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EXECUTIVE SUMMARY

Eutrophication, defined as the excessive accumulation of organic matter, occurs in estuarine systems worldwide, including those in southern California, in response to increased nutrient loading from developed watersheds. Macroalgal blooms can decrease the habitat quality of estuaries by depleting the water column and sediments of oxygen, leading to changes in species composition and community structure. The relationship between nutrient input from watersheds, water column nutrient availability, sediment nutrient fluxes and primary productivity have been studied in Atlantic and Gulf coast systems, but few data are available for Pacific coast estuaries.

The objective of this study was to investigate the relationships between nutrient (nitrogen [N] and phosphorus [P]) concentration in the water and the sediments, and macroalgal biomass in 5 southern California estuaries. Estuaries spanned a latitudinal gradient from San Diego to Santa Barbara and varied in area, watershed size and dominant land use practices, freshwater influence, and tidal flushing. We hypothesized that if the watersheds were the primary nutrient source to an estuary then water column, sediment, and algal tissue nutrient concentrations would be greater at the head of the estuary compared to the mouth, or seaward end. Additionally, we hypothesized that algal abundance would be greater near the primary riverine inflow and that there would be significant wet vs. dry season differences in all measurements.

We established three sampling sites in each of the following estuaries: Carpinteria Salt Marsh Reserve (CSMR), Mugu Lagoon-West[1] (Mugu West), Mugu Lagoon-Calleguas Creek (Mugu CC), Upper Newport Bay (UNB), Los Penasquitos Lagoon (LPL) and Tijuana River Estuary (TJ). Sites were located at the head where the major river enters, at the mouth or lower reach of the system, and mid-way between. Quarterly sampling was conducted over a 15-month period beginning in December 2001. At each site, water column salinity, temperature, dissolved oxygen (DO), NO_3, NH_4, total Kjeldahl N (TKN), soluble reactive P (SRP), and total P were measured. We also measured the percent cover and biomass of macroalgal species as well as algal tissue N and P concentration, and sediment reduction-oxidation potential (redox), organic content, nutrient concentration, and grain size.

NO_3 was often the dominant form of N in our systems. In CSMR, NO_3 was about 1000 μM in February 2002 and in Mugu CC, concentrations were >2000 μM several times during our study. Higher concentrations were often associated with precipitation but in Mugu CC, they may have been associated with seasonal agricultural practices. Concentrations were often highest at the head, and salinity/dilution curves revealed non-conservative decreases in NO_3 with increasing salinity, indicating uptake of NO_3 within the estuary. Exceptions to these patterns were LPL and TJ where NO_3 was often very low.

NH_4 and TKN concentrations were generally low compared to NO_3. As TKN was often comprised mostly of NH_4, its patterns were frequently similar to those of NH_4. TJ was different from all other systems with respect to NH_4 and TKN; concentrations were very high in December 2001 and February 2003, reaching over 500 μM in some cases.

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[1] Mugu Lagoon was divided into two study areas based on its physical layout and separate watershed contributions to each arm.

Salinity/dilution curves in several systems indicated regeneration of NH_4 within the system.

Seasonal patterns varied among and within estuaries with highest SRP concentrations occurring in both wet and dry months at different sites. SRP concentrations generally ranged from 2-6 μM with the exception of the head of Mugu CC, which ranged from 15-30 μM over several months, and the head of TJ, where SRP was >75 μM in February 2003. Total P was often comprised mostly of SRP.

The macroalga *Enteromorpha* was found in all of our systems and *Ulva* was found in four study areas. Macroalgal abundance ranged from low in Mugu CC (<300 g wet wt m^{-2}), where there is little intertidal mudflat suitable for macroalgal growth, to high at the head of UNB (2012 ± 438 g wet wt m^{-2}) and the mouth of Mugu West (2995 ± 873 g wet wt m^{-2}). Despite the occurrences of high macroalgal biomass, no hypoxia (i.e. DO concentration <3 mg/l) was detected at any of our study sites, which may have been due to daily tidal flushing of the intertidal areas we sampled. In almost all systems, macroalgae were present in at least one site during all sampling events, but the period of greatest abundance varied from site to site. There were no consistent spatial patterns of macroalgal distribution, as macroalgae are generally highly mobile and drift around the estuary with the tides. Macroalgal tissue N content was often >2.0% of the dry weight of the algae and tissue P was often >0.20% of the dry weight. These values indicate that nutrients were available in excess of the algae's demand for them such that the algae were able to store nutrients.

In general sediments were reduced and appeared to be seasonal nutrient sinks and sources. Spatial trends in sediment N concentrations that paralleled water column NO_3 availability suggested that NO_3 may have diffused into sediment porewaters. Additionally, increases in total P in wet months probably reflect particulate P loading from storm runoff. Estuary mouths were usually sandier than other portions of the estuary, typically being comprised of >50% sand. As expected, increased sediment nutrients were associated with finer grain sizes and higher organic content at the heads of estuaries. Sediments had higher concentrations of P than other reported literature values and may have been an important P reservoir. N and P may have fluxed from the sediments to the water column, particularly when sediments were reduced.

Spatial and temporal patterns in water column nutrients, salinity and sediment characteristics suggest that the watersheds of individual estuaries were important nutrient sources. Additionally, the proximity of certain land use practices to the estuary may have significant impacts on estuarine water quality. The highest water column NO_3 concentrations were found at the heads of CSMR and Mugu CC, each of which has intensive agriculture just above the estuary. High NH_4 concentrations in TJ may have originated from the urbanized areas adjacent to the estuary. Lastly, higher concentrations of NO_3 in wet months indicate that the nutrient contribution from the watersheds varied seasonally, a pattern similar to that found in other estuaries in Mediterranean climates.

In this study, patterns or macroalgal abundance were largely determined by the combination nutrient availability and the physical characteristics of each estuary. Macroalgae proliferated in areas with suitable habitat, such as broad mudflats and high light availability, like Mugu W and UNB. However, there were no spatial or temporal relationships with water column nutrients, perhaps because large accumulations of algae readily sequester available nutrients. Macroalgal abundance was related spatially to water column and sediment nutrient availability only in CSMR and TJ. Low macroalgal abundance occurred in Mugu CC, which had the highest water column NO_3 but little suitable habitat, and in LPL, which had very low nutrient availability.

In conclusion, even within the relatively small geographic region of southern California, patterns in nutrients and macroalgal abundance varied a great deal. However, there is fairly compelling evidence that watersheds were a key source of nutrients and wet season-associated nutrient inputs from the watershed were stored in the sediments, where they may function as a nutrient source throughout the year. Macroalgae occurred in each estuary but the timing of blooms varied among our systems. Inconsistent relationships between nutrient availability and macroalgal abundance mean that macroalgal blooms cannot be predicted by water column nutrient availability alone. Thus, successful management of these systems may require that the unique conditions within each estuary be considered on a case-by-case basis.

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INTRODUCTION

Eutrophication of coastal aquatic systems, the accumulation of excessive organic matter usually in response to increased nutrient availability, is a major problem in many parts of the world (Nixon 1995). One consequence of increased nutrient availability in shallow estuaries is macroalgal blooms (Peckol and Rivers 1995, Sfriso *et al*. 1987, Taylor *et al*. 1995, Valiela *et al*. 1992). Although macroalgae are a natural component of these systems, their proliferation due to nutrient enrichment reduces habitat quality. Respiration may reduce dissolved O_2 content of estuarine waters at night (e.g., Peckol and Rivers 1995), while decomposition may cause a large microbial O_2 demand both day and night (Sfriso *et al*. 1987). Low dissolved oxygen (DO) has direct negative impacts on fish and can lead to mortality (Coon 1998). Extended periods of low oxygen can lead to changes in overall species composition, shifts in community structure, and loss of biodiversity (Raffaelli *et al*. 1991, Edgar *et al*. 2000, Bostrom *et al*. 2002). Macroalgal blooms also impair beneficial recreational uses such as boating, swimming and fishing.

Many studies have found that the watershed is an important source of nutrients to estuarine waters that may fuel macroalgal blooms. Variability in nutrient supply has been related to precipitation and runoff from the watershed (Cambridge and McComb 1984, Staver *et al*. 1996). Thus, extensive modification of watersheds has often resulted in excessive inputs of nitrogen (N) and phosphorus (P) to coastal systems (Valiela *et al*. 1992, Nixon 1995, Paerl 1997). Studies in many parts of the world have documented the link between anthropogenic nutrient loads (Raffaelli *et al*. 1989, Peckol *et al*. 1994, Marcomini *et al*. 1995, Hernandez *et al*. 1997), increased water column nutrient availability (Delgado and Lapointe 1994, Fong *et al*. 1993 a, b), and macroalgal blooms.

The importance of estuarine sediments as both a source and sink of nutrients to the water is critical in understanding nutrient dynamics in estuaries (Valiela *et al*. 1997). Estuarine sediments may be particularly important in systems where nutrient inputs are episodic and availability of nutrients in the water column fluctuates greatly over time (Litaker *et al*. 1987, Day *et al*. 1995). Nutrients may be stored in sediments during times of high supply; some evidence exists that sediments act as a nutrient storage pool supporting macroalgal blooms as macroalgal tissue nutrients and biomass are elevated in the presence of nutrient-rich sediments (Lavery and McComb 1991, K. Kamer unpub data). When water column nutrients are low, stored nutrients flux out of sediments. Flux of nutrients from sediments is affected by mineralization associated with high organic matter (Hopkinson *et al*. 1999, Dong *et al*. 2000), low redox potential (Koch *et al*. 1992), salinity (Hopkinson *et al*. 1999), and the composition of sediment grain sizes. Therefore, nutrient flux from the sediments may also contribute to the proliferation of macroalgae.

The link between the watershed, water column enrichment, sediment fluxes and resultant algal blooms in estuaries and coastal systems along the Atlantic and Gulf coasts of the US have been investigated. However, there is a general lack of data for Pacific coast estuaries (Bricker *et al*. 1999) and studies of estuarine nutrient dynamics in southern California in particular (Williams and Zedler 1992). Though preliminary, the few studies that measured some aspects of nutrient dynamics in southern California estuaries (Page *et al*. 1995, Fong 1986, Rudnicki 1986, Fong and Zedler 2000, Kamer *et al*. 2001, Boyle 2002) all conclude that southern California estuaries are eutrophic systems.

Because of unique geomorphology and extensive development in southern California watersheds, it is especially important to study eutrophication in these estuaries (Williams and Zedler 1992). Typically estuaries in southern California are relatively small (93 to 720 ha.) with small watersheds due to proximity of the coastal mountains (Zedler 1996). In addition, agricultural and urbanized watersheds of southern California may not have the same nutrient retention capability as watersheds comprised of swamps and forests such as those on the Atlantic and Gulf coasts (Yarbro *et al*. 1984, Correll *et al*. 1992). Therefore runoff may have a more direct impact on southern California estuarine systems, making them more susceptible to eutrophication (Page *et al*. 1995).

Another important reason for studying southern California estuaries is that an estimated 90% of southern California's wetlands have been lost, either to dredging to form marinas or filling to support coastal development (Zedler 1996). Of the remaining 10%, many habitats have been severely degraded by physical modifications to the hydrology such as channelization of inflowing rivers and tidally influenced areas (Ferren *et al*. 1997). The timing and quantity of water entering these ecosystems from the watershed has been altered by upstream dams, while flushing by oceanic waters has been decreased due to long shore drift creating sand berms that block the estuarine mouth (Zedler 2001).

Estuaries in southern California are highly influenced by our Mediterranean climate characterized by long warm and dry summers and short cool and wet winters (Zedler 1996). Prior to extensive watershed development, it is believed that nutrients to these systems were supplied in seasonal pulses associated with individual storms (Zedler 1996, Rudnicki 1986, Fong 1986, Page *et al*. 1995). However, some evidence exists that increased loading of nutrients from developed watersheds combined with altered hydrology have resulted in high concentrations of nutrients that remain in estuaries for longer periods of time (Fong and Zedler 2000, Boyle 2002). At present, it is believed that nutrient inputs associated with agriculture and urban runoff as well as sewage treatment facilities occur year round, and may pose a unique threat to southern California estuaries. With few exceptions, data supporting this believe are lacking.

In southern California and other eutrophic Mediterranean estuaries where macroalgal blooms occur, they are often comprised of green algae in the genera *Enteromorpha* and *Ulva* (e.g. Sfriso *et al*. 1992, Hernandez *et al*. 1997, Raffaelli *et al*. 1999, Kamer *et al*. 2001). *Enteromorpha* is highly adapted to the estuarine conditions unique to Mediterranean systems. It is euryhaline (Fong *et al*. 1996), eurythermal (Fong & Zedler 1993), tolerant of desiccation (Fong and Boyer unpub. data), with relatively low light saturation of photosynthesis (Kentula, unpubl. data). Large accumulations of green macroalgae are facilitated by high nutrient uptake rates (Rosenberg and Ramus 1984, Fujita 1985, Duarte 1995, R. Kennison unpub data), rapid growth rates, and the ability to store nutrients for growth during times of lower supply (Fujita 1985, Fong *et al*. 1994, Aisha *et al*. 1995, K. Kamer unpub data). Although observed to occur in all southern

California estuaries (P.Fong, pers. obs.), macroalgal blooms have only been quantified in one system where they occurred in the dry season (Kamer 2001)**.**

The objective of this study was to further understanding of the relationship between nutrient supply, nutrient availability in the water and the sediments, and resultant algal biomass. We investigated spatial and temporal patterns in water column nutrients, macroalgal abundance, and nutrients and physical characteristics of the sediments in five estuaries of various sizes throughout the southern California region. We hypothesized that if watersheds were the primary nutrient source to estuaries there would be greater nutrient concentrations within all three nutrient pools (water column nutrients, sediment nutrients and algal tissue nutrients) at the head of each estuary compared to the mouth, or opening to the ocean. In addition, we hypothesized that there would be higher algal abundance near the primary riverine inflow. Finally, we hypothesized that there would be wet vs. dry season differences in all parameters measured. It is essential to understand the complex nutrient dynamics of these estuaries in order to manage blooms in the face of increasing watershed development.

METHODS

Study Sites

We conducted a 15-month survey characterizing nutrient dynamics and macroalgal blooms in five southern California estuaries (Fig 1). These systems were chosen because they constitute a latitudinal gradient across the southern California region and include a range of watershed sizes, land use practices (Table 1), freshwater influence and tidal flushing rates. In order to make comparisons both within and between estuaries, we chose three sites along a main channel of each estuary. We included general observations of tidal flushing at each study area. Precipitation data from October 2001 through January 2003 for each estuary were taken from U.S. National Oceanic and Atmospheric Administration (NOAA) weather stations closest to each estuary (Table 2). We calculated nutrient loading rates for Upper Newport Bay from San Diego Creek (SDC) using the only available stream flow data. Mugu Lagoon- Calleguas Creek has one stream gauge with current data, but it is located >5miles upstream from our sampling site. In the other study areas, our most up-estuary sites were not close enough to the mouth of the river to be able to estimate loading accurately.

Carpinteria Salt Marsh Reserve

Carpinteria Salt Marsh Reserve (CSMR), the northwestern most estuary, is located approximately 7 miles east of Santa Barbara, California. It is the smallest estuary and watershed and the watershed is mainly developed by agriculture (Table 1). There are two major streams that enter the marsh, Santa Monica Creek and Franklin Creek (Page *et al.* 1995). Our sites are located on an artificially created channel west of Santa Monica Creek and its tributaries; portions of the tributaries drain into the channel. The upper channel drains the agricultural and urban development to the north. The mouth and middle sections of this channel are narrow (3-6 m), shallow (1-2 m), and fairly straight, allowing tidal action and flushing rates to have strong impacts on the system.

Mugu Lagoon - (West and Calleguas Creek)

Mugu Lagoon is located within a Naval Base at Pt. Mugu, approximately 75 miles northwest of Los Angeles. For this study we have divided the estuary into two areas, Mugu Lagoon-West (Mugu West) and Mugu Lagoon-Calleguas Creek (Mugu CC) because of differing watersheds and physical layouts.

The western arm of the lagoon (Mugu West) is highly developed with roads and runways interrupting the normal flow of tidal water (T. Keeney, pers comm). The watershed drains the agricultural plains of Oxnard as well as adjacent duck ponds through a drainage canal (Table 1). This arm of the lagoon is approximately 1.5 miles long and consists of a broad (~150m wide) shallow channel (<1m). Although roads constrict upper areas, a wide and gently sloping mudflat and high salt marsh habitat border the lower portion, resulting in muted tidal flushing.

Mugu CC is the second largest estuary in our study and comprises the central portion of the lagoon. Although large portions of this watershed are open space, agricultural development is in close proximity to the estuary, immediately upstream of the estuary on the coastal plain (Table 1). Calleguas Creek is the main river flowing into the estuary; it was historically dredged to 30 ft but has filled through time to 15 to 20 ft by natural sedimentation from the river and the ocean inlet. In contrast to Mugu West, this system tends to be well flushed by tides (T. Keeney, pers comm).

Upper Newport Bay

Upper Newport Bay (UNB) is located 35 miles south of Los Angeles and is intermediate in size with a highly urbanized watershed (Table 1). SDC and its major tributary drain 85% of the watershed and are the main freshwater inflow (Gerstenberg 1989). The main channel is wide with extensive broad mudflats and shallow banks; however, the center of the channel is dredged to 5 m below sea level for sediment retention purposes. UNB is separated from the Pacific Ocean by the Lower Bay, which has been dredged and developed into a marina with no natural area remaining. Water residence time in the upper bay can be 1 week during neap tide.

Los Penasquitos Lagoon

Los Penasquitos Lagoon (LPL) is one of the smallest estuaries in our study. The watershed is partially urbanized, but the rest of land use is unknown (Table 1). Our sampling sites were located along the inflow from Carmel Valley Creek; however, there are many creeks that flow into the estuary. LPL is subject to periodic mouth closures due to sand accretion from longshore drift and storms. When the mouth is open, this system tends to be well flushed by tides.

Tijuana River Estuary

Tijuana River Estuary (TJ) is the largest estuary we surveyed, with the largest watershed (Table 1). TJ is located at the US/Mexican border with most of the watershed in Mexico and is highly urbanized just upstream. Freshwater from the Tijuana River flows year-round as a result of sewage discharge (BSI 1994). We sampled the main channel, which is wide (50-100m), shallow (~1m), and bordered by broad mudflats. Tidal flushing is vigorous as it is in CSMR and Mugu CC.

Sampling Protocols

Quarterly sampling was conducted in December 2001, February, June, September, and December 2002, and February 2003, at three permanently established sites within each estuary and six in Mugu Lagoon. LPL was not sampled in December 2001 due to mouth closure and subsequent mechanical opening creating transitory conditions (see Table 3 for missing data). In each estuary, three sampling sites were permanently established along a main channel: at the head of the estuary where the major river enters, at the mouth of the estuary (or lower reach of the natural habitat), and mid-way between.

During each sampling event, we first sampled the water column. Salinity was measured with a handheld refractometer. Water column temperature and DO content (mg/l) were measured at mid-water depth using a DO meter (YSI Model 95). DO values were single measurements sampled during daylight in shallow areas that drain daily; thus they have a low probability of detecting hypoxia. We consider all DO levels above 3.0 mg/l as well oxygenated based on Coon (1998). Three water samples were collected at each site and placed in a dark cooler on ice. Upon return to the lab, samples were filtered (Whatman GF/C), frozen, and sent to DANR Analytical Laboratory at UC Davis where they were analyzed for NO_3 (NO_3 and NO_2), NH_4, TKN (all forms of dissolved N except NO_3 and NO_2) and Total P. Water from September and December 2002 and February 2003 was also analyzed for SRP. For LPL SRP was also analyzed for June 2002. NO_3 was reduced to NO_2 via cadmium reduction and NO_2 was measured spectrophotometrically after diazotation (Switala 1999, Wendt 1999). NH_4 was heated with solutions of salicylate and hypochlorite and determined spectrophotometrically (Switala 1999, Wendt 1999). TKN was determined by the wet oxidation of nitrogen using sulfuric acid and digestion catalyst. This procedure converts organic nitrogen to NH_4 which is subsequently determined (Carlson 1978). Total P in the water was determined by atomic emission spectroscopy following microwave acid digestion. SRP was determined spectrophotometrically following reaction with ammonium molybdate and antimony potassium under acidic conditions (APHA 1998). These automated methods have detection limits of 3.57 μM for all forms of N, 3.226 μM for Total P, and 1.613 μM for SRP.

Within each site we sampled intertidal macroalgae along a 30-m transect parallel to the waterline and 1 meter downslope from the vascular vegetation. We estimated macroalgal abundance by measuring percent cover and algal biomass. At five randomly chosen points along each transect, a 0.25-m^2 quadrat with 36 intercepts was placed on the benthos. The presence or absence of each macroalgal species under each intercept was recorded. When present, algae were collected from a 530.9cm^2 area circumscribed by a plastic cylinder placed on the benthos in the center of each quadrat. Each sample was placed in an individual ziploc bag in a cooler, transported to the laboratory and refrigerated. Algal samples were transferred to low nutrient seawater where they were cleaned of macroscopic debris, mud and animals, and sorted to species. For each sample, individual species were placed in a nylon mesh bag, spun in a salad spinner for 1 minute, wet weighed, rinsed briefly in deinonized water to remove salts, and dried at 60^o C to a constant weight. Macroalgal biomass was normalized to area. Inconsistent measurements between percent cover and algal biomass are possible. When algal abundance is low, fine macroalgal filaments that grow within the sediment may be visible but biomass cannot be collected quantitatively at this early growth stage (making percent cover in this case, a more sensitive measurement). In addition, the quadrat grid may not always intercept the biomass sample resulting in 0% cover, but measurable biomass. Thus it is important to use both methods to estimate abundance.

Dried algal tissue samples were ground with mortar and pestle and sent to DANR Analytical Laboratory at University of California, Davis for tissue N and P analyses. A nitrogen gas analyzer using an induction furnace and thermal conductivity quantified total N in algal tissue. Tissue total P was analyzed with the same method described for water total P.

To characterize the sediments, we measured sediment reduction-oxidation potential (redox), organic content, and nutrient content every sampling season within the same quadrats along the 30m transect as for macroalgae. Redox potential is a quantitative measure of the ability of the sediments to oxidize or reduce substances (Mitsch and Gosselink 1993). In order to minimize disturbance to the sediment, redox was measured before algae were sampled. Redox potential was measured with six brightened platinum electrodes and a calomel reference electrode at 5 cm depth into the sediment. The electrodes stabilized for 10 minutes prior to measurements with a portable pH/millivolt meter. Oxidized sediment, where dissolved oxygen is readily available, is within the range of +400 to +700mV. Sediments become subaerobic around +250mV and the most reduced conditions are between –250 and –400 mV (Mitsch and Gosseling, 1993).

We took three sediment cores to 5cm depth from each of the five quadrats. The three cores were composited, placed in a dark cooler on ice, and returned to the lab within 6 h. Sediments were dried at 60^0 C to a constant weight, ground with mortar and pestle, and sieved to less than 2 mm. All material greater than 2mm was weighed. Total N was analyzed using the combustion gas analyzer method. Total P was analyzed using the same method described for water column total P. Organic content was determined by loss after ignition in a 400^0C-muffle furnace.

To determine if grain size changed over a year, sediment samples from December 2001 and December 2002 were analyzed for grain size for all estuaries except LPL. For LPL we compared sediment samples from February 2002 to February 2003. We determined % silt, % clay, and % sand using the hydrometer method (Bouyoucos 1962).

Statistical Analysis

Two-factor analysis of variance, with ANOVA factors site (head, middle, mouth) and season (December 2001, February, June, September, December 2002 and February 2003), was used to test for differences in water column NO_3, NH_4, TKN, and SRP, algal biomass and percent cover, sediment N and P, organic content, redox potential and grain size within each estuary. Two-factor analysis of variance was also used to test for differences in water column Total P for Mugu CC; all other estuaries total P was BDL too often for statistical analysis. Two-factor analysis of variance was used to test for differences in algal tissue total N and P for Mugu West; for all other estuaries there was not enough sample.

Regressions quantified the relationship between algal biomass and water column NO_3, TKN, and sediment total N. We also regressed water column NO_3 and sediment N. Regressions included all data from all estuaries and used site averages. Salinity/dilution curves quantified the relationship between salinity and water column NO_3 and NH_4 for each estuary. All regression lines were chosen based on least squares best fit. A conservative trend-line (straight line) implies N was being diluted by tidal water. A non-linear curve below the straight line implies uptake or net consumption by the estuary (a non-conservative decrease with increasing salinity), and a curve above the straight line implies nutrient regeneration within the estuary (a non-conservative increase with increasing salinity). Where data were missing, that site or season was excluded from analysis. For data below detection limits (BDL) half the detection limit was used.

Loading rates for UNB from SDC were estimated using water flow data from the County of Orange for February and June 2002. To estimate nutrient loading to UNB on our sampling dates, we multiplied the mean daily discharge of SDC on the sampling date by the mean water column concentration of each nutrient sampled from the mouth of the river. Stream flow data were only available for the water year 2002, and we have data for two sampling periods (February and June 2002).

Data were examined to determine if they complied with ANOVA assumptions of normality and equal variances. Unequal variances were corrected by transformations (Table 4). Means reported throughout the text were generated from untransformed data. Error bars on all graphs=1 S.E. Within factor post-hoc multiple comparisons were made following a significant ANOVA without interactions (Fisher's PLSD). Effects were considered significant if $p<0.05$. Detailed results of the data analysis are presented in Appendix A. If neither factor was significant tables were not included in Appendix A.

RESULTS

Patterns Within Each Study Area

Carpinteria Salt Marsh Reserve

Water Column

CSMR was well oxygenated across all sites and sampling periods during our daytime, low tide sampling (Table 5). There was a salinity gradient during all sampling periods, with the lowest salinities at the head of the estuary indicating there was some freshwater flow throughout the year. This gradient was strongest during the wet seasons (December 2001, February 2002, and February 2003) due to precipitation in these months (Table 2). Overall, water temperatures were colder in the wetter seasons and at the mouth during all sampling periods except in December 2002.

Across all seasons and all sites the most abundant water column nutrient in CSMR was NO_3 (Fig 2a). There were significant effects of site and season as well as interaction (Appendix A). Across all seasons highest NO_3 concentrations were always at the head, decreasing down estuary. NO_3 concentrations were more than twice as high in the February 2002 rainy season compared to other rainy season samples, and over an order of magnitude lower in the June 2002 dry season. There was less rain in February 2002 in Santa Barbara than in December 2001 (Table 2) perhaps causing nutrient inputs to be more concentrated. In June 2002 there appeared to be no change in NO_3 concentration between the mouth and middle of the estuary, resulting in interaction. These patterns suggest that the river input was the NO_3 nutrient source. The salinity/dilution curve reveals a significant non-conservative decrease of NO_3 with increasing salinity (Fig 3a), suggesting that there was uptake of NO_3 within the estuary.

NH_4 concentrations were low relative to NO_3 across all sites and seasons (Fig 2b); maximum values were ~30µM compared to >1,000µM for NO_3. There were significant effects of site and season on water column NH_4 as well as interaction (Appendix A). In most wet seasons (December 2001, December 2002 and February 2002), NH_4 was highest at the mouth, and generally decreased toward the head. In both September 2002 and February 2003, NH_4 was highest in the middle. June was the only season that the mouth had the lowest NH_4 concentrations resulting in interaction. Although there were statistical differences, the relatively low NH_4 concentration suggests that water column NH_4 may not be important compared to NO_3 in overall nutrient availability. Although there was a statistically significant non-conservative increase in NH_4 as salinity increased, the relationship explained little variability (Fig 3b). This suggests there may have been some regeneration of NH_4 via benthic remineralization within the estuary.

TKN was also relatively low and variable (Fig 2c). There was an effect of site due to higher overall TKN at the middle than at other sites (Appendix A). TKN was highest at the middle in June and September 2002, but patterns were inconsistent in other months, resulting in interaction. Overall water column TKN was a small component of water column N relative to NO_3 in this estuary.

There were significant effects of site and season on water column SRP as well as interaction (Appendix A, Fig 2d). The strongest seasonal pattern was at the head, where SRP concentrations were highest in February 2003. There appear to be no seasonal differences in SRP concentrations at the mouth and middle sites, resulting in interaction. Water column total P (Table 6) was almost always detectable at the head and was below detection limit at the mouth and middle site in most seasons.

Macroalgal Community

Enteromorpha was the only genus of green macroalgae found at CSMR. Maximum mean biomass (1760±452 g wet wt m^{-2}) was at the head of the estuary in December 2001, though data were extremely variable (Fig 4a). There were significant effects of site and season on algal biomass as well as interaction (Appendix A). Biomass at the head was lowest in the dry season, and highest in wet seasons. At the mouth, algae were never found in sufficient abundance to measure biomass, in the middle biomass was relatively low and variable and these two patterns resulted in interaction.

There were significant effects of site and season on percent cover of algae; however, these patterns were not consistent over space or time, resulting in interaction (Appendix A). At the head of the estuary there was algal cover year round, with higher values in the wet season (December and February), and lower values in the dry season (June and September, Fig 4b). The only cover at the middle site was in February and June 2002 and at the mouth in February and December 2002.

There was so little collectable biomass in most seasons and sites that tissue N and P showed no clear patterns (Table 7). However, tissue N content of *Enteromorpha* was always >2.0% dry wt and tissue P was >0.25% dry wt.

Sediment Characteristics

There were significant effects of site and season on sand and silt as well as interaction (Appendix A). Sand was the dominant component of the sediment at the mouth of the estuary compared to the other sites (Fig 5a). Silt and clay were relatively more abundant in the middle and head with the exception of sand being more dominant at the head in December 2002, resulting in interaction. The increase of sand at the head and middle in December 2002 may have been associated with the onset of winter rains in Nov/Dec 2002 in Santa Barbara (Table 2).

There was a significant effect of site but not season on organic content with the highest values at the head, decreasing toward the mouth (Appendix A, Fig 5b). Although spatial patterns were consistent, changes over time were complex, resulting in interaction. At the head, the greatest organic content was in February 2003 perhaps reflecting the onset of rains in November 2002 (Table 2), while at the mouth the highest organic content was in June 2002.

There was a significant effect of site but not season on redox potential (Appendix A). Overall, the sediment was reduced (<+400mV, Fig. 5c); however sediment was more reduced at the head of the estuary, becoming relatively more oxidized toward the mouth. An interaction was caused by inconsistent patterns among seasons. Redox potential was highly variable across sampling periods.

There was a significant effect of site, but not season on total N content of sediments (Appendix A, Fig 6a). Sediment total N had the same spatial pattern as organic content, with the highest N at the head of the estuary, decreasing toward the mouth. Different spatial patterns in total N in December 2002 compared to February 2003 resulted in interaction. There was a significant effect of site on total P. The pattern was opposite that of total N, with the mouth and middle higher than the head site (Fig 6b). However, there was an interaction caused by relatively small changes over time that differed among sites. There was an effect of site on sediment N:P (Fig 6c), with the highest N:P ratios at the head, decreasing toward the mouth. This spatial pattern was the same as the sediment total N, indicating that ratios were driven by total N.

Mugu Lagoon-Mugu West

Water Column

Water at Mugu West was always well oxygenated during our daytime sampling (Table 5). In June, September and December 2002 the water was hypersaline in some sites. In general, there was a weak salinity gradient in December 2001 coinciding with precipitation in Nov/Dec 2001 (Table 2), June 2002 when no rain occurred, and February 2003. Water temperatures were warm at the head in both February 2002 and 2003 suggesting warmer water may be entering from the watershed.

Across all seasons and all sites the most abundant water column nutrient in Mugu West was NO_3 (Fig 7a). There were significant effects of site and season on NO_3, as well as interaction (Appendix A). Highest concentrations of NO_3 were at the head decreasing toward the mouth in all seasons except June 2002. In June lowest NO_3 concentrations were at the middle site, resulting in interaction. It is possible that the source of NO_3 at the mouth in June may have been mixing of water from Calleguas Creek where NO_3 concentrations were high (see below). At the middle and head NO_3 concentrations appeared to decrease by more than half from December 2001 to the dry months of June and September 2002, and increase by an order of magnitude in February 2003. The salinity/dilution curve reveals a non-conservative decrease of NO_3 with increased salinity (Fig 8a). These patterns suggest that watershed input was the NO_3 source and that NO_3 was being taken up within the estuary.

