW
Unidentified Jelly	0	0	9	0
Physallia	13	0	1	0
Salps	**96**	8	31	18
Cnidarian Medusa	2	1	7	0
Ctenophore	2	**42**	0	8
Siphonophore	12	0	**235**	**121**
Pyrosome	7	1	1	18
Total	132	52	**284**	**165**
Shannon-Weiner	*0.42*	*0.27*	*0.28*	*0.37*

**Bolded numbers indicate the species that contains the highest number of individuals at each station.*