Appendix D

Marine Water Quality/
Marine Environmental Assessments

ASSESSMENT OF
MARINE WATER CHEMISTRY
FOR THE HONUA‘ULA PROJECT

WAILEA, MAUI

Prepared for:

Honua‘ula Partners LLC
P.O. Box 220
Kihei, Maui, Hawaii 96753

By:

Marine Research Consultants, Inc.
1039 Waakaua Pl.
Honolulu, HI 96722

Submitted
February 2010

I. PURPOSE

The Honua'ula project is situated on the slopes of Haleakala directly mauka of the Wailea Resort in South Maui, Hawaii. The project area is comprised of two parcels totaling 670 acres and is designated Project District 9 in the Kihei/Makena Community Plan (Figure 1). The project area is also zoned Project District 9 in the Maui County code. Current zoning includes provisions for up to 1,400 homes (including affordable workforce homes in conformance with the County's Residential Workforce Housing Policy (Chapter 2.96, MCC), village mixed uses, a homeowner's golf course, and other recreational amenities as well as acreage for parks, and open space that will be utilized for landscape buffers and drainage ways. The project is immediately above three 18-hole golf courses (Blue, Gold and Emerald) within the southern area of Wailea Resort. The composite Wailea Resort/Honua'ula encompasses approximately 1.9 miles of coastline. No aspect of the project involves direct alteration of the shoreline or nearshore marine environment. At the time of submission of this report, development of the project EIS and Phase II submittal is in progress. No construction activities associated with the project have commenced.

There is no *a priori* reason to indicate that responsible construction and operation of Honua'ula will cause any detrimental changes to the marine environment. Current project planning includes detention of surface drainage on the golf course and other areas, and a private wastewater system will treat effluent to the R-1 level which is suitable for irrigation re-use. Yet, there is always potential concern that construction and operation could cause environmental effects to the ocean off the project site. Of particular importance is the potential for cumulative effects from the combined Wailea Resort and Honua'ula projects. As the properties are oriented above one another with respect to the ocean, subsurface groundwater will flow under both project sites prior to discharge at the coastline. Hence, groundwater leachate from fertilizers and other materials that reach the ocean will be a mix from both projects.

While all planning and construction activities will place a high priority on maintaining the existing nature of the marine environment, it is nevertheless important to address any potential impacts that may be associated with the planned community. The potential exists, however, for the project to affect the composition and volume of groundwater that flows beneath the property, as well as surface runoff. As all groundwater and runoff that could be affected by the project could potentially reach the ocean, it is recognized that there is potential for effects to the marine environment. As the shoreline downslope from the planned project is a recreational area and is utilized for surfing, swimming, and fishing, evaluating the potential for alterations to water quality and marine life from material input from the community constitutes an important factor in the planning process.

In the interest of addressing these concerns and assuring maintenance of environmental quality, a marine water quality assessment and potential impact analysis of the nearshore areas downslope from Honuaʻula has been conducted. The foundation of this assessment was based on a monitoring program that was stipulated as a condition of zoning (County of Maui Ordinance No. 3554 Condition 20) which states:

> *Marine monitoring programs shall be conducted which include monitoring and assessment of coastal water resources (groundwater and surface water) that receive surface water or groundwater discharges from the hydrologic unit where the project is located. Monitoring programs shall include both water quality and ecological monitoring.*
>
> *Water Quality Monitoring shall provide water quality data adequate to assess compliance with applicable State water quality standards at Hawaii Administrative Rules Chapter 11-54. Assessment procedures shall be in accordance with the current Hawaii Department of Health ("HIDOH") methodology for Clean Water Act Section 305(b) water quality assessment, including use of approved analytical methods and quality control/quality assurance measures. The water quality data shall be submitted annually to HIDOH for use in the State's Integrated Report of Assessed Waters prepared under Clean Water Act Sections 303(d) and 305(b). If this report lists the receiving waters as impaired and requiring a Total Maximum Daily Load ("TMDL") study, then the monitoring program shall be amended to evaluate land-based pollutants, including: (1) monitoring of surface water and groundwater quality for the pollutants identified as the source of the impairment; and (2) providing estimates of total mass discharge of those pollutants on a daily and annual basis from all sources, including infiltration, injection, and runoff. The results of the land-based pollution water quality monitoring and loading estimate shall be submitted to the HIDOH Environmental Planning Office, TMDL Program.*
>
> *The ecological monitoring shall include ecological assessment in accordance with the Coral Reef Assessment and Monitoring Program protocols used by the Department of Land and Natural Resources. The initial assessment shall use the full protocol. Subsequent annual assessments can use the Rapid Assessment Techniques. Results shall be reported annually to the Aquatic Resources Division, Department of Land and Natural Resources.*

This marine water quality assessment report is prepared in compliance with the above condition. Compliance with the ecological monitoring requirement of this condition will be provided in a separate report. It should be noted that to date, HIDOH, which is the agency responsible for developing TMDL's has not developed any TMDL criteria for any marine areas off the coast of Maui.

At the time of this writing three increments of monitoring have taken place since the establishment of conditions of Zoning (Condition 20), with the most recent survey conducted in September 2009. However, prior to approval of the conditions several increments of monitoring to establish baseline conditions for Honua'ula were conducted in 2005, 2006 and 2008. Data used in the following evaluation of water quality include the overall six phases of the monitoring program for the Honua'ula project, with particular emphasis on the most recent survey in September 2009.

The monitoring program to meet this condition utilizes established scientific methods that are capable of determining the contribution of groundwater to the marine environments offshore of Honua'ula, and to evaluate the effects that this input has on water quality at the present time. As no construction activities for Honua'ula have yet commenced, results of the monitoring program characterize existing conditions, particularly with respect to effects of the existing Wailea Resort. Combining this information with estimates of changes in groundwater and surface water flow rates and chemical composition that could result from the proposed Honua'ula project provides a basis to evaluate the potential future effects to the marine environment. Predicted changes in groundwater composition and flow rates have been supplied by Tom Nance Water Resource Engineering (TNWRE 2010). Results of the combined evaluation will indicate the potential degree of change to the marine environment that could occur as a result of Honua'ula.

II. ANALYTICAL METHODS

Figure 1 is an aerial photograph showing the shoreline and topographical features of the Wailea area, and the location of the three existing Wailea golf courses. Also shown are the boundaries of the proposed Honua'ula project. Ocean survey site locations are depicted as transects perpendicular to the shoreline extending from the highest wash of waves out to what is considered open coastal ocean (approximately the 20 m depth contour). Site 1 is located near the southern boundary of the Wailea Gold Course inside Nahuna Point offshore of an area locally known as "Five Graves"; Site 2 bisects the area off the center of the Wailea Emerald Course at the southern end of Palauea Beach (downslope from the southern boundary of the Honua'ula project site); Site 3 is located off the southern end of Wailea Beach off the approximate boundary of the Emerald and Blue Courses (downslope from approximate center of the Honua'ula project site), and Site 4 is off the northern end of the Blue Course at the northern end of Ulua Beach (downslope from the northern boundary of the Honua'ula project site). Survey Site 5 is located near the northern boundary of the 'Ahihi-kina'u natural area reserve, and just north of the 1790 lava flow. The site is approximately four kilometers (km) south of the Honua'ula project site. Land uses of the coastal area landward of Site 5 include several private residences and pasture for cattle grazing. Site 5 serves as the best available "control" survey site, as it is located offshore of an area with minimal land-based development, and no golf course operations, residential or commercial "development". In order to maximize the similarity of the control and test sites, the location of Site 5 was in an area of similar geologic and oceanographic structure as the sites off of the Wailea Resort and

Honuaʻula. Farther to the south of Site 5, land development is less, but geologic structure consists of the 1790 lava flow, which is dissimilar with respect to hydrologic characteristics from the other survey sites off of Wailea.

All field work for the most recent survey was conducted on September 4, 2009 using a small boat and swimmers working from shore. Environmental conditions during sample collection consisted of calm seas, light winds and sunny skies.

Water samples were collected at five stations along transects that extend from the highest wash of waves to approximately 150 meters (m) offshore at each site. Such a sampling scheme is designed to span the greatest range of salinity with respect to groundwater/surface water efflux at the shoreline. Sampling is more concentrated in the nearshore zone because this area is most likely to show the effects of shoreline modification. With the exception of the two stations closest to the shoreline, samples were collected at two depths; a surface sample was collected within approximately 10 centimeters (cm) of the sea surface, and a bottom sample was collected within 1 m of the sea floor. The intermittent stream located at the base of Wailea Point (Site 3) was not flowing during this survey.

Samples from within 10 m of the shoreline were collected by swimmers working from the shoreline. Samples were collected by filling triple-rinsed 1 liter polyethylene bottles at the estimated distance from the shoreline. Samples beyond 10 m of the shoreline were collected using a small boat. Water samples were collected at stations locations determined by GPS using a 1.8-liter Niskin-type oceanographic sampling bottle. The bottle is lowered to the desired depth where spring-loaded endcaps are triggered to close by a messenger released from the surface. Upon recovery, each sample was transferred into a 1-liter polyethylene bottle until further processing.

Following collection, subsamples for nutrient analyses were immediately placed in 125-milliliter (ml) acid-washed, triple rinsed, polyethylene bottles and stored on ice until returned to Honolulu. Water for other analyses was kept in the 1-liter polyethylene bottles and kept chilled until analysis.

Water samples were collected from Wailea golf course irrigation wells on February 11, 2009. Samples were collected from well #'s 2, 5, 6, 7, 8, 9 and 10) located on the Gold and Emerald courses and one reservoir located on the Gold course.

Water quality parameters evaluated included the 10 specific criteria designated for open coastal waters in Chapter 11-54, Section 06 (Open Coastal waters) of the Water Quality Standards, Department of Health, State of Hawaii. These criteria include: total nitrogen (TN) which is defined as inorganic nitrogen plus dissolved organic nitrogen, nitrate + nitrite nitrogen (NO_3^- + NO_2^-, hereafter referred to as NO_3^-), ammonium (NH_4^+), total phosphorus (TP) which is defined as inorganic phosphorus plus dissolved organic phosphorus, chlorophyll a (Chl *a*), turbidity, temperature, pH and salinity. In addition, orthophosphate phosphorus (PO_4^{-3}) and silica (Si) were reported because these constituents are sensitive indicators of biological activity and the degree of groundwater mixing, respectively.

Analyses for NH_4^+, PO_4^{3-}, and NO_3^- + NO_2^- (hereafter termed NO_3^-) were performed using a Technicon autoanalyzer according to standard methods for seawater analysis (Strickland and Parsons 1968, Grasshoff 1983). TN and TP were analyzed in a similar fashion following digestion. Dissolved organic nitrogen (TON) and dissolved organic phosphorus (TOP) were calculated as the difference between TN and inorganic N, and TP and inorganic P, respectively. Limits of detection for the dissolved nutrients are 0.01 M (0.14 g/L) for NO_3^- and NH_4^+, 0.01 M (0.31 g/L) for PO_4^{3-}, 0.1 M (1.4 g/L) for TN and 0.1 M (3.1 g/L) for TP.

Chl *a* was measured by filtering 300 ml of water through glass fiber filters; pigments on filters were extracted in 90% acetone in the dark at -5°C for 12-24 hours, and the fluorescence before and after acidification of the extract was measured with a Turner Designs fluorometer (level of detection 0.01 g/L). Salinity was determined using an AGE Model 2100 laboratory salinometer with a precision of 0.0003‰.

In situ field measurements included water temperature, pH, dissolved oxygen and salinity which are acquired using an RBR Model XR-620 CTD calibrated to factory specifications. The CTD has a readability of 0.001°C, 0.001pH units, 0.001% oxygen saturation, and 0.001 parts per thousand (‰) salinity.

Analyses of nutrients, turbidity, pH, Chl *a* and salinity were conducted by Marine Analytical Specialists located in Honolulu, Hawaii. This laboratory possesses acceptable ratings from EPA-compliant proficiency and quality control testing.

III. RESULTS

A. Horizontal Stratification

Table 1 shows results of all marine and well water chemical analyses for samples collected off Wailea on September 4, 2009 reported in micromolar units (M). Table 2 shows similar results presented in units of micrograms per liter (g/L). Tables 3 and 4 show geometric means of ocean samples collected at the same sampling stations during surveys conducted since June 2005. Table 5 shows water chemistry measurements (in units of M and g/L) for samples collected from seven irrigation wells and a reservoir located on the Wailea Golf Courses. Concentrations of twelve chemical constituents in surface and deep water samples are plotted as functions of distance from the shoreline in Figures 2 and 3. Mean concentrations (±standard error) of twelve chemical constituents in surface and deep water samples from previous increments of sampling, as well as data from the most recent sampling, are plotted as functions of distance from the shoreline in Figures 4-18.

Evaluation of transect data reveals that at all five sites there was distinct horizontal stratification in the surface concentrations of dissolved Si, NO_3^-, and TN over the entire length of the transects. In addition, nutrient concentrations in surface waters are generally elevated compared to the concentration of the corresponding sample of bottom water (Figure 2, Tables 1 and 2).

For all nutrients with distinct horizontal gradients, slopes of concentrations were steepest within 5 m of the shoreline at all five transect sites. Beyond 5 m from the shoreline concentrations of nutrients decreased progressively with distance from shore but at a substantially reduced gradient compared with the zone within 5 m of the shoreline. Salinity showed the opposite trend, with distinctly lower values within the nearshore zone, and progressive increases with distance from shore (Figure 3). The pattern of decreasing nutrient concentration and increasing salinity with distance from shore is most evident at Sites 1 and 2 (Five Graves, Palauea Beach) , where surface concentrations of NO_3^-near the shoreline were two orders of magnitude higher than samples collected at the seaward ends of the transects. Salinity was correspondingly lower near the shoreline compared to offshore samples, with values differing by 22.3‰ and 14.7‰ between the shoreline and offshore terminus of transects at Sites 1 and 2, respectively (Tables 1 and 2). Transects at Sites 3-5 had elevated nutrient concentrations and correspondingly lower salinities near the shoreline, but the horizontal gradients were far less pronounced compared to the patterns at Transects 1 and 2.

The pattern of elevated Si, NO_3^-, and TN with corresponding low salinity is indicative of groundwater entering the ocean near the shoreline. Low salinity groundwater, which contains high concentrations of Si, and NO_3^-, (see values for well waters in Table 5), percolates to the ocean near the shoreline, resulting in a distinct zone of mixing in the nearshore region. The magnitude of the zone of mixing, in terms of both horizontal extent and range in nutrient concentration, depends on the magnitude of the flux of groundwater entering the ocean from land, and the magnitude of physical mixing processes (primarily wind and wave stirring) at the sampling location.

Surface concentrations of PO_4^{3-} and TP did not show the same horizontal patterns with distance offshore as was evident with the other dissolved nutrients (Figure 2, Tables 1 and 2). A few distinctly higher measurements were recorded at different locations along the transects at various sites, but no obvious gradient is visible.

Dissolved nutrient constituents that are not associated with groundwater input (NH_4^+, TON, TOP) show varying patterns of distribution with respect to distance from the shoreline (Figure 2). With the exception of the shoreline sample at Site 3, the surface concentrations of NH_4^+ were relatively constant along the length of each transect, with values ranging from 0.01 – 0.42   M (Figure 2, Tables 1 and 2). Similar to NH_4^+, surface concentrations of TOP and TON were relatively constant at all sampling locations on all transect sites during the September 2009 survey (Figure 2).

At Transect site 3 (Wailea Beach), surface concentrations of turbidity were nearly an order of magnitude greater near the shoreline compared to offshore measurements. At Sites 4 (Ulua Beach) and 5 ('Ahihi-kina'u) turbidity was also elevated at the shoreline and decreased with distance from shore, but to a lesser extent than at site 3 (Figure 3 and Tables 1 and 2). At Sites 1 (Five Graves) and 2 (Palauea), turbidity did not exhibit elevated levels near the shoreline, and were nearly constant along the length of each transect. Beyond the nearshore area within 10 m of the shoreline, turbidity was similar on all five transects. At all five sites, concentrations of Chl *a* were elevated within the nearshore zone (within 10 m of the shoreline) compared to farther offshore (Figure 3, Tables 1 and 2). With the exception of the high value of Chl *a* in the shoreline sample at Site 4 (2.76 g/L), concentrations were of the same magnitude among the five sites during September 2009. Surface temperature was distinctly lower at Site 5 compared to the other four sites during September 2009 (Figure 3, Tables 1 and 2). At all sites, temperature decreased from the shoreline to a distance of 50 m from the shoreline, beyond which temperature was relatively constant (Figure 3, Tables 1 and 2). During the September 2009 survey, the highest measurements were at Site 4 (28.4°C) and the lowest measurement was at Site 5 (26.1°C).

B. Vertical Stratification

In many areas of the Hawaiian Islands, input of low salinity groundwater to the nearshore ocean creates a distinct buoyant surface lens that can persist for some distance from shore. Buoyant surface layers are generally found in areas with both conspicuous input of groundwater, and turbulent processes (primarily wave action) insufficient to completely mix the water column. During the September 2009 survey, vertical stratification was apparent in that concentrations of nutrients that occur in relatively high concentrations in groundwater (Si, NO_3^-, PO_4^{3-}, TN) were elevated in surface samples relative to bottom samples at all sites, while salinity showed a reverse trend with high values in bottom samples compared to surface values. Such gradients suggest that the groundwater was not completely mixed within the water column in the nearshore zone throughout the region of study.

Contrary to the nutrients listed above, there were no consistent patterns in vertical stratification in the concentrations of NH_4^+, TP, TOP, TON and Chl *a* during the September 2009 survey (Figures 2 and 3). In many instances, concentrations were higher in deep water compared to the surface water and in other cases, the opposite was evident. The lack of consistent trends in the stratification indicate that the variation is not likely a result of groundwater input, or any other factors associated with freshwater input from land. Temperature values did show stratification with the deep water samples colder than the surface water. These results were most likely due to solar warming.

C. Temporal Comparison of Monitoring Results

Figures 4-18 show mean concentrations (and the standard error) of water chemistry constituents from surface and deep samples at all five sites over the course of the Honua'ula monitoring program. Also plotted separately are data from the most recent survey in September 2009.

Examination of the plots in Figures 4-18 reveal some indications of changes in water chemistry between the most recent survey and the average survey results, as well as between the different survey sites over the course of monitoring. With respect to groundwater efflux, similar patterns of decreasing concentrations of Si, NO_3^-, PO_4^{3-} and increasing salinity with distance from shore are evident in the mean values at all five sampling sites, and have been consistently highest at Site 1 (Five Graves), Site 2 (Palauea), and Control Site 5 (Figures 4-18). In the most recent survey (September 2009) the concentrations of Si, NO_3^-, and TN were slightly higher than the mean values at Sites 1 and 3 while salinity was distinctly lower at Sites 1 and 2. In contrast, at Site 5, concentrations of Si, NO_3^-, and PO_4^{3-} were lower and salinity higher than the mean values (Figures 16 and 18). Excursions from the mean values have been observed in past surveys, most notable in the December 2007 survey which was conducted three days after a major storm front moved through the area (rainfall to the area was recorded at 2.95 inches in a 24 hour period).

These comparisons suggest that while there are some differences between surveys, water chemistry of the nearshore zone at Sites 1 and 2 was influenced by greater groundwater efflux during the September 2009 survey compared to the average values of surveys conducted in past years. In addition, the concentrations and gradients in nutrients that occur at Site 5, located beyond the influence of the Wailea Resort and other development in Wailea, were similar to the patterns on the transects located offshore of two of the sites off the Wailea Golf Courses (Sites 3 and 4. Therefore, it is apparent that the golf course operations are not solely responsible for changes that might be depicted in water quality.

D. Conservative Mixing Analysis

A useful treatment of water chemistry data for interpreting the extent of material input from land involves a hydrographic mixing model. In the simplest form, such a model consists of plotting the concentration of a dissolved chemical species as a function of salinity. Comparison of the curves produced by such plots with conservative mixing lines provides an indication of the origin and fate of the material in question (Officer 1979, Dollar and Atkinson 1992, Smith and Atkinson 1993). Figure 19 shows plots of concentrations of four chemical constituents (Si, NO_3^-, PO_4^{3-} and NH_4^+) as functions of salinity for the samples collected at each site in September 2009. Figures 20 and 21 show similar plots with historical data compared with the most recent survey.

Each graph also shows conservative mixing lines that are constructed by connecting the end-member concentrations of open ocean water and groundwater from irrigation wells upslope of the sampling area. The conservative mixing line for Figure 19 was constructed using water from Wailea Well No. 5 located to the northwest of the project area, and ocean water collected from near the bottom at the most offshore sampling locations.

If the parameter in question displays purely conservative behavior (no input or removal from any process other than physical mixing), data points should fall on, or very near, the conservative mixing line. If, however, external material is added to the system through processes such as leaching of fertilizer nutrients to groundwater, data points will fall above the mixing line. If material is being removed from the system by processes such as uptake by biotic metabolic processes, data points will fall below the mixing line.

Dissolved Si represents a check on the model as this material is present in high concentration in groundwater, but is not a major component of fertilizer. In addition, Si is not utilized rapidly within the nearshore environment by biological processes. It can be seen in Figure 19 that all but two data points from Sites 1-5 fall in a linear array on, or very close to the conservative mixing line for Si, indicating that groundwater entering the ocean at these sites is a nearly pure mix of groundwater similar to that from Wailea Well No. 5, and open coastal water. The anomalous data points collected from the shoreline at Sites 1 and 2 fell off the linear array below the conservative mixing line. The deviation of these nearshore points suggest that groundwater entering the ocean at the shoreline at Sites 1 and 2 may have a contribution from another groundwater source lower in Si concentration (possibly rainwater) that is contributing to input to the ocean. It can be seen in Figure 20 that similar deviations in concentrations of silica as functions of salinity have occurred in previous surveys. In addition, it is also evident in Figure 20 that there have been deviations above the mixing line in previous surveys, indicating input of other sources of groundwater enriched in Si relative to groundwater from Wailea Well No. 5.

The plots of NO_3^- versus salinity reveal a generally similar pattern as Si, with most of the data points from all five sites falling on, or very close to the mixing line (Figure 19). Similar to Si, the plots of NO_3^- vs. salinity of the shoreline samples at Sites 1 and 2 also fall below the mixing line.

The linear relationship of the concentrations of NO_3^- as functions of salinity indicates little or no detectable uptake of this material in the marine environment (e.g., no upward concave curvature of the data lines). Lack of uptake indicates that NO_3^- is not being removed from the water column by metabolic reactions that could change the composition of the marine environment. Rather, the nutrients entering the ocean through groundwater efflux are dispersed by physical mixing processes. In addition, the distinct vertical stratification that is usually evident to a distance of at least 100 m from the shoreline suggests that water with increased concentrations of NO_3^- as a result of groundwater input are limited to a buoyant surface plume that does not mix through the entire water column. As a result, these analyses provide valid evidence to indicate that the increased nutrients fluxes from land have little potential to cause alteration in biological community composition or function.