NH_4 concentrations were relatively low compared to NO_3 (except in December 2002 at the head) across all sites and seasons (Fig 7b). There were significant effects of site and season on water column NH_4 as well as interaction (Appendix A). Maximum NH_4 concentrations were at the head in December 2002 but patterns varied across sampling times resulting in interaction. Furthermore, the NH_4 salinity/dilution curve showed no significant trend with salinity (Fig 8b). There was a relatively narrow salinity range, which indicates little freshwater influence (Table 5).

TKN was also relatively low and variable (Fig 7c). Water column TKN concentrations were significantly affected by site but not season with the highest concentrations at the head (Appendix A). The temporal patterns were variable among sampling times, resulting in interaction.

There was a significant effect of site and season on water column SRP (Appendix A, Fig 7d). SRP was significantly higher at the middle than the head site. Across all sites, SRP concentrations were lowest in December 2002. In contrast water column total P (Table 6) was below detection limit (3.226µM P) for all sampling times except at the head site in June 2002 and the mouth in February 2003 where only 1 sample at each site had detectable P.

Macroalgal community

The Mugu West macroalgal community was comprised of both *Enteromorpha* and *Ulva*. Maximum mean biomass (2995±873 g wet wt m^{-2}) was at the mouth in June 2002 (Fig 9a). There was a significant effect of season but not site on total macroalgal biomass as well as interaction (Appendix A). At the mouth and the head maximum biomass occurred in June and September 2002. The interaction was caused by maximum biomass at the middle site in December 2001, September and December 2002. There was greater than 50% cover of macroalgae over most sites and seasons, demonstrating the year-round presence of algae in this estuary (Fig 9b). There was a significant effect of season but not site on percent cover. There was a significant interaction caused by inconsistent patterns over time and space.

Mugu W was the only estuary where there was enough *Enteromorpha* biomass present to do analysis on tissue nutrients. There was a significant effect of season but not site on algal tissue total N. All three sites had elevated tissue N in December 2001 and 2002. Only the middle had higher N in June as well, resulting in interaction (Appendix A, Fig 10a). There was an effect of season but not site on tissue P which was significantly higher in December 2002 across all sites (Fig 10b).

Sediment Characteristics

Overall sand content was highest of all sediment types. There were no differences over time or space for sand and clay. There was a significant effect of site on % silt with the lowest percent at the head (Appendix A, Fig 11a). There was a significant effect of site but not season on organic content (Fig 11b). There was a strong spatial pattern with the highest organic content at the middle site, followed by the head, and then the mouth. Redox potential was extremely variable across all sites and seasons. Overall sediments were reduced with redox potential ≤+400mV (Fig 11c). There was an effect of site with the middle site having an overall higher redox potential (relatively more oxygen available) than the head and the mouth. Temporal patterns were complex and inconsistent across sites resulting in interaction.

There were significant effects of site and season on sediment total N as well as interaction (Appendix A). The spatial trend was the same as that of percent organic content; total N appeared to be highest at the middle site (Fig 12a). The interaction was caused by no changes over time at the mouth, inconsistent patterns at the middle, and apparent increase in sediment N over time at the head.

There was a significant effect of site but not of season on sediment total P with highest total P in the middle site (Appendix A, Fig 12b). There were significant effects of site and season on molar sediment N:P ratios. Overall, highest N:P ratios were at the middle site (Fig12c); however, this was probably an effect of high values in September 2002, which were likely influenced by high sediment N content.

Mugu Lagoon - Calleguas Creek

Water Column

Mugu CC water was well oxygenated at all sites during our daytime sampling, sometimes exceeding 20mg/l (Table 5). Salinity varied spatially during all sampling periods with the lowest salinities at the head of the estuary indicating freshwater flow throughout the year. Water temperatures appear to have been lower in the cooler, wetter seasons.

NO_3 concentrations were >500μM at most sites in every season, with the exception of December 2001 at the mouth and December 2002 at the mouth and the head (Fig 13a). There were significant effects of site and season, but patterns were inconsistent across space and time resulting in interaction (Appendix A). The only clear spatial concentration gradients were in December 2001 and September 2002 with the highest NO_3 concentration at the head, decreasing toward the mouth. Salinity/dilution graph of NO_3 (Fig 14a) revealed no significant trends supporting the conclusion that spatial and temporal patterns were inconsistent and variable.

Water column NH_4 was generally 10 times lower than NO_3 across all sites and most seasons (Fig 13b). There were significant effects of site and season, but patterns were inconsistent across space and time resulting in interaction (Appendix A). The only clear spatial concentration gradients were in September 2002 when high NH_4 at the head decreased to the mouth and in December and February 2002 when the opposite pattern occurred. NH_4 dilution curve (Fig 14b) revealed no significant trends showing neither uptake within the estuary nor consistent production of NH_4. There was a significant effect of season but not site on water column TKN with interaction. At the middle and head sites, the highest TKN concentrations were in December 2001 and 2002 (Fig 13c), while at the mouth high TKN occurred only in December 2002.

There were significant effects of site and season on water column total P as well as interaction (Appendix A). Highest TP concentrations were at the head (Fig 15a). Temporal patterns were similar at the head and the mouth; TP increased from December 2001 to February 2002 corresponding to an increase in precipitation during these months (Table 2). After rains ceased, total P decreased through June and September, then increased again in February 2003, presumably with the onset of rains. At the middle site, the temporal pattern was not consistent, resulting in interaction.

There were significant effects of site and season on water column SRP as well as interaction (Appendix A). Highest SRP concentrations were at the head decreasing toward the mouth (Fig 15b). As for total P, at the head lowest SRP concentrations were in December 2002. At the middle site there appeared to be more SRP in the dryer month of September 2002 in Ventura (Table 2). Thus, temporal patterns were inconsistent among sites resulting in interaction. Total P was mostly comprised of SRP suggesting that P was primarily in inorganic form.

Macroalgal community

Only relatively low and patchy accumulations of E*nteromorpha* were found in Mugu CC. Maximum mean biomass (292±114 g wet wt m^{-2}) was at the mouth in September 2002 (Fig 16a). There were effects of season and site caused by algal biomass in September and June 2002 at the mouth; in all other seasons there was little or no biomass at all sites (Appendix A), resulting in interaction. There were significant effects of site and season on percent cover as well as interaction. Patterns in percent cover reflected biomass, with some macroalgae occurring in September at all sites and June at the mouth and middle (Fig 16b). There was so little biomass that tissue N and P showed no clear patterns (Table 7). However, in algae that were collected tissue nutrients were relatively high; tissue N content of *Enteromorpha* was >2.0% dry wt and tissue P was >0.25% dry wt.

Sediment Characteristics

There were significant effects of season and site on all three classes of grain size with significantly higher percent sand at the mouth where lowest silt and clay occurred (Appendix A, Fig 17a). Percent sand decreased significantly annually between December 2001 and 2002 at each site and % silt and clay increased at each site. This pattern suggests that in December 2002 there was a deposit of silt and clay from the watershed.

There was a significant effect of season but not site on organic content as well as interaction (Appendix A). Organic content generally increased through time from December 2001 to December 2002. At the mouth and middle sites, organic matter decreased in February 2003 (Fig 17b), while at the head organic matter increased in February 2003, resulting in interaction.

There were significant effects of site and season on redox potential with interaction (Appendix A). Sediments were reduced with the redox potential ≤250mV except in

February 2003 at the middle and head sites (Fig 17c). Overall, the lowest redox potential occurred at the mouth. Inconsistent temporal pattern among sites resulted in interaction.

There were significant effects of season and site on sediment N (Appendix A). Sediment N was highest at the mouth and in December 2002 across all sites (Fig 18a). Generally, sediment N increased over time from December 2001 to December 2002 across all sites. There was an effect of site but not season on total P in the sediment with the highest P at the head (Appendix A, Fig 18b). There were significant effects of season and site on the N:P ratio (Appendix A, Fig 18c). N:P was higher at the mouth being driven by highest N:P in December 2002 reflecting sediment N.

Upper Newport Bay

Water Column

Water at UNB was well oxygenated over time and space during our daytime sampling (Table 5). There were salinity gradients during all sampling periods with the lowest salinities at the head of the estuary indicating there was freshwater flow throughout the year. This gradient was stronger during the wet seasons coinciding with precipitation (Table 2). It appears temperatures were generally lower in the cooler, wetter months.

There were significant effects of site and season on NO_3 concentrations as well as interaction (Appendix A). In general, NO_3 concentrations were highest at the head, decreasing toward the mouth indicating the creek was the primary NO_3 source (Fig 19a). NO_3 concentrations were highest in February 2002 and an order of magnitude lower in June across all sites. The mean flow rate for San Diego Creek (SDC) in February 2002 was approximately 15 times higher than the flow rate in June 2002 (Table 8). Loading of N and P was estimated using water samples taken at the mouth of SDC, just upstream of the head site. Estimated NO_3 loading to the bay was over 2 orders of magnitude higher on the February 2002 sampling date than on the June 2002 sampling date. There was a significant non-linear relationship between NO_3 and salinity (Fig 20a), with NO_3 decreasing non-conservatively with increasing salinity, suggesting there was uptake of NO_3 within the estuary.

There were significant effects of site and season on water column NH_4 as well as interaction (Appendix A). NH_4 concentrations were lowest overall at the mouth (Fig 19b). Most of the highest values were in the wet months. However, changes over time differed among sites resulting in interaction. Estimated NH_4 loading to the bay was higher in February 2002 than June (Table 8). There was a significant linear relationship between NH_4 and salinity (Fig 20b) with NH_4 decreasing with increasing salinity. This trend-line suggests that there was dilution of NH_4 as it moved down estuary.

There were significant effects of season and site on water column TKN (Appendix A, Fig 19c). TKN concentrations were highest at the head and decreased toward the mouth. TKN concentrations were highest in December 2001 and 2002 across all sites, and lower in February 2003, reflecting the same pattern as NO_3 and NH_4. Estimated loading of TKN (Table 8) was higher in February 2002 than in June 2002.

There were significant effects of site and season on water column SRP as well as interaction (Appendix A). SRP was highest at the middle site and in February 2003 (Fig 19d). Temporal patterns differed among sites resulting in interaction. As for all nutrients, SRP estimated loading was higher in February 2002 than in June 2002 (Table 8). Water column total P concentrations were below detection limit across most seasons and sites (Table 6); however, estimated loading into the bay based on samples from the mouth of SDC was higher in February 2002 than in June 2002.

Macroalgal Community

The UNB macroalgal community was comprised of both *Enteromorpha* and *Ulva*. Maximum mean biomass (2012±438 g wet wt m^{-2}) was at the head in June 2002 (Fig 21a). There were significant effects of site and season on algal biomass as well as interaction (Appendix A). At the mouth biomass occurred all year while biomass at other sites was extremely patchy, only occurring in June and September 2002. Percent cover is a more sensitive measurement of algal abundance with algae present in low abundance across sites during more seasons (Fig 21b). There were significant effects of site and season on percent cover with ≥50% at the mouth in every season except June. There was an interaction caused by inconsistent changes over time at each site. There was so little biomass that tissue N and P showed no clear patterns (Table 7). However, in algae that were collected, tissue N content of *Enteromorpha* was mostly >2.0% dry wt, and tissue P was >0.17% dry wt.

Sediment Characteristics

There was an effect of site on all grain sizes (Appendix A). Sand dominated grain size at the mouth and silt and clay dominated at the head of the estuary (Fig 22a). There was an effect of season on silt with higher silt in December 2002. There were significant interactions for all grain sizes caused by inconsistent temporal patterns across sites.

There were significant effects of site and season on percent organic content as well as interaction (Appendix A). The highest organic matter occurred at the head, decreasing toward the mouth (Fig 22b). In general organic matter increased over time, although temporal patterns varied resulting in interaction. There was extreme variability in redox potential over time and space which resulted in interaction (Fig 22c). Sediment was always <+400mV, and mostly <+250mV, indicating that sediment oxygen content was low yet not completely reduced.

There were significant effects of site and season on total N in the sediment (Appendix A, Fig 23a). As for organic content, total N was greater at the head compared to the mouth. Overall, sediment N increased over time from December 2001 to September/December 2002, and then decreased. The exception was at the mouth in February 2002, but n=1 for this site and sampling time. There were significant effects of site and season on total P in the sediment as well as interaction (Fig 23b). Sediment P was higher at the head compared to the middle and the mouth site. Seasonal effects were variable across sites resulting in interaction. N:P molar ratios were significantly affected by season (Fig 23c). Temporal patterns were similar to sediment N, indicating that ratios were driven by total N, as P was less variable.

Los Penasquitos Lagoon

Water Column

In LPL, DO was variable across sampling times, but water was well oxygenated during our daytime sampling (Table 5). Salinities were extremely different among seasons: low or zero in February 2002 and 2003, gradients in June and December 2002 and oceanic throughout in September 2002. These patterns may be explained by inconsistent tidal action and periodic mouth closures. There was too little water temperature data to make any inferences.

In general water column NO_3 concentrations were low relative to other estuaries in our study. NO_3 concentrations were BDL at all sites in June and Sept 2002; in December 2002 concentrations were BDL at the middle. Thus only data from February 2002 and 2003 were statistically analyzed. There were significant effects of site and season on water column NO_3 with the highest concentration at the head (Appendix A, Fig 24a). NO_3 was higher in February 2003 than 2002. The salinity/dilution curve revealed a linear decrease of NO_3 with increasing salinity (Fig 25a) suggesting there may have been dilution rather than uptake of NO_3 within the estuary. However, this relationship was probably driven by zero values for salinities and low NO_3 concentrations.

There was a significant effect of season on water column NH_4 (Appendix A, Fig 24b). NH_4 concentrations were higher in June and September 2002 compared to February 2002 and December 2002. NH_4 concentrations were BDL in February 2003. There was a linear increase of NH_4 with increasing salinity (Fig 25b), suggesting that there may have been some regeneration of NH_4 within the estuary. Water column TKN was significantly affected by season with higher TKN concentrations in June 2002 and February 2003 at every site compared with all other seasons (Fig 24c).

There were significant effects of site and season on SRP concentrations as well as interaction (Appendix A, Fig 24d). Like NH_4 SRP concentrations were highest at the head and in June 2002 and February 2003. The interaction was caused by small differences between June 2002 and February 2003 at the mouth and middle sites, compared to higher values in June 2002 at the head site. Water column total P was BDL in 2 of 5 sampling periods at the head and 4 of 5 at the middle and mouth (Table 6).

Macroalgal Community

LPL's macroalgal community was comprised of both *Enteromorpha* and *Ulva*; overall, *Enteromorpha* appeared more common. Maximum mean biomass (532±128 g wet wt m^-

^{2}) was at the mouth in September 2002 (Fig 26a). There were significant effects of site and season on algal biomass as well as interaction (Appendix A). Biomass was highest at the mouth and was measurable in June at all sites and at two sites in September; biomass was low or not measurable in other seasons. Peaks in biomass in different seasons at different sites resulted in interaction. There was a significant effect of season but not site on percent cover. Overall, percent cover reflected biomass with highest cover in June and September 2002 (Fig 26b). The exception was February 2002 where at the middle and head sites there was algal cover but no measurable biomass; macroalgae were growing as small epiphytes on seagrass. There was so little collectable biomass in most seasons and sites that tissue N and P showed no clear patterns (Table 7). However, tissue N content of *Enteromorpha* was mostly >2.0% dry wt in algae that were collected, and tissue P was mostly >0.23% dry wt.

Sediment Characteristics

Sand dominated the mouth and middle sites whereas sediment was mainly comprised of silt and clay at the head resulting in an effect of site on all grain sizes (Appendix A, Fig 27a). There was an effect of season on silt, which decreased from February 2002 to 2003.

There were significant effects of site and season on organic content, as well as interaction (Appendix A). Organic content was higher at the head of the estuary, and lower at the middle and mouth sites (Fig 27b). Overall, organic content was higher in the wet season than in the dry season. There were some inconsistencies in these temporal patterns which resulted in interaction. Sediments were relatively reduced (<150mV) compared to the other estuaries in our study (Fig 27c). There was a significant effect of site on redox as well as interaction. At the middle site in September 2002, redox was highest, whereas there was little difference over time at the other sites resulting in interaction.

There was a significant effect of site on total sediment N with the highest N at the head (Appendix A, Fig 28a). There was a significant effect of season with sediment N highest in September and December 2002. There were also significant effects of site and season on total P, but the patterns were different from N. There was a strong spatial pattern with highest values at the head, intermediate values at the mouth, and the lowest values at the middle site (Fig 28b). At the mouth and middle, total P was highest in the wetter months of February 2002 and 2003 probably reflecting particulate P loading from storm runoff during precipitation (Table 2), compared to June and September, when there was no precipitation. There were significant effects of site and season on molar N:P ratios (Fig 28c). Highest N:P ratios occurred at the middle site compared to the mouth and the head; this pattern was driven by low sediment P at the middle site. N:P ratios were significantly higher in September and December 2002 reflecting higher sediment N.

Tijuana River Estuary

Water Column

Water in TJ was well oxygenated across sites during our daytime sampling (Table 5). The only salinity gradient was in December 2001 and February 2003. In June, September and December 2002, water was hypersaline and not variable across sites. Overall, water temperatures were cooler in the rainy season, and warmer in the summer.

NO_3 concentrations were low or BDL in the dry season (Table 9). In the wet season, NO_3 concentrations were highest at the middle and head in December 2001 and February 2003 but were not as high as NH_4 or TKN concentrations. The salinity/dilution curve revealed a linear decrease of NO_3 with increasing salinity (Fig 30a) suggesting there may have been dilution rather than uptake of NO_3 within the estuary. However, the relationship was probably driven by zero values for salinities and low NO_3 concentrations.

There were significant effects of site and season on NH_4 concentrations as well as interaction (Appendix A). NH_4 values were highest at the middle, intermediate at the head, and lowest at the mouth, but these differences were driven by the high NH_4 concentrations in February 2003 (Fig 29a). Although NH_4 concentrations were also high in December 2001, these data were not included in the statistical analysis because data from the mouth was missing. However, the trend implies that runoff from precipitation may have been a source of NH_4 (Table 2). The salinity/dilution curve revealed a linear decrease of NH_4 with increasing salinity (Fig 30b). Like NO_3, the relationship was probably driven by zero values for salinities and low NH_4 concentrations but suggests there may have been dilution rather than uptake of NH_4 within the estuary.

Spatial and temporal patterns of TKN concentrations mirrored NH_4 suggesting that TKN was comprised almost entirely of NH_4 (Fig 29b). There were significant effects of site and season on TKN concentrations as well as interaction (Appendix A). TKN concentrations were highest at the middle, intermediate values at the head and lowest at the mouth site. The highest TKN concentrations were in February 2003 and December 2001, although the December data were not included in the statistical analysis. The salinity/dilution curve revealed the same linear relationship as for NO_3 and NH_4 (Fig 30c).

There were significant effects of site and season on water column SRP as well as interaction (Appendix A). SRP concentrations were highest at the middle and in February 2003 and lower at all other sampling times resulting in interaction (Fig 29c). When measurable, water column total P concentrations were highest of all the estuaries in the study (Table 9). Spatial and temporal patterns mirrored those of NO_3, with high total P at the middle and head in December 2001 and February 2003 and low or BDL at all other times.

Macroalgal Community

TJ's macroalgal community was comprised of both *Enteromorpha* and *Ulva*; overall, *Enteromorpha* appeared more common. Maximum mean biomass (963±178 g wet wt m^{-2}) was at the head in December 2001 (Fig 31a). Macroalgal biomass was measurable at all sites and in every season except February 2002 and 2003. There were significant effects of site and season on algal biomass as well as interaction (Appendix A). Biomass was higher at the head and middle than the mouth. Biomass was highest in the wet seasons, (December 2001 and 2002, and February 2002) in one site, and lowest in the dry seasons (June and September 2003) at the middle and head sites. At the mouth of the estuary, biomass was not different across sampling times, resulting in interaction.

There were significant effects of site and season on percent cover as well as interaction (Appendix A). There was higher cover at the head and middle compared to the mouth (Fig 31b), and generally there was higher cover in the wet season and less in the dry. The exception was in September 2002, where there was considerable cover; however this coincided with some early precipitation in San Diego (Table 2). There were some differences in temporal patterns resulting in interaction. There was so little collectable biomass in most seasons and sites that tissue N and P showed no clear patterns (Table 7). However, tissue N content of *Enteromorpha* was mostly >1.6% dry wt in algae that were collected, and tissue P was mostly >0.20% dry wt.

Sediment Characteristics

There was a significant effect of site on sand and clay and an effect of season on silt as well as interaction for all grain sizes (Appendix A, Fig 32a). Overall, sand was more abundant at the mouth of the estuary and clay was more abundant at the middle and head. Silt decreased from December 2001 to 2002 at the mouth and the head, but not at the middle resulting in interaction.

There were significant effects of site and season on organic content as well as interaction (Appendix A, Fig 32b). Organic content was lowest at the mouth. At the head and middle sites sediments were richer in organic content in December 2001 and 2002. The mouth had higher organic content only in December 2001, which resulted in interaction.

There was a significant effect of site but not season on sediment redox potential as well as interaction (Appendix A, Fig 32c). The sediment at the mouth of the estuary had relatively more oxygen available then the middle and head sites; however, the sediment was still reduced (<300mV). In September at the head, sediment redox was about –175 mV, almost fully reduced conditions. High variability and a lack of consistent differences in redox potential across sampling times resulted in interaction.

There were significant effects of site and season on total sediment N (Appendix A). Total sediment N was lowest at the mouth but otherwise variable (Fig 33a). Total sediment P reflected the same spatial pattern as N but a different temporal pattern (Fig 33b). There were significant effects of site and season on total P as well as interaction.

Total P was higher in February 2003 at the middle and head sites but not at the mouth, resulting in interaction. There was an effect of site on N:P molar ratios with lowest ratio at the mouth site driven by relatively low N compared to P (Fig 33c).

Relationships between nutrients and algal biomass among all estuaries

There were no significant relationships found between water column NO_3, water column TKN, sediment N and algal biomass (Fig 34a,b,c). In addition, there was no relationship between water column NO_3 and sediment N (Fig 34d).

DISCUSSION

Our year long study of five estuaries spanning the southern California coast has demonstrated that, even within this relatively small geographic region, patterns in nitrogen sources and sinks and macroalgal abundance vary considerably. While some of the estuaries show similarities in each of these factors, important differences occur across all measured parameters. We will summarize these similarities and identify differences in nutrient sources, sinks, and macroalgal dynamics.

The watershed as a source of nutrients

In four of the six study areas (CSMR, Mugu West, UNB and TJ) spatial and temporal patterns in water column nutrients suggested that the watershed was an important nutrient source. One indication that the watershed was a source of NO_3 to the water column was the persistence of concentration gradients. These gradients suggested that inflowing rivers carried a large amount of N from the watershed that was diluted by mixing with tidal water and/or uptake by primary producers and sediments as it traveled down estuary. Salinity/dilution curves for CSMR, Mugu West, and UNB also supported this conclusion; these curves implied that NO_3 from the watershed was a persistent nutrient source across all seasons and that portions of this NO_3 were being taken up within the estuary. Similarly, spatial/temporal patterns of SRP concentrations in CSMR, TJ, and Mugu CC suggested the watershed as a source of P. Page *et al*. (1995) investigated nutrient loading from freshwater sources and the effects of tidal exchange in CSMR in the dry season and found dilution of nitrate in June, but also found possible uptake in May and September. While Winfield (1980) determined that TJ was a sink of oceanic nutrients not a source to coastal waters, we did not find evidence that any estuary we studied was a sink of oceanic nutrients in any season.

Our results demonstrated that there was seasonal variance in the magnitude of watershed sources of N. Although much of our sampling was done in a very dry year, water NO_3 concentrations were generally higher in the wetter season and lower in the dry season, indicating that runoff associated with rainfall had higher levels of NO_3. Estuaries located in other Mediterranean climates such as the Peel-Harvey system in Western Australia and Venice Lagoon in Italy have similar patterns with higher nutrient inputs when river flow was higher (McComb and Lukatelich 1995, Marcomini *et al*. 1995). In a previous UNB study, although water column N concentrations were slightly lower in winter than spring, flow rates into the estuary were 7 times higher (Boyle 2002) resulting in maximum loading in winter. In contrast to Boyle (2002), winter nutrient loading into UNB calculated in this study was higher than summer due to both higher inflow as well as higher concentrations. This may be attributed to the extremely dry year, as winter flows were low and thus did not dilute the concentration of watershed nutrient sources. Thus, wet and dry years may have similar nutrient loading rates from the watershed, but the amount of rain greatly changes the resultant concentration of these loads in the estuaries.

Variance in tidal flushing rates among estuaries and season may have confounded our results regarding nitrogen availability. Tidal amplitude affects flushing rates and can result in dilution of nutrients. In an effort to maintain consistency at each estuary, all water samples were taken within a three to four hour window of low tide; however, tidal amplitude varied among estuaries within the same sampling season because each estuary was sampled on different days. In addition, because estuary size and individual bathymetry were different, flushing rates and water retention times may have varied considerably among estuaries. For example, in UNB water column nutrients were 10 times higher at low vs. high tide at the head of the estuary (K. Kamer unpub. data). In Famosa Slough, another southern California estuary, nutrient concentrations varied significantly (almost doubling) across a 3-hour time period that encompassed inflowing, slack and outflowing tides (Fong and Zedler 2000). Therefore, although our data showed patterns in the magnitude of nutrient availability from the watershed, caution is needed when making broad comparisons regarding these patterns.

Our data suggested proximity with certain land use practices might be more important than the usual metric, overall percent use in the watershed. Agriculture is the prominent land use practice in CSMR and Mugu CC watershed and the developed area is directly upstream of these estuaries. CSMR is a small system and well flushed, but had the second highest nitrate concentrations, possibly because of its close proximity to agricultural development. With very few exceptions, Mugu CC had the highest, although variable, NO_3 concentrations of all the estuaries for all sampling times and across sites. Nutrients were particularly high in June, perhaps due to increased seasonal irrigation directly upstream. Dilution curves revealed no relationship between salinity and NO_3 or NH_4 concentrations probably because Mugu CC estuary is both a well-flushed system due to high tidal influence as well as a system that is highly dominated by the river. This mix of dominance between the tides and the river may make the timing of measurements especially important in this system.

The portion of TJ's watershed that is highly urbanized is directly upstream of the estuary; TE was also the only system with seasonally high NH_4. The spatial gradient of NH_4 suggested the watershed as the source, which is unusual since NH_4 is usually transformed to NO_3 under aerobic conditions typical of rivers. However, TJ has been subjected to periodic sewage spills from the border city of Tijuana, which may have resulted in relatively high NH_4 concentrations compared to other estuaries in our study.

Although variable, many of the estuaries in our study had NO_3 concentrations orders of magnitude higher than estuaries on the East Coast of the U.S. that are considered eutrophic. In addition, P concentrations in our study are comparable to those measured in some of the most eutrophic systems in the world. In CSMR and Mugu CC water column NO_3 levels were extremely high relative to the other estuaries surveyed. NO_3 concentrations in CSMR were an order of magnitude higher than UNB and Mugu West, and 2 orders of magnitude higher than LPL. However, even the lowest NO_3 concentrations were high compared to East Coast systems (Nixon 1995, Taylor *et al.* 1995) which indicated that southern California estuaries are highly nutrified. Similarly, total P values were comparable to eutrophic systems. Total P in the Peel-Harvey estuary ranged from 1 to 5µM (McComb *et al*. 1998), comparable to CSMR. Concentrations of total P in Venice Lagoon and Roskilde Fjord were 16-20 µM and ~10 µM in the south arm of the Mondego River in Portugal (Flindt *et al*. 1997); these values were comparable to Mugu CC, but only one-tenth that in TJ in the rainy seasons. Fong (1986) and Rudnicki (1986) found total P concentrations in TJ ranging from 0 to 57µM in winter which spanned the range of what our study found. Flindt *et al*. (1997) reported that Mondego River, Roskilde Fjord and Venice Lagoon had comparable SRP concentrations (1-13µM) to CSMR, Mugu West, UNB and LPL.

Role of Estuarine Sediments

Our data suggested that estuarine sediments were a sink for nutrients, at least seasonally. In four of the six study areas (CSMR, UNB, LPL and TJ), patterns in sediment N content reflected water column nitrate availability. Therefore, there may have been adsorption of NO_3 by sediments. The same four estuaries also had spatial gradients of sediment organic content, suggesting that accumulation of sediment N may be influenced by the deposition of organic matter from the watershed. In addition, as organic content was frequently higher in wetter months, it is likely that precipitation events led to deposition of organic matter. TJ, CSMR and Mugu West organic content (5.5-7%) was comparable to the Mondego River system (3-9%), and Roskilde Fjord (1-20%, Flindt *et al*. 1997). Sediment N reflected not only organic content, but also grain size composition. Finer textured grain sizes, silt and clay, were more abundant at the heads of the estuaries, where sediment nutrients were higher. Sediments of smaller grain size have greater nutrient adsorption capacities, which affects their ability to act as nutrient sinks (Boyer *et al*. 2000, Hopkinson *et al*. 1999, Sutula *et al*. in prep.). At the lower reaches of the estuaries, sediments were sandier with lower retention capacity for nutrients. Mugu West was an exception to the spatial patterns of organic content, sediment N and grain size; highest sediment N, organic content and finer grain sizes were at the middle site. We observed that this site was a depositional area for algae. Zimmermann and Montgomery (1984) found that decomposing algal mats along with reduced sediments caused a build up of nitrogen in the sediments. Therefore, algae that rafted to this site, deposited and decomposed may have been a source of organic matter and N.

Overall, the range of sediment N values indicated that sediment nitrogen pools in our study were comparable to other eutrophic Mediterranean systems. Estuaries with highest sediment N (~0.05 to 0.25% dry wt., TJ, Mugu West, and CSMR) were lower than in the Peel-Harvey system (approximately 0.45% max. dry wt., McComb *et al*. 1998) but comparable to Venice Lagoon (Total N= 0.27% dry wt), one of the most eutrophic estuaries in the world. UNB had the lowest N ranging from approximately 0.04 to 0.07% dry wt. These values were similar to what Boyle (2002) reported at comparable sites in UNB.

Our results suggested sediments may also be a seasonal source of N in southern California estuaries. Although patterns were weak, salinity/dilution curves for CSMR and LPL suggest inorganic N (NH_4) may have been fluxing from the sediments to the water column. This process has been documented in CSMR (Page *et al*. 1995), a Danish

Bay (Thybo-Christesen *et al*. 1993) and the Parker-River-Plum Island Sound estuary (Hopkinson *et al*. 1999. Page *et al*. 1995 found release of NH_4 in tidal channels, which served as an *in situ* source of NH_4 in CSMR. Previous studies show that macroalgae preferentially select for NH_4 (R.A. Cohen unpub. data), and it may be taken up as quickly as it is regenerated. Therefore, measures of water concentration may not represent the true role of NH_4 in macroalgal blooms, and the importance of NH_4 may be greatly underestimated. Thus, further research in this area is warranted.

Sediments may also be an important reservoir of phosphorus and therefore provide a source to macroalgae. Sediments in all estuaries were moderately to highly reduced; SRP fluxes can be related to anoxic sediments (Berner and Berner 1996). Overall, sediment P was relatively high but comparable to other extremely eutrophic estuaries. Mean sediment P concentrations in both arms of Mugu Lagoon were the highest in our study (0.10 to 0.13% dry wt) and higher than reported literature values. Sediment P values in Venice Lagoon ranged from 0.03-0.07% dry wt (Marcomini *et al*. 1995) and Boyle 2002 reported 0.06 % dry wt in UNB. Sediment P values at CSMR, UNB, and TJ (0.03-0.07%) were comparable to both of these estuaries although LPL was lower.

Macroalgal Dynamics

Complex patterns in macroalgal abundance were not consistent across seasons. Spatial and temporal patterns in algal abundance were related to nutrient availability in two estuaries. In CSMR and TJ maximum algal abundance was at the head of the estuary, and this spatial pattern reflected water column nutrients, organic content and sediment nutrients. CSMR had the second highest water column nutrients, highest sediment N and intermediate levels of algal biomass (1700 g wet wt m^{-2}). There was little algae found at the mouth of CSMR, which had a steep bank and was probably heavily impacted by scouring and high tidal action. These results suggested that physical characteristics coupled with very high nutrients determined algal spatial patterns. Therefore, nutrients stimulated algal growth, but physical scouring may have removed biomass in some sites. In contrast, while water column nutrients were lower in TJ than in CSMR, algae were consistently present across sites and over time. TJ provides a very suitable habitat for algal proliferation with wide banks, broad mudflats and high light penetration; in this system, sufficient nutrients combined with large areas of suitable habitat facilitated prolific blooms. Thus spatial patterns in CSMR and TJ suggested that algae tended to proliferate where water column and sediment N or P were available and were combined with suitable habitat.