It has been documented in other locales in the Hawaiian Islands (e.g., Keauhou Bay on the Big Island) where similar nutrient subsidies from golf course leaching occur that excess NO_3^- does not cause changes in biotic community structure (Dollar and

Atkinson 1992). It was shown at Keauhou that owing to the distinct vertical stratification in the nearshore zone, the excess nutrients do not normally come into contact with benthic communities, thereby limiting the potential for increased uptake by benthic algae. In addition, the residence time of the high nutrient water was short enough within the embayment to preclude phytoplankton blooms. As a result, while NO_3^- concentrations doubled in Keauhou Bay as a result of golf course leaching for a period of at least several years, there is no detectable negative effect to the marine environment. Owing to the unrestricted nature of circulation and mixing off the Wailea site with no confined embayments it is reasonable to assume that the excess NO_3^- subsidies that are apparent in the ongoing monitoring will not result in alteration to biological communities. Inspection of the region during the monitoring surveys indicates that indeed, there are no areas where excessive algal growth is presently occurring, or has occurred in the past.

The other form of dissolved inorganic nitrogen, NH_4^+, does not show a linear pattern of distribution with respect to salinity (Figure 19). Several of the samples with high (34-35‰) salinity also displayed the highest concentrations of NH_4^+, particularly at Transect Sites 1 and 3. The lack of a correlation between salinity and concentration of NH_4^+ suggests that this form of nitrogen is not present in the marine environment as a result of mixing from groundwater sources. Rather, NH_4^+ appears to be generated by natural biological activity in the ocean waters off of Wailea.

PO_4^{3-} is also a major component of fertilizer, but is usually not found to leach to groundwater to the extent of NO_3^-, owing to a high absorptive affinity of phosphorus in soils. It can be seen in Figure 19 that there is a weak correlation between PO_4^{3-} and salinity, when compared to the linearity for Si and NO_3^- (Figure 19). In the cumulative data, most of the data points at salinities below 32‰ from all the sites fall on or below the conservative mixing line (Figure 21). These results suggest that the operation of the golf course is not resulting in increased concentrations of PO_4^{3-} in the nearshore zone.

E. Time Course Mixing Analyses

While it is possible to evaluate temporal changes from repetitive surveys conducted over time in terms of concentrations of water chemistry constituents (See Section D), a more informative and accurate method of evaluating changes over time is to utilize the results of scaling nutrient concentrations to salinity. As discussed above, the simple hydrographic mixing model consisting of plotting concentrations of nutrient constituents versus salinity eliminates the ambiguity associated with comparing nutrient concentrations of samples collected at different stages of tide and sea conditions. Tables 6-8 show the numerical values of the Y-intercepts, slopes, and respective upper and lower 95% confidence limits of linear regressions fitted through the data points for Si, NO_3^-, and PO_4^{3-} as functions of salinity for each year of monitoring at Transect Sites 1-5.

The magnitude of the contribution of nutrients to groundwater originating from land-based activities will be reflected in both the steepness of the slope and the magnitude of the Y-intercept of the regression line fitted through the concentrations scaled to salinity (the Y-intercept can be interpreted as the nutrient concentration that would occur at a salinity of zero if the distribution of data points is linear). This relationship is valid because with increasing contributions from land, nutrient concentrations in any given parcel of water will increase with no corresponding change in salinity. Hence, if the contribution from land to groundwater nutrient composition is increasing over time, there would be progressive increases in the absolute value of the slopes, as well as the Y-intercepts of the regression lines fitted through each set of nutrient concentrations plotted as functions of salinity. Conversely, if the contributions to groundwater from land are decreasing, there will be decreases in the absolute values of the slopes and Y-intercepts.

Plots of the values of the slopes (Figure 22) and Y-intercepts (Figure 23) of regression lines fitted though concentrations of Si, NO_3^- and PO_4^{3-} scaled to salinity during each survey year provide an indication of the changes that have been occurring over time in the nearshore ocean off Wailea. As stated above, Si provides the best case for evaluating the effectiveness of the method, as Si is present in high concentration in groundwater but is not a component of fertilizers. NO_3^- and PO_4^{-3} are the forms of nitrogen and phosphorus, respectively, found in high concentrations in groundwater relative to ocean water, and are the major nutrient constituents found in fertilizers.

Examination of Figures 22 and 23, as well as Tables 6-8 reveal that none of the slopes or Y-intercepts of Si or NO_3^- from 2005 to 2009 at any of the transect sites exhibit any indication of progressively increasing or decreasing values over the course of monitoring. The term "REGSLOPE" in Tables 6-8 denotes the values of the slopes and 95% confidence limits of linear regressions of the values of the yearly slopes and Y-intercepts as a function of time. In most cases, the upper and lower 95% confidence limits of the REGSLOPE coefficients are not significantly different than zero, indicating that there is no statistically significant increase or decrease in the salinity-scaled concentrations of Si, NO_3^- and PO_4^{3-} over the course of the monitoring program (Tables 6-8). Notable excursions from zero in the confidence limits for Sites 2 and 4 occurred during 2005 and 2008 (Tables 6 and 7) and at Site 5 in 2009 (Table 7). The weak linear relationship between Si, NO_3^- and salinity in these instances were possibly a result of extreme physical mixing of the water column during those surveys.

Patterns in the time course mixing analysis for PO_4^{3-} are not as definitive as for Si and NO_3^-. The inconsistent linearity between PO_4^{3-} and salinity between sites and surveys result in a wide variation in the confidence limits. Overall, the lack of any significant slope from zero indicates that there have been no increases or decreases in nutrient input to the ocean from the project site over the course of monitoring (2005-2009).

F. Compliance with DOH Standards

Tables 1 and 2 also show samples that exceed DOH water quality standards for open coastal waters under "wet" and "dry" conditions. The distinction between application of wet and dry criteria is based on whether the survey area is likely to receive less than ("dry") or greater than ("wet") 3 million gallons of freshwater input per mile per day. DOH standards include specific criteria for three situations; criteria that are not to be exceeded during either 10% or 2% of the time, and criteria that are not to be exceeded by the geometric mean of samples. Comparison of the 10% or 2% of the time criteria for the small data set presently acquired is not statistically meaningful. However, comparing sample concentrations to these criteria provide an indication of whether water quality is near the stated specific criteria.

Boxed values in Tables 1 and 2 indicate measurements which exceed the DOH 10% standards under "dry" conditions, while boxed and shaded values show measurements which exceed DOH 10% standards under "wet" conditions. All but sixteen of the sixty samples collected were above the 10% criteria for NO_3^- under "dry" or "wet" conditions in the September 2009 survey (Table 1). Most of the previous surveys have also had a high percentage of the samples exceeding the 10% limit for NO_3^-. In addition to NO_3^-, two measurements of NH_4^+, eight measurements of TN, two measurements of turbidity and nine measurements of Chl *a* exceeded the 10% DOH criteria under "dry" conditions in September 2009. If "wet" criteria are applied, four measurements of NH_4^+, twenty-three measurements of TN, two measurements of turbidity and fourteen measurement of Chl *a* exceeded the DOH water quality standards. During the September 2009 survey, no measurements of TP exceeded either the "dry" or "wet" DOH standards.

Tables 4 and 5 show geometric means of samples collected at the same locations during the six increments of the monitoring program. Also shown in these tables are the samples that exceed the DOH geometric mean limits for open coastal waters under "dry" (boxed) and "wet" (boxed and shaded) conditions. All measurements of NO_3^- in surface waters, and nearly all measurements of NH_4^+, TN and Chl *a* exceeded the DOH geometric mean standards for dry conditions. Conversely, only a few of the geometric means of TP and turbidity were exceeded under dry conditions. It is important to note that a similar pattern of exceedance of geometric means occurred at Site 5 compared to the other four sites. As described above, Site 5 is considered a control that is located beyond the influence of the golf courses or other major land uses. The large number of water chemistry values that exceed the DOH criteria at Site 5, and the similarity in the pattern of these exceedances relative to the four Sites located directly off the existing Wailea Golf Courses and the Honua'ula site indicate that other factors, including natural components of groundwater efflux, are responsible for water chemistry characteristics to exceed stated limits. Thus, the elevated concentrations of water chemistry constituents at sampling stations offshore of the developed Wailea area cannot be attributed completely to anthropogenic factors associated with land use development. As naturally occurring groundwater contains elevated nutrient concentrations relative to open coastal water, input of naturally occurring groundwater is likely a factor in the exceedances of DOH standards which do not include consideration of such natural factors.

IV. DISCUSSION and CONCLUSIONS

The purpose of this assessment is to assemble the information to make valid evaluations of the potential for impact to the marine environments from the proposed Honua'ula project. The information collected in this study provides the basis to understand the processes that are operating in the nearshore ocean, so as to be able to address any concerns that might be raised in the planning process.

The proposed Honua'ula project does not include any plans for any direct alteration of the shoreline or offshore areas. In fact, the shoreline area downslope from Honua'ula is separated by the existing Wailea Resort. Therefore, potential impacts to the marine environment can only be considered from activities on land that may result in delivery of materials (primarily fresh water and nutrients) to the ocean through infiltration to groundwater on land with subsequent discharge to the ocean, and surface runoff. To evaluate the possible magnitude of these processes, a report has been prepared by Tom Nance Water Resource Engineering entitled "*Assessment of the Potential Impact on Water Resources of the Honua'ula Project in Wailea, Maui*" (TNWRE 2010).

For the purposes of analyses of impact on water resources on the property, potable and irrigation water would be provided by six brackish wells; four wells have already been developed (two onsite and two to the north of the project site), with two new wells planned as needed. Onsite reverse osmosis (RO) of brackish well water will provide potable water. Recovery rate of the RO process is on the order of 65% of the feedwater supply, with the remaining 35% being a concentrate that would be mixed with brackish and R-1 water and reused for golf course irrigation. Domestic wastewater would be treated to R-1 quality, either at the Makena Resort treatment plant, or a new onsite treatment plant, and also used for golf course irrigation. Landscape irrigation in areas outside of the golf course would be supplied by brackish well water. Numerous detention basins are also planned so that there will be no increase in the peak rate of storm water runoff leaving the Property compared to existing conditions.

With respect to the potential impacts these proposed scenarios TNWRE (2010) provides the following assumptions and potential impacts to groundwater downgradient of the Honua'ula project site:

1) 70% of the average annual runoff from the project will percolate to groundwater through detention basins. The remainder will be lost to evaporation or overtop the detention basins in severe storm events, and flow through the Wailea Resort to the shoreline.

2) For all the sources of supply used to irrigate the golf course and landscaped areas, the portion percolating through the root zone will have a salinity increase of 10% and a reduction of 50% in the concentration of nitrogen (N) and phosphorus (P) as a result

of nutrient uptake by processes occurring within the soil (e.g., plant uptake and adsorption).

3) R-1 effluent from the Wastewater Treatment Plant that will be reused for golf course irrigation will have an N concentration of 775   M (10.85 mg/L) and a P concentration of 165   M (2.00 mg/L)

4) On a long-term basis, it is assumed that the salinity of the combined brackish well water supply is 0.95‰. With 65% RO product recovery rate, the salinity of the remaining 35% of the brackish water used for golf course irrigation will rise to 2.41‰. Essentially all of the N and P in the brackish water run through the RO process will be contained in the 35% feedwater concentrate that will be used for golf course irrigation.

5) Fertilizer applications in landscaped areas will be approximately 3 lbs. N per 1,000 ft^2 per year, and 0.5 lbs. P per 1,000 ft^2 per year. Of these applications, 10% of the N, and 2% of the P will percolate through the root zone to groundwater.

6). In the hundreds of feet of travel by the percolate through the vadose zone (the unsaturated lavas between the ground surface and groundwater) and the thousands of feet of travel for groundwater to discharge at the shoreline, natural processes will remove approximately 80% of dissolved N and 95% of dissolved P.

7). Computed changes to groundwater reveal a 2.9% reduction in flowrate; a 0.62% increase in salinity; a reduction in N loading of 4.3%, and a reduction in P loading of 4.8%. The largest factor contributing to these results is that most of the groundwater supply (~75%) will come from offsite Kamaole wells.

Hence, based on the projected configuration of the Honuaʻula project, the estimates of changes to groundwater and surface water would result in a decrease in nutrient loading to the ocean relative to the existing condition. With such a scenario, it is evident that there would be no expected impacts to the nearshore marine ecosystem owing to nutrient subsidies related to development of Honuaʻula. As the nearshore marine community composition in Hawaii typically occur in oceanic waters, the small reduction in nutrient loading and, groundwater flow rate cannot be considered as a potential negative impact.

In addition to consideration of effects from nutrient additions, it is also important to consider the potential effect of sedimentation that may occur as a result of construction activities. The property is presently comprised of areas of exposed soil and rock, along with vegetative groundcover. During episodes of heavy rainfall, sediment is undoubtedly suspended in sheetflow drainage which flows off the property in a seaward direction. The proposed plan including numerous onsite detention basins will greatly reduce surface runoff across the project site, with a corresponding decrease in potential discharge to the ocean. In addition, while a portion of water caught in the detention basins will seep back to the groundwater, the particulate sediment load will be retained within the basin. Hence, sediment loading to the ocean will decrease as a result of both lowered storm water discharge volume, and particulate concentrations relative to the present scenario.

During the construction phases, it is likely that permit regulations will limit the area of excavation at any one time, and require dust control measures. In addition, the predominant direction of wind (long-shore tradewinds) will not produce offshore winds that would carry construction-generated dust toward the ocean. As a result, there is little potential for any significant input of sediment to the marine environment resulting from the proposed project.

All of these considerations indicate that the proposed Honuaʻula project will not have any significant negative effect on water quality in the coastal ocean offshore of the property.

IV. SUMMARY

- Six phases of water quality monitoring program for the planned Honuaʻula project have been carried out since 2005, with the most recently taking place in September 2009. During each survey, sixty ocean water samples were collected on four transects spaced along the length of coastline makai of the project and one transect located outside of the project area as a control site. Site 1 was located at the southern boundary of the Gold Course (Five Graves), Site 2 was located near the central part of the Emerald Course (Palauea Beach), Site 3 was located off the juncture of the Emerald and Blue Courses, and Site 4 was located near the northern boundary of the Blue Course. Site 5 served as a control, and was located near the northern end of the 'Ahihi-kina'u Natural Area Reserve, approximately four km to the south of the project site. Transects extended from the shoreline out to the open coastal ocean. Water samples were analyzed for chemical criteria specified by DOH water quality standards, as well as several additional criteria. Water samples were also collected during surveys from seven irrigation wells and a golf-course reservoir in the Wailea area upslope of the sampling area to provide data on composition of groundwater flowing under the site.

- Water chemistry constituents that occur in high concentration in groundwater (Si, NO_3^- and TN) typically displayed steeply sloping horizontal gradients with highest concentrations nearest to shore and decreasing concentrations moving seaward. Salinity showed the opposite trend, with lowest values closest to shore, and increasing values with distance seaward. Gradients were steepest within 10 m of the shoreline, but often continued across the entire length of all transects. The steep nearshore gradients had the greatest magnitude (i.e., highest concentrations at the shoreline) at Sites 1and 2. The steep horizontal gradients signify mixing of low salinity/high nutrient groundwater that discharges to the ocean at the shoreline and high salinity/low nutrient ocean water.

- Vertical stratification of the water column was also clearly evident at all sites for the chemical constituents that occur in high concentrations in groundwater relative to ocean water. Vertical stratification indicates that physical mixing processes generated by wind, waves and currents were often not sufficient to completely break down the density differences between the buoyant low salinity surface layer and denser underlying water.

- Most water chemistry constituents that do not occur in high concentrations in groundwater (NH_4^+, TOP, TON, Chl *a*, turbidity) did not display distinct horizontal or vertical trends.

- Scaling nutrient concentrations to salinity indicates that during the September 2009 survey there was no apparent subsidy of NO_3^- to the nearshore ocean at any of the sites. During previous surveys, substantial subsidies of NO_3^- at some locations had been evident. The likely cause of the subsidies of NO_3^- in past surveys was either leaching of golf course or landscaping fertilizers to groundwater that flows under the Wailea golf courses, or possibly leakage from old septic systems or cesspools that served residences in the vicinity of Site 1.

- Linear regression statistics of nutrient concentration plotted as functions of salinity are useful for evaluating changes to water quality over time. When the regression values of nutrient concentrations versus salinity are plotted as a function of time, there are no statistically significant increases or decreases over the five years of monitoring at any of the survey sites. The lack of increases in these slopes and intercepts indicate that there has been no consistent change in nutrient input from land to groundwater that enters the ocean from 2005 to 2009. Further monitoring will be of interest to note the future direction of the oscillating trends noted in the last six years.

- Comparing water chemistry parameters to DOH standards revealed numerous measurements of NO_3^- exceeded the DOH "not to exceed more than 10% of the time" criteria for both wet and dry conditions of open coastal waters. Numerous values of NO_3^-, NH_4^+, TN, Chl *a*, and to a lesser extent TP and turbidity, exceeded specified limits for geometric means. Such exceedances occurred at all survey sites, including the control site which is not influenced by the golf courses or other large-scale land uses. Such results indicate that the exceedances of the geometric mean water quality standards are not solely associated with golf course operation or other anthropogenic land uses. Rather, natural groundwater discharge can cause water chemistry characteristics to exceed DOH standards.

- With potable water supplied by reverse osmosis of brackish well water and irrigation water supplied from brackish well water and R-1 effluent from the wastewater treatment plant, there will be no adverse affect to groundwater resources in areas in the vicinity of the project. Evaluations of changes to groundwater flux and composition resulting from the project performed by Tom Nance Water Resources Engineering indicate a 2.9% reduction in flowrate; a 0.62% increase in salinity; a reduction in N loading of 4.3%, and a reduction in P loading of 4.8%. The largest factor contributing to these results are that most of the groundwater supply (~75%) will come from offsite Kamaole wells to the north of the project area. In detaining onsite runoff, the detention basins will: 1) ensure that the volume of rain water runoff leaving the Property will not increase over current conditions; and 2) capture floatables and suspended solids in the basins, thus reducing sediment loads discharging to the marine environment at the shoreline.

- Based on the projected planning for the Honuaʻula project, the estimates of changes to groundwater and surface water would result in a decrease in nutrient and sediment loading to the ocean relative to the existing condition. With such a scenario, it is evident that there would be no expected impacts to the nearshore marine ecosystem owing to development of Honuaʻula.

REFERENCES CITED

Dollar, S. J. and M. J. Atkinson. 1992. Effects of nutrient subsidies from groundwater to nearshore marine ecosystems off the Island of Hawaii. Est. Coast. Shelf Sci. 35. 409-424.

Grasshoff, K. 1983. Methods of seawater analysis. Verlag Chemie, Weinheim, 419 pp.

Tom Nance Water Resources Engineering. 2010. Assessment of the potential impact on water resources of the Honuaʻula project in Wailea, Maui. Prepared for Honuaʻula Partners, LLC, Kihei Maui.

Officer, C. B. 1979. Discussion of the behavior of nonconservative dissolved constituents in estuaries. Est. Coast. Mar. Sci. 9:569-576.

Smith, S. V. and M. J. Atkinson. 1993. Mass balance analysis of C, N, and P fluxes in coastal water bodies, including lagoons. (ed.) B. Kjerve. Elsevier Oceanography Series, Elsevier Publishing Co. pp. 123-145.

Strickland J. D. H. and T. R. Parsons. 1968. A practical handbook of sea-water analysis. Fisheries Research Bd. of Canada, Bull. 167. 311 p.

FIGURE 1. Aerial photograph of Wailea area showing boundaries of Honuaʻula Project (in yellow) and locations of marine water quality sampling transects. Transect W-5 is considered a control and is located in the 'Ahihi-kina'u Natural Area Reserve approximately four km south of the Honuaʻula Project site.

TABLE 1. Water chemistry measurements from ocean water samples collected in the vicinity of the Honua'ula project site on September 4, 2009. Abbreviations as follows: DFS=distance from shore; S=surface; D=deep, BDL=below detection limit. Also shown are the State of Hawaii, Department of Health (DOH) "not to exceed more than 10% of the time" and "not to exceed more than 2% of the time" water quality standards for open coastal waters under "dry" and "wet" conditions. Boxed values exceed DOH 10% "dry" standards; boxed and shaded values exceed DOH 10% "wet" standards. For sampling site locations, see Figure 1.