Algal spatial/temporal patterns in Mugu West and UNB were not related to patterns in water column nutrients. Both of these estuaries had high algal biomass and intermediate levels of nutrients. Of all the estuaries in our study, Mugu West had the highest maximum mean biomass of about 3000 g wet wt m^{-2}, followed by UNB (2000 g wet wt m^{-2}). Kamer *et al*. (2001) reported patchily distributed blooms of up to 1800 g wet wt m^{-2} in UNB in 1997. Even though these estuaries did not have highest levels of nutrients across sites, they were sufficient to stimulate accumulation of algae because of suitable habitat throughout the entire estuary. UNB and Mugu West have all of the characteristics of suitable habitat for macroalgal proliferation: wide relatively shallow channels with broad areas of mudflat, high light and little scouring. However, UNB has a dredged central channel with higher water flow and probably higher turbidity, perhaps contributing to lower biomass compared to Mugu West. Patterns in these estuaries highlight the importance of suitable habitat to algal proliferation.

Mugu CC and LPL had relatively low macroalgal abundance; maximum mean biomass ranged from around 300 to 1000 g wet wt m^{-2}. Though low for the estuaries measured in this study, these values are comparable to the 600 g m^{-2} biomass found in Waquoit Bay, an East Coast estuary subject to nuisance algal blooms (Valiela *et al*. 1997). Whereas Mugu CC had highest water column and sediment nutrients and lowest algal biomass, LPL had lowest water column nutrients and slightly higher algal biomass. These data suggest that other factors such as physical extremes may function to limit macroalgal bloom development. In Mugu CC there is limited mudflat area, high scouring, and high turbidity, making this an unsuitable habitat for blooms. LPL had lowest nutrients, as well as extreme variability in salinity and these factors possibly limited algal growth. Overall, extremes in salinity, light availability, and tidal scouring may prohibit algal growth, regardless of nutrient availability.

Timing of blooms was variable among estuaries. The 2001-2002 water year was a dry year so even the "wet" season was relatively dry. Mugu West, UNB and LPL had blooms during the warm dry season whereas TJ and CSMR had blooms during the cool wet season. Each system has unique geomorphology, water flow characteristics, and watershed development, all of which may impact timing of blooms. For example, Mugu Lagoon and CSMR have watersheds that are heavily dominated by agriculture, which could have increased nutrient loading in the driest part of the year because of intense fertilization and irrigation in the summer. However, blooms in CSMR and TJ were only in the wet season, perhaps because these estuaries were so well flushed in the dry season. In UNB and Mugu West algae were able to proliferate year round regardless of the degree of precipitation. Longer-term studies combined with a more in depth understanding of the hydrology of these systems as well as specific nutrient loading data would help address the complexity of the timing of blooms.

Although we identify the watersheds of these six study areas as major sources of nutrients to these estuaries, we hypothesize they are not the only important nutrient source. In each estuary, proliferation of algal biomass occurred at some point during the year, yet the seasons differed greatly among estuaries. Additionally, the lack of fit between water column nutrients and algal biomass demonstrated that algal blooms can not be predicted by water column nutrient concentrations alone. Ultimately there were no predictive relationships between biomass and water column or sediment N. Although these relationships have been used to predict level of eutrophication and subsequent algal proliferation extensively in the past, particularly for phytoplankton, our results demonstrate it is not appropriate to use water column nutrient concentration as a predictor for macroalgal blooms in southern California estuaries.

Even within the relatively small southern California region, there was considerable variance in measures of physical, chemical and biological parameters over space and time. Therefore, generalizations based on one system are bound to be misleading. Consequently management of these systems is complex and may need to be set on a case by case basis. Future work investigating and identifying sources and cycling of nutrients is essential to understanding overall nutrient dynamics. Our data suggest investigating the role of sediments as sources and sinks of nutrients is one important direction for future research. Another important direction is to quantify different sources of nutrients such as groundwater and aerial deposition; only recently have these begun to be studied, and results may help explain some of the variability found in our study.

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Table 1. General comparative information on estuary size, watershed size and land use. ND=No Data

Estuary	Size (ha)	Watershed Size (km^2)	Land Use (%)	Reference
Carpinteria Salt Marsh Reserve (34^{0}24' N, 119^{0}31'30"W)	93	283	72% Agriculture	Page et al. 1995
Mugu Lagoon (34^{0}33'N, 117^{0}05'W)				
Mugu Lagoon-West	ND	ND	Agriculture and Duck Ponds	R. A. Cohen, unpub. data
Mugu Lagoon-Calleguas Creek	607	888	50% Open Space 26% Agriculture 24% Urban	California Regional Water Quality Control Board 2002
Upper Newport Bay	304	376	64% Urban 22% Open Space 12% Agriculture	Gerstenberg 1989
Los Penasquitos Lagoon (34^0 24'N, 119^0 , 32'W)	154	246	50% Urban	Ward et al. 2001
Tijuana River Estuary (34^{0}24.16N, 119^{0}32.00W)	720	4403	Unknown	ENTRIX et al. 1991

Table 2. Total cumulative precipitation recorded near each estuary. Santa Barbara-Carpinteria Salt Marsh Reserve; Ventura-Mugu Lagoon; Laguna Beach-Upper Newport Bay; Oceanside-Los Penasquitos Lagoon; San Diego-Tijuana River Estuary; ND=No Data. Data generated from NOAA (2003)

	Total Cumulative Precipitation (inches)				
	Santa Barbara (CSMR)	**Ventura (Mugu Lagoon)**	**Laguna Beach (UNB)**	**Oceanside (LPL)**	**San Diego (TJ)**
2001					
Oct	0.62	0.01	0	0	0
Nov	4.24	5.81	1.61	1.09	0.95
Dec	2.23	3.8	1.35	1.14	0.7
Annual Total	**27.39**	**11.7**	**16.55**	**10.46**	**9.89**
2002					
Jan	1.03	7.29	0.3	0.41	0.52
Feb	0.46	5.44	0.3	0.38	0.17
Mar	0.4	ND	1.07	0.56	0.45
Apr	0.08	1.62	0.15	0.39	0.72
May	0.1	0.1	0.1	0	0.02
June	0.03	0	0.05	0	0
Jul	0	0.02	0	0	0
Aug	0	0.01	0.05	0	0
Sep	0.23	0	0	0.33	0.31
Oct	0.03	ND	0	0.09	0.19
Nov	6.82	1.54	1.54	1.17	0.58
Dec	6.15	2.84	2.84	2.01	2.31
Annual Total	**15.33**	**19.41**	**6.4**	**5.34**	**5.27**
2003					
Jan	0	0.02	0	0.2	0.04

Table 3. Record of missing data for each estuary. NES=Not Enough Sample; sample too small to be analyzed. NS=No Sample. ND=No Data; sample destroyed due to oven failure. *ND= No Data; data missing.

	Dec 2001	Feb 2002	Jun 2002	Sep 2002	Dec 2002	Feb 2003
Carpinteria Salt Mash Reserve						
Algae						
Total N	NES	ND	NES	NES	NES	NES
Total P	NES	ND	NES	NES	NES	NES
Mugu Lagoon-West						
Algae						
Total N		ND				NES
Total P		ND				NES
Sediments						
Organic Content		ND				
Total N		ND				
Total P		ND				
Mugu Lagoon-Calleguas Creek						
Algae						
Total N	NS	NS	NES	NES	NS	NS
Total P	NS	NS	NES	NES	NS	NS
Upper Newport Bay						
Algae						
Total N	NES	NES	NES	NES	NES	NES
Total P	NES	NES	NES	NES	NES	NES
Sediments						
Redox Potential			NS			
Total N		*ND				
Total P		*ND				
Los Penasquitos Lagoon						
Water						
NO_3, NH_4, TP, TKN	NS					
Algae						
Biomass	NS					
% cover	NS					
Total N	NS	ND		NES	NS	NS
Sediments						
Organic Content	NS					
Redox Potential	NS	NS				
Total N	NS					
Total P	NS					
Grain Size	NS					
Tijuana River Estuary						
Water						
NO_3, NH_4, TP, TKN	NES	NES				
Algae						
Biomass		NES				
Total N	NES	ND		NES	NS	
Total P	NES	ND		NES	NS	
Sediments						
Organic Content		NES				
Redox Potential		NS				
Total N		NES				
Total P		NES				

Table 4. Transformations needed to correct for unequal variances. * Kruskal-Wallis

ANALYSIS	SITE					
	Carpinteria Salt Marsh Reserve	**Mugu Lagoon-West**	**Mugu Lagoon-Calleguas Creek**	**Upper Newport Bay**	**Los Penasquitos Lagoon**	**Tijuana River Estuary**
Water						
NO_3	log (x+1)	log	-	square root	-	log
NH_4	log	-	log	-	log	log
TKN	log (x+1)	-	-	-	-	square root
SRP	-	-	-	-	-	log
Algae						
Biomass	log (x+1)	log ($x^{1/4}$)	log (x+1)	log ($x^{1/4}$)	log	log ($x^{1/4}$)
% cover	log ($x^{1/4}$)	log ($x^{1/4}$)	log (x+1)	*	-	log ($x^{1/4}$)
Sediments						
Total N	log ($x^{1/4}$)	-	-	-	-	-
N:P	log ($x^{1/4}$)	-	-	log	log	-
Redox	-	-	square root	square root	square root	square root
Organic Content	-	log (x+1)	-	log	-	-
% silt	log ($x^{1/4}$)	-	-	-	-	-
% clay	-	log	-	-	-	-

Table 5. Dissolved Oxygen, Salinity, and Water Temperature for each estuary. One measurement at each site (Mouth, Middle (Mid), Head). NS=not sampled.

	Dissolved Oxygen (mg/l)			**Salinity (ppt)**			**Water Temp. (^{0}C)**		
Carpinteria Salt Marsh Reserve	**Mouth**	**Mid**	**Head**	**Mouth**	**Mid**	**Head**	**Mouth**	**Mid**	**Head**
December, 2001	10.6	15.0	11.3	27.0	15.0	2.0	13.9	17.0	17.0
February, 2002	4.1	16.6	13	22.0	12.0	2.0	13.0	16.0	16.6
June, 2002	7.6	7.6	10.7	36.0	25.0	10.0	24.3	32.0	29.0
September, 2002	NS	6.5	NS	NS	30.00	21.0	19.6	23.8	NS
December, 2002	7.8	6.8	7.3	40.0	35.0	NS	17.4	17.8	14.9
February, 2003	6.5	10.0	12.4	26.0	10.0	3.0	9.2	11.5	14.6
Mugu Lagoon West									
December, 2001	10.6	NS	13.3	34.0	NS	28.0	14.3	NS	13.1
February, 2002	10.2	6.5	9.4	34.0	34.0	35.0	14.9	15.1	20.0
June, 2002	NS	NS	8.3	40.0	NS	32.0	NS	NS	NS
September, 2002	15.5	11.0	7.8	38.0	39.0	36.0	NS	NS	NS
December, 2002	18.0	7.1	8.9	32.0	40.0	35.0	16.1	15.7	13.6
February, 2003	7.6	10.7	15.0	35.0	28.0	24.0	14.8	21.5	20.0
Mugu Lagoon Calleguas Creek									
December, 2001	15.0	NS	12.0	22.0	15.0	2.0	15.2	11.0	12.5
February, 2002	9.5	10.2	9.9	25.0	16.0	10.0	18.0	17.4	16.8
June, 2002	22.0	9.7	10.4	21.0	14.0	5.0	24.3	20.6	NS
September, 2002	11.5	10.0	9.8	26.0	16.0	9.0	NS	NS	NS
December, 2002	8.5	7.9	8.9	16.0	8.0	5.0	15.7	14.2	14.5
February, 2003	10.7	6.6	10.3	20.0	16.0	10.0	17.1	15.3	15.7
Upper Newport Bay									
December, 2001	6.2	6.1	7.0	28.0	23.0	15.0	14.2	15.4	15.0
February, 2002	8.5	5.6	9.0	26.0	13.0	10.0	19.2	17.8	17.4
June, 2002	NS	5.9	NS	40.0	31.0	30.0	NS	25.6	NS
September, 2002	5.5	5.6	6.8	37.0	34.0	25.0	20.5	NS	NS
December, 2002	12.6	19.0	16.3	37.0	35.0	19.0	16.0	16.6	16.0
February, 2003	7.7	7.9	8.4	32.0	27.0	27.0	13.8	20.5	16.6
Los Penasquitos Lagoon									
December, 2001	NS	NS	NS	NS	NS	NS	NS	NS	NS
February, 2002	9.6	14.0	10.0	13.0	13.0	15.0	13.4	15.2	16.9
June, 2002	4.4	3.5	5.0	35.0	34.0	19.0	21.0	NS	NS
September, 2002	7.9	4.0	4.3	35.0	35.0	36.0	NS	NS	NS
December, 2002	7.1	8.6	8.5	26.0	35.0	11.0	15.3	15.5	14.9
February, 2003	8.2	10.1	10.9	0.0	0.0	0.0	17.7	17.4	17.3
Tijuana River Estuary									
December, 2001	7.6	9.0	7.4	34.0	10.0	4.0	14.3	15.3	14.4
February, 2002	8.2	9.3	NS	35.0	28.0	NS	22.7	21.0	NS
June, 2002	4.5	8.5	7.5	39.0	35.0	37.0	21.4	27.3	24.9
September, 2002	NS	NS	7.8	40.0	40.0	40.0	21.3	18.9	17.5
December, 2002	8.1	41.6	8.8	41.0	40.0	36.0	16.4	20.1	17.8
February, 2003	8.8	4.0	5.9	30.0	0.0	0.0	17.0	19.9	20.0

Table 6. Water column total phosphorus concentrations. Data presented are means with either SE or sample size in ( ). Sampling size=3 unless otherwise indicated. If n<3, remainder are below detection limit (BDL) of 3.226 µM. NS= Not Sampled. Data from Mugu Lagoon-Calleguas Creek are presented in Figure 15.

		Total P (µM)	
	Mouth	**Middle**	**Head**
Carpinteria Salt Marsh Reserve			
December, 2001	BDL	3.230 (n=2)	6.450 (0.0)
February, 2002	BDL	BDL	3.230 (n=2)
June, 2002	BDL	BDL	3.230 (n=2)
September, 2002	BDL	BDL	BDL
December, 2002	BDL	BDL	3.226 (n=1)
February, 2003	3.226 (0.0)	3.226 (0.0)	6.452 (0.0)
Mugu Lagoon-West			
December, 2001	BDL	BDL	BDL
February, 2002	BDL	BDL	BDL
June, 2002	BDL	BDL	3.250 (n=1)
September, 2002	BDL	BDL	BDL
December, 2002	BDL	BDL	BDL
February, 2003	3.226 (n=1)	BDL	BDL
Upper Newport Bay			
December, 2001	BDL	BDL	BDL
February, 2002	BDL	BDL (n=2)	BDL
June, 2002	BDL	BDL	BDL
September, 2002	BDL	BDL	BDL
December, 2002	BDL	3.226 (n=1)	BDL
February, 2003	3.226 (n=1)	4.301 (1.075)	3.226 (0.0)
Los Penasquitos Lagoon			
December, 2001	NS	NS	NS
February, 2002	BDL	BDL	BDL
June, 2002	BDL	BDL	3.226 (n=1)
September, 2002	BDL	BDL	BDL
December, 2002	BDL	BDL	3.226 (n=1)
February, 2003	4.30 (1.075)	4.30 (1.075)	4.30 (1.075)
Tijuana River Estuary			
December, 2001	NS	53.763 (1.075)	68.817 (3.876)
February, 2002	BDL	NS	NS
June, 2002	BDL (n=2)	BDL	BDL
September, 2002	BDL	BDL	BDL
December, 2002	BDL	BDL	BDL
February, 2003	3.226 (n=1)	88.172 (1.075)	73.118 (1.075)

Table 7. *Enteromorpha* spp. tissue nitrogen and phosphorus content as a percentage of the dry wt. Date presented are means with (SE). Sample size = 5 unless otherwise indicated. For n<5, remainder are no algae present (NS). NES=Not Enough Sample.

		Total N (% dry wt)			**Total P (% dry wt)**	
	Mouth	**Middle**	**Head**	**Mouth**	**Middle**	**Head**
Carpinteria Salt Marsh Reserve						
December, 2001	NS	NS	2.26(0.13)	NS	NS	0.268(0.010)
February, 2002	NS	NS	NS	NS	NS	NS
June, 2002	NS	2.34(0.30) n=3	2.52 n=1	NS	0.283(0.013) n=6	0.280 n=1
September, 2002	NS	NS	2.32(0.05) n=3	NS	NS	0.285(0.028) n=3
December, 2002	NS	NS	3.19(0.33) n=3	NS	NS	0.285 n=2
February, 2003	NS	NS	3.04(0.16)	NS	NS	0.290(0.116)
Mugu Lagoon-West						
December, 2001	2.94(n=1)	3.41(0.16)	2.97(n=1)	0.230(n=1)	0.180(0.02)	0.230(n=1)
February, 2002	NS	NS	NS	NS	NS	NS
June, 2002	2.35(0.28)	3.14(0.04) n=3	2.22(0.24) n=4	0.240(0.016)	1.591(1.267) n=3	0.225(0.045) n=4
September, 2002	2.06(0.06) n=4	2.11(0.10)	2.34(0.14)	0.263(0.007) n=4	0.240(0.016)	0.204(0.022)
December, 2002	3.09(0.15) n=4	3.56(0.55)	3.79(0.09)	0.330(0.025) n=4	0.370(0.061) n=4	0.340(0.014)
February, 2003	2.82(0.19) n=4	NS	NS	NS	NS	NS
Mugu Lagoon-Calleguas Creek						
December, 2001	NS	NS	NS	NS	NS	NS
February, 2002	NS	NS	NS	NS	NS	NS
June, 2002	3.16 n=2	NS	2.83(0.256)	NES	NS	0.282(0.020)
September, 2002	2.60(0.10)	NS	3.69 n=1	0.336(0.013)	NS	0.450 n=1
December, 2002	NS	NS	NS	NS	NS	NS
February, 2003	NS	NS	NS	NS	NS	NS
Upper Newport Bay						
December, 2001	2.67(0.07) n=4	NS	NS	0.255(0.010) n=4	NS	NS
February, 2002	2.07(0.15) n=4	NS	NS	0.24(0.010) n=4	NS	NS
June, 2002	1.77 n=2	NS	2.83(.26)	NES	NS	0.282(0.018)

September, 2002	1.36(0.08) n=3	NS	2.65 n=1	0.173(0.003) n=3	NS	0.300 n=1
December, 2002	2.05(0.22)	NS	NS	0.220(0.030)	NS	NS
February, 2003	1.78(0.07) n=3	NS	NS	0.180(0.003) n=3	NS	NS
Los Penasquitos Lagoon						
December, 2001	NS	NS	NS	NS	NS	NS
February, 2002	NS	NS	NS	NS	NS	NS
June, 2002	1.68(0.14) n=4	2.16(0.18) n=4	2.52 n=2	0.185(0.010) n=4	0.245(0.021) n=4	0.290 n=2
September, 2002	2.05(0.17) n=5	2.02 n=2	NS	0.228(0.012) n=5	0.245 n=2	NS
December, 2002	NS	NS	NS	NS	NS	NS
February, 2003	NS	NS	NS	NS	NS	NS
Tijuana River Estuary						
December, 2001	NS	2.38(0.40) n=3	1.99(0.07)	NS	0.273(0.04) n=3	0.32(0.010)
February, 2002	NS	NS	NS	NS	NS	NS
June, 2002	1.61 n=1	2.42 n=1	2.40(0.29) n=3	0.180 n=1	0.270 n=1	0.233(0.018) n=3
September, 2002	1.60 n=1	NS	1.35 n=2	NES	NS	0.180 n=2
December, 2002	2.00(0.37) n=3	1.85(0.13)	1.73(0.06)	0.20(0.026) n=3	0.23(0.011)	0.21(0.006)
February, 2003	NS	NS	NS	NS	NS	NS

Table 8. Estimated nutrient loading to Upper Newport Bay via San Diego Creek (SDC). Flow rate data are daily mean flows of SDC recorded by a continuously operating stream gauging station (County of Orange, California) near the point where San Diego Creek enters Upper Newport Bay (SDC at Campus Drive). Estimations of nutrient loads were calculated using mean water column concentrations of the respective nutrients measured at the river mouth on each sampling date.

Sampling Period	Mean flow rate (m^3 sec^{-1})	NO_3 Loading (mol h^{-1})	NH_4 Loading (mol h^{-1})	TKN Loading (mol h^{-1})	TP Loading (mol h^{-1})	SRP Loading (mol h^{-1})
Feb. 2002	2.75	3255.21	127.29	495.0	21.29	27.68
June 2002	0.18	17.59	14.50	40.11	1.05	1.95

Table 9. Tijuana River Estuary water column nitrate and total phosphorus. Data presented are means with either SE or sample size in ( ). Sampling size=3 unless otherwise indicated. If n<3, remainder are below detection limit (BDL) of 3.57 μM (NO_3) or 3.226 μM (total P). NS= Not Sampled.

	NO3 (μM)	TP (μM)
Mouth		
12/01	NS	NS
2/02	3.57 (n=1)	BDL
6/02	5.24 (0.24)	BDL (n=2)
9/02	BDL	BDL
12/02	BDL	BDL
2/03	BDL	3.2 (n=1)
Middle		
12/01	125.0 (0.71)	53.76 (1.08)
2/02	NS	NS
6/02	BDL	BDL
9/02	BDL	BDL
12/02	BDL	BDL
2/03	75.23(0.48)	88.17(1.08)
Head		
12/01	143.10(3.12)	68.82 (3.88)
2/02	NS	NS
6/02	BDL	BDL
9/02	BDL	BDL
12/02	5.24(0.24)	BDL
2/03	70.95(0.48)	73.12(1.08)

FIGURES

Legend for figure captions

ND=No data. BDL=below detection limit. NES=not enough sample for laboratory analysis. Sample size in ( ).

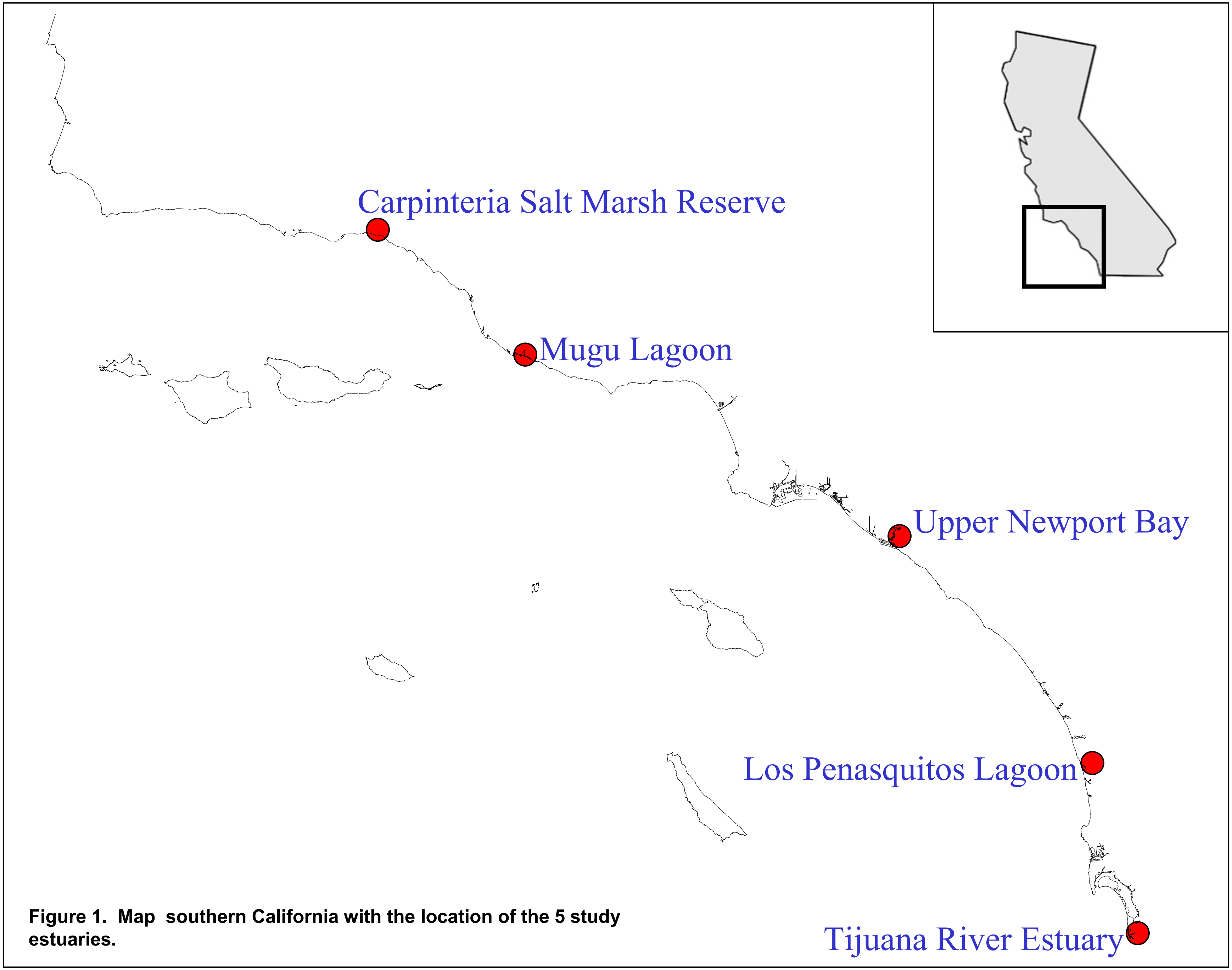

Figure 1. Map southern California with the location of the 5 study estuaries.

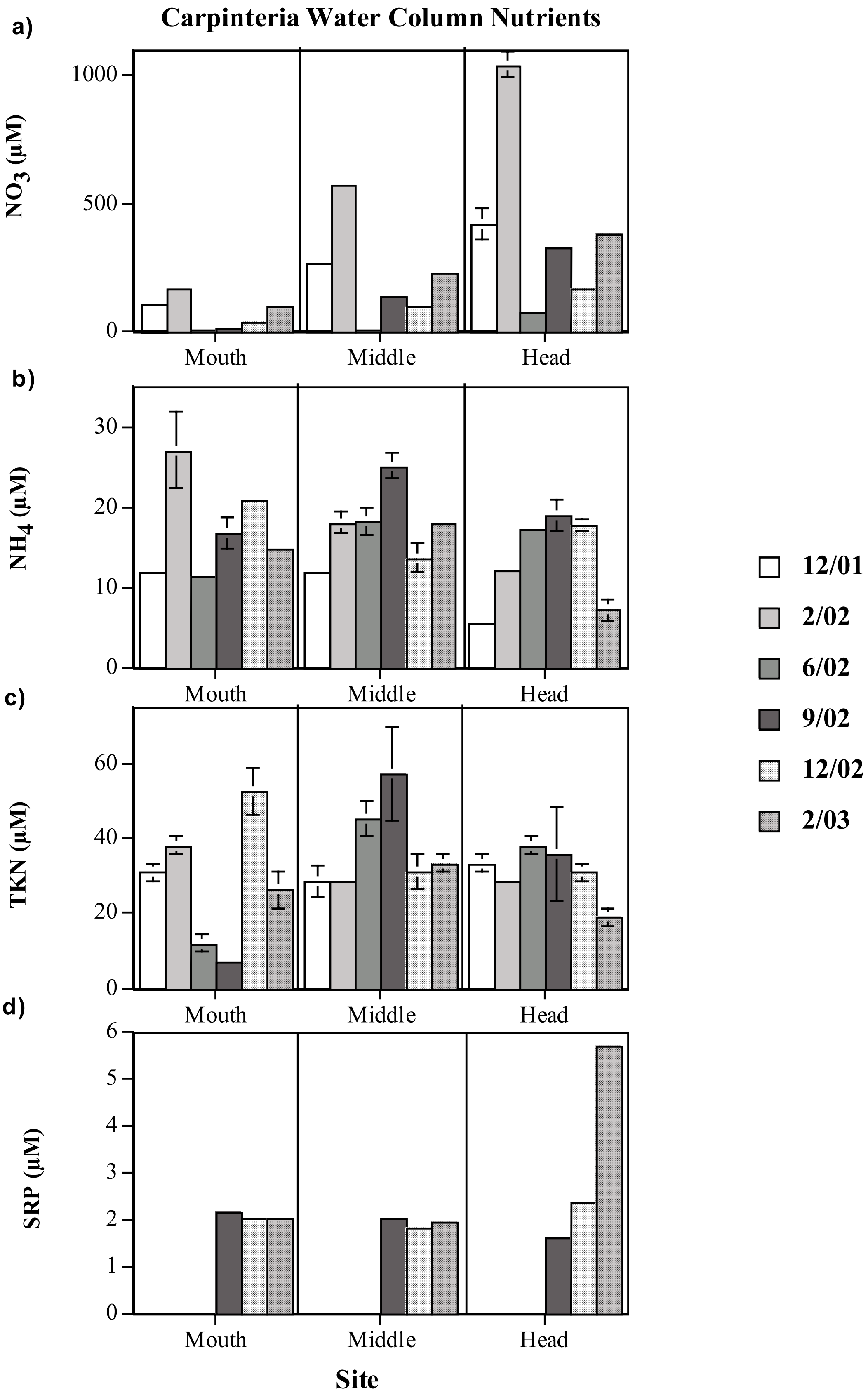

Figure 2. CSMR water column nutrients for a) NO_3 b) NH_4 c) TKN d) SRP.

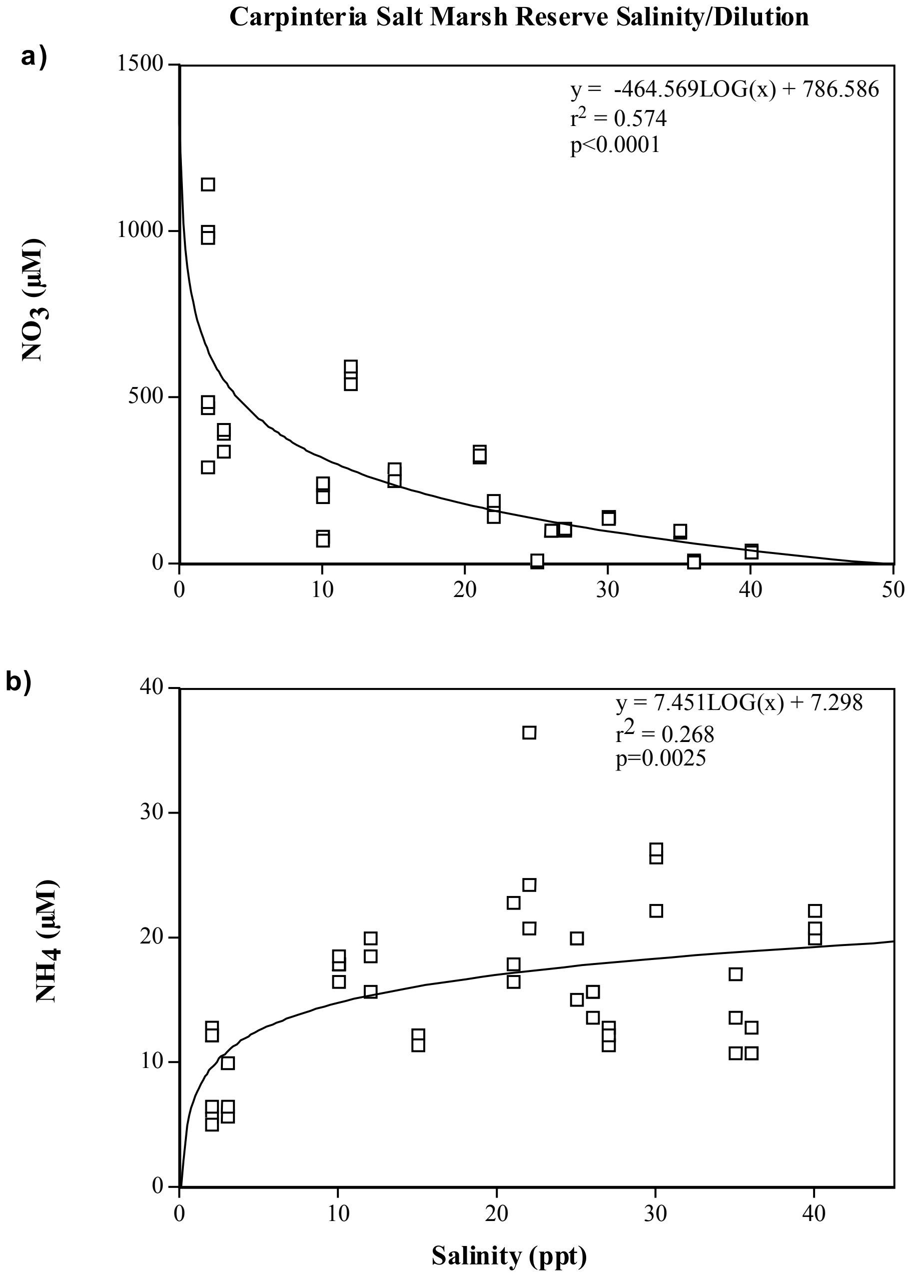

Figure 3. CSMR salinity/dilution curves. Raw data were used and included only when both salinity and nutrients were measured for that sample a) salinity vs. water column NO_3 b) salinity vs. water column NH_4.