TRANSECT SITE	DFS (m)	DEPTH (m)	PO4 (µM)	NO3 (µM)	NH4 (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURB (NTU)	SALINITY (ppt)	CHL a (µg/L)	TEMP (deg.C)	pH (std.units)	O2 % Sat
WAILEA 1	0 S	0.1	0.12	143.0	0.03	255.3	0.25	1.65	0.37	144.7	0.20	12.819	0.50	27.5	8.11	113.4
	2 S	0.1	0.30	57.36	0.14	108.18	0.27	4.32	0.57	61.82	0.29	27.397	1.20	27.6	8.19	111.2
	5 S	0.1	0.04	15.94	0.05	33.11	0.29	6.77	0.33	22.76	0.25	33.019	0.38	27.6	8.18	110.2
	5 D	1.0	0.44	10.54	2.69	25.00	0.36	11.02	0.80	24.25	0.21	33.588	0.44	27.5	8.16	109.2
	10 S	0.1	0.05	19.52	0.13	40.34	0.30	6.66	0.35	26.31	0.29	32.601	0.21	27.5	8.18	109.5
	10 D	1.7	0.06	4.86	0.06	12.19	0.33	7.25	0.39	12.17	0.18	34.457	0.26	27.0	8.16	108.9
	50 S	0.1	0.11	10.74	0.26	19.12	0.35	9.28	0.46	20.28	0.19	34.001	0.18	26.7	8.17	108.0
	50 D	4.4	0.13	0.92	0.08	3.50	0.34	7.23	0.47	8.23	0.13	35.096	0.73	26.7	8.16	104.8
	100 S	0.1	0.04	11.22	0.11	19.73	0.30	6.93	0.34	18.26	0.16	33.959	0.23	26.8	8.18	107.7
	100 D	6.2	0.03	0.11	0.04	2.85	0.31	7.33	0.34	7.48	0.13	35.135	0.12	26.7	8.17	105.9
	150 S	0.1	0.03	1.12	0.09	3.40	0.32	8.14	0.35	9.35	0.18	35.083	0.06	27.0	8.17	102.5
	150 D	11.7	0.03	0.06	0.05	2.05	0.32	7.00	0.35	7.11	0.12	35.219	0.09	26.7	8.17	105.0
WAILEA 2	0 S	0.1	0.05	170.5	0.02	146.0	0.24	4.33	0.29	174.8	0.22	16.982	0.60	27.3	8.24	111.0
	2 S	0.1	0.18	27.23	0.23	22.92	0.29	8.56	0.47	36.02	0.20	33.149	1.11	27.3	8.19	110.9
	5 S	0.1	0.05	5.47	0.06	9.28	0.30	6.80	0.35	12.33	0.18	34.790	0.24	27.3	8.16	108.2
	5 D	1.0	0.24	2.65	0.06	5.66	0.32	7.21	0.56	9.92	0.19	34.965	0.25	27.3	8.17	110.9
	10 S	0.1	0.31	2.46	0.42	5.92	0.37	12.97	0.68	15.85	0.24	34.991	0.14	27.2	8.17	109.5
	10 D	2.0	0.04	0.93	0.22	3.62	0.32	7.46	0.36	8.61	0.17	35.084	0.58	27.0	8.17	108.5
	50 S	0.1	0.05	6.15	BDL	12.09	0.31	8.96	0.36	15.11	0.18	34.678	0.19	26.9	8.17	105.4
	50 D	4.9	0.04	0.16	0.10	2.31	0.30	7.34	0.34	7.60	0.19	35.218	0.25	26.8	8.17	102.4
	100 S	0.2	0.04	4.93	0.03	9.95	0.32	7.33	0.36	12.29	0.16	34.928	0.18	26.8	8.16	103.0
	100 D	8.7	0.03	0.02	0.06	1.70	0.29	8.02	0.32	8.10	0.14	35.252	0.18	26.8	8.18	104.1
	150 S	0.1	0.03	4.49	0.08	9.27	0.28	7.60	0.31	12.17	0.19	34.724	0.14	27.1	8.14	99.6
	150 D	14.4	0.04	0.22	0.13	2.35	0.28	7.50	0.32	7.85	0.17	35.247	0.33	26.6	8.17	104.6
WAILEA 3	0 S	0.1	0.09	27.76	1.39	58.98	0.45	12.92	0.54	42.07	0.97	31.650	1.62	27.3	8.30	104.8
	2 S	0.1	0.19	32.63	0.13	65.75	0.29	5.32	0.48	38.08	0.33	31.137	0.39	27.3	8.18	103.7
	5 S	0.1	0.04	4.57	0.11	9.64	0.28	7.87	0.32	12.55	0.17	34.618	0.23	28.4	8.18	103.4
	5 D	1.0	0.13	4.01	0.14	9.91	0.29	7.16	0.42	11.31	0.20	34.623	0.24	28.2	8.19	104.2
	10 S	0.1	0.16	26.97	0.12	55.68	0.30	5.68	0.46	32.77	0.16	31.933	0.23	28.1	8.15	103.4
	10 D	1.0	0.03	8.73	0.13	19.52	0.28	8.42	0.31	17.28	0.28	34.086	0.27	27.5	8.17	102.3
	50 S	0.1	0.07	2.29	0.20	6.04	0.40	8.56	0.47	11.05	0.32	34.987	0.19	27.2	8.16	101.2
	50 D	4.0	0.12	0.01	0.44	1.56	0.37	8.54	0.49	8.99	0.13	35.161	0.19	27.2	8.18	100.9
	100 S	0.1	0.04	0.84	0.18	3.41	0.35	7.79	0.39	8.81	0.17	35.060	0.12	27.0	8.17	100.8
	100 D	6.1	0.07	0.02	0.13	1.38	0.34	8.33	0.41	8.48	0.12	35.196	0.19	26.8	8.19	103.5
	150 S	0.1	0.03	1.18	0.13	4.33	0.32	6.45	0.35	7.76	0.14	35.063	0.10	27.0	8.16	101.7
	150 D	11.2	0.12	0.07	0.15	1.09	0.31	7.43	0.43	7.65	0.09	35.203	0.09	26.7	8.19	106.9
WAILEA 4	0 S	0.1	0.03	24.63	0.04	37.00	0.31	6.95	0.34	31.62	0.41	32.242	0.67	28.4	8.25	118.3
	2 S	0.1	0.03	24.02	BDL	24.88	0.31	6.42	0.34	30.44	0.53	32.708	2.76	28.4	8.25	113.7
	5 S	0.1	0.04	2.36	0.06	5.27	0.32	8.20	0.36	10.62	0.35	34.829	0.65	28.4	8.19	116.4
	5 D	1.0	0.04	1.87	0.07	4.75	0.30	6.91	0.34	8.85	0.32	34.936	0.81	28.4	8.18	109.2
	10 S	0.1	0.04	0.61	0.10	4.56	0.32	8.19	0.36	8.90	0.37	35.085	0.20	28.1	8.25	106.5
	10 D	1.0	0.04	0.31	0.03	3.39	0.34	7.24	0.38	7.58	0.25	35.166	0.16	27.5	8.18	105.2
	50 S	0.1	0.25	25.32	0.32	39.61	0.37	7.10	0.62	32.74	0.13	33.011	0.14	27.0	8.11	104.1
	50 D	5.2	0.11	0.36	0.24	2.07	0.33	7.91	0.44	8.51	0.15	35.132	0.08	26.7	8.16	101.1
	100 S	0.1	0.04	7.14	0.17	10.55	0.34	6.40	0.38	13.71	0.17	34.550	0.21	27.4	8.13	101.1
	100 D	9.8	0.03	0.09	0.32	2.04	0.31	6.88	0.34	7.29	0.12	35.170	0.16	26.7	8.17	107.3
	150 S	0.1	0.03	BDL	0.04	1.74	0.33	7.27	0.36	7.31	0.09	35.205	0.12	27.7	8.18	102.4
	150 D	12.3	0.06	BDL	0.01	1.47	0.35	6.58	0.41	6.59	0.11	35.181	0.25	26.7	8.19	112.0
WAILEA 5	0 S	0.1	0.03	8.55	0.12	55.70	0.34	6.76	0.37	15.43	0.40	32.410	0.58	26.1	8.15	112.9
	2 S	0.1	0.01	7.05	0.22	49.39	0.32	7.46	0.33	14.73	0.29	32.877	0.42	26.7	8.16	115.7
	5 S	0.1	0.08	5.27	0.32	39.96	0.32	7.45	0.40	13.04	0.28	33.307	0.46	26.8	8.14	111.7
	5 D	1.0	0.02	4.76	0.33	37.44	0.35	9.34	0.37	14.43	0.21	33.491	0.50	26.7	8.14	112.7
	10 S	0.1	0.06	2.96	0.29	24.33	0.29	7.27	0.35	10.52	0.18	34.223	0.20	26.5	8.13	105.9
	10 D	2.0	0.07	2.44	0.17	20.48	0.31	6.66	0.38	9.27	0.18	34.763	0.14	26.2	8.12	100.3
	50 S	0.1	0.04	0.88	0.05	7.88	0.30	7.24	0.34	8.17	0.26	34.908	0.16	26.3	8.09	99.0
	50 D	4.4	0.11	0.16	0.04	4.98	0.31	7.02	0.42	7.22	0.15	35.138	1.71	26.3	8.10	102.8
	100 S	0.1	0.13	1.76	0.06	10.69	0.31	6.94	0.44	8.76	0.19	34.772	0.37	26.5	8.09	100.6
	100 D	6.4	0.05	0.05	0.02	2.68	0.31	7.03	0.36	7.10	0.26	35.154	0.29	26.7	8.12	102.8
	150 S	0.1	0.08	0.02	0.14	1.82	0.33	7.68	0.41	7.84	0.11	35.276	0.09	26.7	8.16	102.5
	150 D	7.7	0.08	0.01	0.02	2.12	0.34	7.76	0.42	7.79	0.12	35.185	0.07	26.6	8.16	104.6
DOH WQS	DRY		10%	0.71	0.36				0.96	12.86	0.50	*	0.50	**	***	****
			2%	1.43	0.64				1.45	17.86	1.00		1.00			
	WET		10%	1.00	0.61				1.29	17.85	1.25	*	0.90	**	***	****
			2%	1.78	1.07				1.93	25.00	2.00		1.75			

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.
** Temperature shall not vary by more than one degree C. from ambient conditions.
***pH shall not deviate more than 0.5 units from a value of 8.1.
****Dissolved Oxygen not to be below 75% saturation.

TABLE 2. Water chemistry measurements from ocean water samples (in µg/L) collected off the Honua'ula project site on September 4, 2009. Abbreviations as follows: DFS=distance from shore; S=surface; D=deep, BDL=below detection limit. Also shown are the State of Hawaii, Department of Health (DOH) "not to exceed more than 10% of the time" and "not to exceed more than 2% of the time" water quality standards for open coastal waters under "dry" and "wet" conditions. Boxed values exceed DOH 10% "dry" standards; boxed and shaded values exceed DOH 10% "wet" standards. For sampling site locations, see Figure 1.

TRANSECT SITE	DFS (m)	DEPTH (m)	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (NTU)	SALINITY (ppt)	CHL a (µg/L)	TEMP (deg.C)	pH (std.units)	O2 % Sat
WAILEA 1	0 S	0.1	3.72	2003	0.42	7173	7.74	23.11	11.46	2026	0.20	12.819	0.50	27.5	8.11	113.4
	2 S	0.1	9.29	803.4	1.96	3040	8.36	60.51	17.65	865.9	0.29	27.397	1.20	27.6	8.19	111.2
	5 S	0.1	1.24	223.3	0.70	930.4	8.98	94.82	10.22	318.8	0.25	33.019	0.38	27.6	8.18	110.2
	5 D	1.0	13.63	147.6	37.68	702.5	11.15	154.3	24.78	339.6	0.21	33.588	0.44	27.5	8.16	109.2
	10 S	0.1	1.55	273.4	1.82	1134	9.29	93.28	10.84	368.5	0.29	32.601	0.21	27.5	8.18	109.5
	10 D	1.7	1.86	68.07	0.84	342.5	10.22	101.5	12.08	170.5	0.18	34.457	0.26	27.0	8.16	108.9
	50 S	0.1	3.41	150.4	3.64	537.3	10.84	130.0	14.25	284.0	0.19	34.001	0.18	26.7	8.17	108.0
	50 D	4.4	4.03	12.89	1.12	98.35	10.53	101.3	14.56	115.3	0.13	35.096	0.73	26.7	8.16	104.8
	100 S	0.1	1.24	157.1	1.54	554.4	9.29	97.06	10.53	255.7	0.16	33.959	0.23	26.8	8.18	107.7
	100 D	6.2	0.93	1.54	0.56	80.09	9.60	102.7	10.53	104.8	0.13	35.135	0.12	26.7	8.17	105.9
	150 S	0.1	0.93	15.69	1.26	95.54	9.91	114.0	10.84	131.0	0.18	35.083	0.06	27.0	8.17	102.5
	150 D	11.7	0.93	0.84	0.70	57.61	9.91	98.04	10.84	99.58	0.12	35.219	0.09	26.7	8.17	105.0
WAILEA 2	0 S	0.1	1.55	2388	0.28	4101	7.43	60.65	8.98	2449	0.22	16.982	0.60	27.3	8.24	111.0
	2 S	0.1	5.58	381.4	3.22	644.1	8.98	119.9	14.56	504.5	0.20	33.149	1.11	27.3	8.19	110.9
	5 S	0.1	1.55	76.61	0.84	260.8	9.29	95.24	10.84	172.7	0.18	34.790	0.24	27.3	8.16	108.2
	5 D	1.0	7.43	37.12	0.84	159.0	9.91	101.0	17.34	138.9	0.19	34.965	0.25	27.3	8.17	110.9
	10 S	0.1	9.60	34.45	5.88	166.4	11.46	181.7	21.06	222.0	0.24	34.991	0.14	27.2	8.17	109.5
	10 D	2.0	1.24	13.03	3.08	101.7	9.91	104.5	11.15	120.6	0.17	35.084	0.58	27.0	8.17	108.5
	50 S	0.1	1.55	86.14	BDL	339.7	9.60	125.5	11.15	211.6	0.18	34.678	0.19	26.9	8.17	105.4
	50 D	4.9	1.24	2.24	1.40	64.91	9.29	102.8	10.53	106.4	0.19	35.218	0.25	26.8	8.17	102.4
	100 S	0.2	1.24	69.05	0.42	279.6	9.91	102.7	11.15	172.1	0.16	34.928	0.18	26.8	8.16	103.0
	100 D	8.7	0.93	0.28	0.84	47.77	8.98	112.3	9.91	113.4	0.14	35.252	0.18	26.8	8.18	104.1
	150 S	0.1	0.93	62.89	1.12	260.5	8.67	106.4	9.60	170.5	0.19	34.724	0.14	27.1	8.14	99.6
	150 D	14.4	1.24	3.08	1.82	66.04	8.67	105.0	9.91	109.9	0.17	35.247	0.33	26.6	8.17	104.6
WAILEA 3	0 S	0.1	2.79	388.8	19.47	1657	13.94	181.0	16.73	589.2	0.97	31.650	1.62	27.3	8.30	104.8
	2 S	0.1	5.88	457.0	1.82	1848	8.98	74.51	14.87	533.3	0.33	31.137	0.39	27.3	8.18	103.7
	5 S	0.1	1.24	64.01	1.54	270.9	8.67	110.2	9.91	175.8	0.17	34.618	0.23	28.4	8.18	103.4
	5 D	1.0	4.03	56.16	1.96	278.5	8.98	100.3	13.01	158.4	0.20	34.623	0.24	28.2	8.19	104.2
	10 S	0.1	4.96	377.7	1.68	1565	9.29	79.55	14.25	459.0	0.16	31.933	0.23	28.1	8.15	103.4
	10 D	1.0	0.93	122.3	1.82	548.5	8.67	117.9	9.60	242.0	0.28	34.086	0.27	27.5	8.17	102.3
	50 S	0.1	2.17	32.07	2.80	169.7	12.39	119.9	14.56	154.8	0.32	34.987	0.19	27.2	8.16	101.2
	50 D	4.0	3.72	0.14	6.16	43.84	11.46	119.6	15.18	125.9	0.13	35.161	0.19	27.2	8.18	100.9
	100 S	0.1	1.24	11.77	2.52	95.82	10.84	109.1	12.08	123.4	0.17	35.060	0.12	27.0	8.17	100.8
	100 D	6.1	2.17	0.28	1.82	38.78	10.53	116.7	12.70	118.8	0.12	35.196	0.19	26.8	8.19	103.5
	150 S	0.1	0.93	16.53	1.82	121.7	9.91	90.34	10.84	108.7	0.14	35.063	0.10	27.0	8.16	101.7
	150 D	11.2	3.72	0.98	2.10	30.63	9.60	104.1	13.32	107.1	0.09	35.203	0.09	26.7	8.19	106.9
WAILEA 4	0 S	0.1	0.93	345.0	0.56	1040	9.60	97.34	10.53	442.9	0.41	32.242	0.67	28.4	8.25	118.3
	2 S	0.1	0.93	336.4	BDL	699.1	9.60	89.92	10.53	426.3	0.53	32.708	2.76	28.4	8.25	113.7
	5 S	0.1	1.24	33.05	0.84	148.1	9.91	114.8	11.15	148.7	0.35	34.829	0.65	28.4	8.19	116.4
	5 D	1.0	1.24	26.19	0.98	133.5	9.29	96.78	10.53	124.0	0.32	34.936	0.81	28.4	8.18	109.2
	10 S	0.1	1.24	8.54	1.40	128.1	9.91	114.7	11.15	124.7	0.37	35.085	0.20	28.1	8.25	106.5
	10 D	1.0	1.24	4.34	0.42	95.26	10.53	101.4	11.77	106.2	0.25	35.166	0.16	27.5	8.18	105.2
	50 S	0.1	7.74	354.6	4.48	1113	11.46	99.44	19.20	458.6	0.13	33.011	0.14	27.0	8.11	104.1
	50 D	5.2	3.41	5.04	3.36	58.17	10.22	110.8	13.63	119.2	0.15	35.132	0.08	26.7	8.16	101.1
	100 S	0.1	1.24	100.0	2.38	296.5	10.53	89.64	11.77	192.0	0.17	34.550	0.21	27.4	8.13	101.1
	100 D	9.8	0.93	1.26	4.48	57.32	9.60	96.36	10.53	102.1	0.12	35.170	0.16	26.7	8.17	107.3
	150 S	0.1	0.93	BDL	0.56	48.89	10.22	101.8	11.15	102.4	0.09	35.205	0.12	27.7	8.18	102.4
	150 D	12.3	1.86	BDL	0.14	41.31	10.84	92.16	12.70	92.30	0.11	35.181	0.25	26.7	8.19	112.0
WAILEA 5	0 S	0.1	0.93	119.8	1.68	1565	10.53	94.68	11.46	216.1	0.40	32.410	0.58	26.1	8.15	112.9
	2 S	0.1	0.31	98.74	3.08	1388	9.91	104.5	10.22	206.3	0.29	32.877	0.42	26.7	8.16	115.7
	5 S	0.1	2.48	73.81	4.48	1123	9.91	104.3	12.39	182.6	0.28	33.307	0.46	26.8	8.14	111.7
	5 D	1.0	0.62	66.67	4.62	1052	10.84	130.8	11.46	202.1	0.21	33.491	0.50	26.7	8.14	112.7
	10 S	0.1	1.86	41.46	4.06	683.7	8.98	101.8	10.84	147.3	0.18	34.223	0.20	26.5	8.13	105.9
	10 D	2.0	2.17	34.17	2.38	575.5	9.60	93.28	11.77	129.8	0.18	34.763	0.14	26.2	8.12	100.3
	50 S	0.1	1.24	12.33	0.70	221.4	9.29	101.4	10.53	114.4	0.26	34.908	0.16	26.3	8.09	99.0
	50 D	4.4	3.41	2.24	0.56	139.9	9.60	98.32	13.01	101.1	0.15	35.138	1.71	26.3	8.10	102.8
	100 S	0.1	4.03	24.65	0.84	300.39	9.60	97.20	13.63	122.7	0.19	34.772	0.37	26.5	8.09	100.6
	100 D	6.4	1.55	0.70	0.28	75.31	9.60	98.46	11.15	99.44	0.26	35.154	0.29	26.7	8.12	102.8
	150 S	0.1	2.48	0.28	1.96	51.14	10.22	107.6	12.70	109.8	0.11	35.276	0.09	26.7	8.16	102.5
	150 D	7.7	2.48	0.14	0.28	59.57	10.53	108.7	13.01	109.1	0.12	35.185	0.07	26.6	8.16	104.6
DOH WQS		DRY	10%	10.00	5.00				30.00	180.0	0.50	*	0.50	**	***	****
			2%	20.00	9.00				45.00	250.0	1.00		1.00			
		WET	10%	14.00	8.50				40.00	250.0	1.25	*	0.90	**	***	****
			2%	25.00	15.00				60.00	350.0	2.00		1.75			

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.

** Temperature shall not vary by more than one degree C. from ambient conditions.

***pH shall not deviate more than 0.5 units from a value of 8.1.

****Dissolved Oxygen not to be below 75% saturation.

TABLE 3. Geometric mean data from water chemistry measurements (in µM) collected at five sites off of Honua'ula, Wailea, Maui since the inception of monitoring in June 2005 (N=6). For geometric mean calculations, detection limits were used in cases where sample was below detection limit. Abbreviations as follows: DFS=distance from shore; S=surface; D=deep. Also shown are State of Hawaii, Department of Health (DOH) geometric mean water quality standards for open coastal waters under "dry" and "wet" conditions. Boxed values exceed DOH GM 10% "dry" standards; boxed and shaded values exceed DOH GM 10% "wet" standards. For sampling site locations, see Figure 1.

TRANSECT SITE	DFS (m)	DEPTH (m)	PO4 (µM)	NO3 (µM)	NH4 (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURB (NTU)	SALINITY (ppt)	CHL a (µg/L)	TEMP (deg.C)	pH (std.units)	O2 % Sat
WAILEA 1	0 S	1	0.13	51.56	0.26	89.05	0.27	5.53	0.43	63.69	0.20	25.260	1.00	26.22	8.14	105.5
	2 S	1	0.13	35.38	0.06	67.94	0.28	6.94	0.44	45.72	0.18	29.813	1.39	26.26	8.17	106.7
	5 S	1	0.05	12.22	0.04	27.22	0.30	8.70	0.36	22.49	0.16	32.859	0.53	26.27	8.13	104.9
	5 D	2.5	0.09	6.86	0.33	17.59	0.30	9.14	0.42	16.88	0.10	33.869	0.32	26.25	8.13	103.9
	10 S	1	0.06	5.92	0.20	15.54	0.29	8.22	0.36	16.13	0.13	33.790	0.36	26.30	8.13	108.3
	10 D	3	0.06	1.96	0.20	6.46	0.30	8.33	0.37	11.15	0.12	34.546	0.32	26.14	8.12	107.5
	50 S	1	0.05	3.47	0.32	9.53	0.30	8.72	0.37	14.49	0.11	34.241	0.30	26.04	8.13	103.0
	50 D	4.5	0.07	0.33	0.16	2.48	0.31	8.50	0.39	9.32	0.10	34.792	0.33	25.81	8.12	96.3
	100 S	1	0.05	3.35	0.21	8.86	0.29	8.05	0.37	13.81	0.11	34.246	0.24	26.13	8.13	99.2
	100 D	10	0.04	0.12	0.17	1.97	0.30	8.36	0.35	8.88	0.11	34.893	0.16	25.81	8.14	95.9
	150 S	1	0.05	0.74	0.26	3.32	0.31	9.75	0.38	11.84	0.17	34.689	0.19	26.22	8.13	97.4
	150 D	15	0.06	0.08	0.17	1.52	0.31	9.06	0.38	9.45	0.10	34.907	0.17	25.78	8.14	95.0
WAILEA 2	0 S	1	0.16	28.98	0.09	44.19	0.20	5.98	0.56	54.54	0.17	23.642	0.45	26.29	8.11	100.0
	2 S	1	0.20	16.71	0.18	27.09	0.27	7.36	0.57	33.41	0.16	30.588	0.54	26.30	8.12	102.6
	5 S	1	0.10	6.37	0.16	12.49	0.28	8.40	0.42	17.01	0.16	33.892	0.31	26.36	8.12	102.6
	5 D	2.5	0.13	3.52	0.19	7.90	0.29	8.43	0.44	12.73	0.16	34.488	0.35	26.31	8.13	103.2
	10 S	1	0.10	1.42	0.22	6.13	0.30	9.09	0.42	11.97	0.13	34.678	0.20	26.31	8.13	101.8
	10 D	3	0.06	1.10	0.20	3.70	0.29	7.46	0.38	9.16	0.12	34.766	0.31	26.31	8.13	102.1
	50 S	1	0.08	3.27	0.13	6.93	0.28	8.07	0.38	11.86	0.13	34.594	0.20	26.20	8.13	98.2
	50 D	4.5	0.10	0.21	0.29	1.93	0.28	7.53	0.41	8.31	0.12	34.919	0.23	25.89	8.13	93.6
	100 S	1	0.09	1.17	0.25	3.72	0.29	8.25	0.41	10.41	0.12	34.784	0.17	25.87	8.14	96.0
	100 D	10	0.07	0.07	0.19	1.49	0.29	7.31	0.37	7.71	0.12	34.949	0.20	25.84	8.15	94.0
	150 S	1	0.06	0.33	0.17	2.88	0.29	8.30	0.36	9.76	0.13	34.799	0.14	26.39	8.14	96.8
	150 D	15	0.07	0.08	0.19	1.38	0.29	8.15	0.36	8.54	0.09	34.975	0.16	25.84	8.15	94.4
WAILEA 3	0 S	1	0.14	8.13	0.51	23.67	0.32	8.98	0.49	21.92	0.26	31.437	0.69	26.47	8.15	100.4
	2 S	1	0.12	4.71	0.32	14.43	0.30	7.54	0.44	16.10	0.22	33.597	0.51	26.50	8.14	99.7
	5 S	1	0.08	2.60	0.26	8.94	0.29	7.16	0.39	11.12	0.17	34.376	0.40	26.80	8.13	100.1
	5 D	2.5	0.11	2.89	0.35	9.71	0.30	8.33	0.43	12.58	0.20	34.351	0.35	26.77	8.13	100.6
	10 S	1	0.12	3.39	0.34	12.06	0.28	7.12	0.41	13.36	0.15	33.883	0.24	26.79	8.13	99.9
	10 D	5	0.08	1.90	0.34	8.79	0.28	7.29	0.38	10.82	0.18	34.365	0.33	26.54	8.13	100.3
	50 S	1	0.14	1.20	0.51	5.54	0.33	9.04	0.50	11.63	0.16	34.671	0.34	26.20	8.14	98.0
	50 D	10	0.09	0.13	0.50	2.18	0.34	8.27	0.44	9.23	0.13	34.890	0.27	26.08	8.15	95.8
	100 S	1	0.08	0.81	0.38	4.42	0.31	8.48	0.40	10.49	0.16	34.697	0.27	26.26	8.14	97.2
	100 D	15	0.07	0.04	0.21	1.82	0.32	9.01	0.40	9.41	0.12	34.927	0.21	25.91	8.14	94.3
	150 S	1	0.06	0.42	0.36	3.07	0.30	7.56	0.38	8.98	0.14	34.827	0.16	26.24	8.14	94.4
	150 D	20	0.08	0.07	0.35	1.61	0.29	7.55	0.38	8.16	0.10	34.952	0.17	25.85	8.15	93.1
WAILEA 4	0 S	1	0.08	12.63	0.21	23.27	0.27	6.85	0.40	29.37	0.28	31.969	0.50	26.81	8.14	105.6
	2 S	1	0.07	8.15	0.26	15.40	0.28	7.53	0.39	22.68	0.23	33.286	0.71	26.79	8.17	103.7
	5 S	1	0.08	2.01	0.20	6.43	0.30	8.19	0.41	12.21	0.18	34.483	0.53	26.80	8.16	108.0
	5 D	2.5	0.08	1.83	0.20	6.28	0.30	8.70	0.39	12.60	0.16	34.488	0.39	26.79	8.15	105.5
	10 S	1	0.10	0.80	0.34	4.57	0.30	10.21	0.42	12.39	0.19	34.769	0.33	26.75	8.15	105.2
	10 D	3	0.12	0.47	0.20	3.60	0.30	7.67	0.45	9.13	0.16	34.843	0.29	26.65	8.14	103.8
	50 S	1	0.13	4.58	0.29	9.12	0.31	8.68	0.46	15.69	0.19	34.201	0.34	26.59	8.11	96.8
	50 D	10	0.09	0.20	0.18	2.43	0.27	8.72	0.39	9.51	0.12	34.922	0.28	25.92	8.13	93.4
	100 S	1	0.08	3.70	0.31	8.17	0.29	8.22	0.41	14.32	0.15	34.272	0.25	26.41	8.12	96.0
	100 D	15	0.08	0.10	0.17	1.84	0.33	8.78	0.44	9.43	0.10	34.955	0.19	25.87	8.13	93.8
	150 S	1	0.07	0.44	0.14	3.25	0.33	7.81	0.41	9.21	0.10	34.826	0.15	26.53	8.13	94.8
	150 D	25	0.06	0.05	0.09	1.60	0.33	7.54	0.42	7.92	0.11	34.943	0.20	25.80	8.14	94.6
WAILEA 5	0 S	1	0.24	19.19	0.66	85.95	0.29	5.11	0.66	34.77	0.27	27.291	0.90	25.49	8.07	96.3
	2 S	1	0.17	14.40	1.10	66.76	0.25	6.88	0.62	30.13	0.24	28.746	0.66	25.82	8.07	98.2
	5 S	1	0.13	5.87	0.70	33.60	0.30	8.94	0.48	17.05	0.22	32.914	0.49	25.86	8.09	100.7
	5 D	1.5	0.05	3.68	0.44	21.96	0.30	8.50	0.40	12.88	0.15	33.781	0.44	25.88	8.11	101.0
	10 S	1	0.05	1.75	0.45	11.19	0.28	8.19	0.36	10.54	0.13	34.415	0.25	25.97	8.09	99.6
	10 D	2.5	0.11	1.76	0.48	11.22	0.27	6.88	0.39	9.30	0.14	34.476	0.38	25.81	8.09	97.6
	50 S	1	0.08	0.86	0.39	6.97	0.30	7.86	0.40	9.39	0.15	34.654	0.25	25.66	8.11	94.0
	50 D	9	0.07	0.16	0.27	3.09	0.30	7.20	0.39	7.79	0.13	34.869	0.38	25.65	8.11	93.5
	100 S	1	0.12	0.39	0.36	5.99	0.30	7.12	0.44	8.32	0.15	34.677	0.19	25.91	8.11	95.1
	100 D	14	0.06	0.11	0.22	2.81	0.30	6.85	0.37	7.55	0.15	34.846	0.22	25.73	8.13	93.3
	150 S	1	0.06	0.18	0.31	2.50	0.29	7.72	0.38	8.53	0.12	34.888	0.16	25.93	8.13	95.3
	150 D	18	0.05	0.03	0.14	1.72	0.30	7.66	0.38	7.99	0.11	34.935	0.18	25.76	8.14	94.4
DOH WQS GEOMETRIC MEAN	DRY			0.25	0.14				0.52	7.86	0.20	*	0.15	**	***	
	WET			0.36	0.25				0.64	10.71	0.50		0.30			

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.

** Temperature shall not vary by more than one degree C. from ambient conditions.

***pH shall not deviate more than 0.5 units from a value of 8.1.

TABLE 4. Geometric mean data from water chemistry measurements (in µg/L) collected at five sites off of Honua'ula, Wailea, Maui since the inception of monitoring in June 2005 (N=6). For geometric mean calculations, detection limits were used in cases where sample was below detection limit. Abbreviations as follows: DFS=distance from shore; S=surface; D=deep. Also shown are State of Hawaii, Department of Health (DOH) geometric mean water quality standards for open coastal waters under "dry" and "wet" conditions. Boxed values exceed DOH GM 10% "dry" standards; boxed and shaded values exceed DOH GM 10% "wet" standards. For sampling site locations, see Figure 1.

TRANSECT SITE	DFS (m)	DEPTH (m)	PO4 (µg/L)	NO3 (µg/L)	NH4 (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	TURB (NTU)	SALINITY (ppt)	CHL a (µg/L)	TEMP (deg.C)	pH (std.units)	O2 % Sat
WAILEA 1	0 S	1	4.02	722.14	3.64	2,501.41	8.36	77.45	13.31	892.04	0.20	25.26	1.00	26.22	8.14	105.48
	2 S	1	4.02	495.53	0.84	1,908.43	8.67	97.20	13.62	640.35	0.18	29.81	1.39	26.26	8.17	106.69
	5 S	1	1.54	171.15	0.56	764.61	9.29	121.85	11.15	314.99	0.16	32.86	0.53	26.27	8.13	104.91
	5 D	2.5	2.78	96.08	4.62	494.10	9.29	128.01	13.00	236.42	0.10	33.87	0.32	26.25	8.13	103.93
	10 S	1	1.85	82.91	2.80	436.52	8.98	115.12	11.15	225.91	0.13	33.79	0.36	26.30	8.13	108.29
	10 D	3	1.85	27.45	2.80	181.46	9.29	116.66	11.46	156.16	0.12	34.55	0.32	26.14	8.12	107.45
	50 S	1	1.54	48.60	4.48	267.70	9.29	122.13	11.46	202.94	0.11	34.24	0.30	26.04	8.13	103.04
	50 D	4.5	2.16	4.62	2.24	69.66	9.60	119.05	12.07	130.53	0.10	34.79	0.33	25.81	8.12	96.34
	100 S	1	1.54	46.92	2.94	248.88	8.98	112.74	11.46	193.42	0.11	34.25	0.24	26.13	8.13	99.16
	100 D	10	1.23	1.68	2.38	55.34	9.29	117.09	10.84	124.37	0.11	34.89	0.16	25.81	8.14	95.90
	150 S	1	1.54	10.36	3.64	93.26	9.60	136.55	11.76	165.83	0.17	34.69	0.19	26.22	8.13	97.36
	150 D	15	1.85	1.12	2.38	42.70	9.60	126.89	11.76	132.35	0.10	34.91	0.17	25.78	8.14	95.01
WAILEA 2	0 S	1	4.95	405.89	1.26	1,241.30	6.19	83.75	17.34	763.88	0.17	23.64	0.45	26.29	8.11	100.00
	2 S	1	6.19	234.04	2.52	760.96	8.36	103.08	17.65	467.94	0.16	30.59	0.54	26.30	8.12	102.58
	5 S	1	3.09	89.21	2.24	350.84	8.67	117.65	13.00	238.24	0.16	33.89	0.31	26.36	8.12	102.61
	5 D	2.5	4.02	49.30	2.66	221.91	8.98	118.07	13.62	178.29	0.16	34.49	0.35	26.31	8.13	103.19
	10 S	1	3.09	19.88	3.08	172.19	9.29	127.31	13.00	167.65	0.13	34.68	0.20	26.31	8.13	101.75
	10 D	3	1.85	15.40	2.80	103.93	8.98	104.48	11.76	128.29	0.12	34.77	0.31	26.31	8.13	102.13
	50 S	1	2.47	45.79	1.82	194.66	8.67	113.02	11.76	166.11	0.13	34.59	0.20	26.20	8.13	98.17
	50 D	4.5	3.09	2.94	4.06	54.21	8.67	105.46	12.69	116.38	0.12	34.92	0.23	25.89	8.13	93.64
	100 S	1	2.78	16.38	3.50	104.49	8.98	115.54	12.69	145.80	0.12	34.78	0.17	25.87	8.14	95.96
	100 D	10	2.16	0.98	2.66	41.85	8.98	102.38	11.46	107.98	0.12	34.95	0.20	25.84	8.15	93.99
	150 S	1	1.85	4.62	2.38	80.90	8.98	116.24	11.15	136.69	0.13	34.80	0.14	26.39	8.14	96.84
	150 D	15	2.16	1.12	2.66	38.76	8.98	114.14	11.15	119.61	0.09	34.98	0.16	25.84	8.15	94.41
WAILEA 3	0 S	1	4.33	113.86	7.14	664.89	9.91	125.77	15.17	307.01	0.26	31.44	0.69	26.47	8.15	100.41
	2 S	1	3.71	65.96	4.48	405.34	9.29	105.60	13.62	225.49	0.22	33.60	0.51	26.50	8.14	99.67
	5 S	1	2.47	36.41	3.64	251.12	8.98	100.28	12.07	155.74	0.17	34.38	0.40	26.80	8.13	100.11
	5 D	2.5	3.40	40.47	4.90	272.75	9.29	116.66	13.31	176.19	0.20	34.35	0.35	26.77	8.13	100.56
	10 S	1	3.71	47.48	4.76	338.77	8.67	99.72	12.69	187.12	0.15	33.88	0.24	26.79	8.13	99.87
	10 D	5	2.47	26.61	4.76	246.91	8.67	102.10	11.76	151.54	0.18	34.37	0.33	26.54	8.13	100.32
	50 S	1	4.33	16.80	7.14	155.62	10.22	126.61	15.48	162.88	0.16	34.67	0.34	26.20	8.14	98.03
	50 D	10	2.78	1.82	7.00	61.24	10.53	115.82	13.62	129.27	0.13	34.89	0.27	26.08	8.15	95.78
	100 S	1	2.47	11.34	5.32	124.16	9.60	118.77	12.38	146.92	0.16	34.70	0.27	26.26	8.14	97.22
	100 D	15	2.16	0.56	2.94	51.12	9.91	126.19	12.38	131.79	0.12	34.93	0.21	25.91	8.14	94.31
	150 S	1	1.85	5.88	5.04	86.24	9.29	105.88	11.76	125.77	0.14	34.83	0.16	26.24	8.14	94.35
	150 D	20	2.47	0.98	4.90	45.22	8.98	105.74	11.76	114.28	0.10	34.95	0.17	25.85	8.15	93.07
WAILEA 4	0 S	1	2.47	176.89	2.94	653.65	8.36	95.94	12.38	411.35	0.28	31.97	0.50	26.81	8.14	105.64
	2 S	1	2.16	114.14	3.64	432.59	8.67	105.46	12.07	317.65	0.23	33.29	0.71	26.79	8.17	103.71
	5 S	1	2.47	28.15	2.80	180.62	9.29	114.70	12.69	171.01	0.18	34.48	0.53	26.80	8.16	108.01
	5 D	2.5	2.47	25.63	2.80	176.41	9.29	121.85	12.07	176.47	0.16	34.49	0.39	26.79	8.15	105.51
	10 S	1	3.09	11.20	4.76	128.37	9.29	143.00	13.00	173.53	0.19	34.77	0.33	26.75	8.15	105.19
	10 D	3	3.71	6.58	2.80	101.12	9.29	107.42	13.93	127.87	0.16	34.84	0.29	26.65	8.14	103.82
	50 S	1	4.02	64.14	4.06	256.18	9.60	121.57	14.24	219.75	0.19	34.20	0.34	26.59	8.11	96.81
	50 D	10	2.78	2.80	2.52	68.26	8.36	122.13	12.07	133.19	0.12	34.92	0.28	25.92	8.13	93.39
	100 S	1	2.47	51.82	4.34	229.50	8.98	115.12	12.69	200.56	0.15	34.27	0.25	26.41	8.12	96.03
	100 D	15	2.47	1.40	2.38	51.69	10.22	122.97	13.62	132.07	0.10	34.96	0.19	25.87	8.13	93.77
	150 S	1	2.16	6.16	1.96	91.29	10.22	109.38	12.69	128.99	0.10	34.83	0.15	26.53	8.13	94.83
	150 D	25	1.85	0.70	1.26	44.94	10.22	105.60	13.00	110.92	0.11	34.94	0.20	25.80	8.14	94.64
WAILEA 5	0 S	1	7.43	268.77	9.24	2,414.34	8.98	71.57	20.44	486.98	0.27	27.29	0.90	25.49	8.07	96.25
	2 S	1	5.26	201.68	15.40	1,875.29	7.74	96.36	19.20	422.00	0.24	28.75	0.66	25.82	8.07	98.15
	5 S	1	4.02	82.21	9.80	943.82	9.29	125.21	14.86	238.80	0.22	32.91	0.49	25.86	8.09	100.66
	5 D	1.5	1.54	51.54	6.16	616.86	9.29	119.05	12.38	180.39	0.15	33.78	0.44	25.88	8.11	101.04
	10 S	1	1.54	24.51	6.30	314.33	8.67	114.70	11.15	147.62	0.13	34.42	0.25	25.97	8.09	99.63
	10 D	2.5	3.40	24.65	6.72	315.17	8.36	96.36	12.07	130.25	0.14	34.48	0.38	25.81	8.09	97.55
	50 S	1	2.47	12.04	5.46	195.79	9.29	110.08	12.38	131.51	0.15	34.65	0.25	25.66	8.11	94.02
	50 D	9	2.16	2.24	3.78	86.80	9.29	100.84	12.07	109.10	0.13	34.87	0.38	25.65	8.11	93.45
	100 S	1	3.71	5.46	5.04	168.26	9.29	99.72	13.62	116.52	0.15	34.68	0.19	25.91	8.11	95.09
	100 D	14	1.85	1.54	3.08	78.93	9.29	95.94	11.46	105.74	0.15	34.85	0.22	25.73	8.13	93.31
	150 S	1	1.85	2.52	4.34	70.23	8.98	108.12	11.76	119.47	0.12	34.89	0.16	25.93	8.13	95.25
	150 D	18	1.54	0.42	1.96	48.31	9.29	107.28	11.76	111.90	0.11	34.94	0.18	25.76	8.14	94.39
DOH WQS GEOMETRIC MEAN		DRY		3.50	2.00				16.00	110.00	0.20	*	0.15	**	***	
		WET		5.00	3.50				20.00	150.00	0.50		0.30			

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.

** Temperature shall not vary by more than one degree C. from ambient conditions.

***pH shall not deviate more than 0.5 units from a value of 8.1.

TABLE 4. Geometric mean data from water chemistry measurements (in μg/L) collected at five sites off of Honua'ula, Wailea, Maui since the inception of monitoring in June 2005 (N=6). For geometric mean calculations, detection limits were used in cases where sample was below detection limit. Abbreviations as follows: DFS=distance from shore; S=surface; D=deep. Also shown are State of Hawaii, Department of Health (DOH) geometric mean water quality standards for open coastal waters under "dry" and "wet" conditions. Boxed values exceed DOH GM 10% "dry" standards; boxed and shaded values exceed DOH GM 10% "wet" standards. For sampling site locations, see Figure 1.

TRANSECT SITE	DFS (m)	DEPTH (m)	PO4 (μg/L)	NO3 (μg/L)	NH4 (μg/L)	Si (μg/L)	TOP (μg/L)	TON (μg/L)	TP (μg/L)	TN (μg/L)	TURB (NTU)	SALINITY (ppt)	CHL a (μg/L)	TEMP (deg.C)	pH (std.units)	O2 % Sat
WAILEA 1	0 S	1	4.02	722.14	3.64	2,501.41	8.36	77.45	13.31	892.04	0.20	25.26	1.00	26.22	8.14	105.48
	2 S	1	4.02	495.53	0.84	1,908.43	8.67	97.20	13.62	640.35	0.18	29.81	1.39	26.26	8.17	106.69
	5 S	1	1.54	171.15	0.56	764.61	9.29	121.85	11.15	314.99	0.16	32.86	0.53	26.27	8.13	104.91
	5 D	2.5	2.78	96.08	4.62	494.10	9.29	128.01	13.00	236.42	0.10	33.87	0.32	26.25	8.13	103.93
	10 S	1	1.85	82.91	2.80	436.52	8.98	115.12	11.15	225.91	0.13	33.79	0.36	26.30	8.13	108.29
	10 D	3	1.85	27.45	2.80	181.46	9.29	116.66	11.46	156.16	0.12	34.55	0.32	26.14	8.12	107.45
	50 S	1	1.54	48.60	4.48	267.70	9.29	122.13	11.46	202.94	0.11	34.24	0.30	26.04	8.13	103.04
	50 D	4.5	2.16	4.62	2.24	69.66	9.60	119.05	12.07	130.53	0.10	34.79	0.33	25.81	8.12	96.34
	100 S	1	1.54	46.92	2.94	248.88	8.98	112.74	11.46	193.42	0.11	34.25	0.24	26.13	8.13	99.16
	100 D	10	1.23	1.68	2.38	55.34	9.29	117.09	10.84	124.37	0.11	34.89	0.16	25.81	8.14	95.90
	150 S	1	1.54	10.36	3.64	93.26	9.60	136.55	11.76	165.83	0.17	34.69	0.19	26.22	8.13	97.36
	150 D	15	1.85	1.12	2.38	42.70	9.60	126.89	11.76	132.35	0.10	34.91	0.17	25.78	8.14	95.01
WAILEA 2	0 S	1	4.95	405.89	1.26	1,241.30	6.19	83.75	17.34	763.88	0.17	23.64	0.45	26.29	8.11	100.00
	2 S	1	6.19	234.04	2.52	760.96	8.36	103.08	17.65	467.94	0.16	30.59	0.54	26.30	8.12	102.58
	5 S	1	3.09	89.21	2.24	350.84	8.67	117.65	13.00	238.24	0.16	33.89	0.31	26.36	8.12	102.61
	5 D	2.5	4.02	49.30	2.66	221.91	8.98	118.07	13.62	178.29	0.16	34.49	0.35	26.31	8.13	103.19
	10 S	1	3.09	19.88	3.08	172.19	9.29	127.31	13.00	167.65	0.13	34.68	0.20	26.31	8.13	101.75
	10 D	3	1.85	15.40	2.80	103.93	8.98	104.48	11.76	128.29	0.12	34.77	0.31	26.31	8.13	102.13
	50 S	1	2.47	45.79	1.82	194.66	8.67	113.02	11.76	166.11	0.13	34.59	0.20	26.20	8.13	98.17
	50 D	4.5	3.09	2.94	4.06	54.21	8.67	105.46	12.69	116.38	0.12	34.92	0.23	25.89	8.13	93.64
	100 S	1	2.78	16.38	3.50	104.49	8.98	115.54	12.69	145.80	0.12	34.78	0.17	25.87	8.14	95.96
	100 D	10	2.16	0.98	2.66	41.85	8.98	102.38	11.46	107.98	0.12	34.95	0.20	25.84	8.15	93.99
	150 S	1	1.85	4.62	2.38	80.90	8.98	116.24	11.15	136.69	0.13	34.80	0.14	26.39	8.14	96.84
	150 D	15	2.16	1.12	2.66	38.76	8.98	114.14	11.15	119.61	0.09	34.98	0.16	25.84	8.15	94.41
WAILEA 3	0 S	1	4.33	113.86	7.14	664.89	9.91	125.77	15.17	307.01	0.26	31.44	0.69	26.47	8.15	100.41
	2 S	1	3.71	65.96	4.48	405.34	9.29	105.60	13.62	225.49	0.22	33.60	0.51	26.50	8.14	99.67
	5 S	1	2.47	36.41	3.64	251.12	8.98	100.28	12.07	155.74	0.17	34.38	0.40	26.80	8.13	100.11
	5 D	2.5	3.40	40.47	4.90	272.75	9.29	116.66	13.31	176.19	0.20	34.35	0.35	26.77	8.13	100.56
	10 S	1	3.71	47.48	4.76	338.77	8.67	99.72	12.69	187.12	0.15	33.88	0.24	26.79	8.13	99.87
	10 D	5	2.47	26.61	4.76	246.91	8.67	102.10	11.76	151.54	0.18	34.37	0.33	26.54	8.13	100.32
	50 S	1	4.33	16.80	7.14	155.62	10.22	126.61	15.48	162.88	0.16	34.67	0.34	26.20	8.14	98.03
	50 D	10	2.78	1.82	7.00	61.24	10.53	115.82	13.62	129.27	0.13	34.89	0.27	26.08	8.15	95.78
	100 S	1	2.47	11.34	5.32	124.16	9.60	118.77	12.38	146.92	0.16	34.70	0.27	26.26	8.14	97.22
	100 D	15	2.16	0.56	2.94	51.12	9.91	126.19	12.38	131.79	0.12	34.93	0.21	25.91	8.14	94.31
	150 S	1	1.85	5.88	5.04	86.24	9.29	105.88	11.76	125.77	0.14	34.83	0.16	26.24	8.14	94.35
	150 D	20	2.47	0.98	4.90	45.22	8.98	105.74	11.76	114.28	0.10	34.95	0.17	25.85	8.15	93.07
WAILEA 4	0 S	1	2.47	176.89	2.94	653.65	8.36	95.94	12.38	411.35	0.28	31.97	0.50	26.81	8.14	105.64
	2 S	1	2.16	114.14	3.64	432.59	8.67	105.46	12.07	317.65	0.23	33.29	0.71	26.79	8.17	103.71
	5 S	1	2.47	28.15	2.80	180.62	9.29	114.70	12.69	171.01	0.18	34.48	0.53	26.80	8.16	108.01
	5 D	2.5	2.47	25.63	2.80	176.41	9.29	121.85	12.07	176.47	0.16	34.49	0.39	26.79	8.15	105.51
	10 S	1	3.09	11.20	4.76	128.37	9.29	143.00	13.00	173.53	0.19	34.77	0.33	26.75	8.15	105.19
	10 D	3	3.71	6.58	2.80	101.12	9.29	107.42	13.93	127.87	0.16	34.84	0.29	26.65	8.14	103.82
	50 S	1	4.02	64.14	4.06	256.18	9.60	121.57	14.24	219.75	0.19	34.20	0.34	26.59	8.11	96.81
	50 D	10	2.78	2.80	2.52	68.26	8.36	122.13	12.07	133.19	0.12	34.92	0.28	25.92	8.13	93.39
	100 S	1	2.47	51.82	4.34	229.50	8.98	115.12	12.69	200.56	0.15	34.27	0.25	26.41	8.12	96.03
	100 D	15	2.47	1.40	2.38	51.69	10.22	122.97	13.62	132.07	0.10	34.96	0.19	25.87	8.13	93.77
	150 S	1	2.16	6.16	1.96	91.29	10.22	109.38	12.69	128.99	0.10	34.83	0.15	26.53	8.13	94.83
	150 D	25	1.85	0.70	1.26	44.94	10.22	105.60	13.00	110.92	0.11	34.94	0.20	25.80	8.14	94.64
WAILEA 5	0 S	1	7.43	268.77	9.24	2,414.34	8.98	71.57	20.44	486.98	0.27	27.29	0.90	25.49	8.07	96.25
	2 S	1	5.26	201.68	15.40	1,875.29	7.74	96.36	19.20	422.00	0.24	28.75	0.66	25.82	8.07	98.15
	5 S	1	4.02	82.21	9.80	943.82	9.29	125.21	14.86	238.80	0.22	32.91	0.49	25.86	8.09	100.66
	5 D	1.5	1.54	51.54	6.16	616.86	9.29	119.05	12.38	180.39	0.15	33.78	0.44	25.88	8.11	101.04
	10 S	1	1.54	24.51	6.30	314.33	8.67	114.70	11.15	147.62	0.13	34.42	0.25	25.97	8.09	99.63
	10 D	2.5	3.40	24.65	6.72	315.17	8.36	96.36	12.07	130.25	0.14	34.48	0.38	25.81	8.09	97.55
	50 S	1	2.47	12.04	5.46	195.79	9.29	110.08	12.38	131.51	0.15	34.65	0.25	25.66	8.11	94.02
	50 D	9	2.16	2.24	3.78	86.80	9.29	100.84	12.07	109.10	0.13	34.87	0.38	25.65	8.11	93.45
	100 S	1	3.71	5.46	5.04	168.26	9.29	99.72	13.62	116.52	0.15	34.68	0.19	25.91	8.11	95.09
	100 D	14	1.85	1.54	3.08	78.93	9.29	95.94	11.46	105.74	0.15	34.85	0.22	25.73	8.13	93.31
	150 S	1	1.85	2.52	4.34	70.23	8.98	108.12	11.76	119.47	0.12	34.89	0.16	25.93	8.13	95.25
	150 D	18	1.54	0.42	1.96	48.31	9.29	107.28	11.76	111.90	0.11	34.94	0.18	25.76	8.14	94.39
DOH WQS		DRY		3.50	2.00				16.00	110.00	0.20	*	0.15	**	***	
GEOMETRIC MEAN		WET		5.00	3.50				20.00	150.00	0.50		0.30			

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.