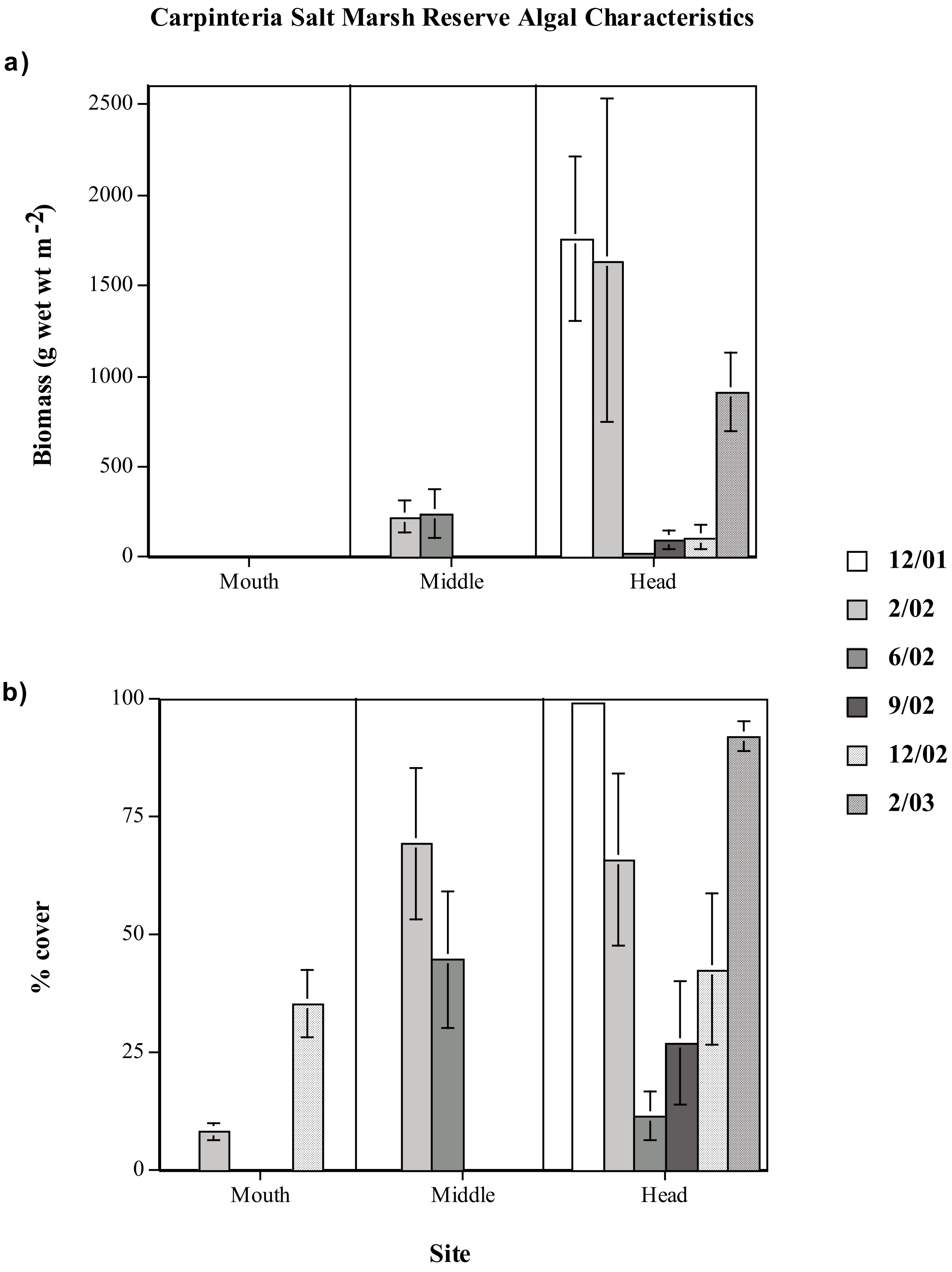

Figure 4. CSMR macroalgal abundance a) biomass b) % cover.

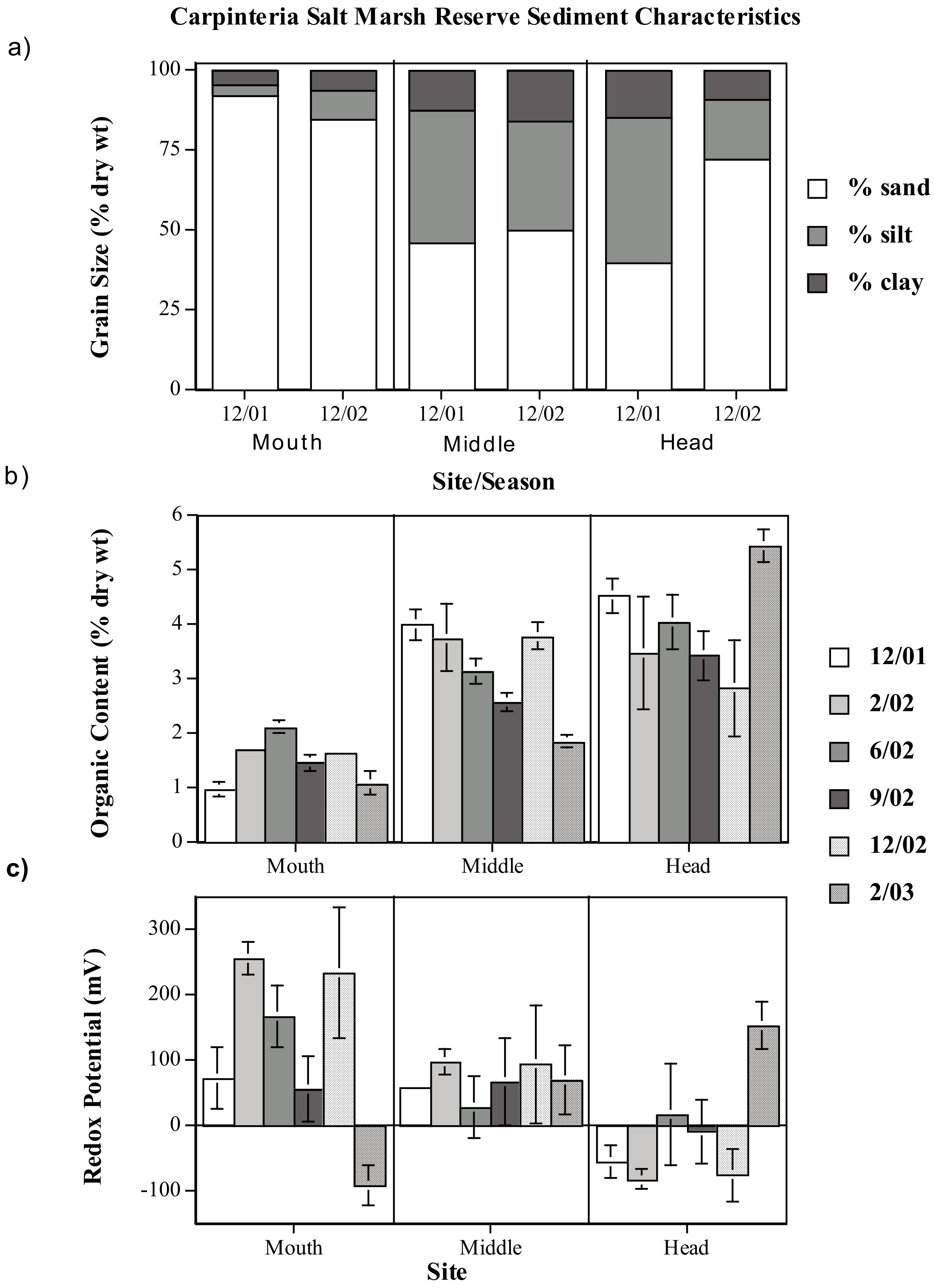

Figure 5. CSMR sediment characteristics a) grain size b) organic content c) redox potential.

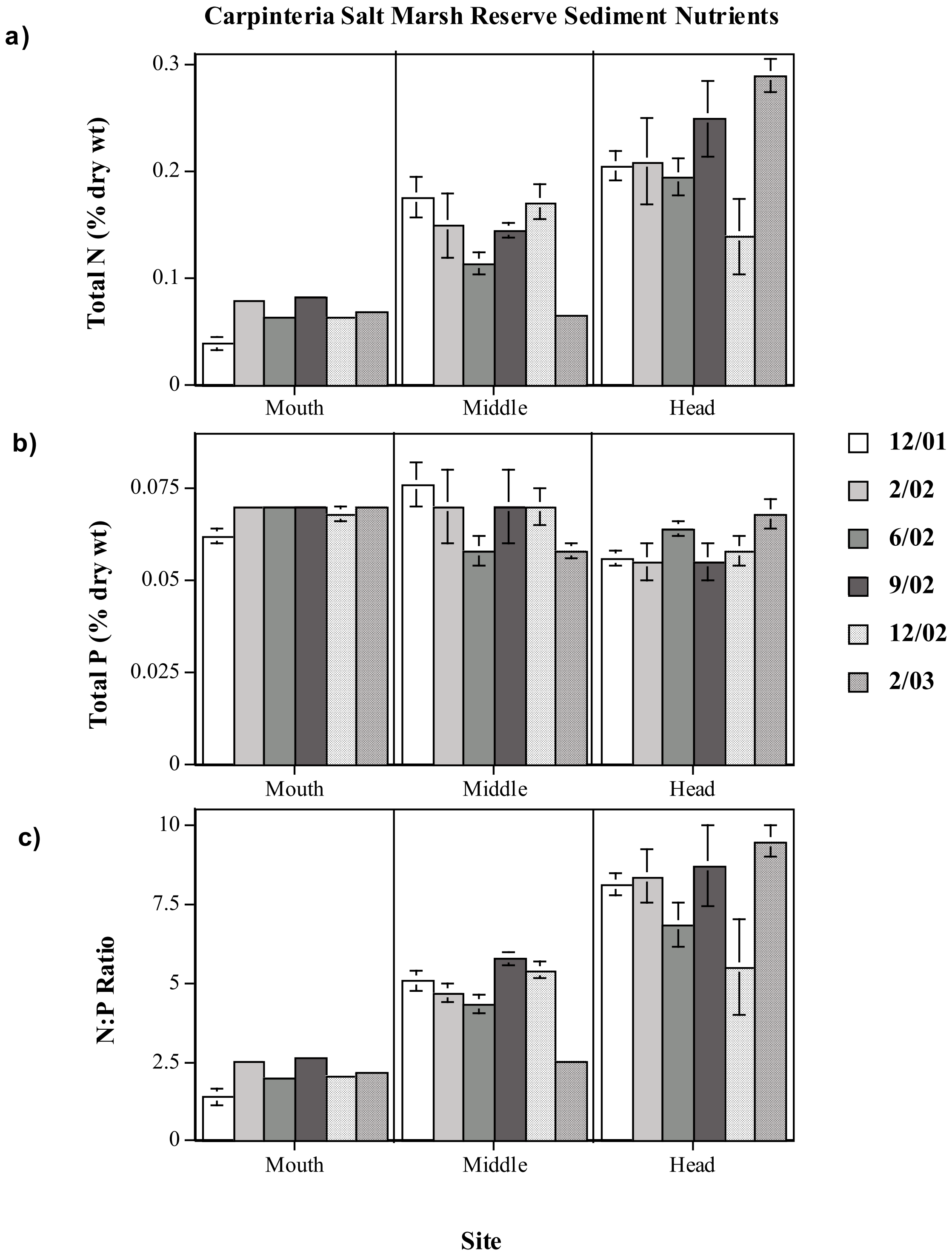

Figure 6. CSMR sediment nutrients a) total N b) total P c) molar N:P ratio. n = 5 for all means except the following: For total N, except for 12/01 when n=3 at the mouth, 2/02 when n=2 at all sites, 9/02 when n=3 at the mouth, 12/02 when n=4 at the mouth, and 2/03 when n=1 at the mouth. For total P, 2/02 all sites, n=2. N:P sample sizes were the same as for total N.

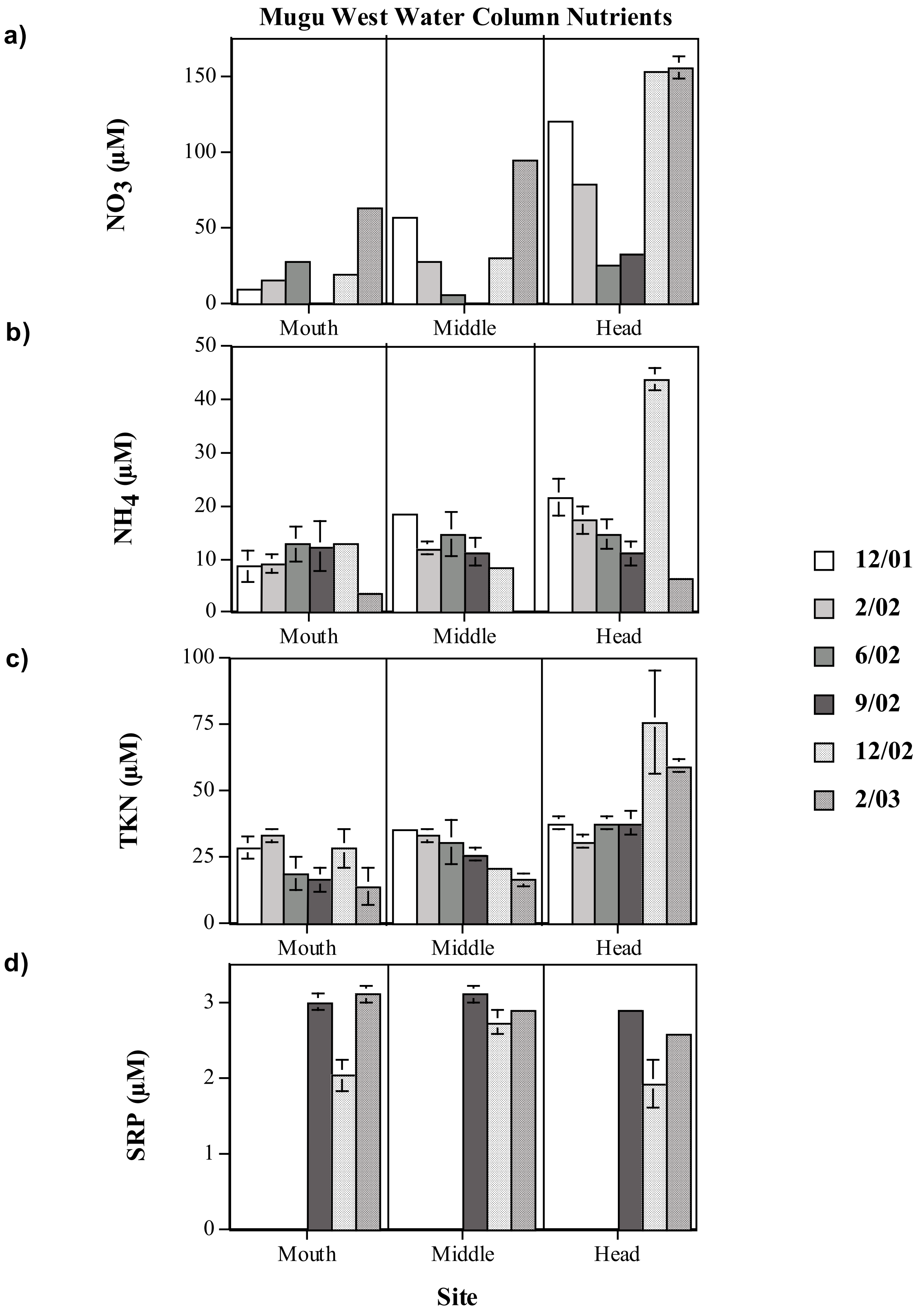

Figure 7. Mugu W water column nutrients a) NO_3 b) NH_4 c) TKN d) SRP. Samples from 9/02 at the mouth and middle were BDL for NO_3, thus NO_3 data for that month were not included in the analysis. For NH_4 data from 2/03 at the mouth n=1 and others BDL and all middle samples were BDL; thus data for this month were not included in the analysis.

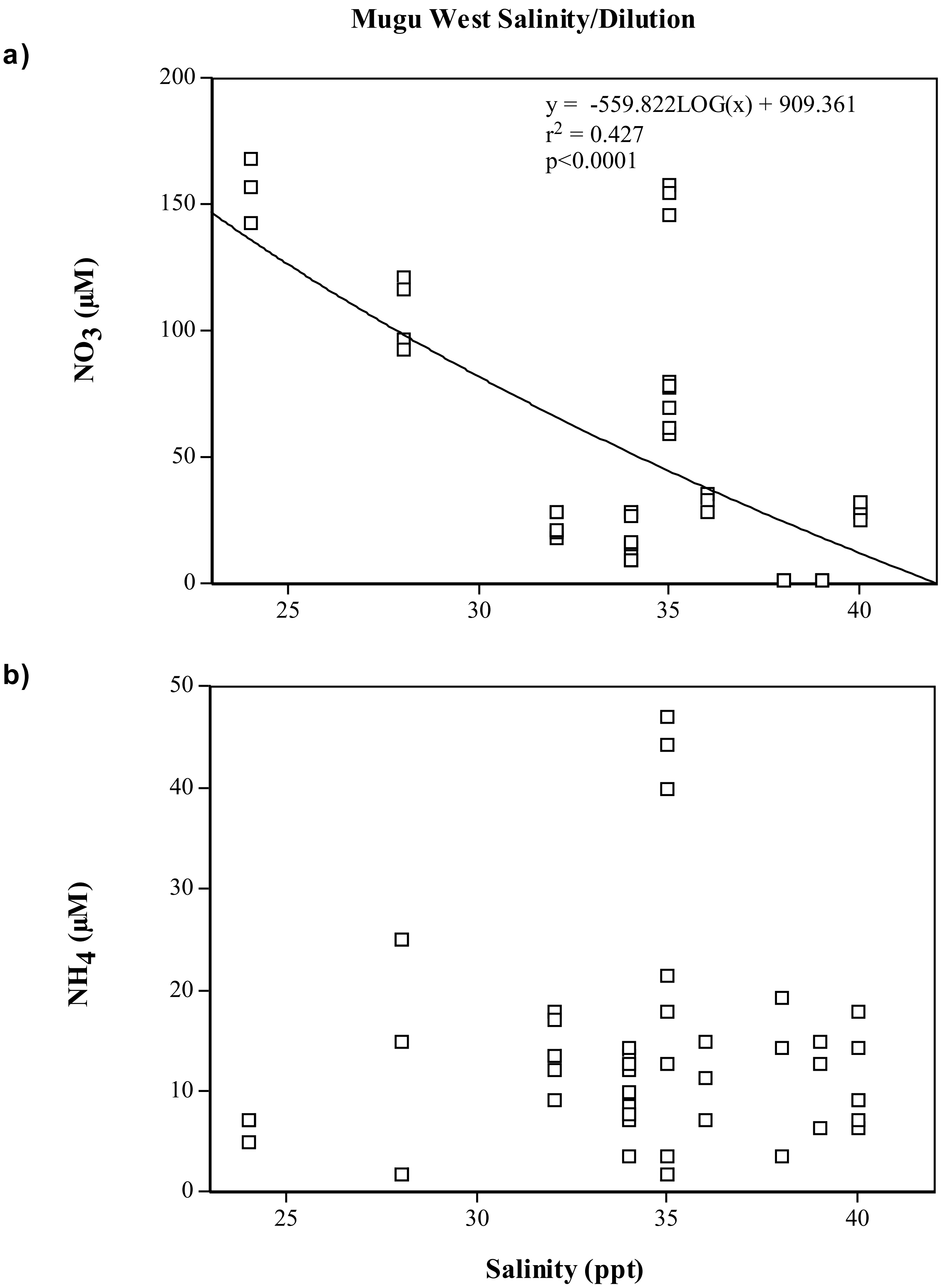

Figure 8. Mugu W salinity/dilution curves. Raw data were used and included only when both salinity and nutrients were measured for that sample a) salinity vs. water column NO_3 b) salinity vs. water column NH_4.

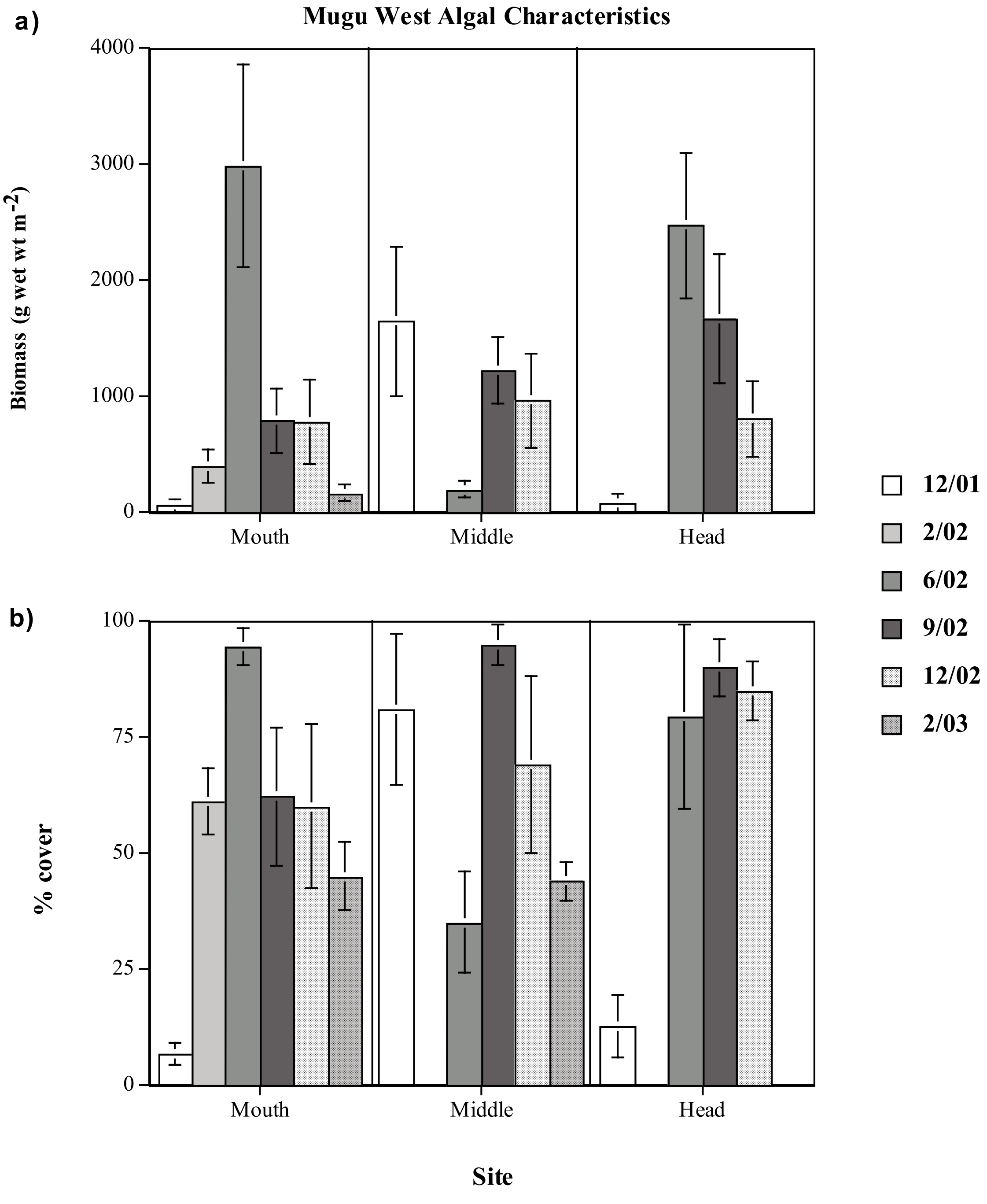

Figure 9. Mugu W macroalgal abundance a) biomass b) % cover.

a)

b)

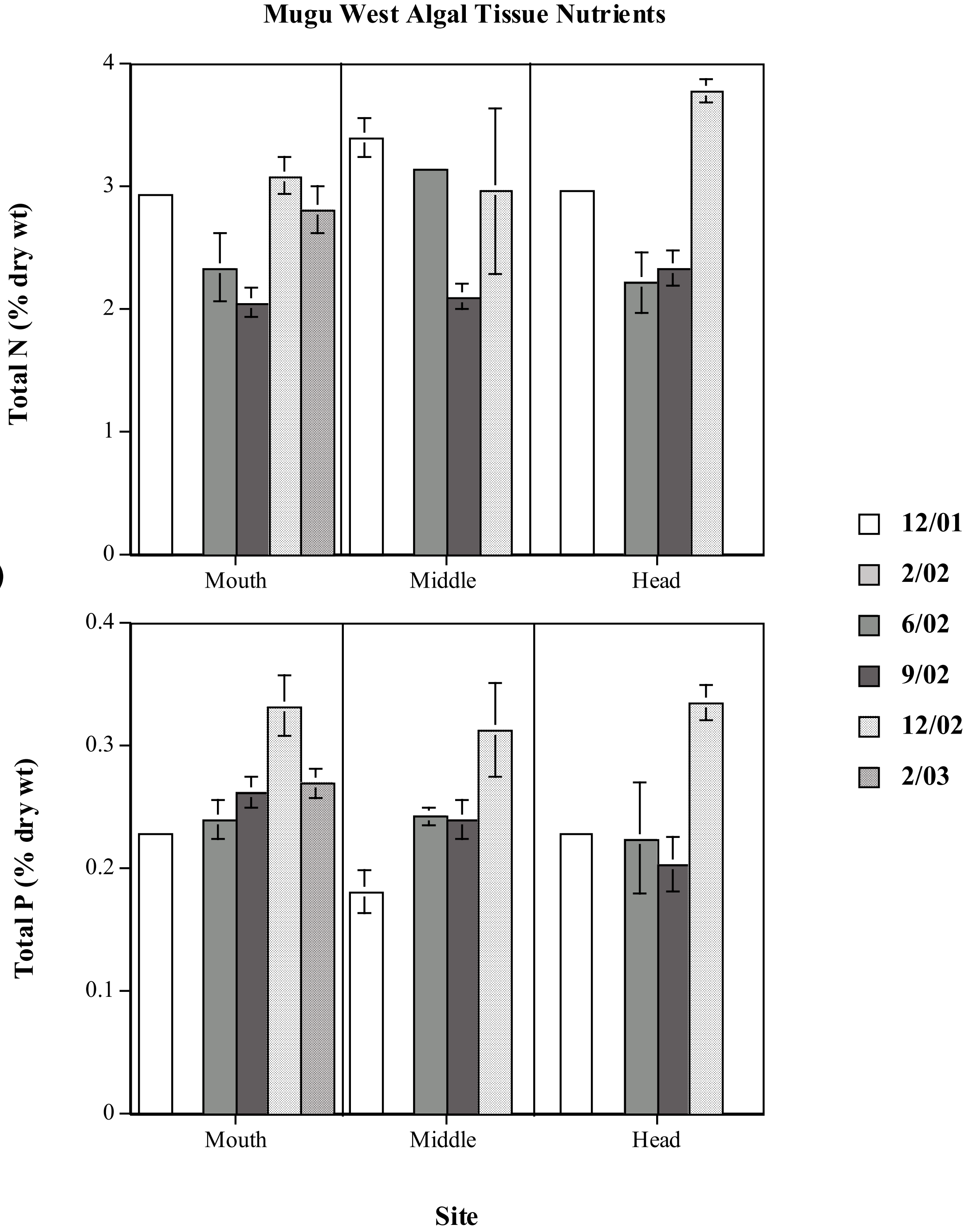

Figure 10. Mugu W macroalgal tissue nutrients a) total N b) total P. Samples size is n = 5 with the following exceptions: Total N 12/01 mouth and head, n=1, 2/02=NES, 6/02 middle n=3, head n=4, 9/02 mouth n=4, 2/03 mouth n=4, middle and head = NES, thus no data were included in the analysis for these months. Total P sample sizes are the same as total N except for 2/03 mouth n=3.

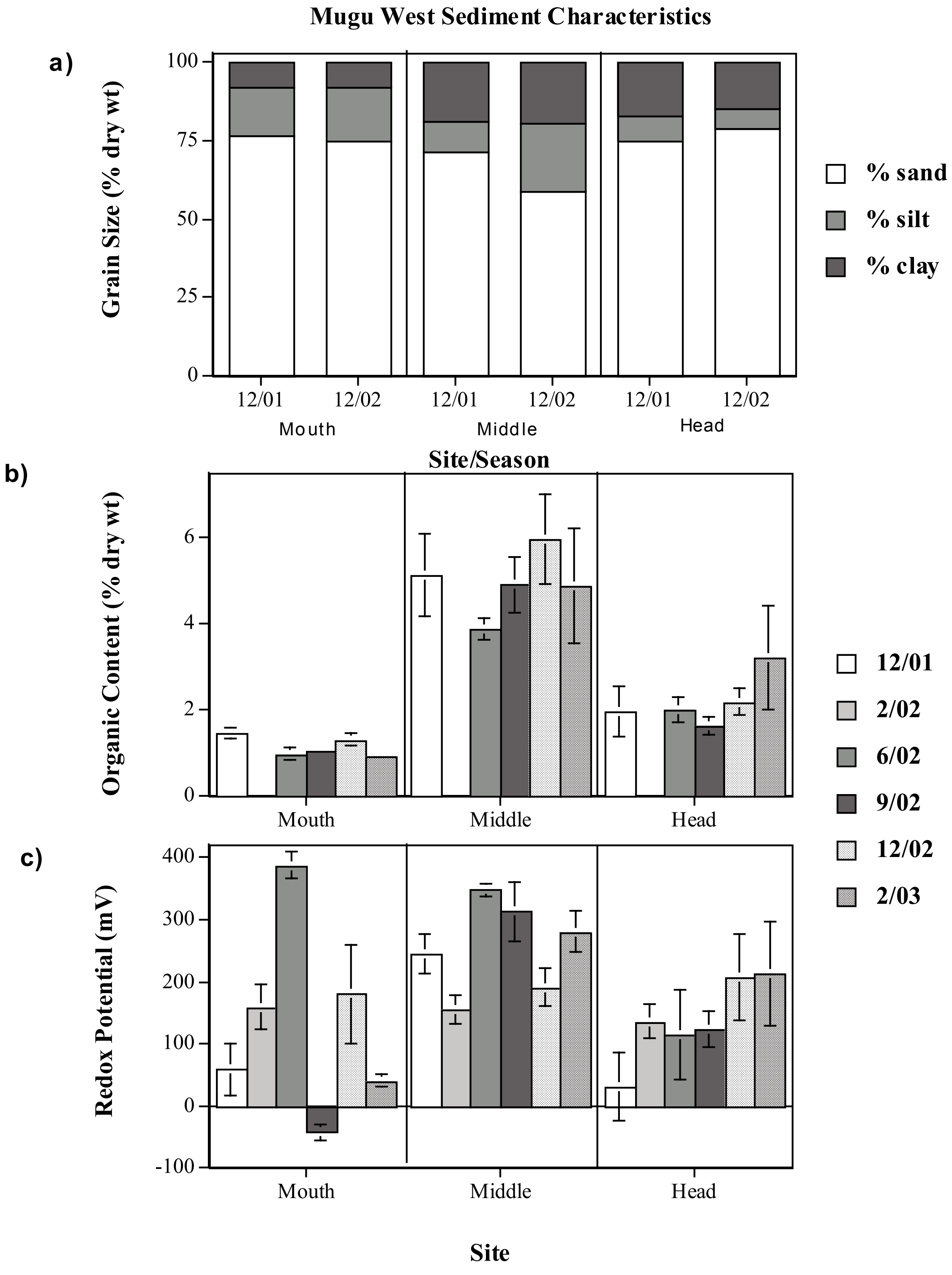

Figure 11. Mugu W sediment characteristics a) grain size b) organic content 2/02=ND c) redox potential.