** Temperature shall not vary by more than one degree C. from ambient conditions.

***pH shall not deviate more than 0.5 units from a value of 8.1.

TABLE 5. Water chemistry measurements in μM and μg/L (shaded) from irrigation wells and an irrigation lake (Res) collected at the Wailea Golf Courses in the vicinity of the Honua'ula project site on February 11, 2009. For sampling site locations, see Figure 1.

WELLS	PO4 (μM)	PO4 (μg/L)	NO3 (μM)	NO3 (μg/L)	NH4 (μM)	NH4 (μg/L)	Si (μM)	Si (μg/L)	TOP (μM)	TOP (μg/L)	TON (μM)	TON (μg/L)	TP (μM)	TP (μg/L)	TN (μM)	TN (μg/L)	SALINITY (ppt)
2	2.00	62.00	225.6	3159	0.00	0.00	524.2	14729	0.16	4.96	9.36	131.0	2.16	66.96	235.0	3290	1.48
5	2.16	66.96	337.6	4727	1.96	27.44	513.1	14418	0.08	2.48	2.40	33.6	2.24	69.44	342.0	4788	1.78
6	2.00	62.00	158.7	2222	1.96	27.44	516.6	14515	0.16	4.96	33.48	468.7	2.16	66.96	194.2	2718	1.27
7	2.32	71.92	257.6	3606	1.60	22.40	511.6	14375	0.16	4.96	4.40	61.6	2.48	76.88	263.6	3690	1.89
8	1.96	60.76	170.2	2383	2.48	34.72	495.2	13915	0.36	11.16	24.08	337.1	2.32	71.92	196.8	2755	2.13
9	1.84	57.04	142.0	1987	0.60	8.40	482.5	13559	0.60	18.60	72.94	1021.2	2.44	75.64	215.5	3017	1.84
10	2.00	62.00	218.9	3065	0.64	8.96	479.3	13469	0.44	13.64	17.28	241.9	2.44	75.64	236.8	3316	1.58
Res	0.44	13.64	145.3	2034	4.48	62.72	301.8	8482	1.36	42.16	53.56	749.8	1.80	55.80	203.3	2846	1.98

TABLE 6. Linear regression statistics (y-intercept and slope) of surface concentrations of silica as functions of salinity from five ocean transect sites in the vicinity of Honua'ula collected during monitoring surveys from June 2005 to September 2009. Also shown are standard errors and upper and lower 95% confidence limits around the y-intercepts and slopes."REGSLOPE" indicates regression statistics for slope of yearly coefficients as a function of time. Surveys were conducted once per year between 2005-2008 (N=7), twice per year beginning in 2009 (N=14). For location of transect sites, see Figure 1.

SILICA -Y-INTERCEPT

YEAR	*Coefficients*	*Std Err*	*Lower 95%*	*Upper 95%*
SITE 1				
2005	497.88	3.56	488.73	507.03
2006	539.75	3.21	531.50	548.00
2007	301.46	37.05	206.21	396.70
2008	441.78	21.87	385.57	497.98
2009	410.31	16.55	374.24	446.38
REGSLOPE	-27.31	29.39	-120.83	66.20
SITE 2				
2005	448.61	94.10	206.72	690.51
2006	445.83	27.79	374.40	517.26
2007	605.37	2.41	599.18	611.55
2008	736.44	124.97	415.20	1057.68
2009	348.37	26.00	291.71	405.03
REGSLOPE	9.01	55.78	-168.49	186.52
SITE 3				
2005	471.10	29.51	395.24	546.97
2006	521.67	9.12	498.22	545.12
2007	264.62	10.69	237.14	292.10
2008	389.25	28.52	315.95	462.55
2009	580.96	11.67	555.53	606.39
REGSLOPE	8.73	44.69	-133.51	150.96
SITE 4				
2005	539.62	153.92	143.97	935.28
2006	415.26	8.33	393.86	436.66
2007	388.49	16.11	347.07	429.90
2008	310.16	38.90	210.18	410.15
2009	476.61	535.93	441.76	545.61
REGSLOPE	-23.11	28.91	-115.11	68.89
SITE 5				
2005	736.03	2.23	730.30	741.75
2006	711.37	7.83	691.25	731.48
2007	712.08	6.64	695.02	729.15
2008	739.31	9.75	714.26	764.36
2009	648.43	51.18	536.92	759.94
REGSLOPE	-14.73	10.27	-47.41	17.96

SILICA - SLOPE

YEAR	*Coefficients*	*Std Err*	*Lower 95%*	*Upper 95%*
SITE 1				
2005	-14.29	0.11	-14.57	-14.02
2006	-15.51	0.10	-15.76	-15.25
2007	-8.33	1.18	-11.37	-5.29
2008	-12.59	0.66	-14.29	-10.90
2009	-11.42	0.51	-12.53	-10.31
REGSLOPE	0.87	0.88	-1.94	3.67
SITE 2				
2005	-12.84	2.72	-19.84	-5.85
2006	-12.76	0.81	-14.83	-10.68
2007	-17.27	0.08	-17.47	-17.07
2008	-21.03	3.60	-30.28	-11.77
2009	-9.71	0.81	-11.47	-7.94
REGSLOPE	-0.20	1.62	-5.34	4.94
SITE 3				
2005	-13.49	0.86	-15.69	-11.29
2006	-14.95	0.27	-15.65	-14.26
2007	-7.39	0.32	-8.22	-6.56
2008	-11.04	0.82	-13.14	-8.93
2009	-16.51	0.34	-17.26	-15.77
REGSLOPE	-0.21	1.30	-4.35	3.92
SITE 4				
2005	-15.47	4.45	-26.91	-4.04
2006	-11.88	0.24	-12.51	-11.25
2007	-10.93	0.48	-12.17	-9.69
2008	-8.77	1.11	-11.63	-5.90
2009	-13.50	0.81	-15.26	-11.73
REGSLOPE	0.71	0.83	-1.95	3.36
SITE 5				
2005	-21.13	0.07	-21.30	-20.96
2006	-20.28	0.23	-20.87	-19.68
2007	-20.28	0.23	-20.86	-19.70
2008	-21.16	0.29	-21.90	-20.42
2009	-18.42	1.50	-21.68	-15.16
REGSLOPE	0.45	0.31	-0.53	1.44

TABLE 7. Linear regression statistics (y-intercept and slope) of surface concentrations of nitrate as functions of salinity from five ocean transect sites in the vicinity of Honua'ula collected during monitoring surveys from June 2005 to September 2009. Also shown are standard errors and upper and lower 95% confidence limits around the y-intercepts and slopes. "REGSLOPE" indicates regression statistics for slope of yearly coefficients as a function of time. For location of transect sites, see Figure 1.

NITRATE -Y-INTERCEPT

YEAR	*Coefficients*	*Std Err*	*Lower 95%*	*Upper 95%*
SITE 1				
2005	317.11	3.22	308.84	325.38
2006	342.14	4.13	331.53	352.76
2007	382.01	8.64	359.80	404.22
2008	279.63	6.14	263.85	295.42
2009	227.71	6.24	214.11	241.31
REGSLOPE	-24.13	16.47	-76.56	28.29
SITE 2				
2005	292.69	62.62	131.73	453.65
2006	368.09	7.37	349.13	387.04
2007	494.07	15.55	454.10	534.04
2008	248.17	183.53	-223.62	719.95
2009	321.60	4.51	311.76	331.43
REGSLOPE	-6.21	34.17	-114.96	102.54
SITE 3				
2005	306.11	22.88	247.30	364.91
2006	164.55	6.45	147.98	181.11
2007	83.21	1.95	78.20	88.23
2008	124.87	19.93	73.64	176.09
2009	291.51	15.21	258.38	324.65
REGSLOPE	-6.89	36.30	-122.40	108.62
SITE 4				
2005	437.11	80.65	229.78	644.43
2006	467.97	2.22	462.26	473.68
2007	447.63	6.29	431.45	463.81
2008	243.43	78.23	42.33	444.53
2009	297.19	15.13	264.23	330.15
REGSLOPE	-50.44	22.83	-123.09	22.21
SITE 5				
2005	123.09	4.56	111.38	134.80
2006	121.10	2.08	115.77	126.44
2007	272.43	1.83	267.72	277.15
2008	63.82	5.48	49.73	77.91
2009	216.23	58.47	88.84	343.63
REGSLOPE	12.90	29.59	-81.26	107.06

NITRATE - SLOPE

YEAR	*Coefficients*	*Std Err*	*Lower 95%*	*Upper 95%*
SITE 1				
2005	-9.13	0.10	-9.38	-8.88
2006	-9.85	0.13	-10.18	-9.53
2007	-11.02	0.28	-11.73	-10.31
2008	-8.05	0.19	-8.53	-7.58
2009	-6.48	0.19	-6.90	-6.06
REGSLOPE	0.71	0.48	-0.82	2.24
SITE 2				
2005	-8.40	1.81	-13.06	-3.75
2006	-10.59	0.21	-11.14	-10.04
2007	-14.13	0.51	-15.44	-12.81
2008	-7.09	5.29	-20.68	6.51
2009	-9.12	0.14	-9.43	-8.82
REGSLOPE	0.21	0.98	-2.90	3.32
SiTE 3				
2005	-8.83	0.66	-10.53	-7.12
2006	-4.72	0.19	-5.21	-4.23
2007	-2.35	0.06	-2.50	-2.20
2008	-3.56	0.57	-5.03	-2.09
2009	-8.28	0.45	-9.25	-7.30
REGSLOPE	0.23	1.04	-3.09	3.54
SITE 4				
2005	-12.59	2.33	-18.58	-6.60
2006	-13.45	0.07	-13.62	-13.29
2007	-12.88	0.19	-13.36	-12.39
2008	-6.94	2.24	-12.70	-1.17
2009	-8.44	0.45	-9.42	-7.46
REGSLOPE	1.48	0.66	-0.62	3.58
SITE 5				
2005	-3.56	0.14	-3.91	-3.21
2006	-3.46	0.06	-3.62	-3.30
2007	-7.86	0.06	-8.02	-7.70
2008	-1.82	0.16	-2.24	-1.41
2009	-6.15	1.71	-9.88	-2.43
REGSLOPE	-0.36	0.85	-3.07	2.36

TABLE 8. Linear regression statistics (y-intercept and slope) of surface concentrations of orthophosphate phosphorus as functions of salinity from five ocean transect sites in the vicinity of Honua'ula collected during monitoring surveys from June 2005 to September 2009. Also shown are standard errors and upper and lower 95% confidence limits around the y-intercepts and slopes."REGSLOPE" indicates regression statistics for slope of yearly coefficients as a function of time. For location of transect sites, see Figure 1.

PHOSPHATE -Y-INTERCEPT

YEAR	*Coefficients*	*Std Err*	*Lower 95%*	*Upper 95%*
SITE 1				
2005	0.09	0.09	-0.13	0.32
2006	1.19	0.13	0.85	1.53
2007	0.31	0.20	-0.21	0.82
2008	0.04	0.01	0.03	0.06
2009	0.27	0.13	-0.01	0.56
REGSLOPE	-0.08	0.16	-0.60	0.44
SITE 2				
2005	1.09	1.19	-1.98	4.16
2006	-0.78	2.81	-7.99	6.44
2007	2.08	0.03	2.00	2.16
2008	-0.56	13.34	-34.85	33.73
2009	0.78	0.26	0.21	1.34
REGSLOPE	-0.04	0.43	-1.42	1.34
SITE 3				
2005	1.28	1.92	-3.67	6.22
2006	2.69	0.12	2.38	3.01
2007	0.57	0.11	0.28	0.86
2008	-0.45	4.30	-11.49	10.60
2009	0.58	0.60	-0.73	1.88
REGSLOPE	-0.45	0.33	-1.51	0.61
SITE 4				
2005	-2.26	7.50	-21.53	17.02
2006	0.71	1.29	-2.62	4.03
2007	0.12	0.57	-1.35	1.58
2008	-0.79	4.43	-12.18	10.61
2009	2.31	0.63	0.93	3.69
REGSLOPE	0.76	0.44	-0.63	2.15
SITE 5				
2005	1.92	0.67	0.18	3.65
2006	2.33	0.26	1.65	3.01
2007	2.66	0.08	2.46	2.86
2008	2.85	1.24	-0.34	6.04
2009	-0.08	0.32	-0.77	0.61
REGSLOPE	-0.35	0.38	-1.56	0.87

PHOSPHATE - SLOPE

YEAR	*Coefficients*	*Std Err*	*Lower 95%*	*Upper 95%*
SITE 1				
2005	0.00	0.00	-0.01	0.01
2006	-0.03	0.00	-0.04	-0.02
2007	-0.01	0.01	-0.02	0.01
2008	0.00	0.00	0.00	0.00
2009	-0.01	0.00	-0.01	0.00
REGSLOPE	0.00	0.00	-0.01	0.02
SITE 2				
2005	-0.03	0.03	-0.12	0.06
2006	0.03	0.08	-0.18	0.24
2007	-0.06	0.00	-0.06	-0.05
2008	0.02	0.38	-0.97	1.01
2009	-0.02	0.01	-0.04	0.00
REGSLOPE	0.00	0.01	-0.04	0.04
SITE 3				
2005	-0.04	0.06	-0.18	0.11
2006	-0.07	0.00	-0.08	-0.06
2007	-0.01	0.00	-0.02	0.00
2008	0.02	0.12	-0.30	0.33
2009	-0.01	0.02	-0.05	0.02
REGSLOPE	0.01	0.01	-0.02	0.04
SITE 4				
2005	0.07	0.22	-0.49	0.62
2006	-0.02	0.04	-0.11	0.08
2007	0.00	0.02	-0.04	0.04
2008	0.02	0.13	-0.30	0.35
2009	-0.06	0.02	-0.11	-0.02
REGSLOPE	-0.02	0.01	-0.06	0.02
SITE 5				
2005	-0.05	0.02	-0.10	0.00
2006	-0.06	0.01	-0.08	-0.04
2007	-0.07	0.00	-0.08	-0.07
2008	-0.08	0.04	-0.17	0.01
2009	0.00	0.01	-0.02	0.02
REGSLOPE	0.01	0.01	-0.02	0.04

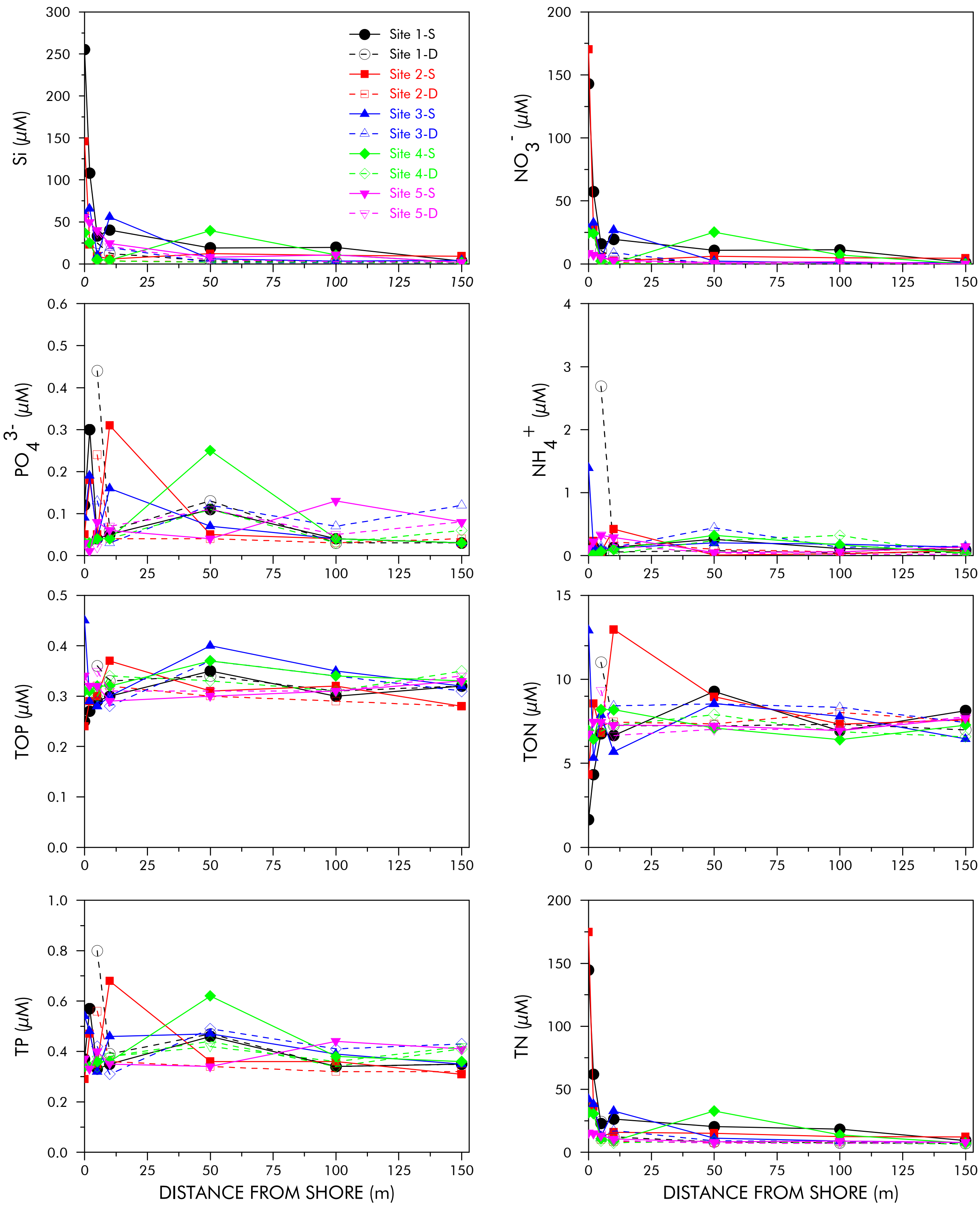

FIGURE 2. Plots of dissolved nutrients in surface (S) and deep (D) samples collected on September 4, 2009 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. For site locations, see Figure 1.

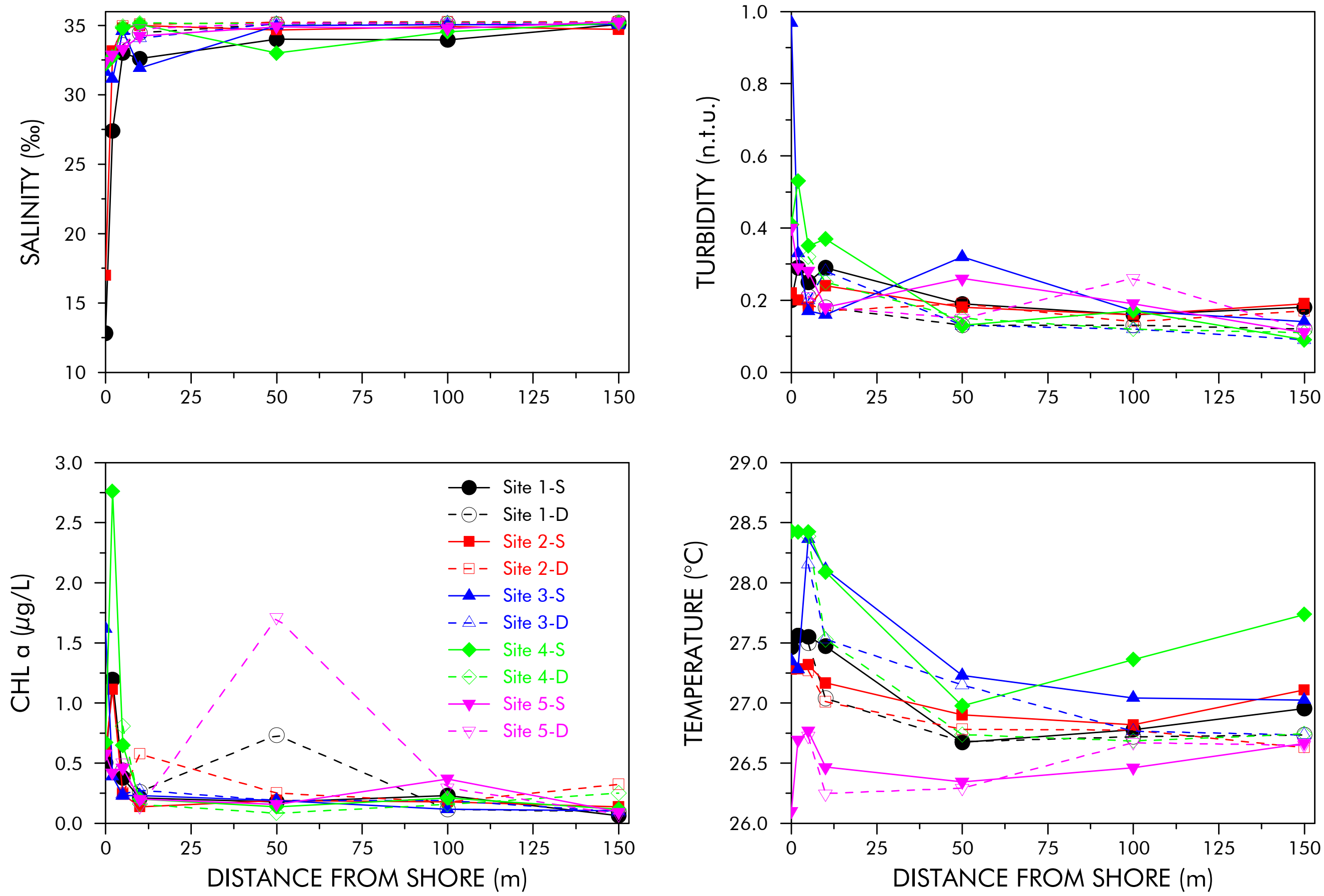

FIGURE 3. Plots of water chemistry constituents in surface (S) and deep (D) samples collected on September 4, 2009 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. For site locations, see Figure 1.

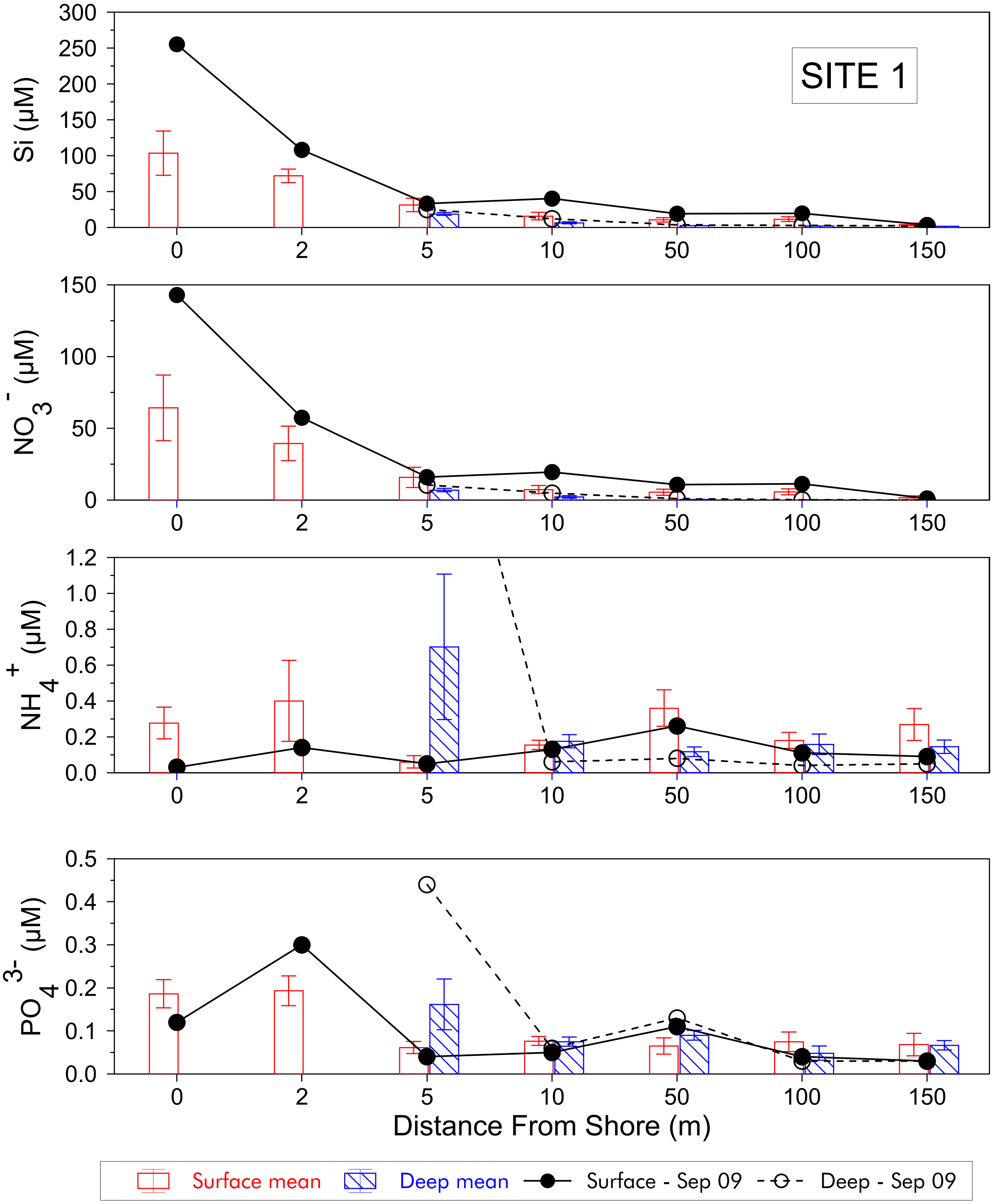

FIGURE 4. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

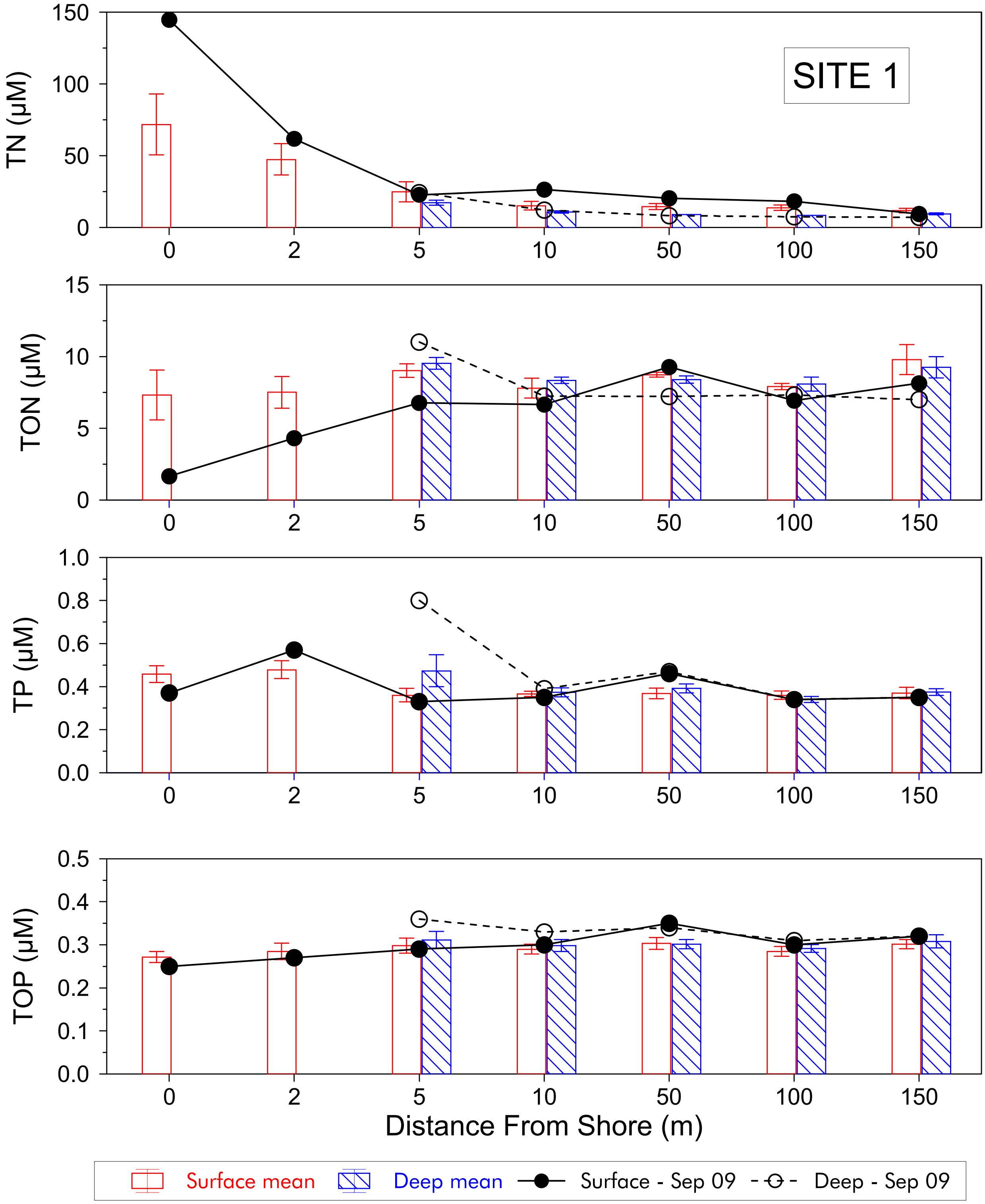

FIGURE 5. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

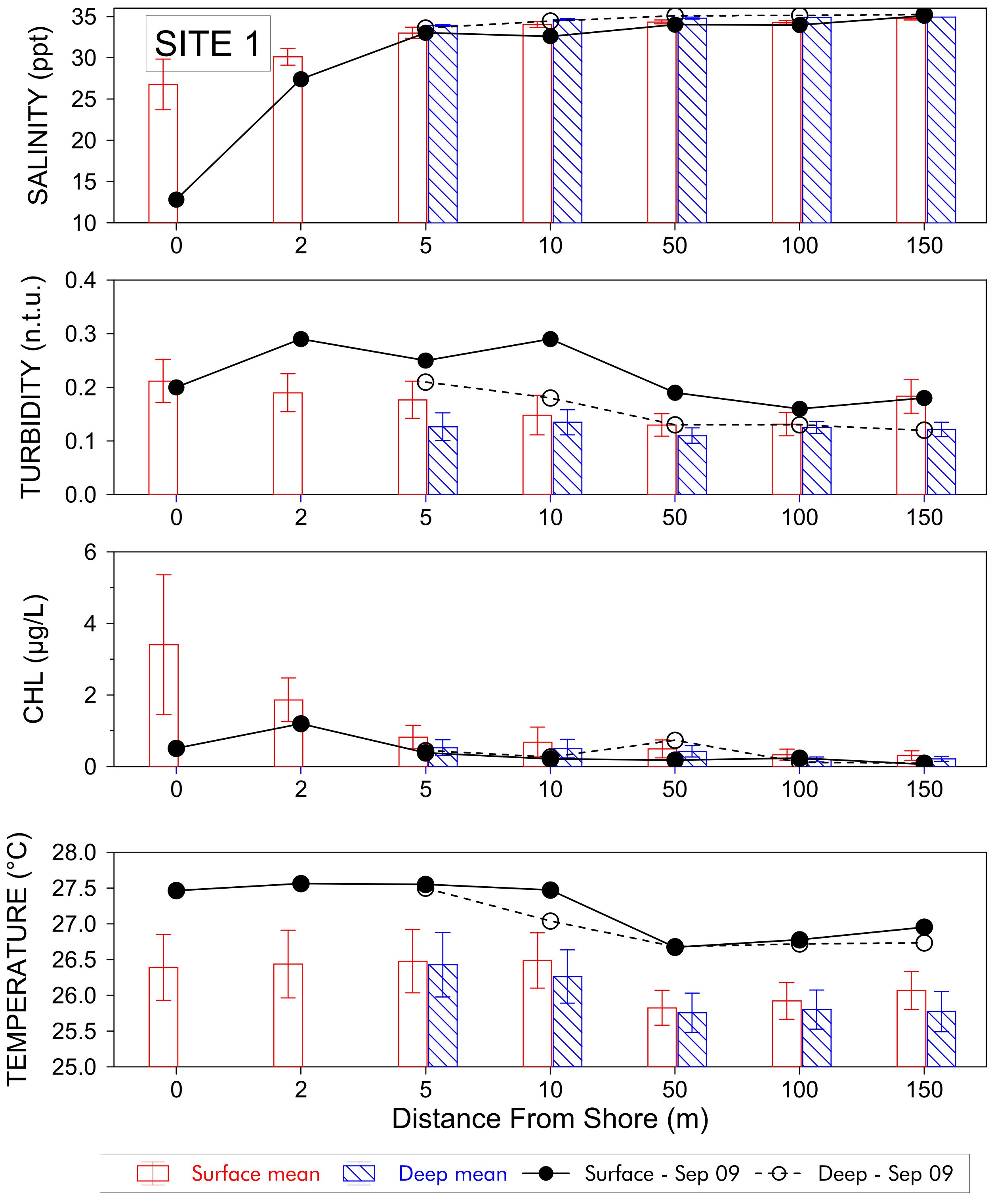

FIGURE 6. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

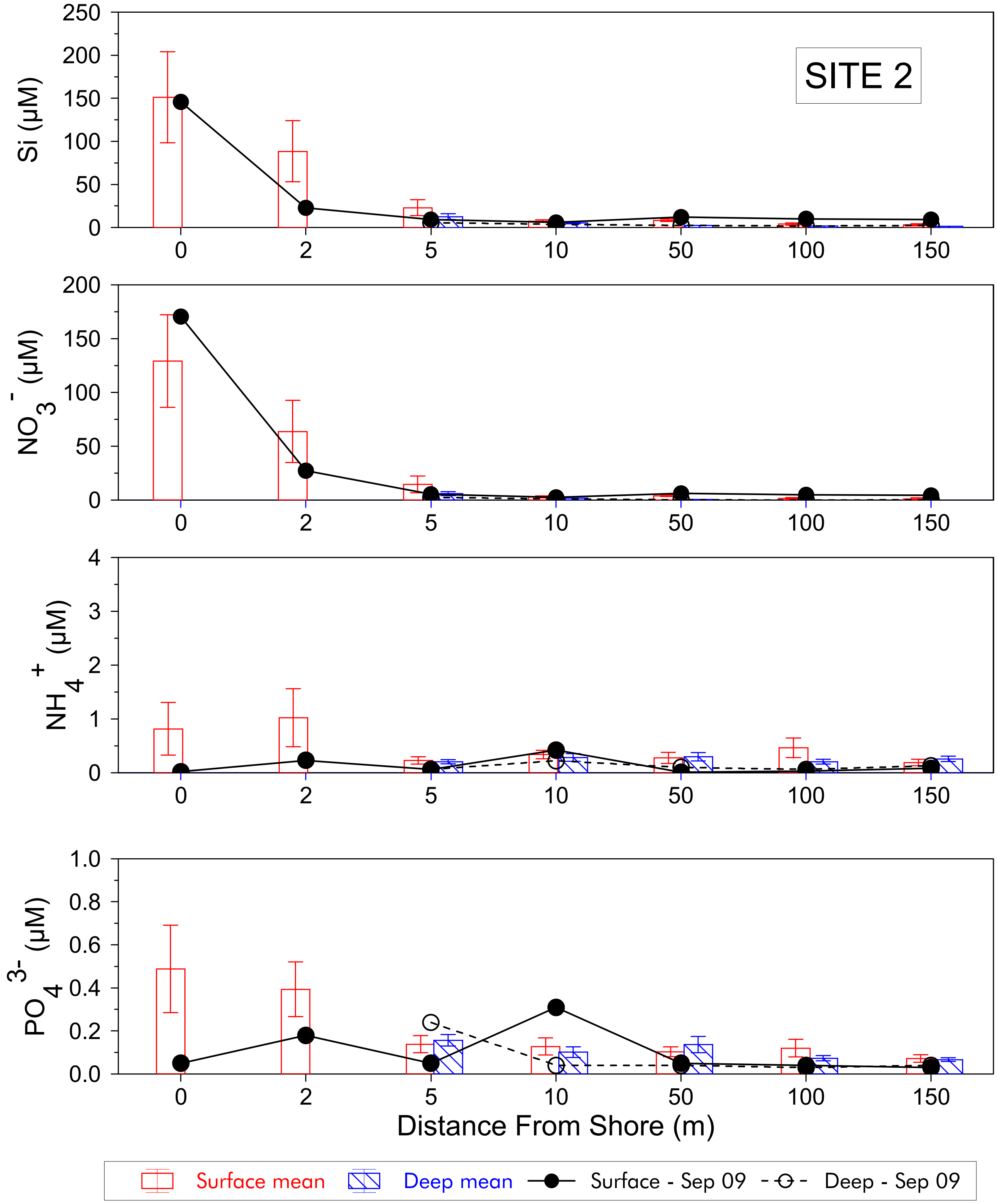

FIGURE 7. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

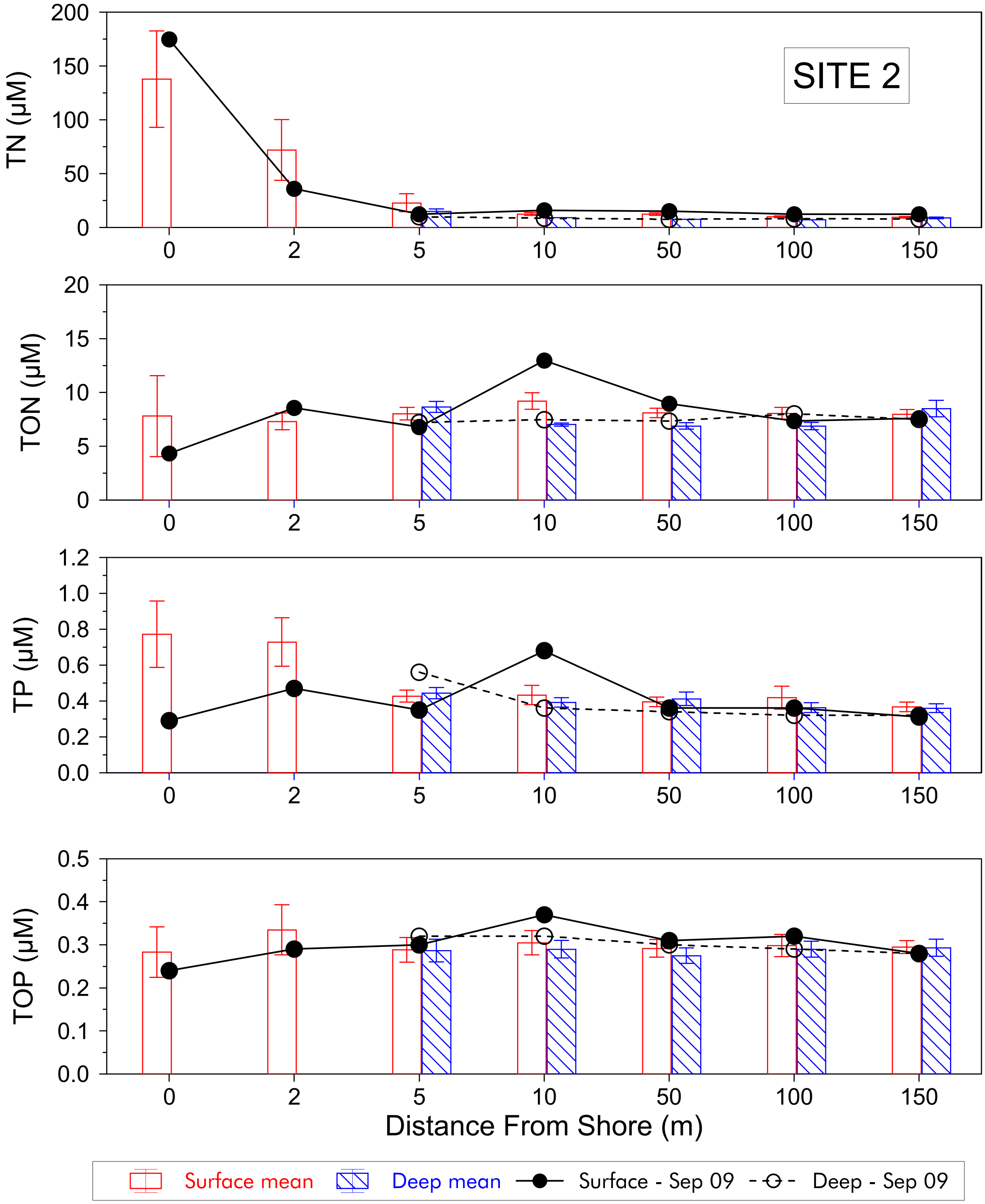

FIGURE 8. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

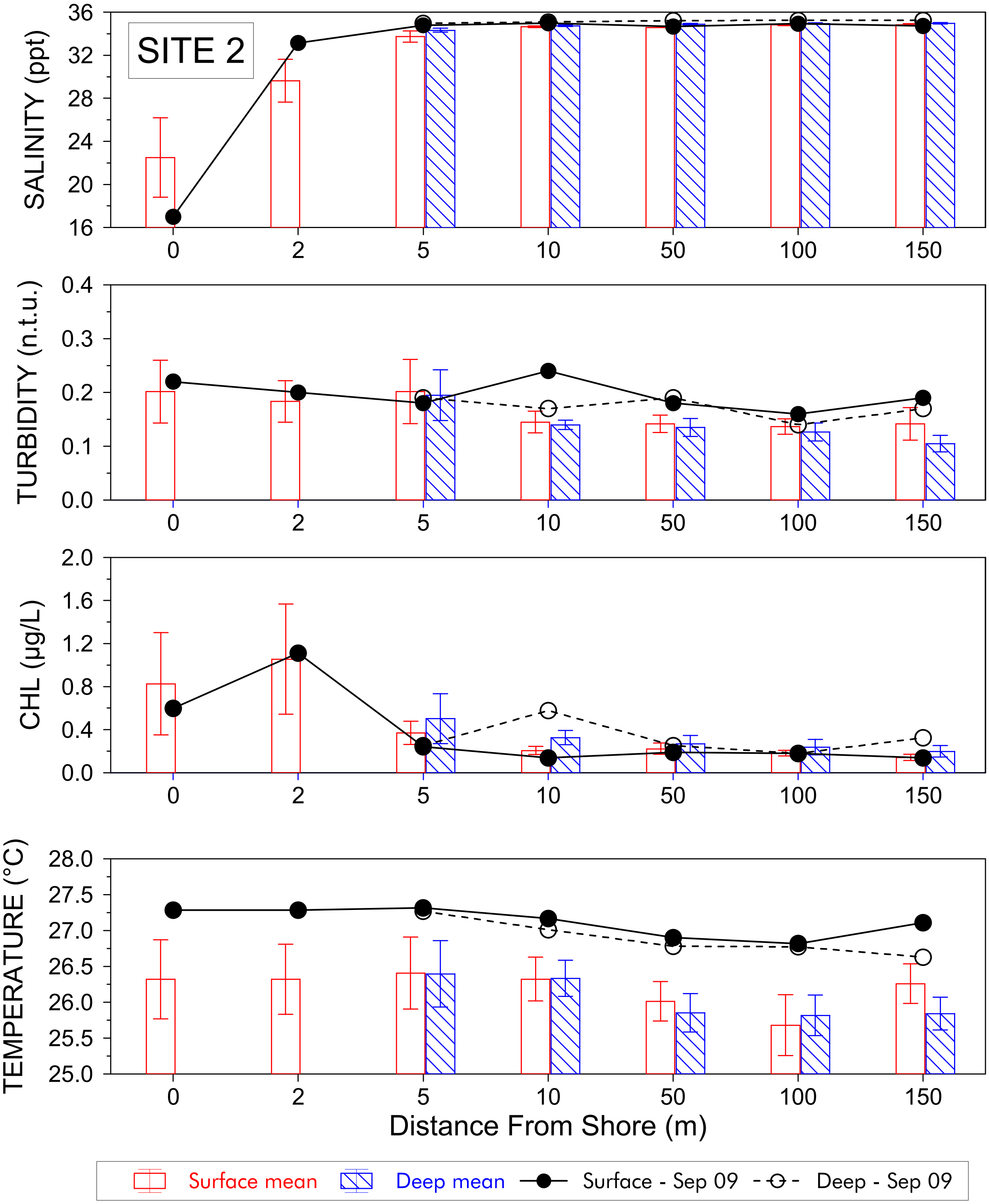

FIGURE 9. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

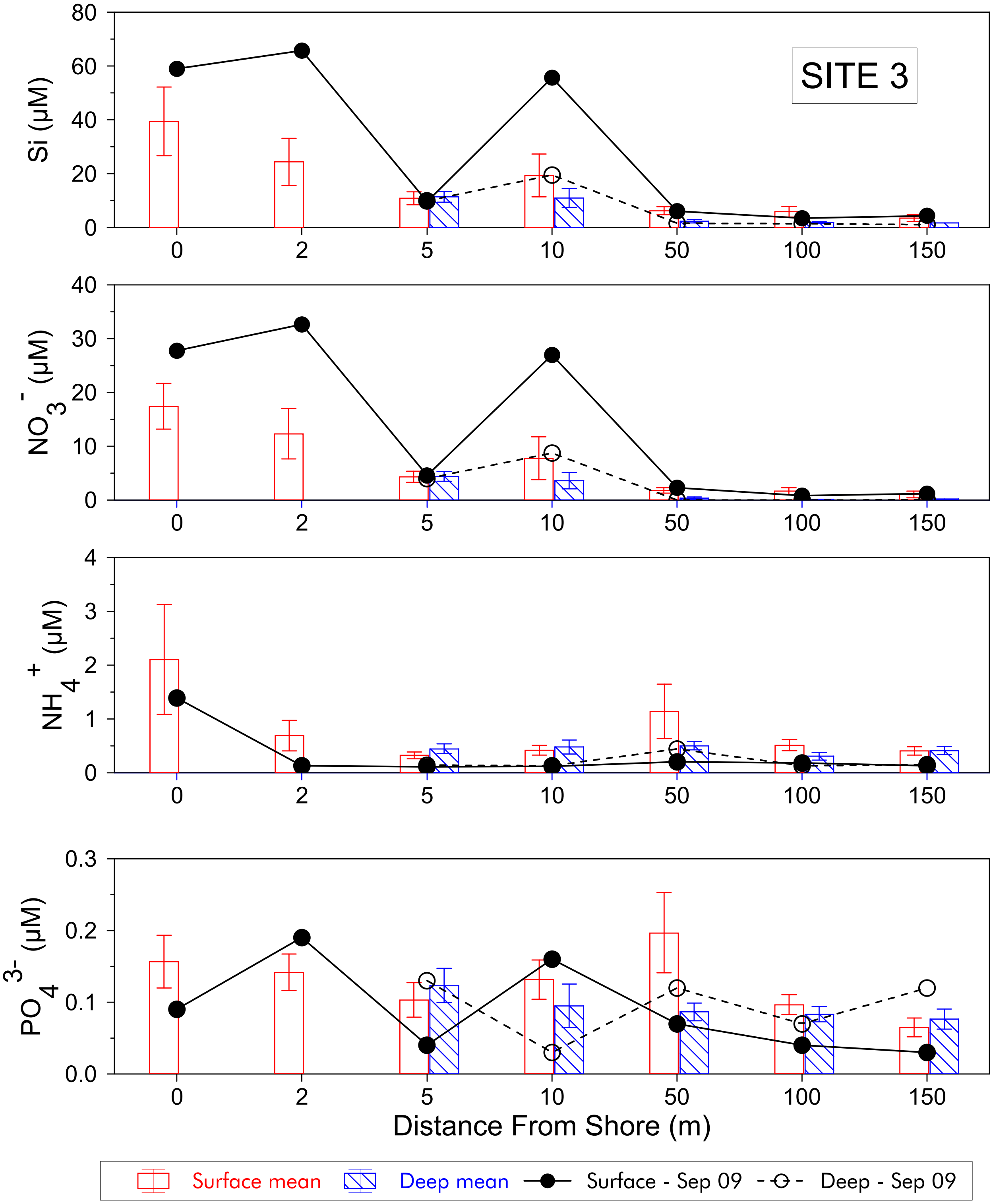

FIGURE 10. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

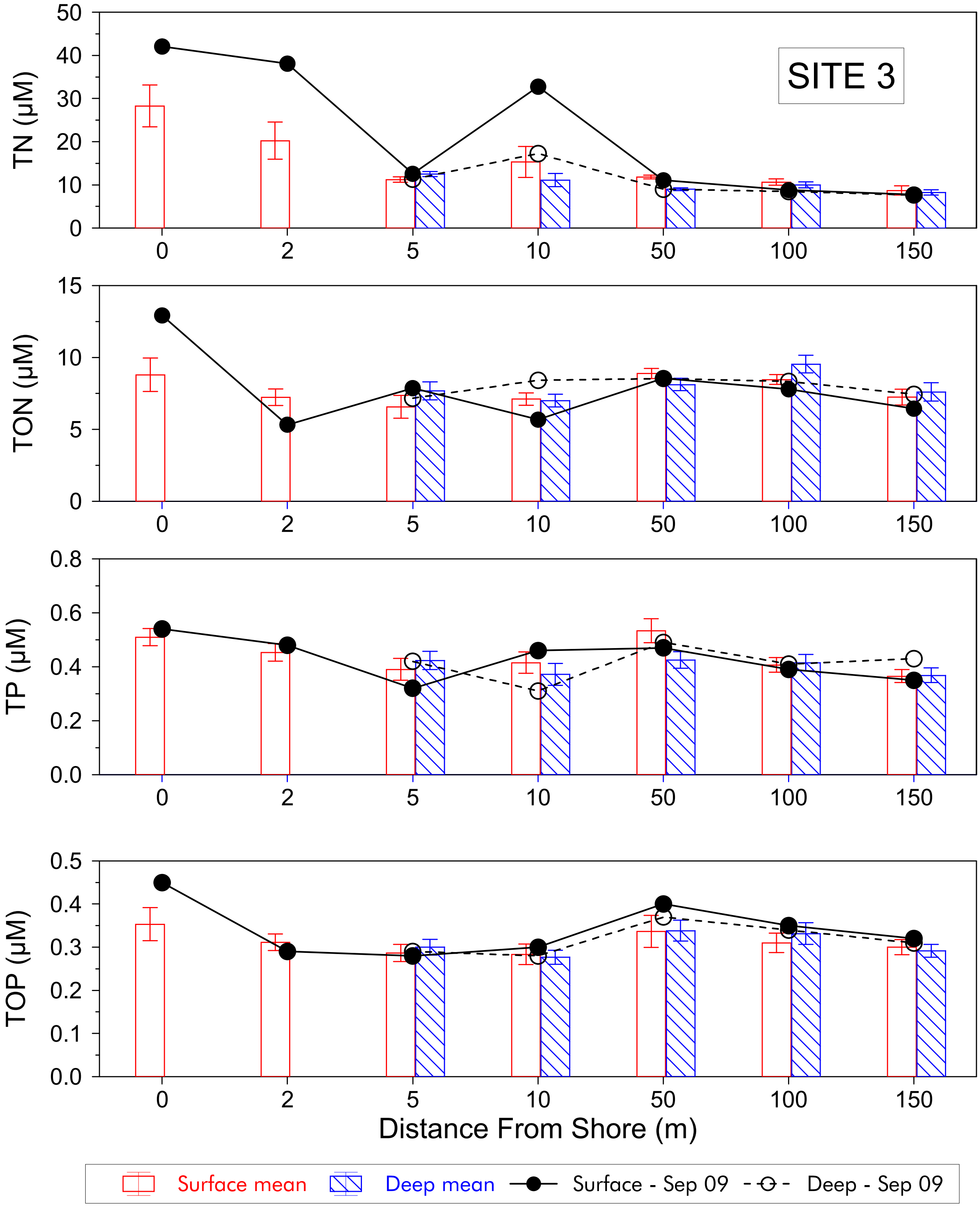

FIGURE 11. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

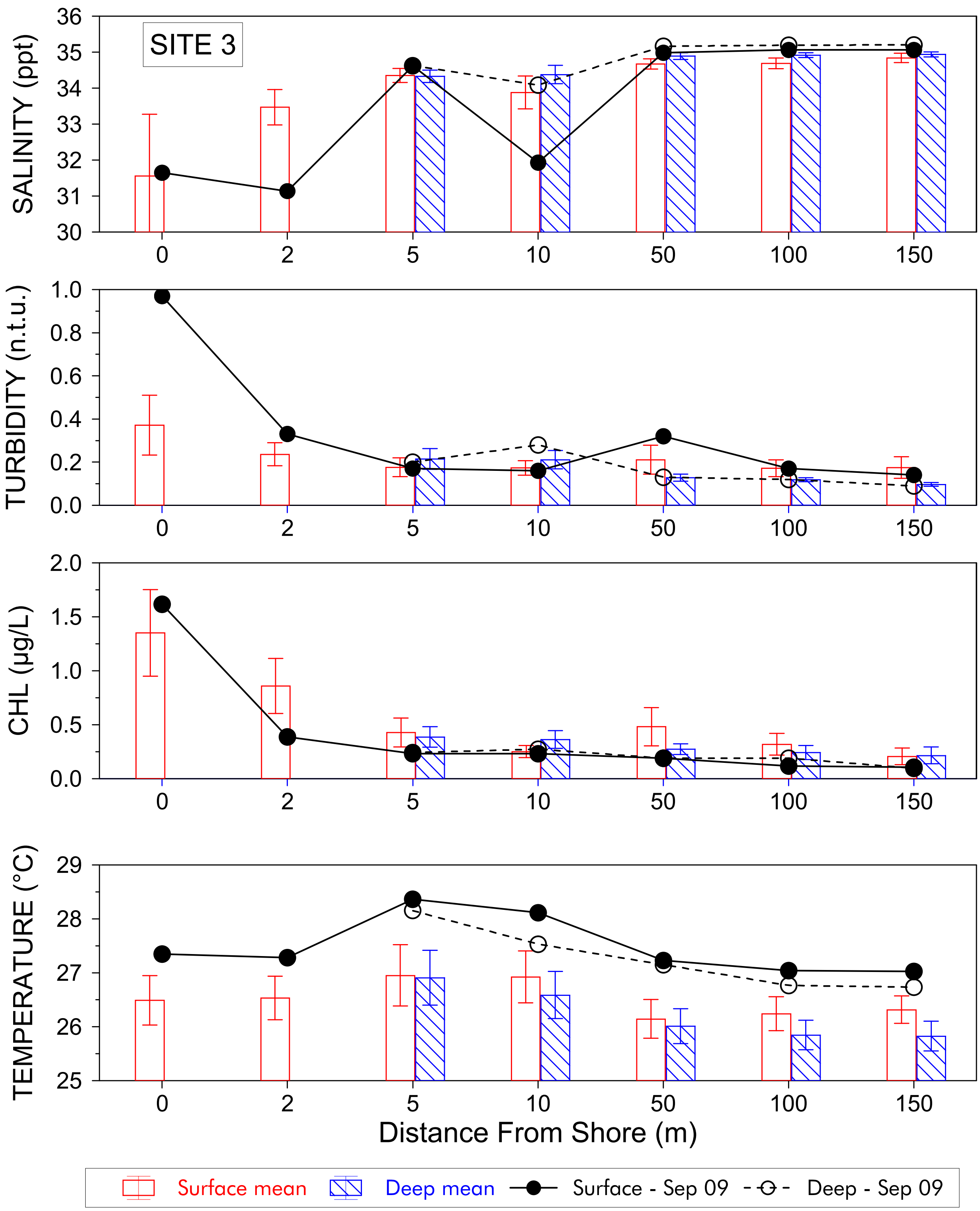

FIGURE 12. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

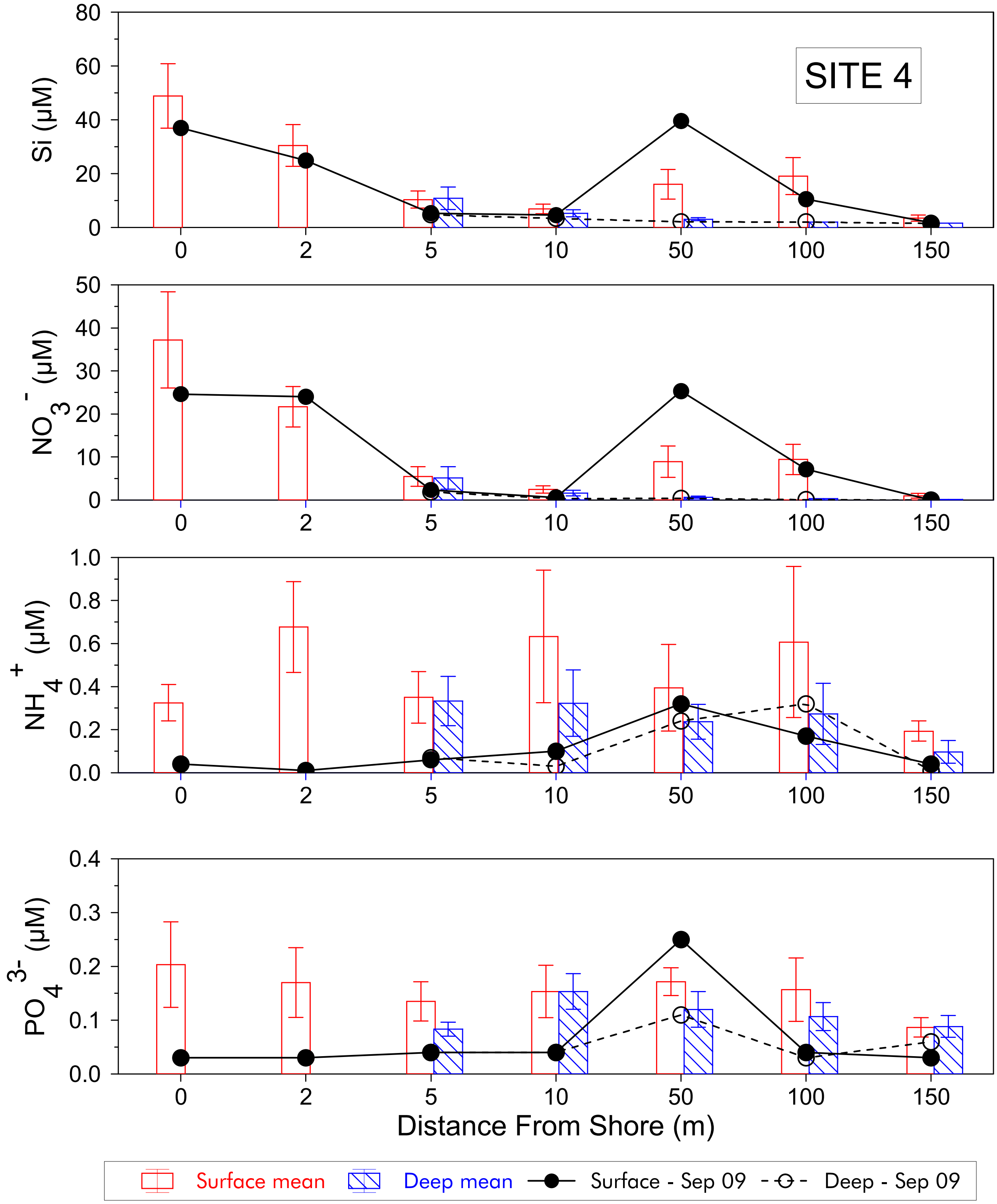