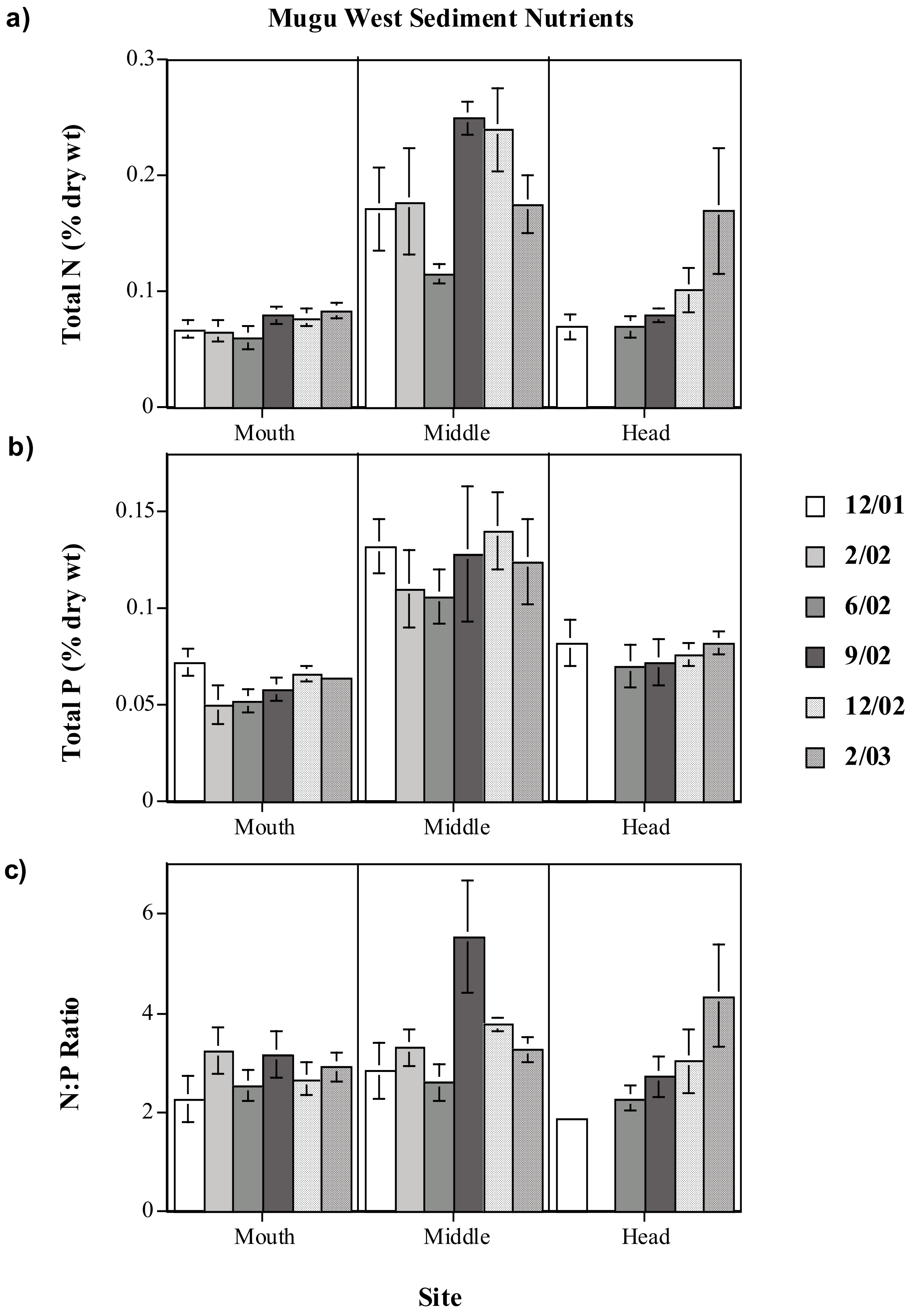

Figure 12. Mugu W sediment nutrients a) total N b) total P c) molar N:P ratio. N = 5 fo rall means, except in 2/02 there was no data for head. Thus data for this month were not included in the analysis.

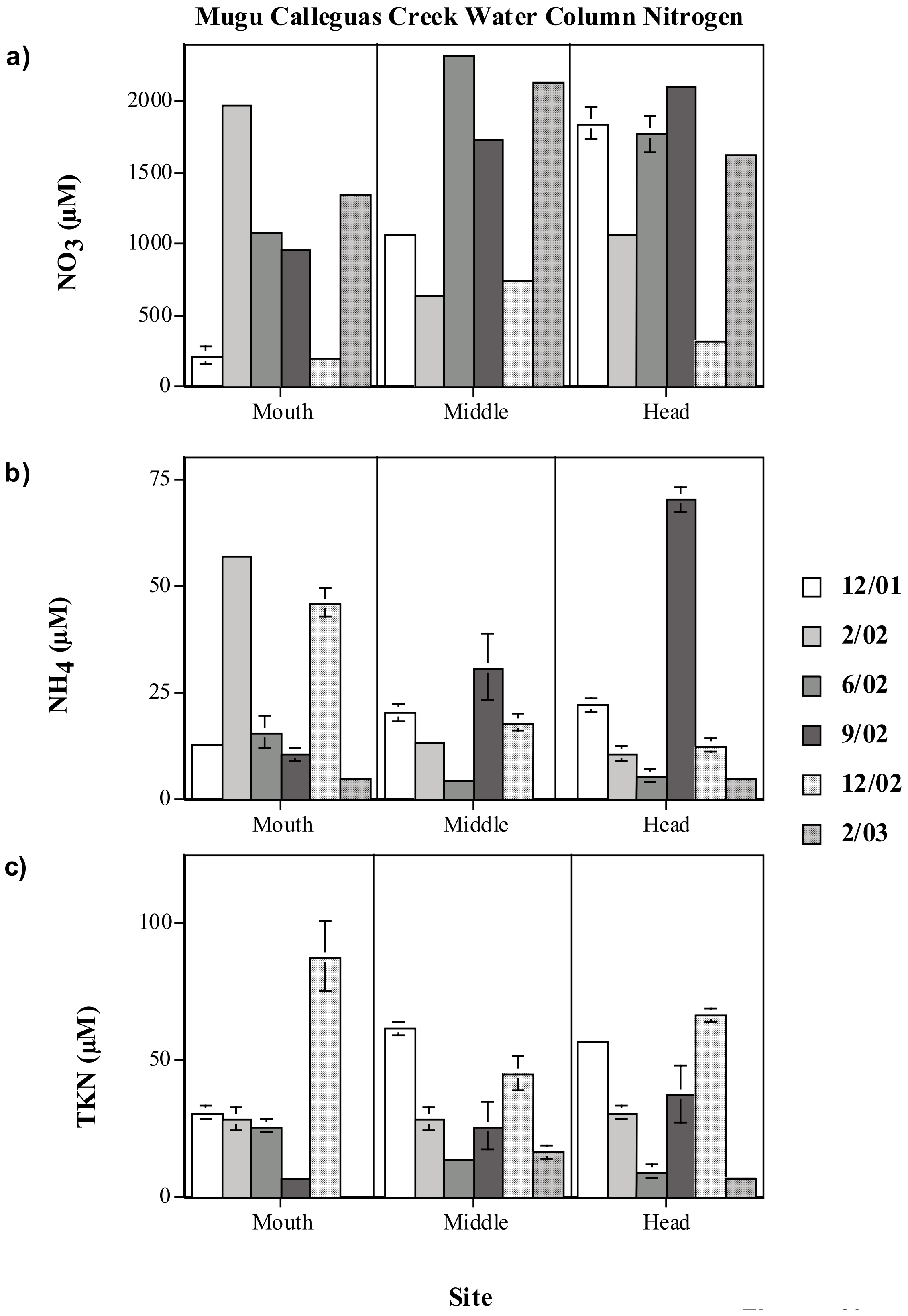

Figure 13. Mugu CC water column nitrogen a) NO_3 b) NH_4 c) TKN. All n = 5, except: For NH_4 in 2/03, mouth n=2, middle are all BDL; thus data for this month were not included in analysis. For TKN in 2/03, mouth=BDL, head n=1 thus Feb 03 data were not included in the analysis.

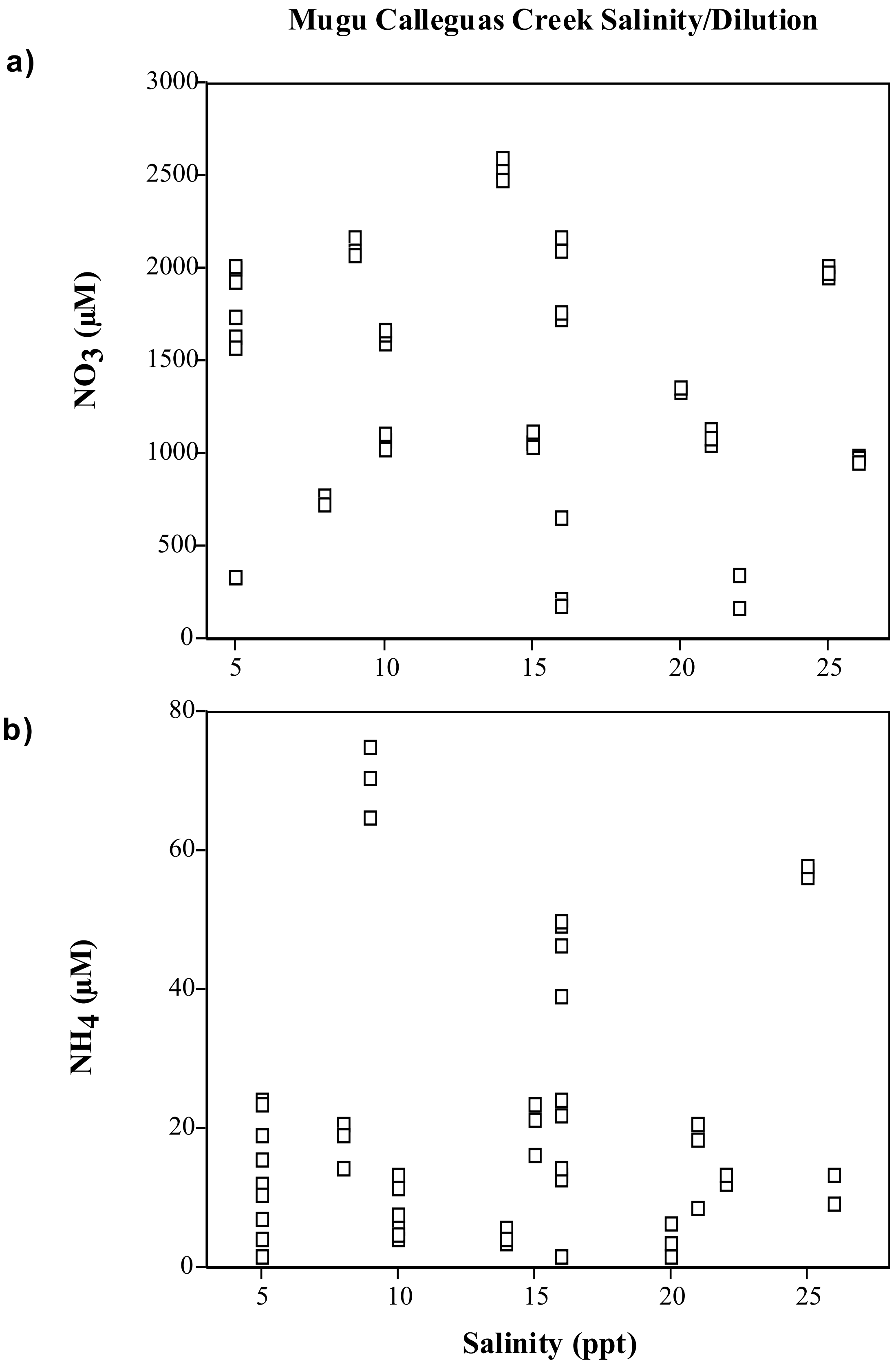

Figure 14. Mugu CC salinity/dilution curves. Raw data were used and included only when both salinity and nutrients were measured for that sample a) salinity vs. water column NO_3 b) salinity vs. water column NH_4.

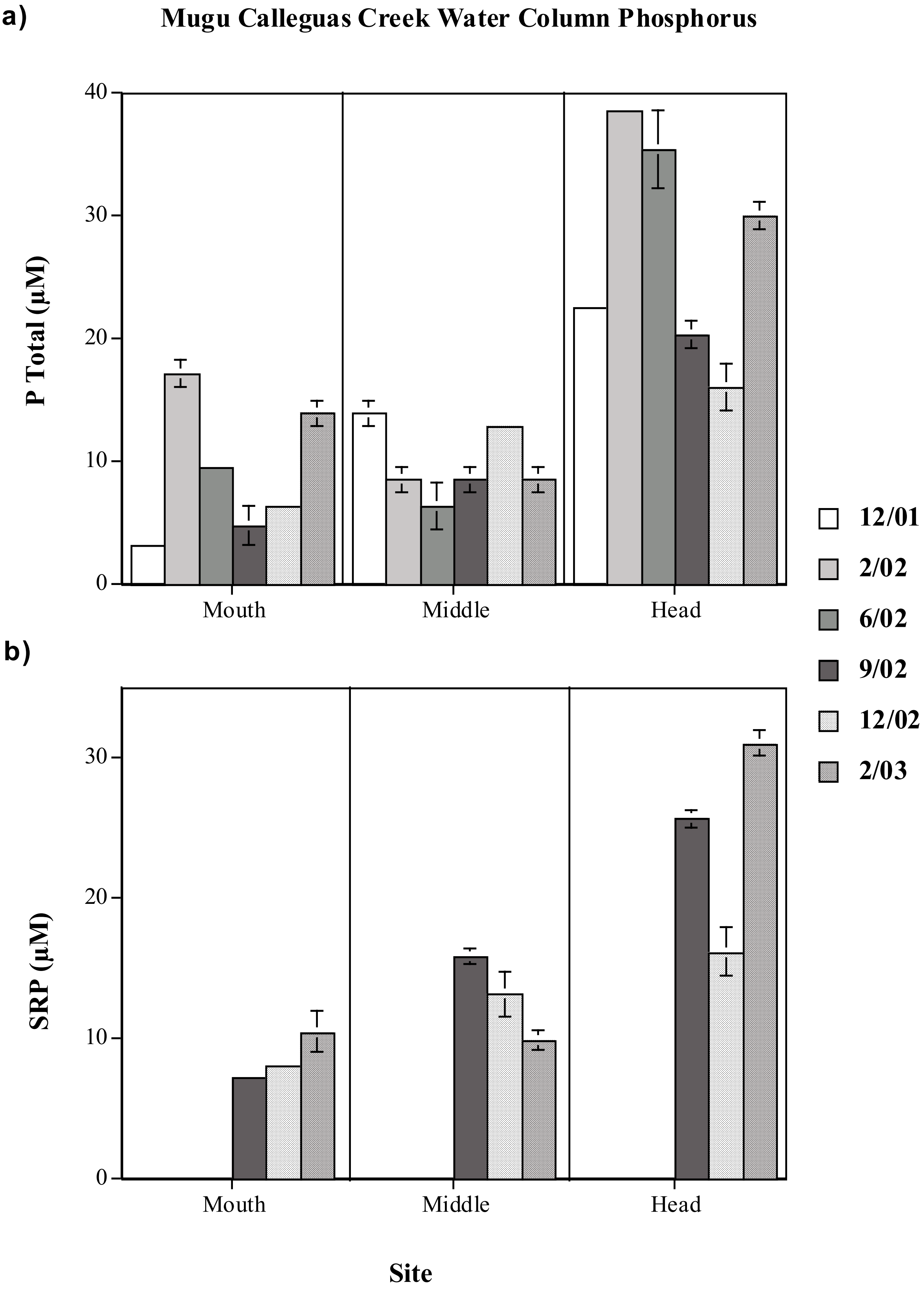

Figure 15. Mugu CC water column phosphorus a) total P b) SRP.

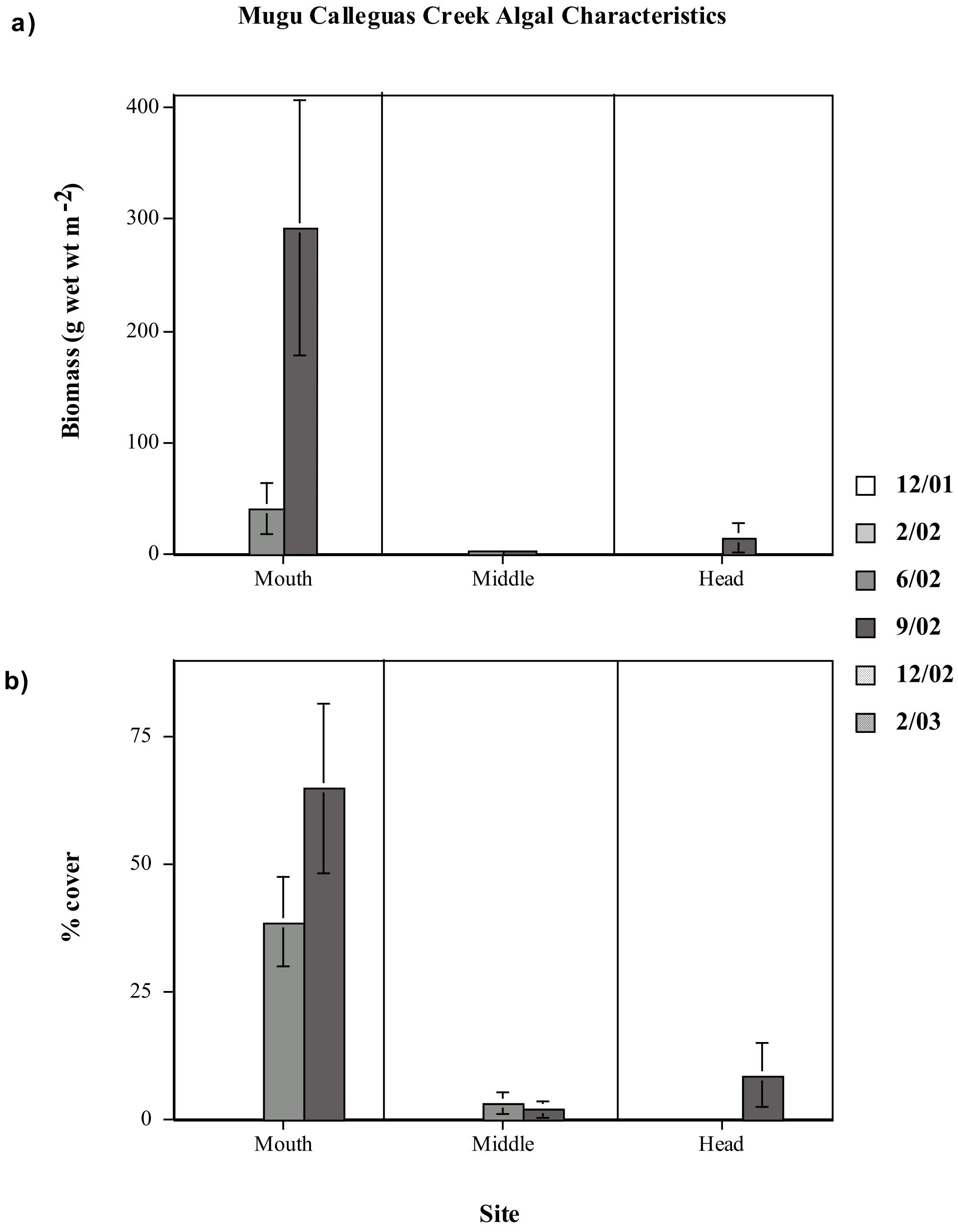

Figure 16. Mugu CC macroalgal abundance a) biomass b) % cover.

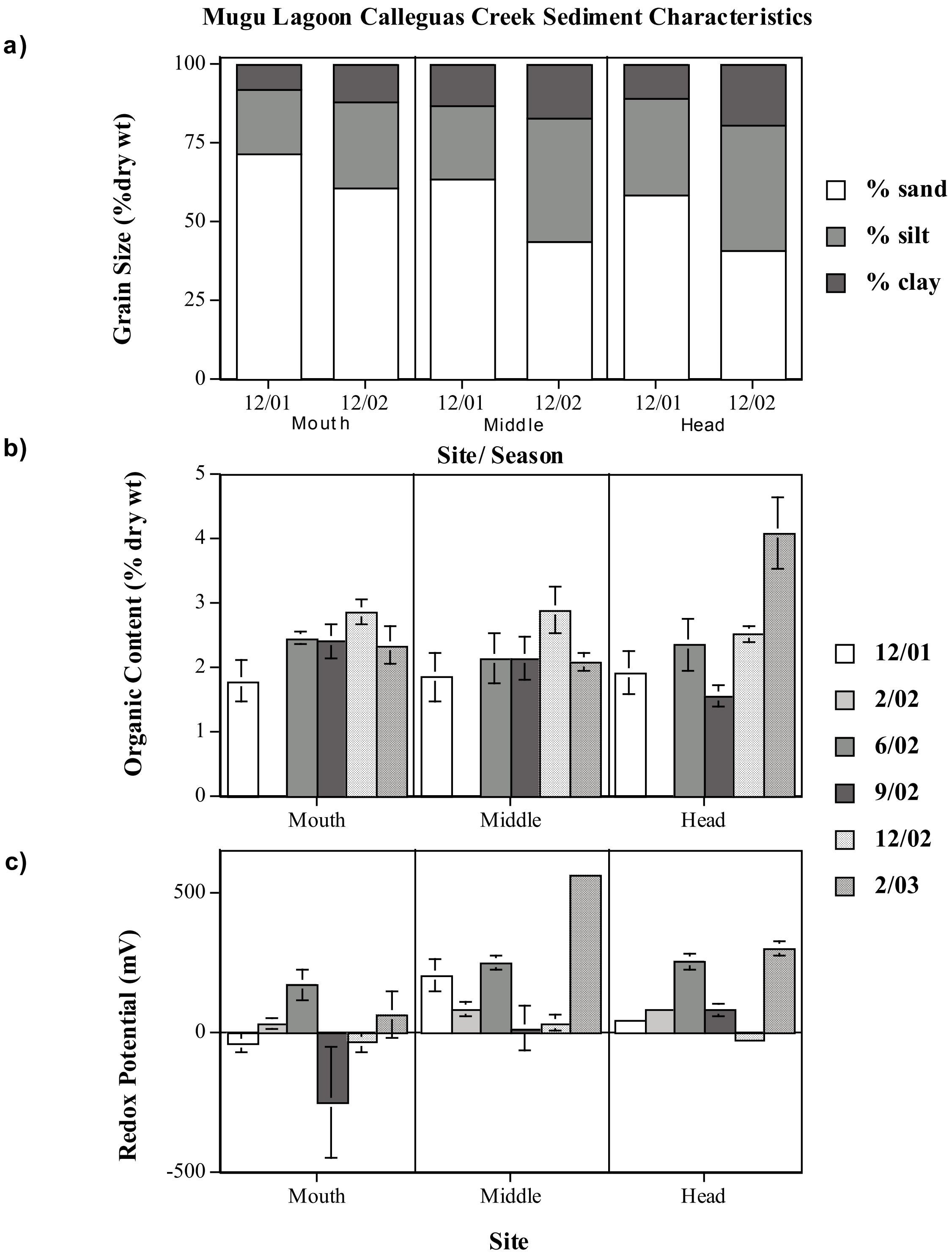

Figure 17. Mugu CC sediment characteristics a) grain size b) organic content 2/02=ND c) redox potential.

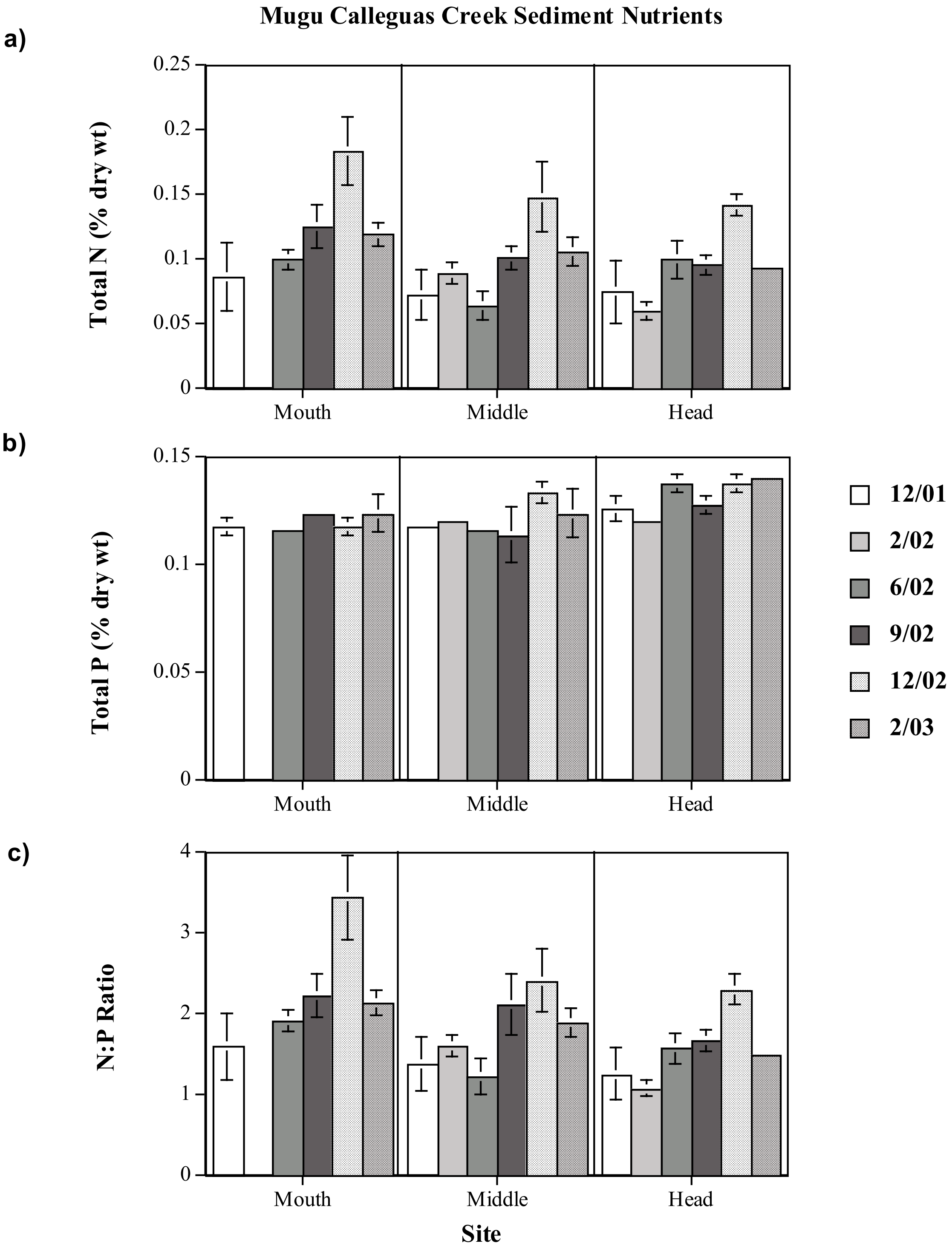

Figure 18. Mugu CC sediment nutrients a) total N b) total P c) molar N:P ratio. All n = 5, except in 2/02, when there was ND for any nutrient for the mouth. For Total N, in 2/02 n = 4 for the head. Sampling periods without complete data sets were not included in analysis.

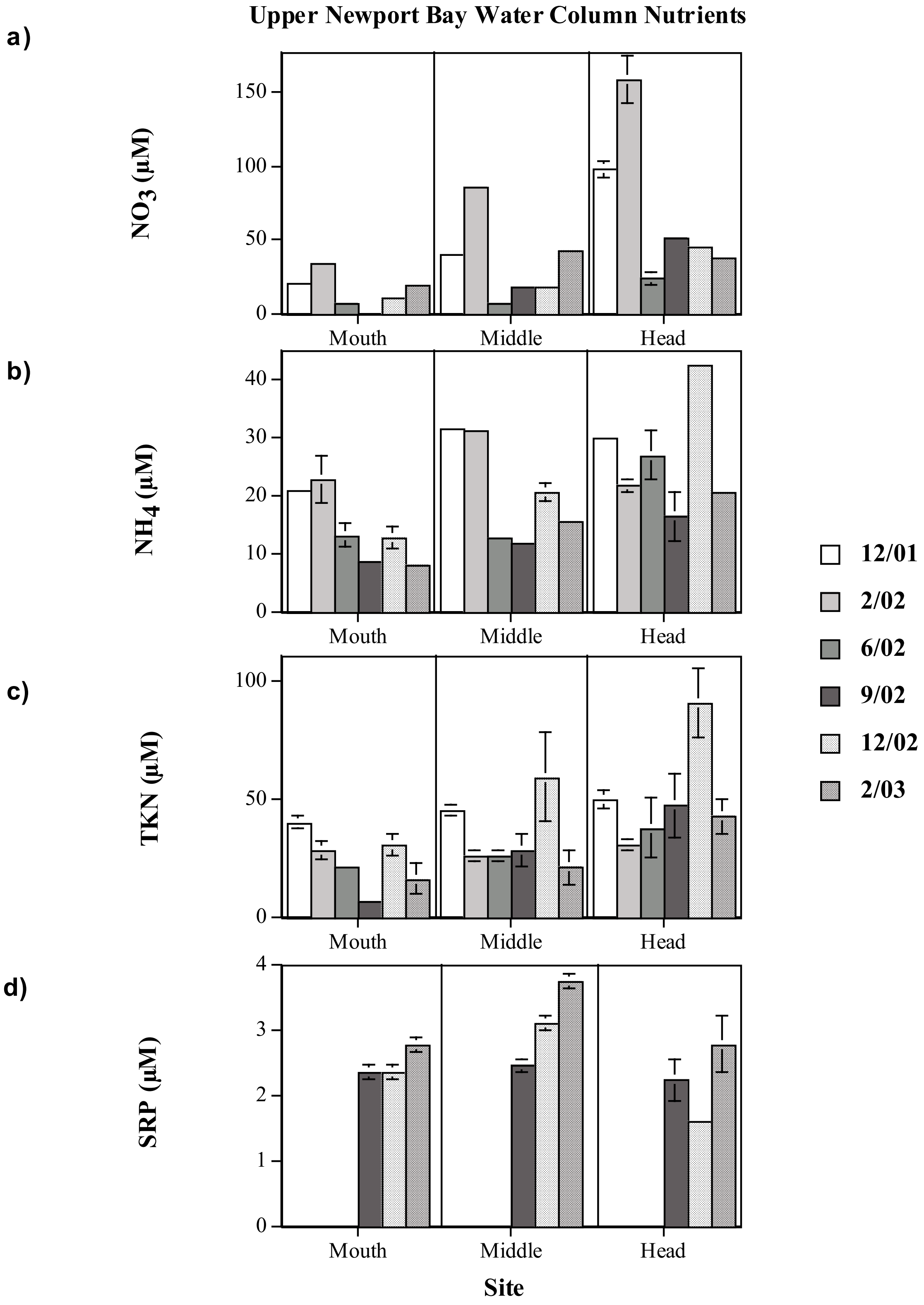

Figure 19. UNB water column nutrients a) NO_3 b) NH_4 c) TKN d) SRP. All n = 3, except for NO_3 in 9/02 at the mouth where all samples were BDL; thus data for this month were not included in analysis.