FIGURE 13. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

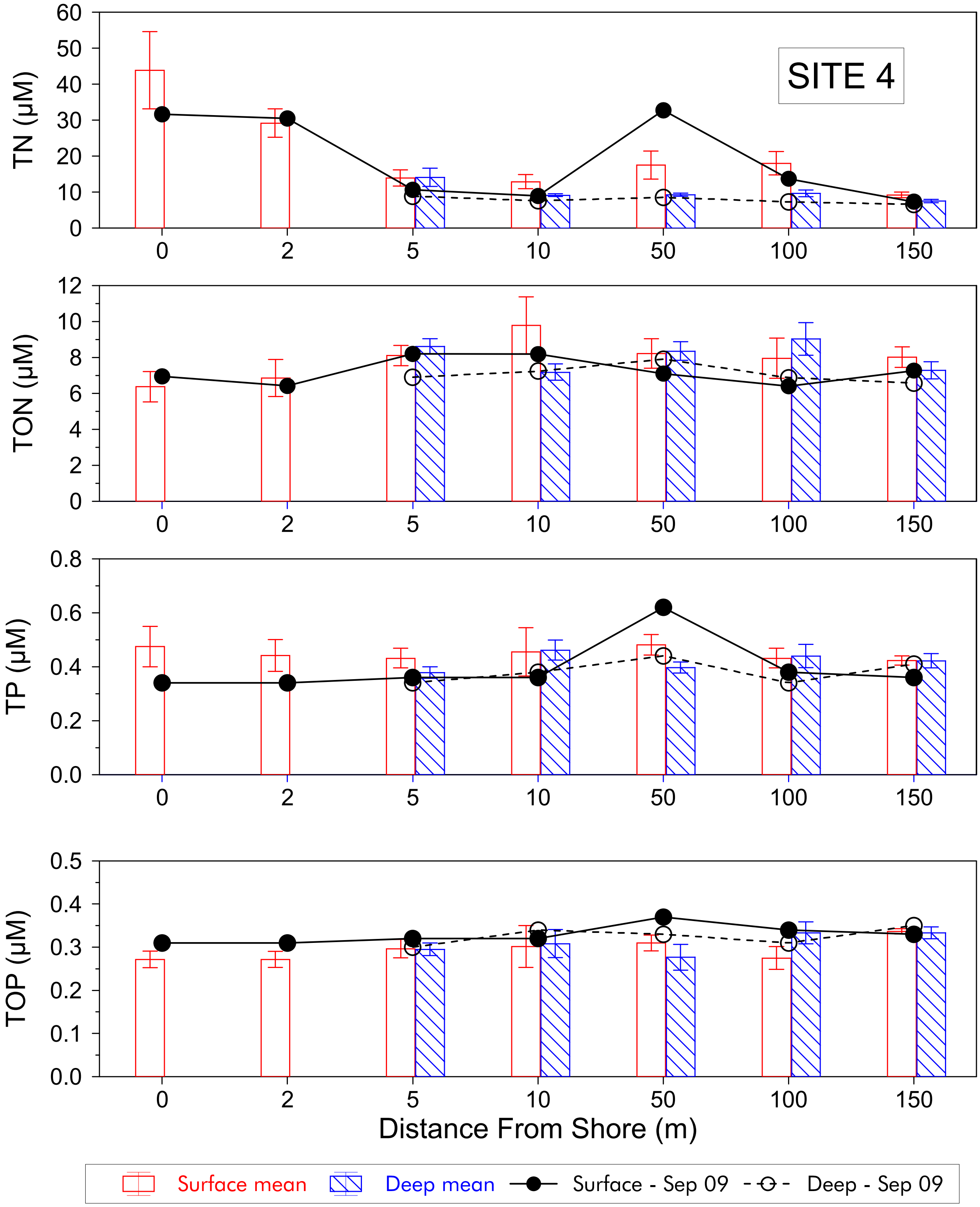

FIGURE 14. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

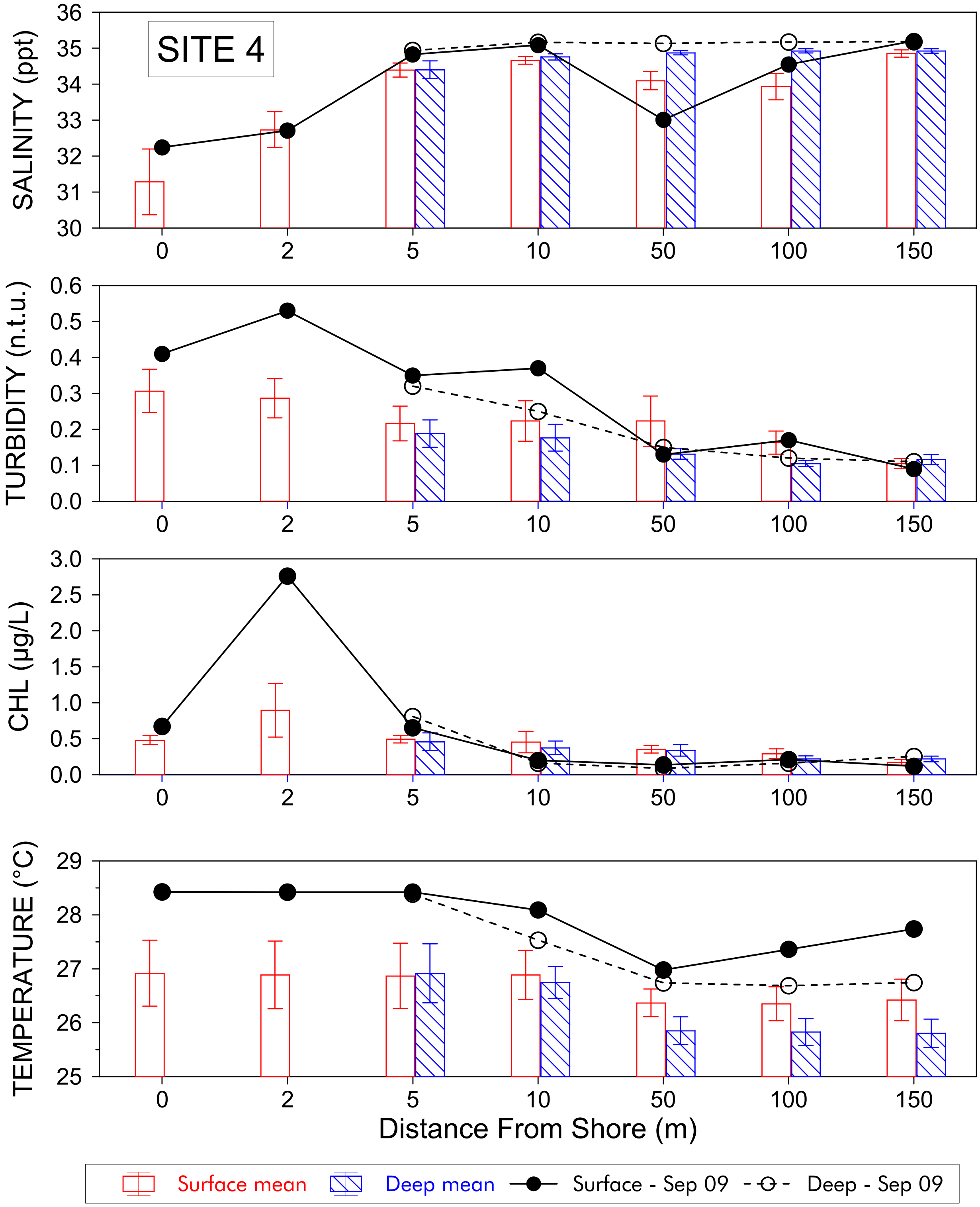

FIGURE 15. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

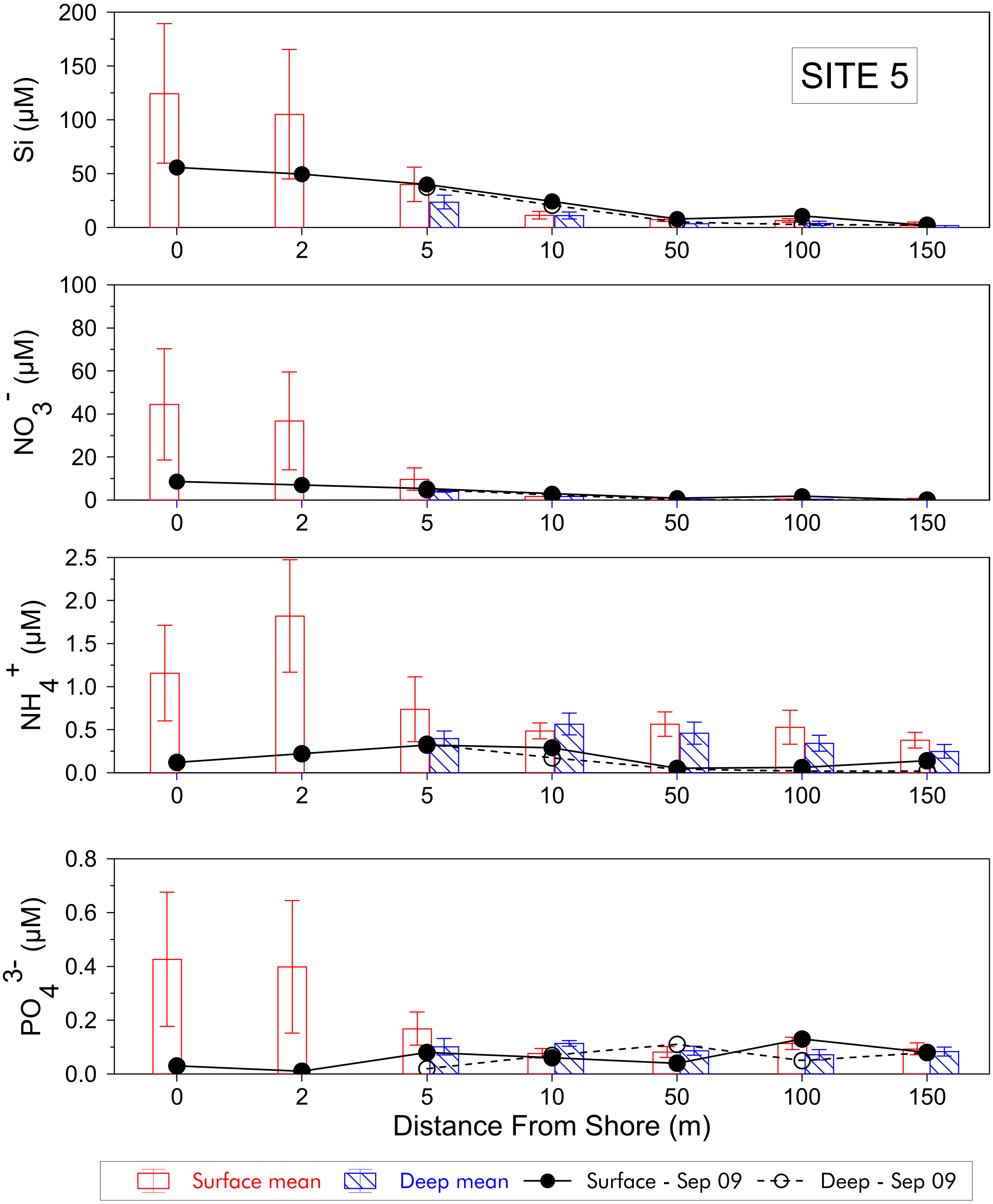

FIGURE 16. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

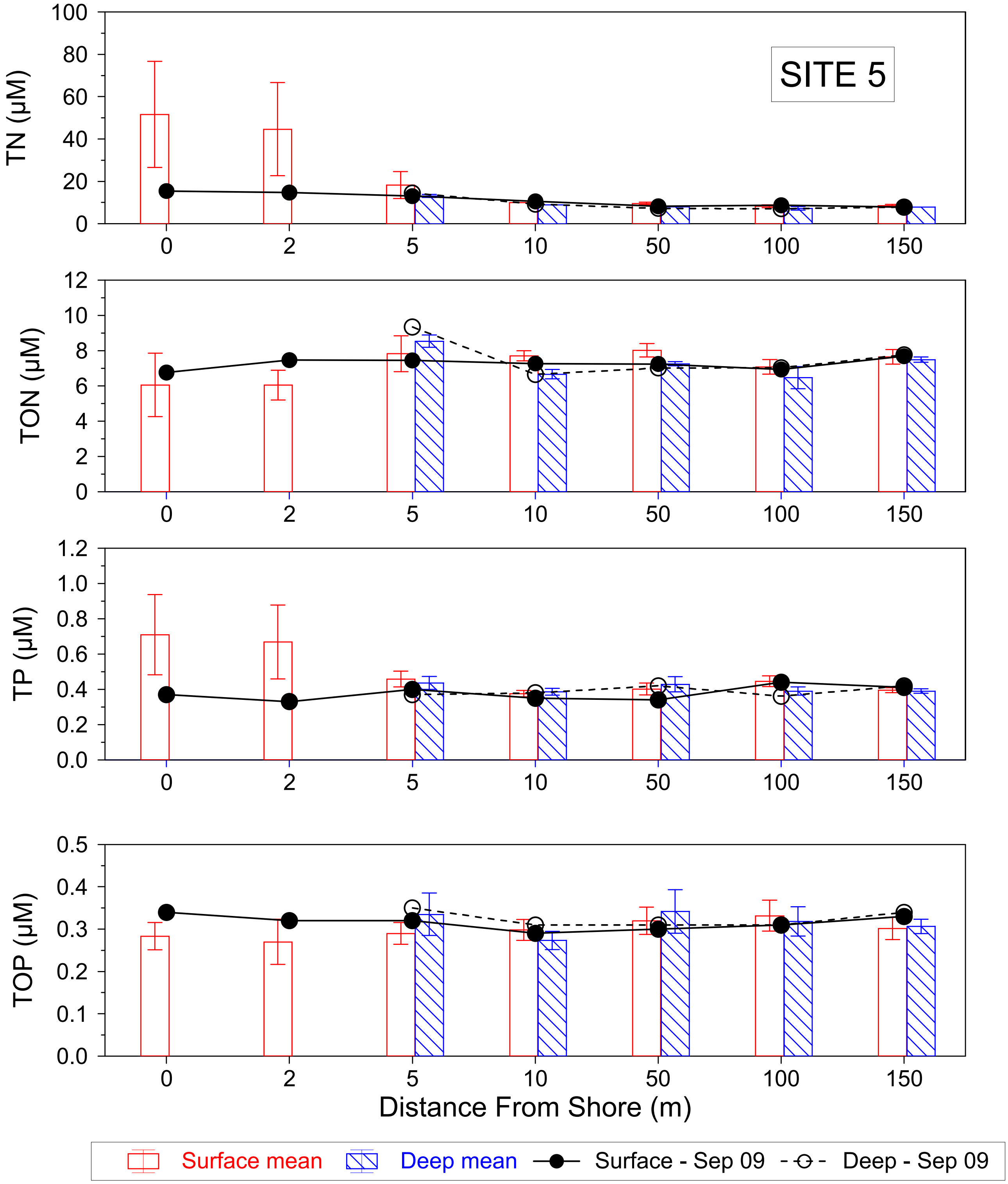

FIGURE 17. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

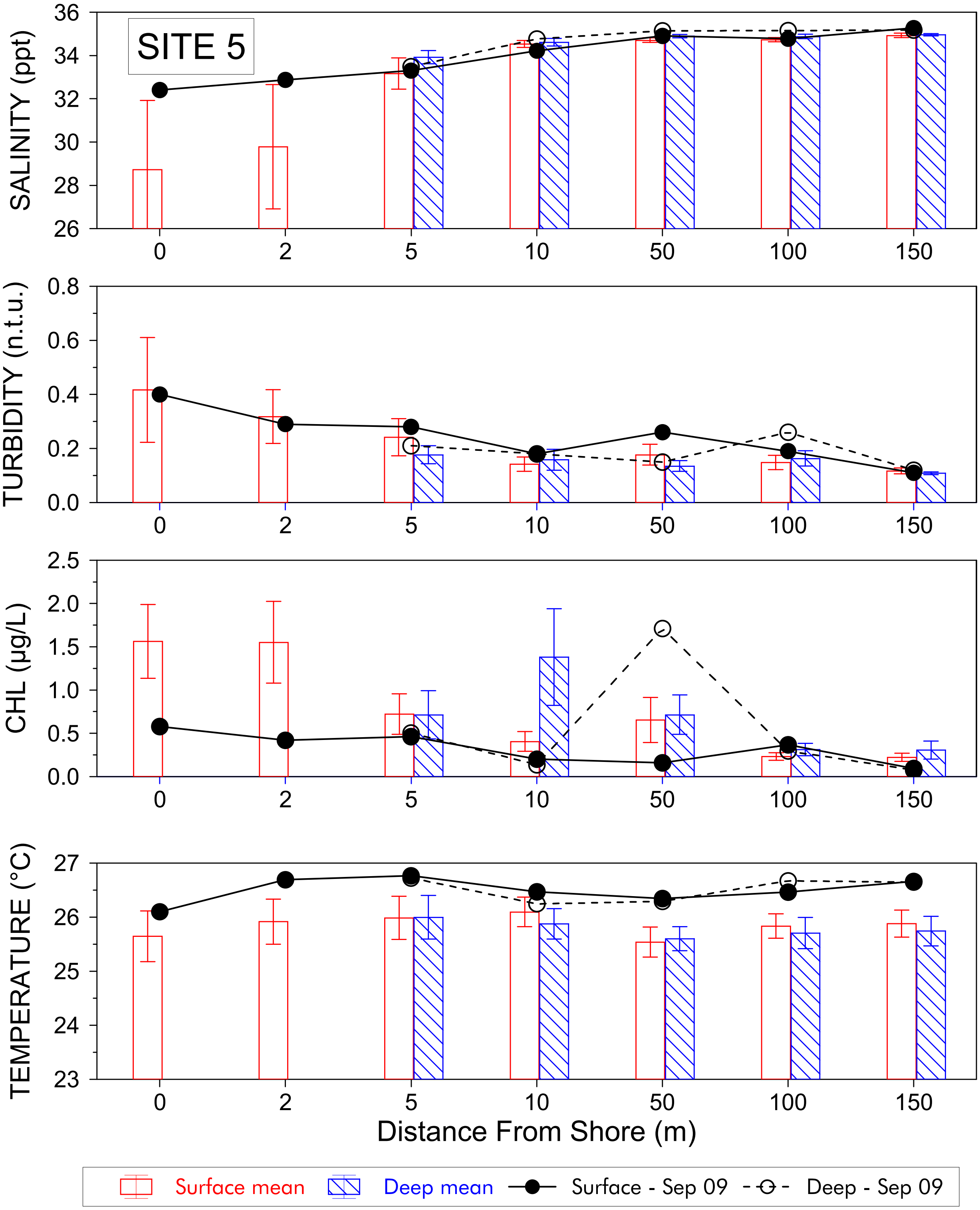

FIGURE 18. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=6). Error bars represent standard error of the mean. For site location, see Figure 1.

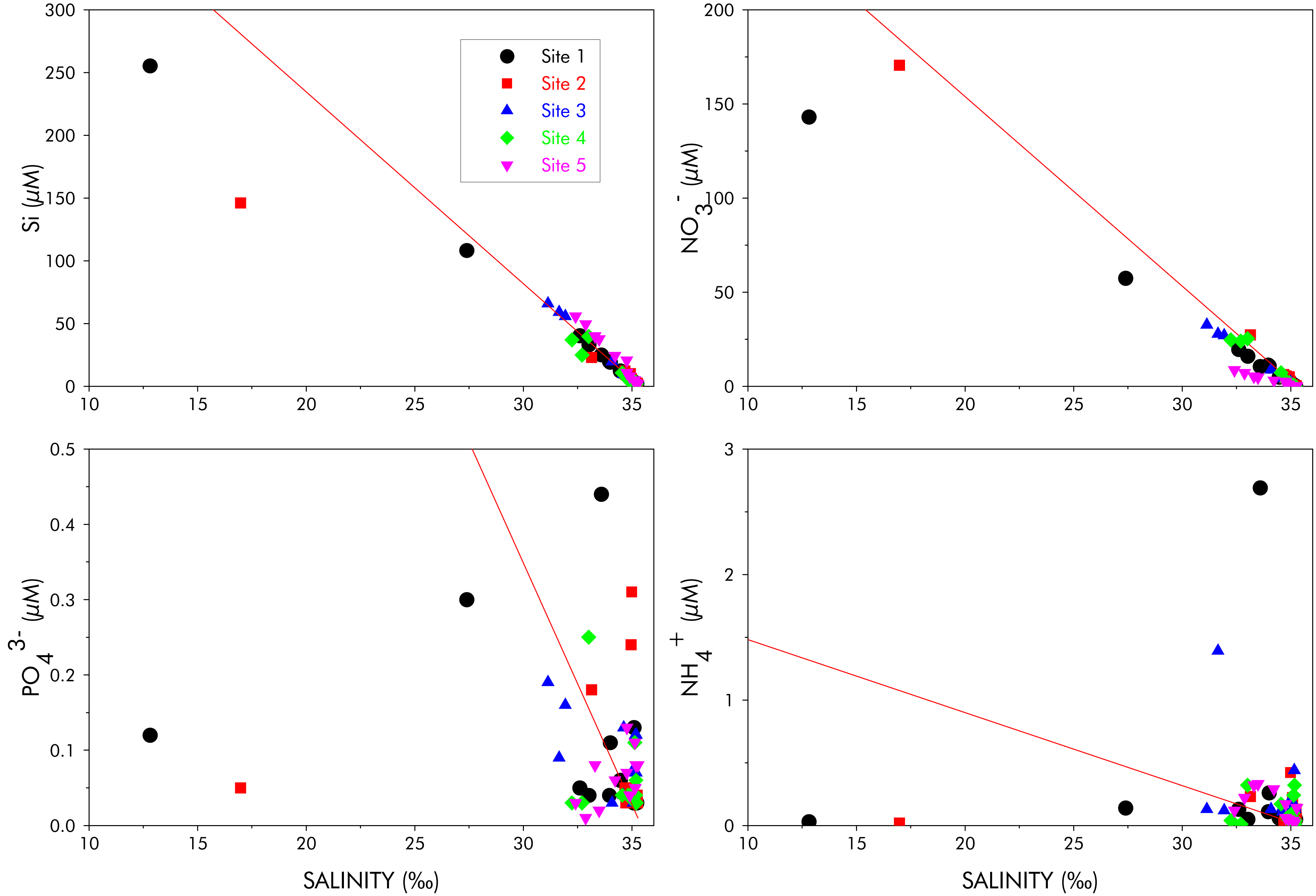

FIGURE 19. Mixing diagram showing concentration of dissolved nutrients from samples collected at five transect sites offshore of the Honua`ula project site in Wailea, Maui on September 4, 2009 as functions of salinity. Straight line in each plot is conservative mixing