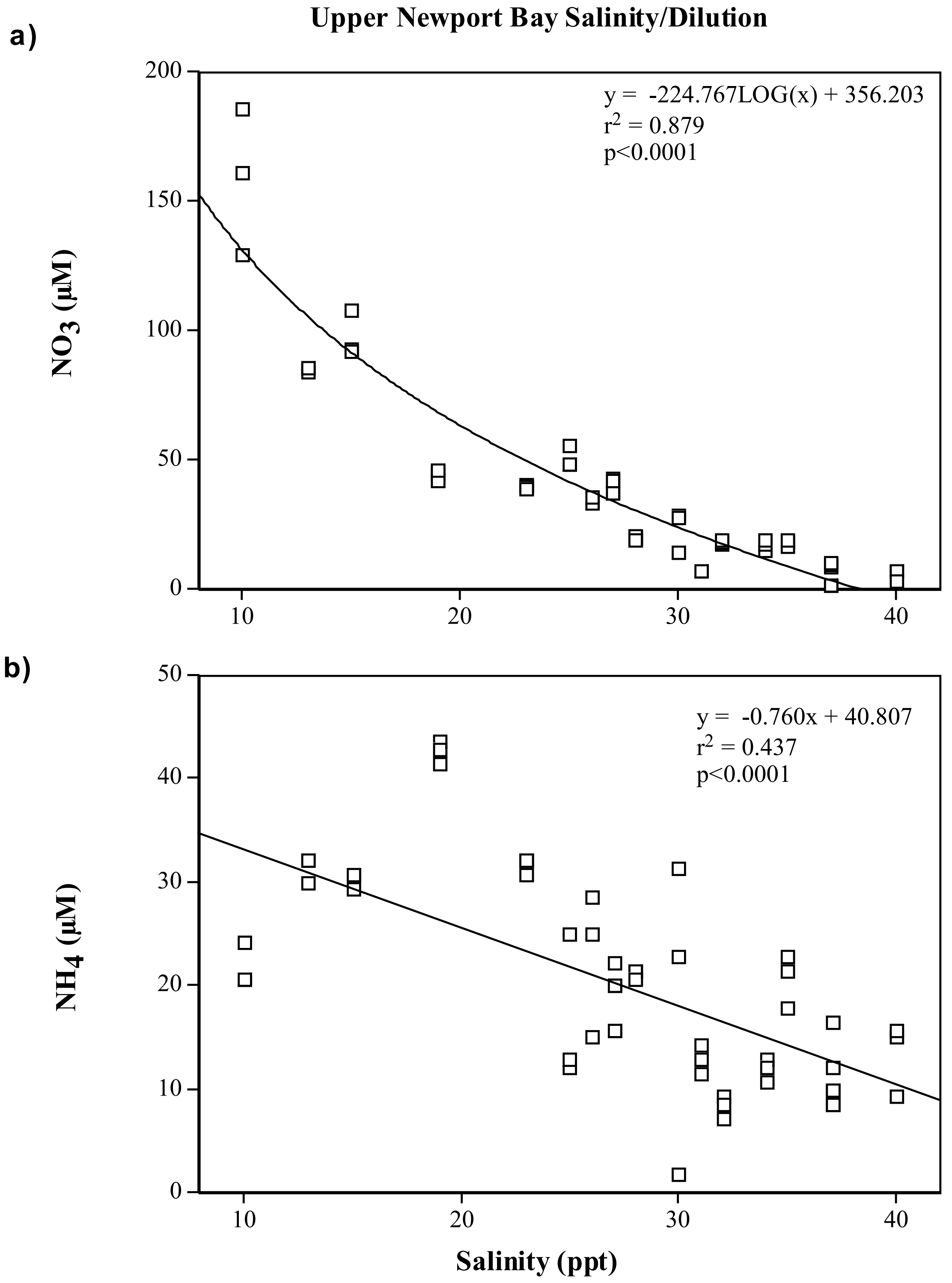

Figure 20. UNB salinity/dilution curves. Raw data were used and included only when both salinity and nutrients were measured for that sample a) salinity vs. water column NO_3 b) salinity vs. water column NH_4.

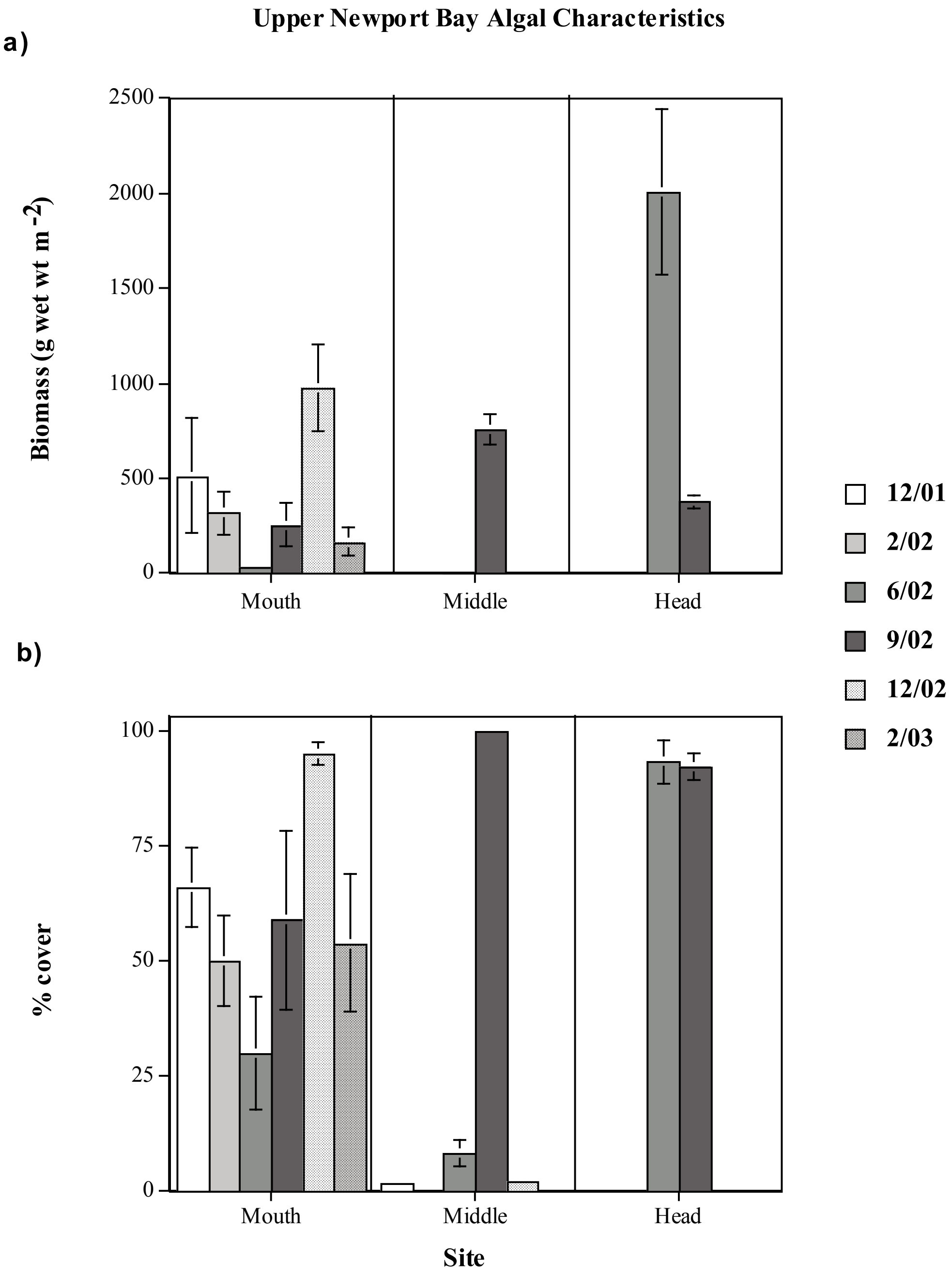

Figure 21. UNB macroalgal abundance a) biomass b) % cover.

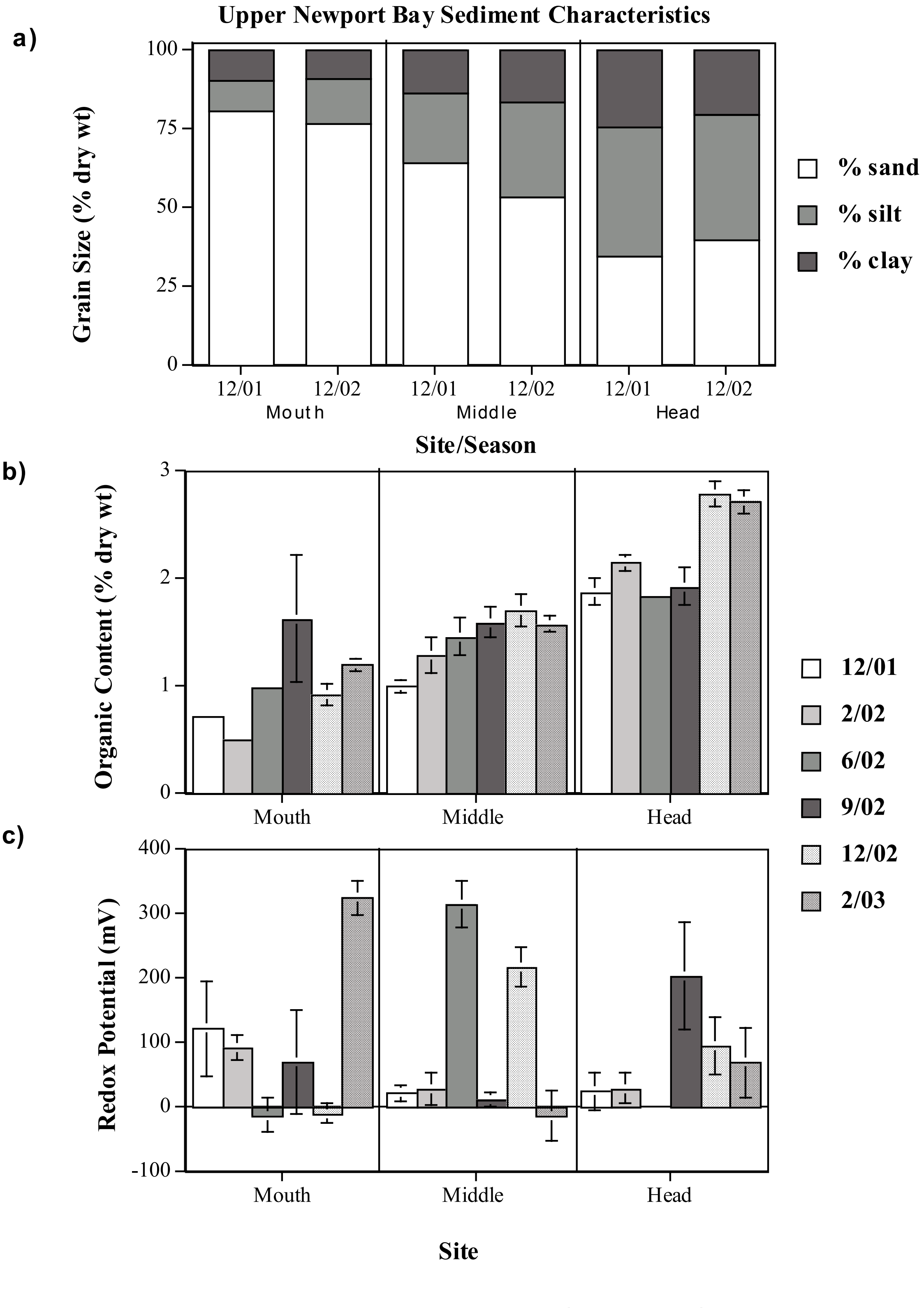

Figure 22. UNB sediment characteristics a) grain size b) organic content c) redox potential. All samples n = 5, except for 6/02 at the head where no data were collected, and thus were not included in the analysis.

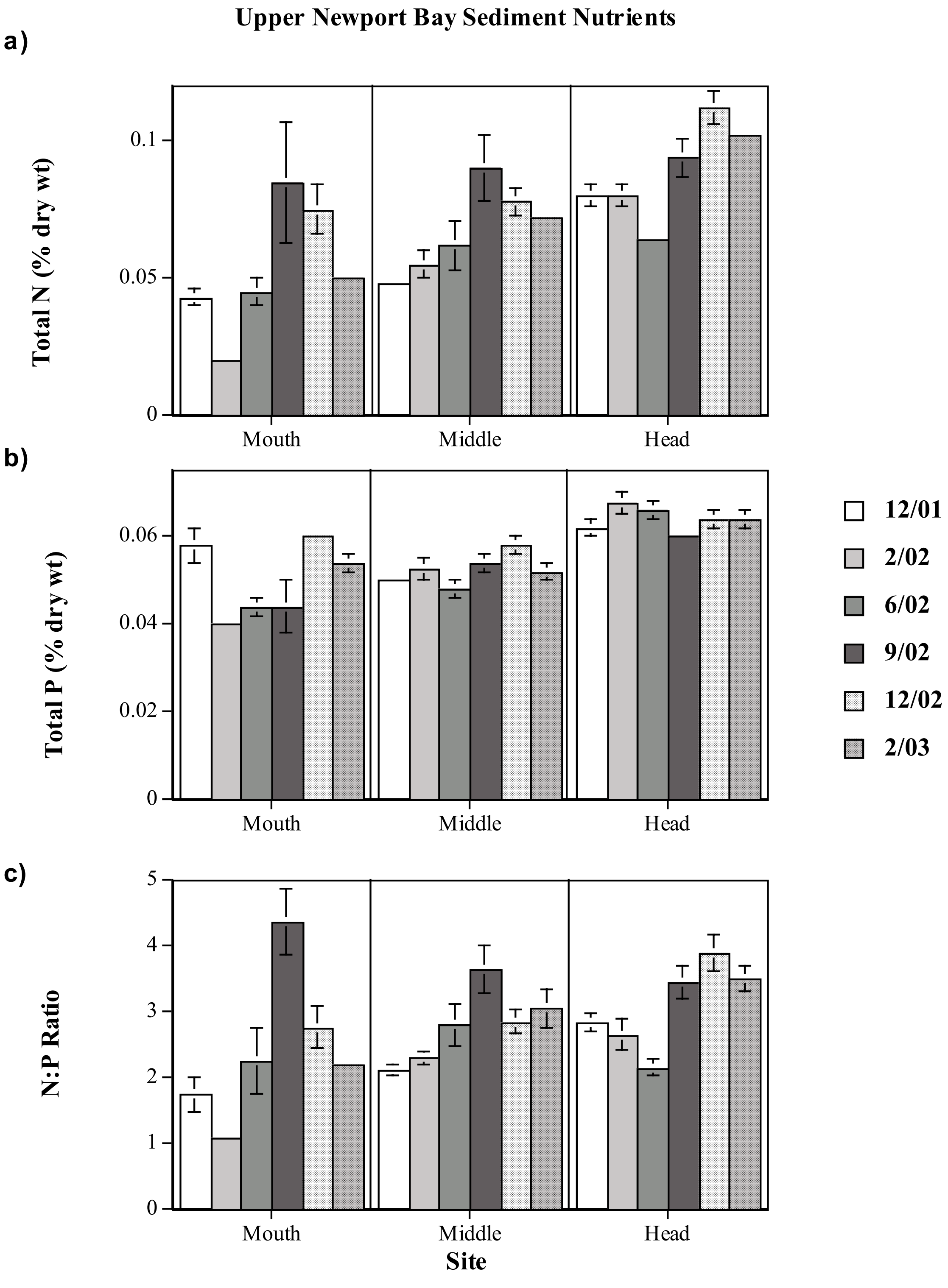

Figure 23. UNB sediment nutrients a) total N b) total P c) N:P molar ratio. For all means n = 5, except: total N in 12/01 at the mouth n=3, in 2/02 at the mouth n=1, in 6/02 at the mouth n=2, in 9/02 at the mouth n=4, in 12/02 at the mouth n=4, at the middle n=4, in 2/03 at the mouth n=1. All samples sizes for N:P ratios are the same as for total N.

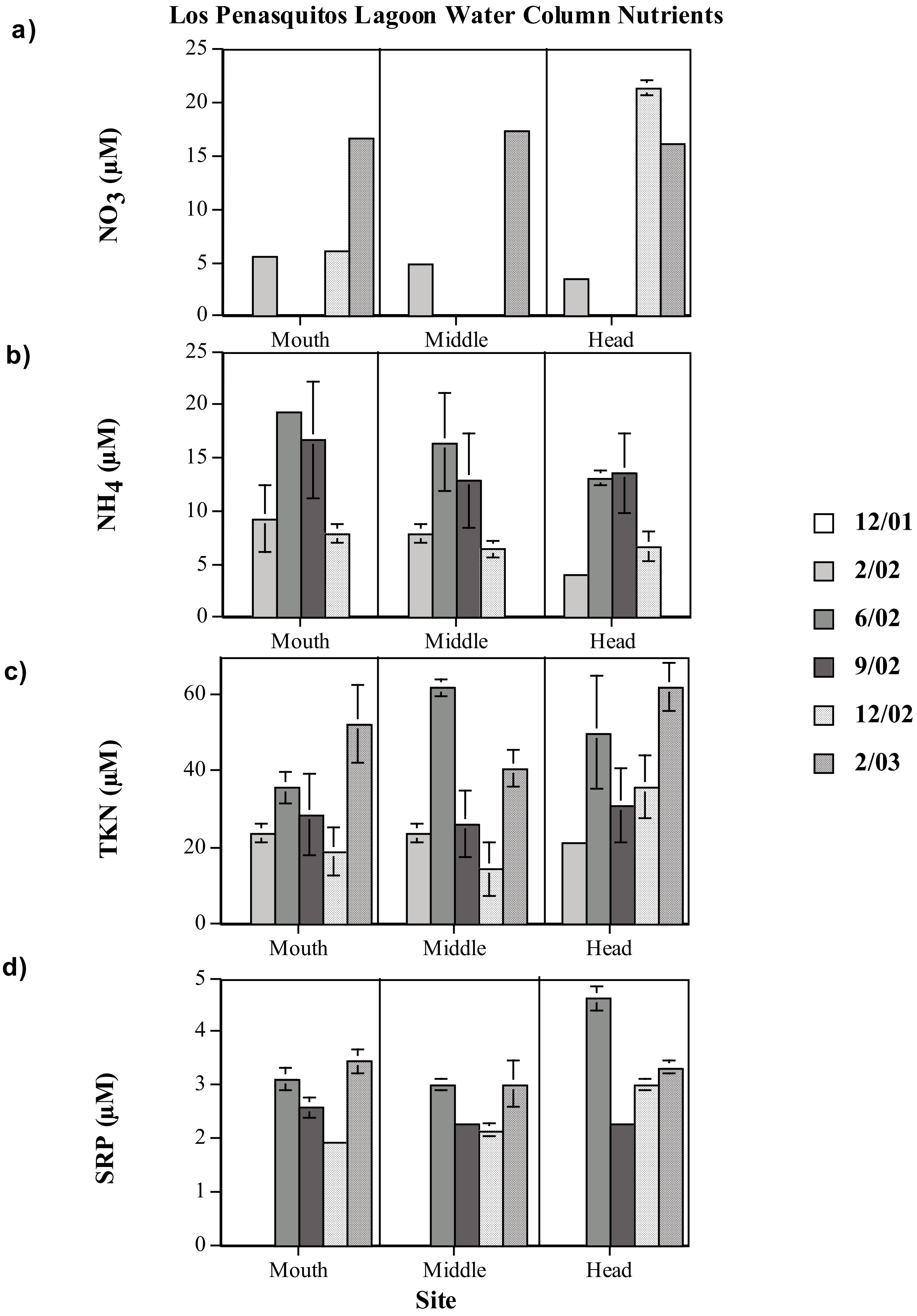

Figure 24. LPL water column nutrients a) NO_3 b) NH_4 c) TKN d) SRP. All n = 3 except: for NO_3 in 6/02 and 9/02 all samples were BDL, for 12/02 middle samples were BDL. For NH_4 in 6/02 at the mouth n=1, in 2/03 all samples BDL; thus data for these months were not included in the analysis.

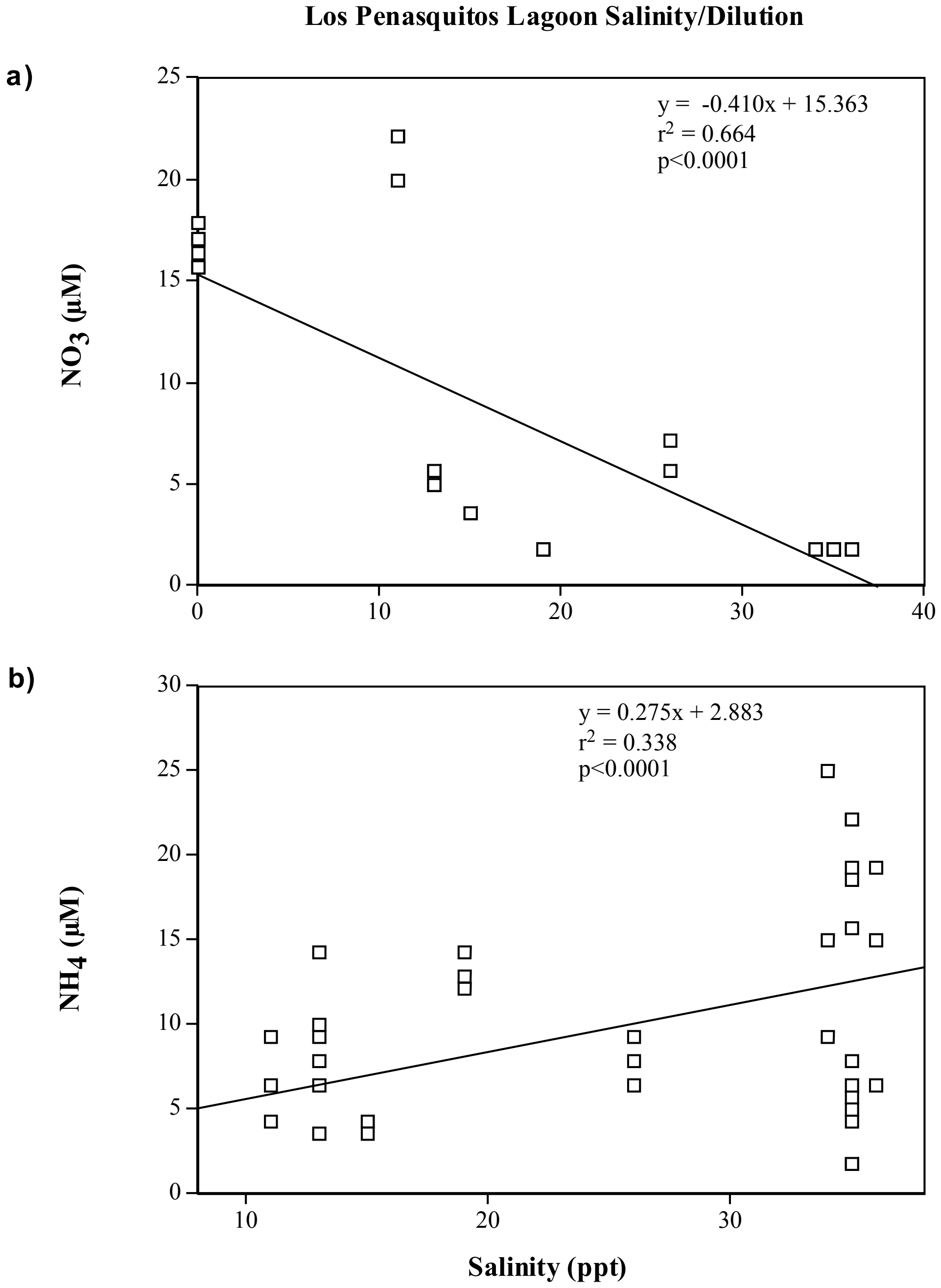

Figure 25. LPL salinity/dilution curves. Raw data were used and included only when both salinity and nutrients were measured for that sample a) salinity vs. water column NO_3 b) salinity vs. water column NH_4.

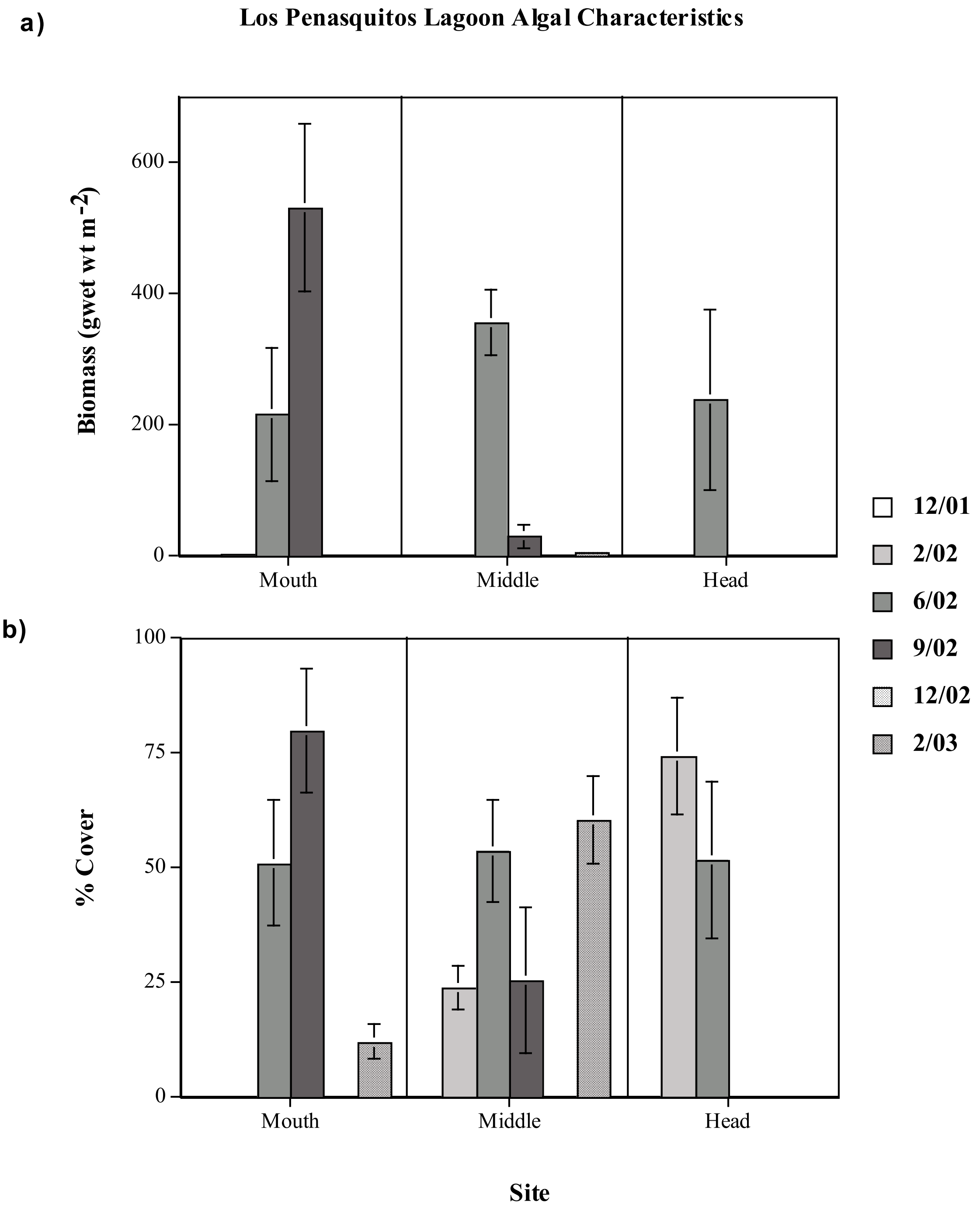

Figure 26. LPL macroalgal abundance a) biomass b) % cover

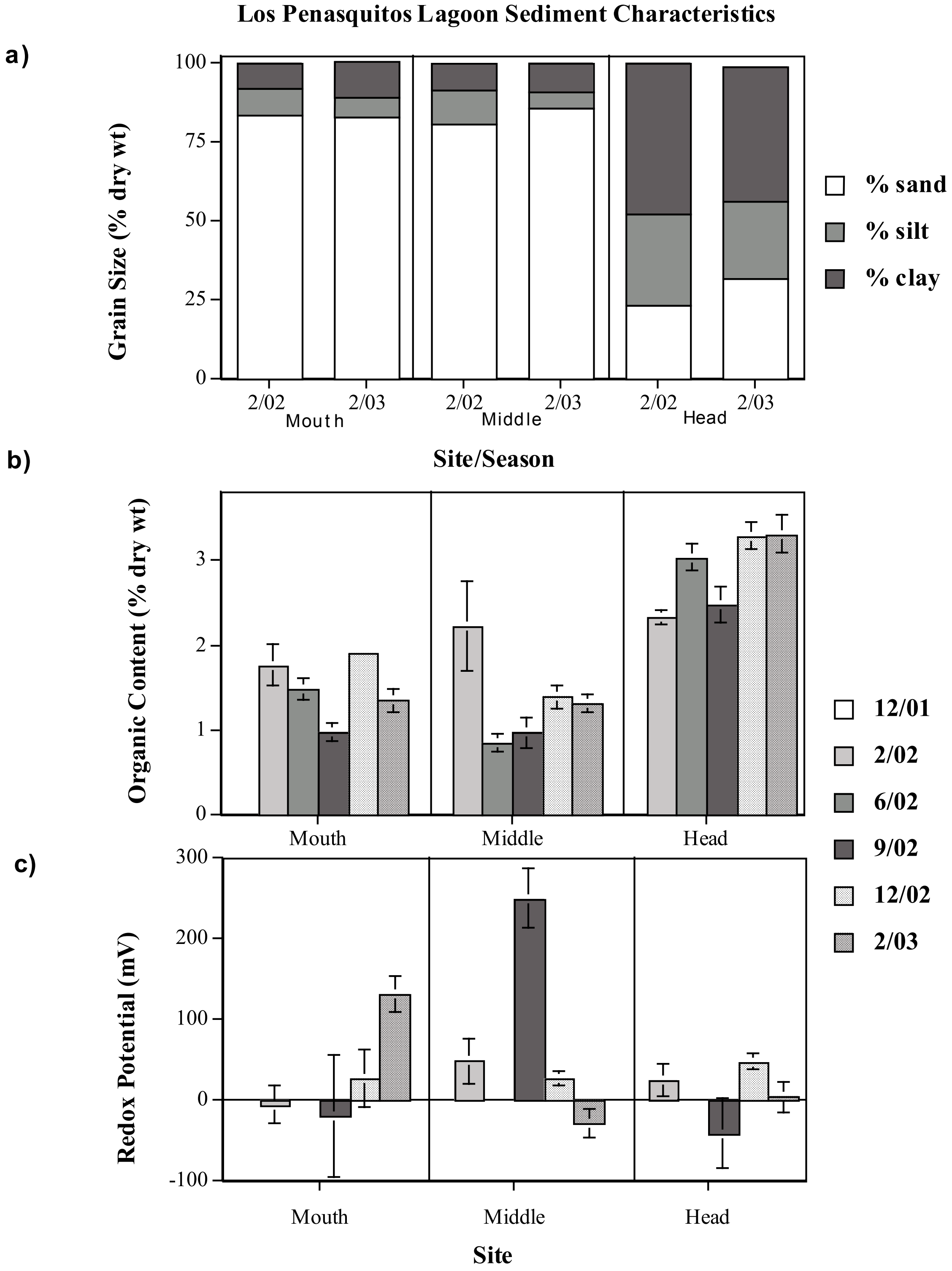

Figure 27. LPL sediment characteristics a) grain size b) organic content c) redox potential 6/02=ND.

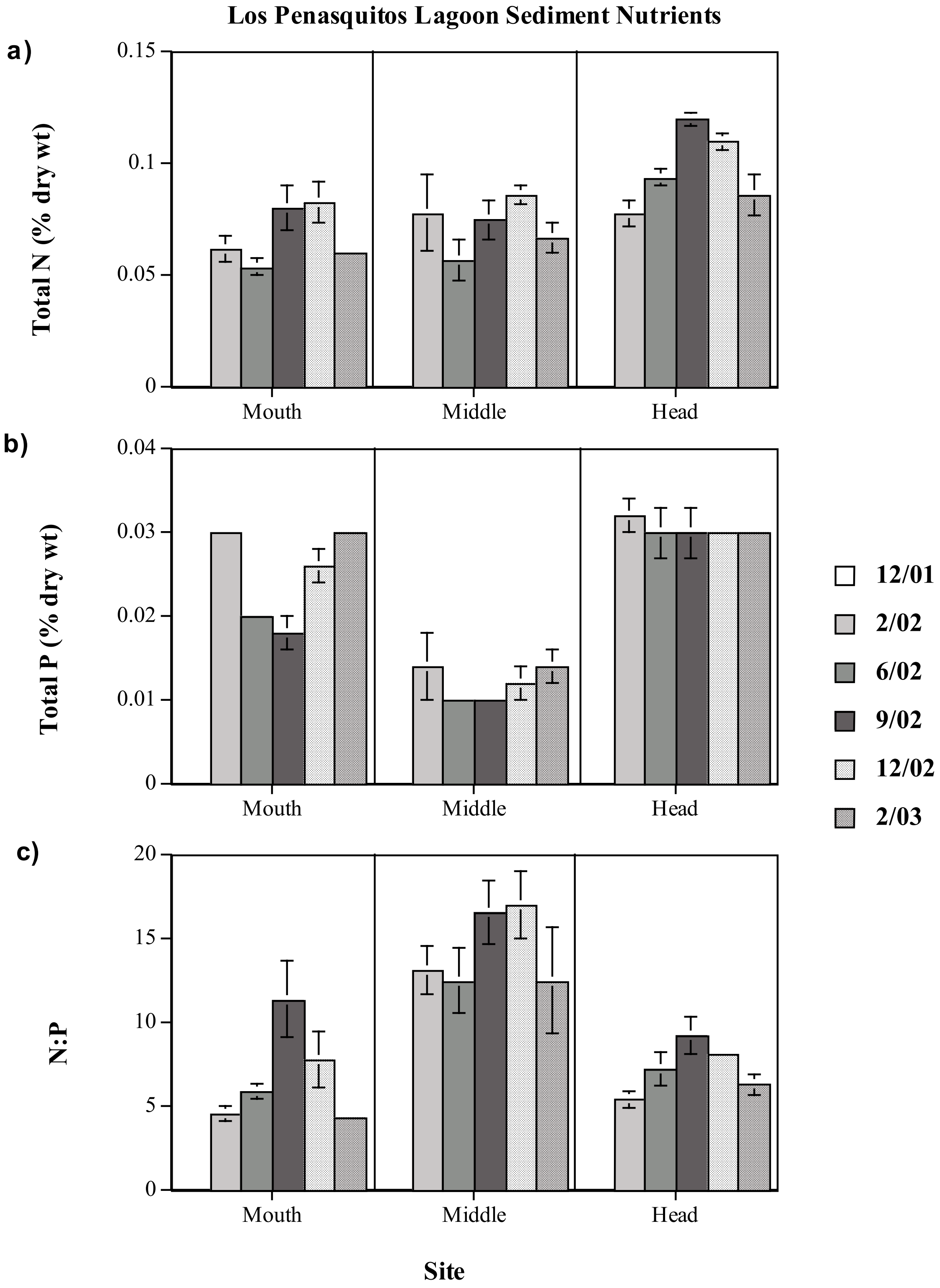

Figure 28. LPL sediment nutrients a) total N b) total P c) molar N:P ratio. All n = 5, except: for total N, in 6/02 at the middle n=3, in 9/02 at the mouth n=3 and the middle n=4, in 12/02 at the mouth n=4, in 2/03 at the mouth n=1 and middle n=3. For N:P ratios sample sizes are the same as for total N.

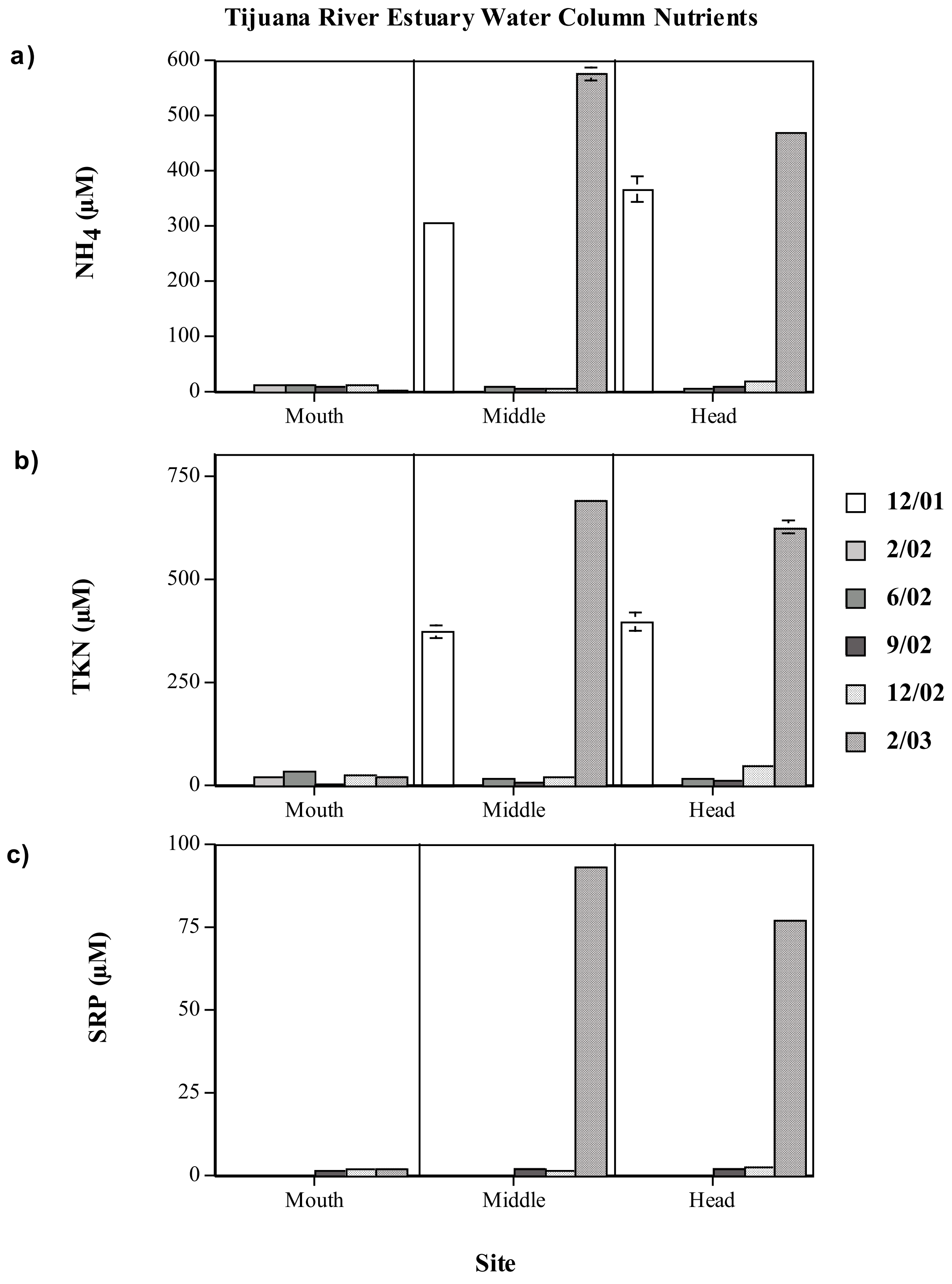

Figure 29. TJ water column nutrients. a) NH$_4$ b) TKN c) SRP. All n = 3 except: for NH$_4$ and TKN in12/01 at the mouth there is ND, and in 2/02 middle and head there is ND. For NH$_4$ in 6/02 at the middle n=2, in 9/02 at the middle n=2, in 2/03 at the mouth=1. Months without complete data sets are not included in analysis.

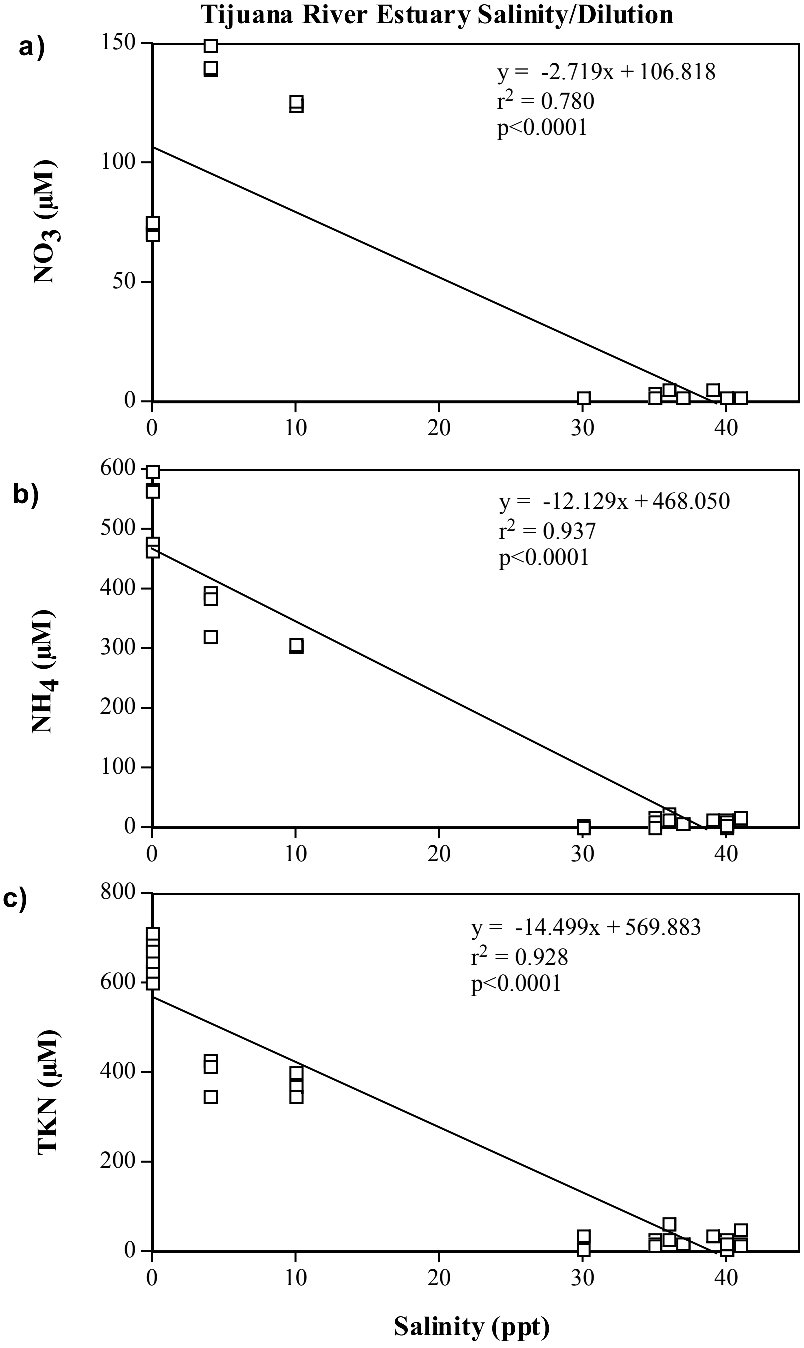

Figure 30. TJ salinity/dilution curves. Raw data were used and included only when both salinity and nutrients were measured for that sample a) salinity vs. water column NO_3 b) salinity vs. water column NH_4.

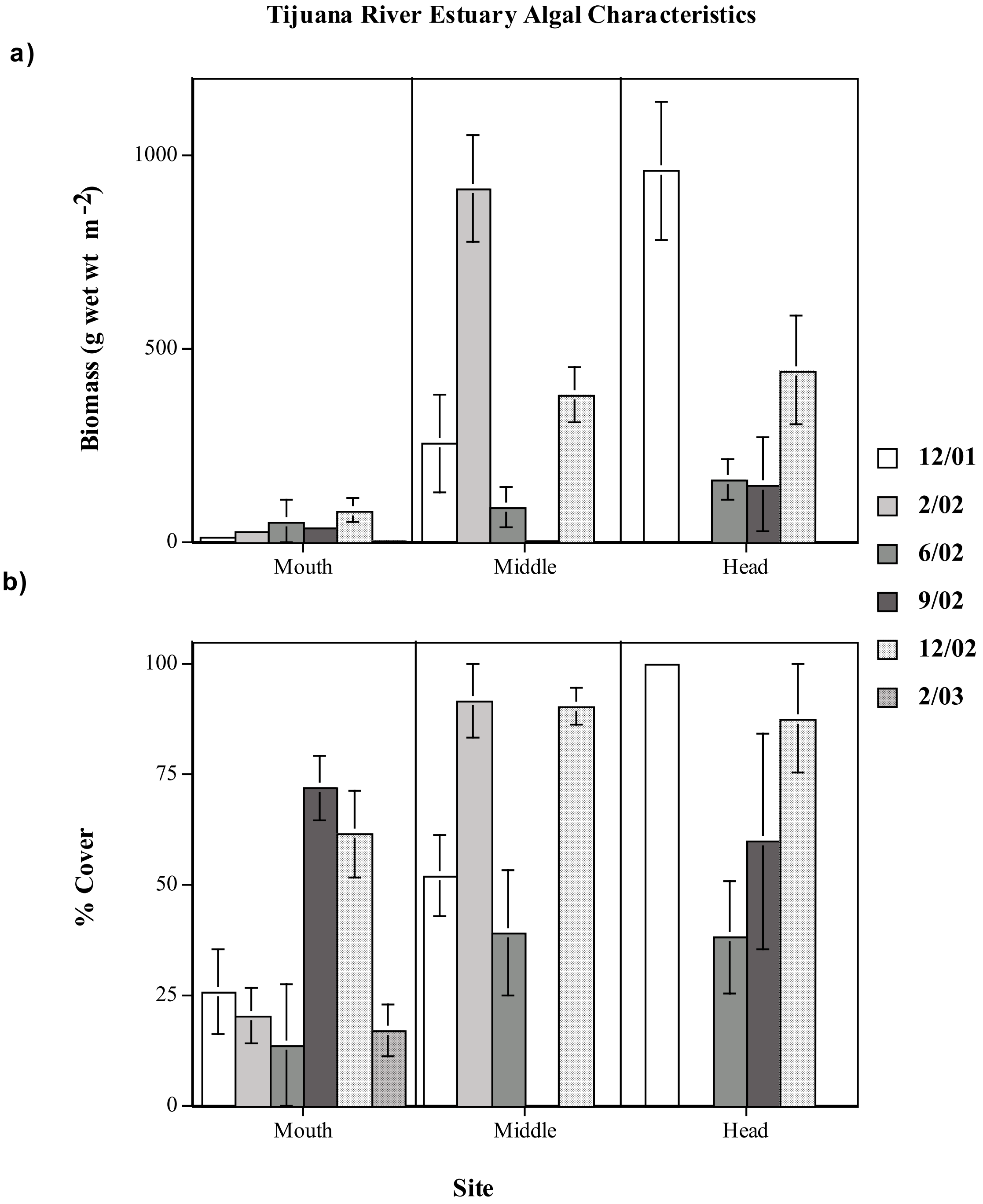

Figure 31. TJ macroalgal abundance a) biomass b) % cover. N = 5 for all means, except in 2/02 where no data was collected at the head, and for biomass in 2/02 at the mouth where n=1, and in 9/02 at the mouth where n=4.

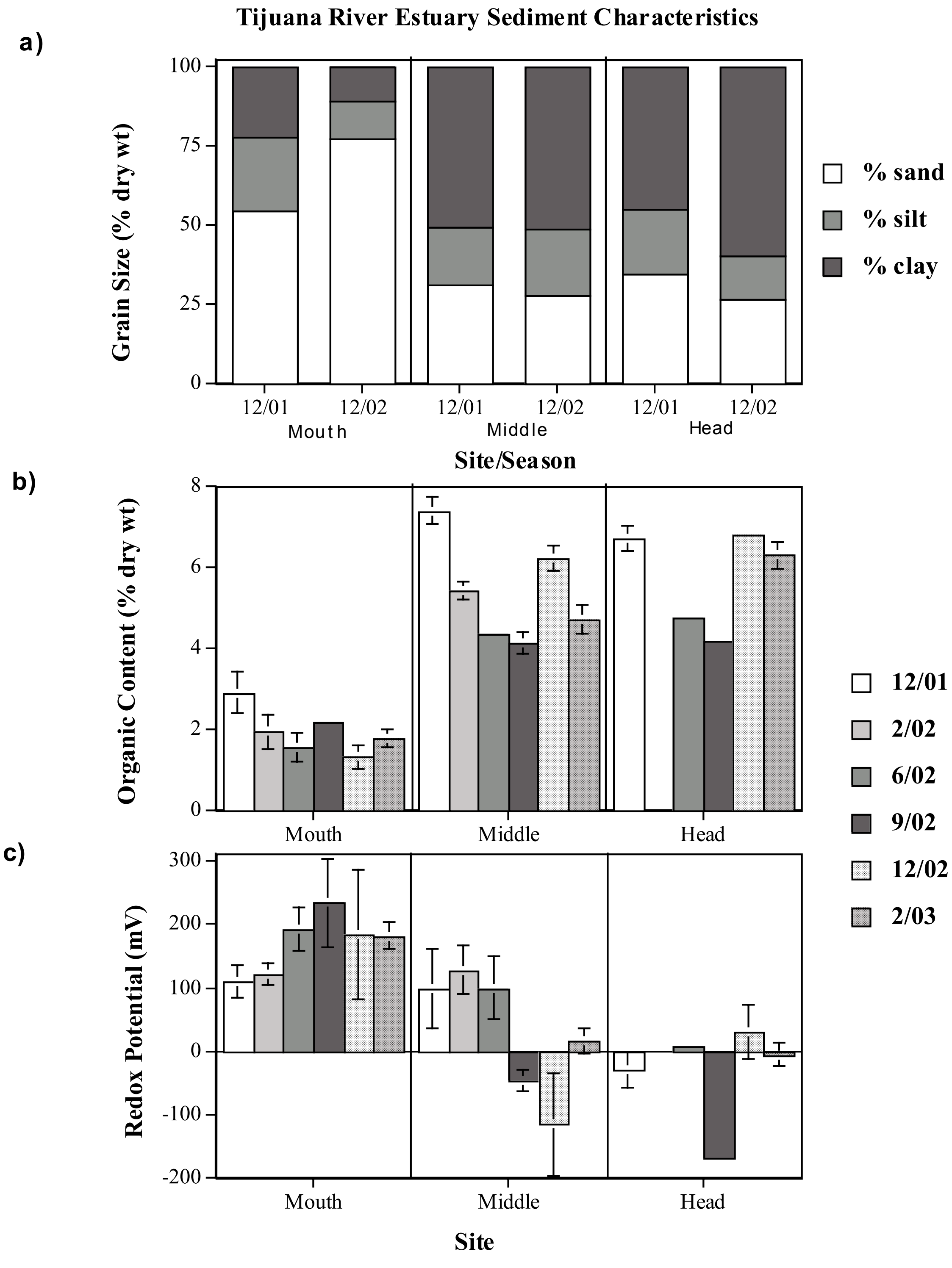

Figure 32. TJ sediment characteristics a) grain size b) organic content 2/02=ND c) redox potential. All samples sizes n = 5 except or organic content and redox, in 2/02 where no data was collected.

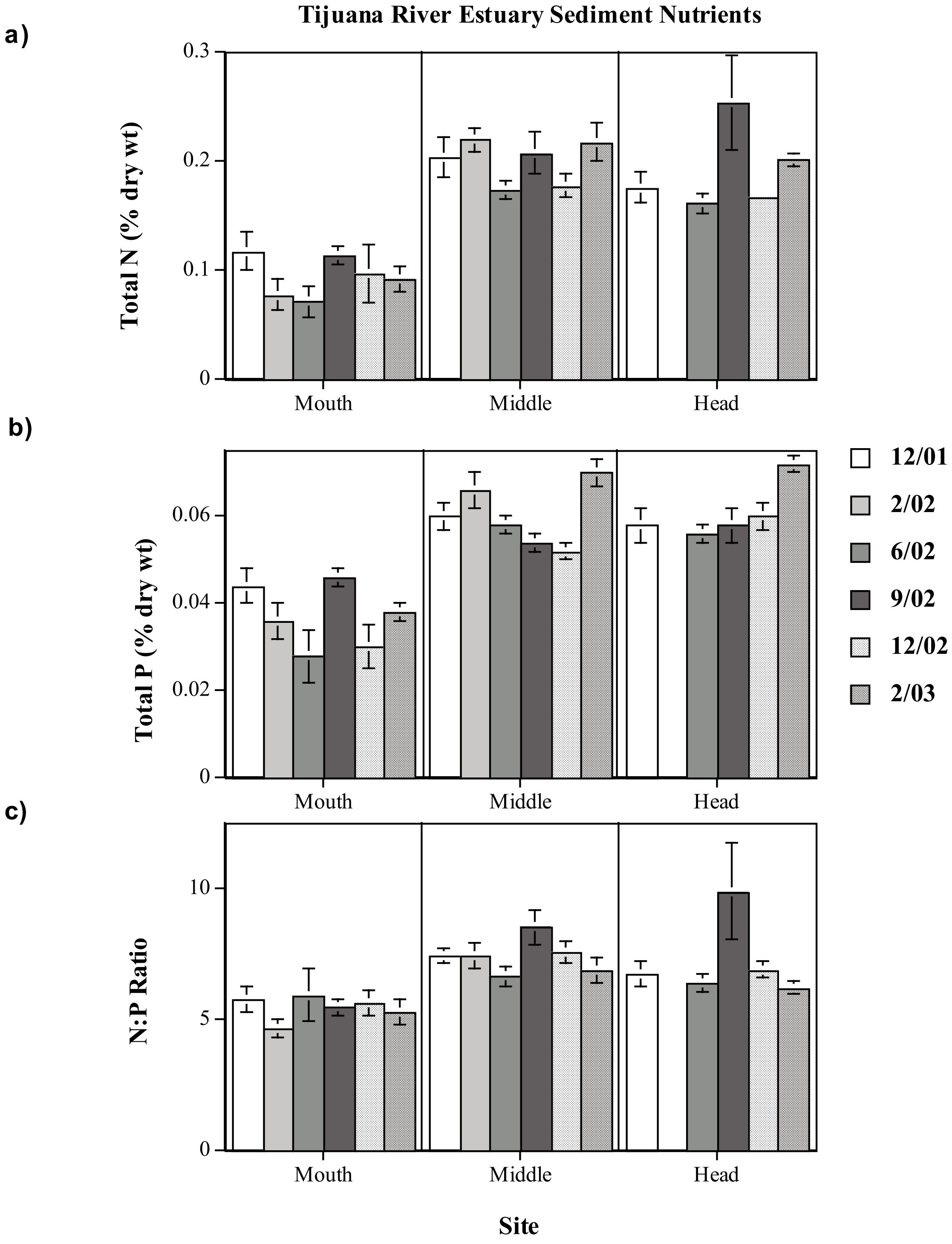

Figure 33. TJ sediment nutrients a) total N b) total P c) molar N:P ratio. All n = 5, except no samples were collected in 2/02 at the head. For total N, in 6/02 at the mouth n=4, in 12/02 at the mouth n=3. N:P ratio sample sizes were the same as for total N. Only months with complete data sets were included in the analysis.

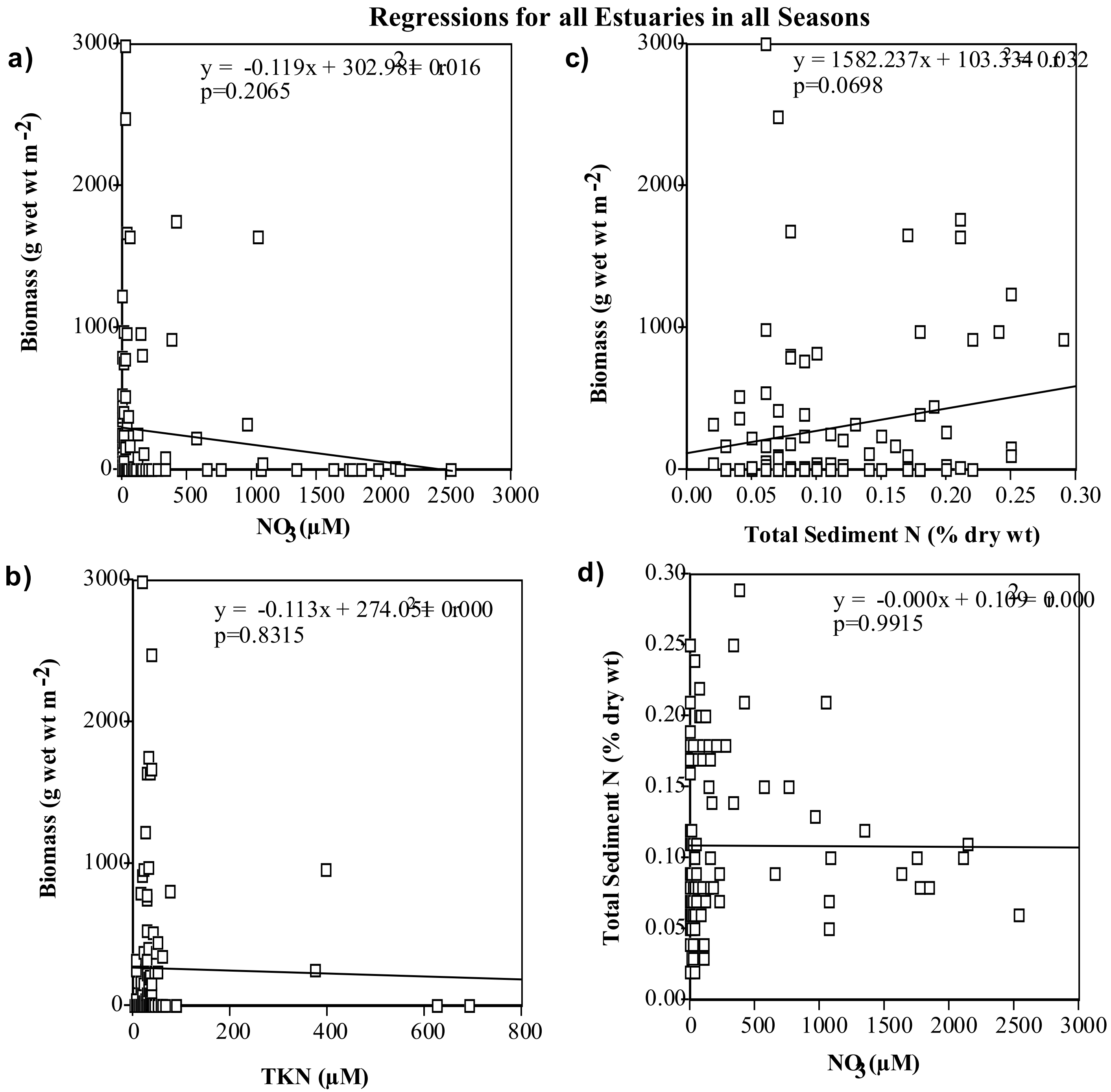

Figure 34. Relationships between field measures of nutrients and algal abundance for all data from all estuaries.

Appendix A

Carpinteria –Water column nutrients

ANOVA Table for NO3(µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	985495.919	492747.959	366.850	<.0001	733.699	1.000
Date	5	1752294.190	350458.838	260.916	<.0001	1304.579	1.000
Site * Date	10	605773.923	60577.392	45.100	<.0001	450.997	1.000
Residual	36	48354.762	1343.188				

ANOVA Table for NH4 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	205.291	102.646	13.665	<.0001	27.331	.999
Date	5	677.712	135.542	18.045	<.0001	90.225	1.000
Site * Date	10	662.623	66.262	8.822	<.0001	88.216	1.000
Residual	36	270.408	7.511				

ANOVA Table for TKN (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	846.561	423.280	5.333	.0094	10.667	.815
Date	5	665.155	133.031	1.676	.1654	8.381	.509
Site * Date	10	6216.931	621.693	7.833	<.0001	78.333	1.000
Residual	36	2857.143	79.365				

ANOVA Table for P sol (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	9.003	4.501	166.857	<.0001	333.714	1.000
Date	2	9.003	4.501	166.857	<.0001	333.714	1.000
Site * Date	4	19.463	4.866	180.357	<.0001	721.429	1.000
Residual	18	.486	.027				

Algae

ANOVA Table for Total Wet wt. (g/m^2)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	10341027.856	5170513.928	16.943	<.0001	33.887	1.000
Date	5	5397388.396	1079477.679	3.537	.0065	17.687	.905
Transect * Date	10	10704637.507	1070463.751	3.508	.0008	35.078	.989
Residual	71	21666579.949	305163.098				

Appendix A

Carpinteria - Algae

ANOVA Table for Total macro (% cover)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	39710.048	19855.024	53.971	<.0001	107.942	1.000
Date	5	13148.834	2629.767	7.148	<.0001	35.742	.999
Transect * Date	10	46578.018	4657.802	12.661	<.0001	126.611	1.000
Residual	72	26487.654	367.884				

Sediments

ANOVA Table for % sand

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	9008.835	4504.417	32.956	<.0001	65.911	1.000
Date	1	701.994	701.994	5.136	.0327	5.136	.579
Transect * Date	2	2103.992	1051.996	7.697	.0026	15.393	.930
Residual	24	3280.349	136.681				

ANOVA Table for % silt

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	5494.307	2747.153	36.023	<.0001	72.047	1.000
Date	1	659.414	659.414	8.647	.0071	8.647	.818
Transect * Date	2	1345.983	672.992	8.825	.0013	17.650	.961
Residual	24	1830.241	76.260				

ANOVA Table for % clay

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	436.965	218.482	11.873	.0003	23.747	.993
Date	1	.663	.663	.036	.8510	.036	.054
Transect * Date	2	108.571	54.286	2.950	.0715	5.900	.512
Residual	24	441.629	18.401				

Fisher's PLSD for % clay
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-9.067	3.959	<.0001	S
1, 3	-6.505	3.959	.0024	S
2, 3	2.562	3.959	.1942	

Appendix A

Carpinteria – *Sediments*

ANOVA Table for Organic Content

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	76.296	38.148	62.006	<.0001	124.011	1.000
Date	5	4.687	.937	1.524	.1952	7.618	.493
Transect * Date	10	36.954	3.695	6.006	<.0001	60.065	1.000
Residual	63	38.760	.615				

ANOVA Table for Redox

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	238843.094	119421.547	8.712	.0004	17.423	.974
Date	5	54325.773	10865.155	.793	.5585	3.963	.264
Transect * Date	10	577826.106	57782.611	4.215	.0001	42.151	.998
Residual	72	987004.993	13708.403				

ANOVA Table for Total N

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.201	.100	62.224	<.0001	124.449	1.000
Season	5	.011	.002	1.393	.2415	6.966	.447
Transect * Season	10	.098	.010	6.048	<.0001	60.484	1.000
Residual	54	.087	.002				

ANOVA Table for Total P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.001	2.816E-4	5.458	.0065	10.916	.841
Season	5	1.177E-4	2.353E-5	.456	.8073	2.281	.161
Transect * Season	10	.002	2.343E-4	4.543	<.0001	45.427	.999
Residual	63	.003	5.159E-5				

ANOVA Table for N:P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	302.516	151.258	77.737	<.0001	155.475	1.000
Season	5	16.539	3.308	1.700	.1504	8.500	.539
Transect * Season	10	67.127	6.713	3.450	.0015	34.499	.984
Residual	54	105.071	1.946				

Mugu West - Water column nutrients

ANOVA Table for NO3 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	52781.927	26390.964	1244.085	<.0001	2488.170	1.000
Date	4	36257.937	9064.484	427.305	<.0001	1709.220	1.000
Site * Date	8	19319.206	2414.901	113.840	<.0001	910.718	1.000
Residual	30	636.395	21.213				

ANOVA Table for NH4 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	946.553	473.277	22.785	<.0001	45.571	1.000
Date	4	572.971	143.243	6.896	.0005	27.585	.988
Site * Date	8	1650.839	206.355	9.935	<.0001	79.478	1.000
Residual	30	623.129	20.771				

ANOVA Table for TKN (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	5533.551	2766.776	24.127	<.0001	48.254	1.000
Date	5	1251.037	250.207	2.182	.0785	10.909	.640
Site * Date	10	4906.894	490.689	4.279	.0006	42.790	.993
Residual	35	4013.605	114.674				

ANOVA Table for P sol

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	.677	.339	6.359	.0108	12.718	.829
Date	2	2.373	1.187	22.275	<.0001	44.550	1.000
Site * Date	4	.629	.157	2.952	.0581	11.808	.633
Residual	14	.746	.053				

Algae

ANOVA Table for Total wet wt (g/m^2)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	659606.944	329803.472	.472	.6255	.945	.122
Date	5	36187473.284	7237494.657	10.365	<.0001	51.823	1.000
Transect * Date	10	32009848.825	3200984.883	4.584	<.0001	45.841	.999
Residual	71	49578214.738	698284.715				

Appendix A

Mugu West - *Algae*

ANOVA Table for Total macro (% cover)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	1975.995	987.997	1.818	.1698	3.636	.355
Date	5	51686.643	10337.329	19.020	<.0001	95.098	1.000
Transect * Date	10	48422.154	4842.215	8.909	<.0001	89.092	1.000
Residual	72	39132.716	543.510				

ANOVA Table for Total N (% dry wt)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.522	.261	1.281	.2913	2.561	.249
Date	3	8.662	2.887	14.165	<.0001	42.495	1.000
Transect * Date	6	3.076	.513	2.515	.0408	15.092	.761
Residual	33	6.726	.204				

ANOVA Table for Total P (% dry wt)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.003	.001	.640	.5339	1.279	.144
Date	3	.076	.025	11.424	<.0001	34.273	.999
Transect * Date	6	.009	.002	.698	.6527	4.191	.234
Residual	33	.073	.002				

Fisher's PLSD for Total P (% dry wt)
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	-.133	.045	<.0001	S
12/01, 6/02	-.040	.045	.0815	
12/01, 9/02	-.038	.044	.0908	
12/02, 6/02	.093	.039	<.0001	S
12/02, 9/02	.096	.038	<.0001	S
6/02, 9/02	.002	.038	.9032	

Mugu West - *Sediments*

ANOVA Table for % silt

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	512.759	256.380	4.600	.0204	9.201	.725
Date	1	101.973	101.973	1.830	.1888	1.830	.242
Transect * Date	2	257.919	128.960	2.314	.1205	4.628	.412
Residual	24	1337.546	55.731				

Fisher's PLSD for % silt
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	.308	6.891	.9273	
1, 3	8.920	6.891	.0133	S
2, 3	8.612	6.891	.0164	S

ANOVA Table for Organic Content

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	193.266	96.633	45.868	<.0001	91.736	1.000
Date	4	7.522	1.881	.893	.4740	3.570	.261
Transect * Date	8	11.963	1.495	.710	.6818	5.678	.294
Residual	60	126.406	2.107				

Fisher's PLSD for Organic Content
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-3.809	.821	<.0001	S
1, 3	-1.058	.821	.0124	S
2, 3	2.751	.821	<.0001	S

ANOVA Table for Redox

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	294423.752	147211.876	14.180	<.0001	28.360	.999
Date	5	276540.091	55308.018	5.327	.0003	26.637	.988
Transect * Date	10	528573.585	52857.359	5.091	<.0001	50.914	1.000
Residual	72	747488.192	10381.780				

Appendix A

Mugu West - *Sediments*

ANOVA Table for Total N

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.190	.095	38.608	<.0001	77.215	1.000
Date	4	.044	.011	4.483	.0031	17.931	.930
Transect * Date	8	.054	.007	2.734	.0122	21.874	.908
Residual	60	.147	.002				

ANOVA Table for Total P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lam…	Power
Transect	2	.056	.028	26.324	<.0001	5.3E1	1.000
Date	4	.004	.001	.854	.4971	3.414	.251
Transect * Date	8	.001	1.713E-4	.162	.9950	1.292	.092
Residual	60	.064	.001				

Fisher's PLSD for Total P
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Va…	
1, 2	-.064	.018	<.0001	S
1, 3	-.014	.018	.1338	
2, 3	.050	.018	<.0001	S

ANOVA Table for N/P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	11.405	5.703	4.008	.0232	8.017	.695
Date	4	24.752	6.188	4.350	.0037	17.399	.922
Transect * Date	8	22.719	2.840	1.996	.0622	15.970	.769
Residual	60	85.356	1.423				

Fisher's PLSD for N/P
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-.887	.675	.0109	S
1, 3	-.136	.675	.6882	
2, 3	.751	.675	.0298	S

Mugu West - *Sediments*

Fisher's PLSD for N/P
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	-.830	.871	.0614	
12/01, 2/03	-1.187	.871	.0084	S
12/01, 6/02	-.151	.871	.7305	
12/01, 9/02	-1.480	.871	.0012	S
12/02, 2/03	-.357	.871	.4159	
12/02, 6/02	.679	.871	.1240	
12/02, 9/02	-.650	.871	.1408	
2/03, 6/02	1.036	.871	.0205	S
2/03, 9/02	-.293	.871	.5033	
6/02, 9/02	-1.330	.871	.0034	S

Mugu Calleguas Creek – *Water column nutrients*

ANOVA Table for NO3 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	3047877.607	1523938.803	241.887	<.0001	483.773	1.000
Date	5	11950870.181	2390174.036	379.380	<.0001	1896.898	1.000
Site * Date	10	10348843.365	1034884.336	164.262	<.0001	1642.617	1.000
Residual	36	226807.823	6300.217				

ANOVA Table for NH4 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	940.550	470.275	19.938	<.0001	39.876	1.000
Date	4	3768.461	942.115	39.943	<.0001	159.771	1.000
Site * Date	8	10884.087	1360.511	57.681	<.0001	461.451	1.000
Residual	29	684.014	23.587				

ANOVA Table for TKN (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	233.560	116.780	1.304	.2864	2.608	.251
Date	4	15249.433	3812.358	42.563	<.0001	170.253	1.000
Site * Date	8	6104.308	763.039	8.519	<.0001	68.152	1.000
Residual	30	2687.075	89.569				

Appendix A

Mugu Calleguas Creek – *Water column nutrients*

ANOVA Table for Total P (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	3657.590	1828.795	377.394	<.0001	754.788	1.000
Date	5	685.211	137.042	28.280	<.0001	141.402	1.000
Site * Date	10	1041.634	104.163	21.495	<.0001	214.954	1.000
Residual	34	164.759	4.846				

ANOVA Table for P sol (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	1181.578	590.789	184.245	<.0001	368.490	1.000
Date	2	110.656	55.328	17.255	<.0001	34.510	1.000
Site * Date	4	299.657	74.914	23.363	<.0001	93.452	1.000
Residual	18	57.718	3.207				

Algae

ANOVA Table for Total wet wt (g/m^2)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	58009.963	29004.981	7.634	.0010	15.269	.951
Date	5	128793.087	25758.617	6.780	<.0001	33.899	.998
Transect * Date	10	214999.985	21499.998	5.659	<.0001	56.589	1.000
Residual	72	273549.449	3799.298				

ANOVA Table for Total macro (% cover)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	5195.988	2597.994	23.319	<.0001	46.638	1.000
Date	5	8736.368	1747.274	15.683	<.0001	78.416	1.000
Transect * Date	10	11340.021	1134.002	10.179	<.0001	101.785	1.000
Residual	72	8021.605	111.411				

Sediments

ANOVA Table for % sand

	DF	Sum of Squares	Mean Square	F-Value	P-V…	Lambda	Power
Transect	2	1415.768	707.884	7.165	.0036	14.329	.909
Date	1	1884.169	1884.169	19.070	.0002	19.070	.993
Transect * Date	2	102.679	51.340	.520	.6013	1.039	.123
Residual	24	2371.232	98.801				

Mugu Calleguas Creek - *Sediments*

Fisher's PLSD for % sand
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	12.085	9.175	.0120	S
1, 3	16.183	9.175	.0013	S
2, 3	4.098	9.175	.3658	

Fisher's PLSD for % sand
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	15.850	7.491	.0002	S

ANOVA Table for % silt

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	622.359	311.180	7.618	.0027	15.236	.927
Date	1	796.499	796.499	19.499	.0002	19.499	.994
Transect * Date	2	96.538	48.269	1.182	.3240	2.363	.226
Residual	24	980.339	40.847				

Fisher's PLSD for % silt
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-6.930	5.899	.0232	S
1, 3	-11.037	5.899	.0007	S
2, 3	-4.107	5.899	.1637	

Fisher's PLSD for % silt
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	-10.305	4.817	.0002	S

Mugu Calleguas Creek - *Sediments*

ANOVA Table for % clay

	DF	Sum of Squares	Mean Square	F-Va…	P-Value	Lambda	Power
Transect	2	176.817	88.408	4.270	.0259	8.540	.689
Date	1	230.741	230.741	11.144	.0027	11.144	.909
Transect * Date	2	34.345	17.173	.829	.4484	1.659	.170
Residual	24	496.937	20.706				

Fisher's PLSD for % clay
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-5.154	4.200	.0183	S
1, 3	-5.146	4.200	.0184	S
2, 3	.008	4.200	.9969	

Fisher's PLSD for % clay
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	-5.547	3.429	.0027	S

ANOVA Table for Organic Content

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.902	.451	.912	.4071	1.825	.194
Date	4	11.247	2.812	5.687	.0006	22.747	.978
Transect * Date	8	13.515	1.689	3.417	.0027	27.332	.966
Residual	60	29.667	.494				

Appendix A

Mugu Calleguas Creek - *Sediments*

ANOVA Table for Redox

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	626742.352	313371.176	16.937	<.0001	33.873	1.000
Date	5	1438830.781	287766.156	15.553	<.0001	77.764	1.000
Transect * Date	10	497894.450	49789.445	2.691	.0074	26.909	.948
Residual	72	1332185.053	18502.570				

ANOVA Table for Total N

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.009	.004	3.617	.0334	7.235	.641
Date	4	.052	.013	10.926	<.0001	43.704	1.000
Transect * Date	8	.005	.001	.477	.8671	3.817	.199
Residual	55	.066	.001				

Fisher's PLSD for Total N
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	.024	.020	.0201	S
1, 3	.022	.020	.0304	S
2, 3	-.002	.020	.8650	

Fisher's PLSD for Total N
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	-.079	.027	<.0001	S
12/01, 2/03	-.028	.027	.0492	S
12/01, 6/02	-.008	.028	.5652	
12/01, 9/02	-.029	.027	.0395	S
12/02, 2/03	.051	.025	.0002	S
12/02, 6/02	.071	.026	<.0001	S
12/02, 9/02	.050	.025	.0002	S
2/03, 6/02	.020	.026	.1339	
2/03, 9/02	-.001	.025	.9162	
6/02, 9/02	-.021	.026	.1099	

Appendix A

Mugu Calleguas Creek - *Sediments*

ANOVA Table for Total P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.003	.002	13.205	<.0001	26.409	.999
Date	4	.001	2.787E-4	2.444	.0561	9.778	.663
Transect * Date	8	.001	1.637E-4	1.436	.2006	11.485	.591
Residual	60	.007	1.140E-4				

Fisher's PLSD for Total P
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-.001	.006	.6925	
1, 3	-.014	.006	<.0001	S
2, 3	-.013	.006	<.0001	S

Fisher's PLSD for Total P
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	-.009	.008	.0198	S
12/01, 2/03	-.009	.008	.0300	S
12/01, 6/02	-.003	.008	.4966	
12/01, 9/02	-.001	.008	.7336	
12/02, 2/03	.001	.008	.8648	
12/02, 6/02	.007	.008	.0924	
12/02, 9/02	.008	.008	.0445	S
2/03, 6/02	.006	.008	.1291	
2/03, 9/02	.007	.008	.0648	
6/02, 9/02	.001	.008	.7336	

ANOVA Table for N/P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	4.714	2.357	6.286	.0035	12.573	.892
Date	4	14.266	3.566	9.511	<.0001	38.046	1.000
Transect * Date	8	2.292	.286	.764	.6355	6.113	.314
Residual	55	20.623	.375				

Appendix A

Mugu Calleguas Creek - *Sediments*

Fisher's PLSD for N/P
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	.450	.358	.0147	S
1, 3	.617	.358	.0011	S
2, 3	.166	.362	.3612	

Fisher's PLSD for N/P
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	-1.306	.487	<.0001	S
12/01, 2/03	-.423	.487	.0874	
12/01, 6/02	-.154	.494	.5338	
12/01, 9/02	-.591	.487	.0183	S
12/02, 2/03	.883	.448	.0002	S
12/02, 6/02	1.151	.456	<.0001	S
12/02, 9/02	.714	.448	.0023	S
2/03, 6/02	.269	.456	.2431	
2/03, 9/02	-.168	.448	.4549	
6/02, 9/02	-.437	.456	.0601	

Upper Newport Bay – *Water column nutrients*

ANOVA Table for NO3 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	21847.939	10923.969	168.119	<.0001	336.237	1.000
Date	4	34557.908	8639.477	132.961	<.0001	531.842	1.000
Site * Date	8	13574.325	1696.791	26.113	<.0001	208.907	1.000
Residual	29	1884.354	64.978				

ANOVA Table for NH4 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	1234.357	617.178	65.472	<.0001	130.944	1.000
Date	5	1803.681	360.736	38.268	<.0001	191.339	1.000
Site * Date	10	1204.577	120.458	12.778	<.0001	127.785	1.000
Residual	35	329.932	9.427				

Upper Newport Bay – *Water column nutrients*

ANOVA Table for TKN (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	6067.649	3033.825	15.587	<.0001	31.175	1.000
Date	5	8420.257	1684.051	8.652	<.0001	43.262	1.000
Site * Date	10	3490.174	349.017	1.793	.0976	17.932	.729
Residual	36	7006.803	194.633				

Fisher's PLSD for TKN (µM)
Effect: Site
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-10.317	9.431	.0329	S
1, 3	-25.794	9.431	<.0001	S
2, 3	-15.476	9.431	.0020	S

Fisher's PLSD for TKN (µM)
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	-15.079	13.338	.0278	S
12/01, 2/02	16.667	13.338	.0158	S
12/01, 2/03	18.254	13.338	.0087	S
12/01, 6/02	16.667	13.338	.0158	S
12/01, 9/02	17.460	13.338	.0117	S
12/02, 2/02	31.746	13.338	<.0001	S
12/02, 2/03	33.333	13.338	<.0001	S
12/02, 6/02	31.746	13.338	<.0001	S
12/02, 9/02	32.540	13.338	<.0001	S
2/02, 2/03	1.587	13.338	.8106	
2/02, 6/02	-2.222E-9	13.338	>.9999	
2/02, 9/02	.794	13.338	.9046	
2/03, 6/02	-1.587	13.338	.8106	
2/03, 9/02	-.794	13.338	.9046	
6/02, 9/02	.794	13.338	.9046	

ANOVA Table for P sol (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	3.559	1.780	17.445	<.0001	34.890	1.000
Date	2	3.314	1.657	16.243	.0001	32.487	.999
Site * Date	4	1.472	.368	3.606	.0264	14.424	.762
Residual	17	1.734	.102				

Upper Newport Bay - *Algae*

ANOVA Table for Total wet wt (g/m^2)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	1370073.086	685036.543	6.574	.0024	13.148	.912
Date	5	4340953.206	868190.641	8.332	<.0001	41.658	1.000
Transect * Date	10	17041728.868	1704172.887	16.354	<.0001	163.541	1.000
Residual	72	7502755.329	104204.935				

Kruskal-Wallis Test for Total % cover
Grouping Variable: Transect

DF	2
# Groups	3
# Ties	11
H	14.101
P-Value	.0009
H corrected for ties	15.105
Tied P-Value	.0005

Kruskal-Wallis Test for Total % cover
Grouping Variable: Date

DF	5
# Groups	6
# Ties	11
H	28.499
P-Value	<.0001
H corrected for ties	30.527
Tied P-Value	<.0001

Sediments

ANOVA Table for % sand

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	8677.706	4338.853	175.359	<.0001	350.718	1.000
Date	1	69.586	69.586	2.812	.1065	2.812	.348
Transect * Date	2	305.814	152.907	6.180	.0068	12.360	.857
Residual	24	593.824	24.743				

Appendix A

Upper Newport Bay - *Sediments*

ANOVA Table for % silt

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	4087.705	2043.852	188.230	<.0001	376.460	1.000
Date	1	97.128	97.128	8.945	.0063	8.945	.832
Transect * Date	2	99.545	49.773	4.584	.0206	9.168	.724
Residual	24	260.598	10.858				

ANOVA Table for % clay

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	856.395	428.197	83.732	<.0001	167.465	1.000
Date	1	2.269	2.269	.444	.5117	.444	.096
Transect * Date	2	57.403	28.701	5.612	.0100	11.225	.818
Residual	24	122.733	5.114				

ANOVA Table for Organic Content

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	18.367	9.184	55.941	<.0001	111.882	1.000
Date	5	4.801	.960	5.849	.0002	29.244	.994
Transect * Date	10	4.079	.408	2.485	.0137	24.848	.922
Residual	65	10.671	.164				

ANOVA Table for Redox

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	55997.331	27998.666	2.793	.0692	5.585	.520
Date	4	62494.943	15623.736	1.558	.1971	6.233	.445
Transect * Date	8	526745.891	65843.236	6.567	<.0001	52.537	1.000
Residual	60	601571.421	10026.190				

ANOVA Table for Total N

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.009	.004	13.002	<.0001	26.004	.998
Date	4	.012	.003	9.026	<.0001	36.106	.999
Transect * Date	8	.003	4.044E-4	1.181	.3299	9.450	.478
Residual	48	.016	3.423E-4				

Fisher's PLSD for Total N

Effect: Transect

Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-.005	.013	.4649	
1, 3	-.025	.012	.0002	S
2, 3	-.021	.011	.0003	S

Upper Newport Bay - *Sediments*

Fisher's PLSD for Total N
Effect: Date
Significance Level: 5 %

	Mean D…	Crit. Diff.	P-Value	
12/01, 12/02	-.031	.015	.0001	S
12/01, 2/03	-.024	.015	.0023	S
12/01, 6/02	-.001	.015	.9177	
12/01, 9/02	-.031	.014	<.0001	S
12/02, 2/03	.006	.015	.4053	
12/02, 6/02	.030	.015	.0002	S
12/02, 9/02	1.388E-17	.014	>.9999	
2/03, 6/02	.024	.016	.0036	S
2/03, 9/02	-.006	.015	.3975	
6/02, 9/02	-.030	.015	.0001	S

ANOVA Table for Total P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.002	.001	29.686	<.0001	59.373	1.000
Date	4	.001	1.680E-4	4.941	.0016	19.765	.954
Transect * Date	8	.001	1.110E-4	3.265	.0037	26.118	.957
Residual	60	.002	3.400E-5				

ANOVA Table for N/P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	2.150	1.075	3.150	.0518	6.300	.570
Date	4	20.333	5.083	14.898	<.0001	59.592	1.000
Transect * Date	8	9.427	1.178	3.454	.0032	27.629	.962
Residual	48	16.378	.341				

Los Penasquitos Lagoon –*Water column nutrients*

ANOVA Table for NO3 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	6.859	3.430	10.083	.0027	20.167	.957
Date	1	646.287	646.287	1900.083	<.0001	1900.083	1.000
Site * Date	2	2.438	1.219	3.583	.0602	7.167	.544
Residual	12	4.082	.340				

Los Penasquitos Lagoon –Water column nutrients

Fisher's PLSD for NO3 (µM)
Effect: Site
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-3.000E-9	.734	>.9999	
1, 3	1.310	.734	.0022	S
2, 3	1.310	.734	.0022	S

Fisher's PLSD for NO3 (µM)
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
2/02, 2/03	-11.984	.599	<.0001	S

ANOVA Table for NH4 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	74.086	37.043	1.376	.2734	2.752	.256
Date	3	531.409	177.136	6.581	.0024	19.742	.949
Site * Date	6	33.215	5.536	.206	.9713	1.234	.091
Residual	22	592.177	26.917				

Fisher's PLSD for NH4 (µM)
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/02, 2/02	-.079	5.072	.9744	
12/02, 6/02	-8.424	5.422	.0039	S
12/02, 9/02	-7.381	5.072	.0063	S
2/02, 6/02	-8.345	5.422	.0042	S
2/02, 9/02	-7.302	5.072	.0068	S
6/02, 9/02	1.043	5.422	.6938	

ANOVA Table for TKN (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	555.804	277.902	1.612	.2169	3.224	.302
Date	4	7056.823	1764.206	10.232	<.0001	40.930	1.000
Site * Date	8	1910.491	238.811	1.385	.2443	11.081	.510
Residual	29	5000.000	172.414				

Los Penasquitos Lagoon –Water column nutrients

Fisher's PLSD for TKN (µM)
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/02, 2/02	1.091	13.049	.8654	
12/02, 2/03	-27.480	13.049	.0002	S
12/02, 6/02	-25.099	13.049	.0005	S
12/02, 9/02	-4.464	13.049	.4897	
2/02, 2/03	-28.571	12.660	<.0001	S
2/02, 6/02	-26.190	12.660	.0002	S
2/02, 9/02	-5.556	12.660	.3768	
2/03, 6/02	2.381	12.660	.7033	
2/03, 9/02	23.016	12.660	.0009	S
6/02, 9/02	20.635	12.660	.0024	S

ANOVA Table for P soluble (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Site	2	3.214	1.607	15.886	<.0001	31.771	.999
Date	3	10.530	3.510	34.695	<.0001	104.086	1.000
Site * Date	6	4.116	.686	6.781	.0003	40.686	.997
Residual	24	2.428	.101				

Algae

ANOVA Table for Total wet wt (g/m^2)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	138766.642	69383.321	4.309	.0178	8.619	.731
Date	4	988343.222	247085.806	15.346	<.0001	61.385	1.000
Transect * Date	8	809575.788	101196.973	6.285	<.0001	50.282	1.000
Residual	60	966041.925	16100.699				

ANOVA Table for Total % cover

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	715.432	357.716	.814	.4479	1.628	.177
Date	4	21828.189	5457.047	12.418	<.0001	49.671	1.000
Transect * Date	8	40703.292	5087.912	11.578	<.0001	92.622	1.000
Residual	60	26367.284	439.455				

Los Penasquitos Lagoon – Sediments

ANOVA Table for % sand

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	19915.195	9957.598	177.156	<.0001	354.311	1.000
Date	1	165.534	165.534	2.945	.0990	2.945	.362
Transect * Date	2	130.280	65.140	1.159	.3308	2.318	.223
Residual	24	1348.996	56.208				

Fisher's PLSD for % sand
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-.036	6.920	.9915	
1, 3	54.638	6.920	<.0001	S
2, 3	54.674	6.920	<.0001	S

ANOVA Table for % silt

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	2257.269	1128.634	88.789	<.0001	177.578	1.000
Date	1	125.215	125.215	9.851	.0045	9.851	.869
Transect * Date	2	20.024	10.012	.788	.4663	1.575	.164
Residual	24	305.074	12.711				

Fisher's PLSD for % silt
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-.557	3.291	.7299	
1, 3	-18.673	3.291	<.0001	S
2, 3	-18.116	3.291	<.0001	S

Fisher's PLSD for % silt
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
2/02, 2/03	4.086	2.687	.0045	S

ANOVA Table for % clay

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	8767.239	4383.619	181.178	<.0001	362.356	1.000
Date	1	2.766	2.766	.114	.7382	.114	.062
Transect * Date	2	87.448	43.724	1.807	.1857	3.614	.329
Residual	24	580.682	24.195				

Los Penasquitos Lagoon – Sediments

Fisher's PLSD for % clay
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	.591	4.540	.7905	
1, 3	-35.965	4.540	<.0001	S
2, 3	-36.556	4.540	<.0001	S

ANOVA Table for Organic Content

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	20.614	10.307	52.918	<.0001	105.836	1.000
Date	4	4.917	1.229	6.311	.0003	25.246	.989
Transect * Date	8	22.993	2.874	14.756	<.0001	118.052	1.000
Residual	60	11.686	.195				

ANOVA Table for Redox

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	43765.174	21882.587	3.951	.0258	7.902	.681
Date	3	13659.044	4553.015	.822	.4882	2.466	.209
Transect * Date	6	298972.993	49828.832	8.996	<.0001	53.978	1.000
Residual	48	265862.899	5538.810				

ANOVA Table for Total N

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.010	.005	18.819	<.0001	37.638	1.000
Date	4	.007	.002	6.205	.0004	24.821	.985
Transect * Date	8	.003	3.632E-4	1.318	.2576	10.544	.532
Residual	48	.013	2.756E-4				

Fisher's PLSD for Total N
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-.007	.011	.1836	
1, 3	-.030	.010	<.0001	S
2, 3	-.023	.010	<.0001	S

Appendix A

Los Penasquitos Lagoon – Sediments

Fisher's PLSD for Total N
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/02, 2/02	.021	.012	.0014	S
12/02, 2/03	.017	.014	.0212	S
12/02, 6/02	.024	.013	.0006	S
12/02, 9/02	-.001	.013	.8278	
2/02, 2/03	-.004	.014	.5704	
2/02, 6/02	.003	.013	.6735	
2/02, 9/02	-.022	.013	.0011	S
2/03, 6/02	.007	.014	.3590	
2/03, 9/02	-.018	.015	.0157	S
6/02, 9/02	-.025	.013	.0005	S

ANOVA Table for Total P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.004	.002	111.200	<.0001	222.400	1.000
Date	4	4.347E-4	1.087E-4	5.433	.0008	21.733	.972
Transect * Date	8	2.853E-4	3.567E-5	1.783	.0982	14.267	.709
Residual	60	.001	2.000E-5				

Fisher's PLSD for Total P
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	.013	.003	<.0001	S
1, 3	-.006	.003	<.0001	S
2, 3	-.018	.003	<.0001	S

Fisher's PLSD for Total P

Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/02, 2/02	-.003	.003	.1077	
12/02, 2/03	-.002	.003	.2255	
12/02, 6/02	.003	.003	.1077	
12/02, 9/02	.003	.003	.0456	S
2/02, 2/03	.001	.003	.6845	
2/02, 6/02	.005	.003	.0018	S
2/02, 9/02	.006	.003	.0005	S
2/03, 6/02	.005	.003	.0059	S
2/03, 9/02	.005	.003	.0018	S
6/02, 9/02	.001	.003	.6845	

ANOVA Table for N/P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	659.991	329.996	41.537	<.0001	83.074	1.000
Date	4	204.802	51.200	6.445	.0003	25.779	.989
Transect * Date	8	35.705	4.463	.562	.8036	4.494	.227
Residual	48	381.342	7.945				

Fisher's PLSD for N/P

Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-7.805	1.841	<.0001	S
1, 3	-.480	1.752	.5844	
2, 3	7.326	1.700	<.0001	S

Fisher's PLSD for N/P

Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/02, 2/02	3.504	2.106	.0016	S
12/02, 2/03	3.029	2.421	.0153	S
12/02, 6/02	3.224	2.183	.0046	S
12/02, 9/02	-1.041	2.229	.3524	
2/02, 2/03	-.476	2.390	.6908	
2/02, 6/02	-.280	2.147	.7943	
2/02, 9/02	-4.545	2.195	.0001	S
2/03, 6/02	.196	2.457	.8735	
2/03, 9/02	-4.070	2.499	.0020	S
6/02, 9/02	-4.265	2.269	.0004	S

Appendix A

Tijuana River Estuary – Water Column Nutrients

ANOVA Table for NH4 (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	95437.013	47718.506	1004.780	<.0001	2009.560	1.000
Season	3	509177.663	169725.888	3573.816	<.0001	10721.449	1.000
Transect * Season	6	216599.033	36099.839	760.133	<.0001	4560.796	1.000
Residual	20	949.830	47.491				

ANOVA Table for TKN (µM)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	200861.678	100430.839	545.108	<.0001	1090.215	1.000
Season	3	1219528.061	406509.354	2206.408	<.0001	6619.223	1.000
Transect * Season	6	610068.027	101678.005	551.877	<.0001	3311.262	1.000
Residual	24	4421.769	184.240				

ANOVA Table for P sol

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	4349.649	2174.824	17914.338	<.0001	35828.676	1.000
Season	2	16666.719	8333.359	68643.072	<.0001	137286.143	1.000
Transect * Season	4	7795.414	1948.854	16052.985	<.0001	64211.940	1.000
Residual	17	2.064	.121				

Algae

ANOVA Table for Total wet wt (g/m^2)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	1159264.890	579632.445	17.832	<.0001	35.663	1.000
Date	4	1788935.576	447233.894	13.759	<.0001	55.034	1.000
Transect * Date	8	1672582.269	209072.784	6.432	<.0001	51.455	1.000
Residual	59	1917839.624	32505.756				

ANOVA Table for Total macro (% cover)

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	6632.305	3316.152	5.900	.0046	11.799	.871
Date	4	47685.802	11921.451	21.209	<.0001	84.837	1.000
Transect * Date	8	27965.432	3495.679	6.219	<.0001	49.753	1.000
Residual	60	33725.309	562.088				

Appendix A

Tijuana River Estuary – *Sediments*

ANOVA Table for % sand

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	8418.288	4209.144	65.523	<.0001	131.047	1.000
Date	1	99.299	99.299	1.546	.2258	1.546	.211
Transect * Date	2	1396.613	698.306	10.870	.0004	21.741	.987
Residual	24	1541.730	64.239				

ANOVA Table for % silt

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	35.296	17.648	1.046	.3669	2.091	.204
Date	1	196.557	196.557	11.647	.0023	11.647	.922
Transect * Date	2	286.723	143.361	8.495	.0016	16.990	.953
Residual	24	405.028	16.876				

ANOVA Table for % clay

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	8116.859	4058.430	106.256	<.0001	212.513	1.000
Date	1	16.428	16.428	.430	.5182	.430	.094
Transect * Date	2	862.359	431.180	11.289	.0004	22.578	.990
Residual	24	916.674	38.195				

ANOVA Table for Organic Content

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Date	4	49.698	12.425	32.426	<.0001	129.702	1.000
Transect	2	219.040	109.520	285.826	<.0001	571.652	1.000
Date * Transect	8	26.117	3.265	8.520	<.0001	68.160	1.000
Residual	60	22.990	.383				

ANOVA Table for Redox

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	632161.854	316080.927	26.904	<.0001	53.808	1.000
Date	4	72973.601	18243.400	1.553	.1986	6.211	.443
Transect * Date	8	263851.844	32981.481	2.807	.0104	22.458	.917
Residual	60	704908.524	11748.475				

Tijuana River Estuary – *Sediments*

ANOVA Table for Total N

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.141	.071	48.300	<.0001	96.600	1.000
Date	4	.025	.006	4.191	.0048	16.763	.908
Transect * Date	8	.014	.002	1.160	.3390	9.281	.480
Residual	57	.083	.001				

Fisher's PLSD for Total N
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-.096	.022	<.0001	S
1, 3	-.096	.022	<.0001	S
2, 3	4.000E-4	.022	.9706	

Fisher's PLSD for Total N
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	.004	.029	.7999	
12/01, 2/03	-.005	.028	.7396	
12/01, 6/02	.025	.028	.0806	
12/01, 9/02	-.026	.028	.0679	
12/02, 2/03	-.008	.029	.5665	
12/02, 6/02	.022	.030	.1483	
12/02, 9/02	-.030	.029	.0452	S
2/03, 6/02	.030	.028	.0395	S
2/03, 9/02	-.021	.028	.1322	
6/02, 9/02	-.051	.028	.0007	S

ANOVA Table for Total P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	.009	.004	74.674	<.0001	149.349	1.000
Date	4	.002	4.187E-4	7.302	<.0001	29.209	.996
Transect * Date	8	.001	1.797E-4	3.134	.0050	25.070	.948
Residual	60	.003	5.733E-5				

Tijuana River Estuary – *Sediments*

ANOVA Table for N/P

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Transect	2	43.401	21.701	10.069	.0002	20.137	.988
Date	4	30.551	7.638	3.544	.0119	14.175	.844
Transect * Date	8	26.495	3.312	1.537	.1651	12.293	.625
Residual	57	122.849	2.155				

Fisher's PLSD for N/P
Effect: Transect
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
1, 2	-1.808	.859	<.0001	S
1, 3	-1.625	.859	.0004	S
2, 3	.184	.831	.6601	

Fisher's PLSD for N/P
Effect: Date
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
12/01, 12/02	-.214	1.114	.7016	
12/01, 2/03	.524	1.073	.3329	
12/01, 6/02	.299	1.092	.5863	
12/01, 9/02	-1.312	1.073	.0175	S
12/02, 2/03	.738	1.114	.1901	
12/02, 6/02	.513	1.132	.3683	
12/02, 9/02	-1.097	1.114	.0534	
2/03, 6/02	-.225	1.092	.6817	
2/03, 9/02	-1.835	1.073	.0012	S
6/02, 9/02	-1.610	1.092	.0046	S