line constructed by connecting the concentrations in open coastal water with water from a golf course irrigation well. For transect site locations, see Figure 1.

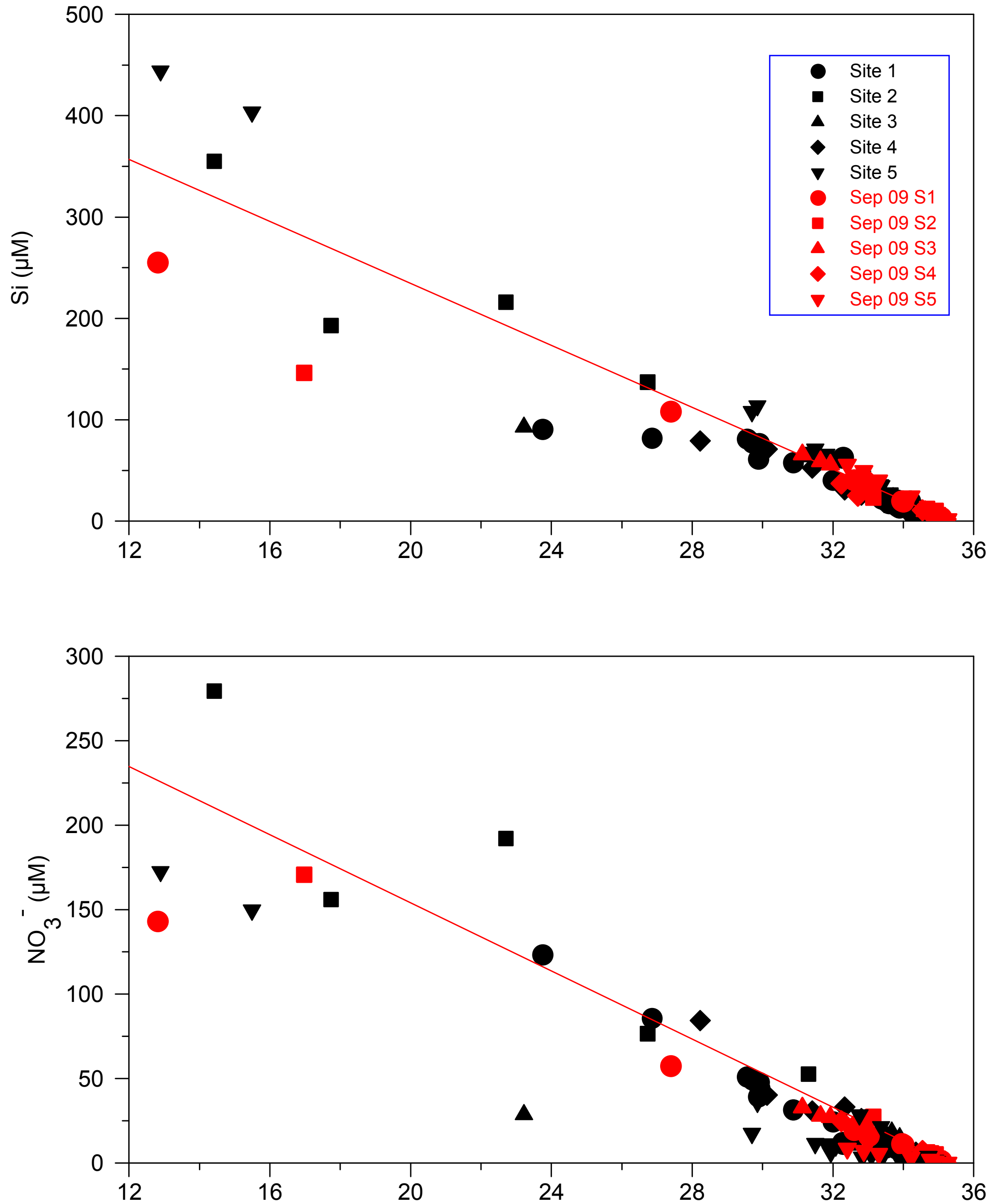

FIGURE 20. Silicate and nitrate, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and January 2009 (N=5). Red symbols are data from the most recent survey. Solid red line in each plot is conservative mixing line constructed by connecting the concentrations in open coastal water with water from a golf course irrigation well. For sampling site locations, see Figure 1.

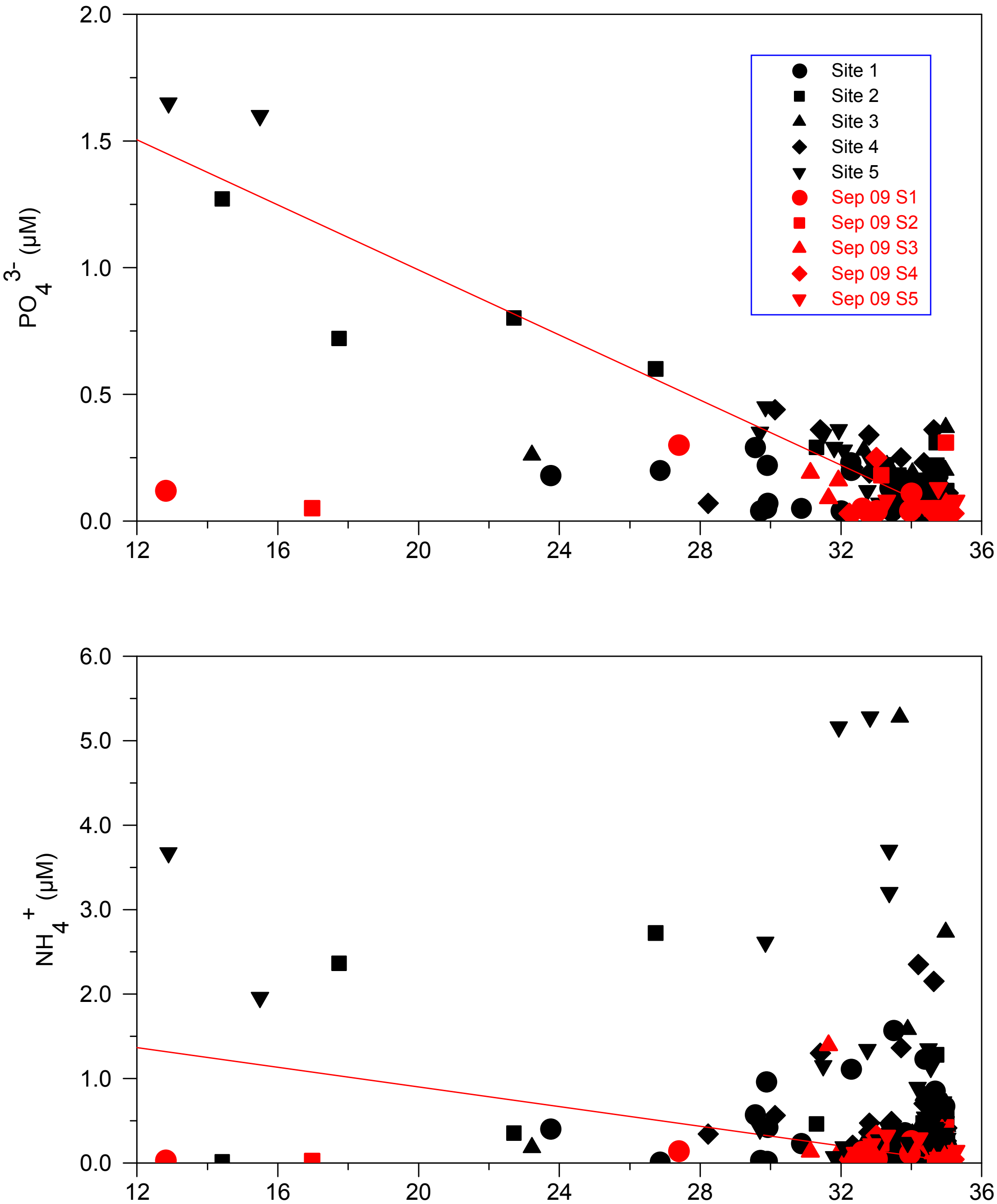

FIGURE 21. Phosphate and ammonium, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and January 2009 (N=5). Red symbols are data from the most recent survey. Solid red line in each plot is conservative mixing line constructed by connecting the concentrations in open coastal water with water from a golf course irrigation well. For sampling site locations, see Figure 1.

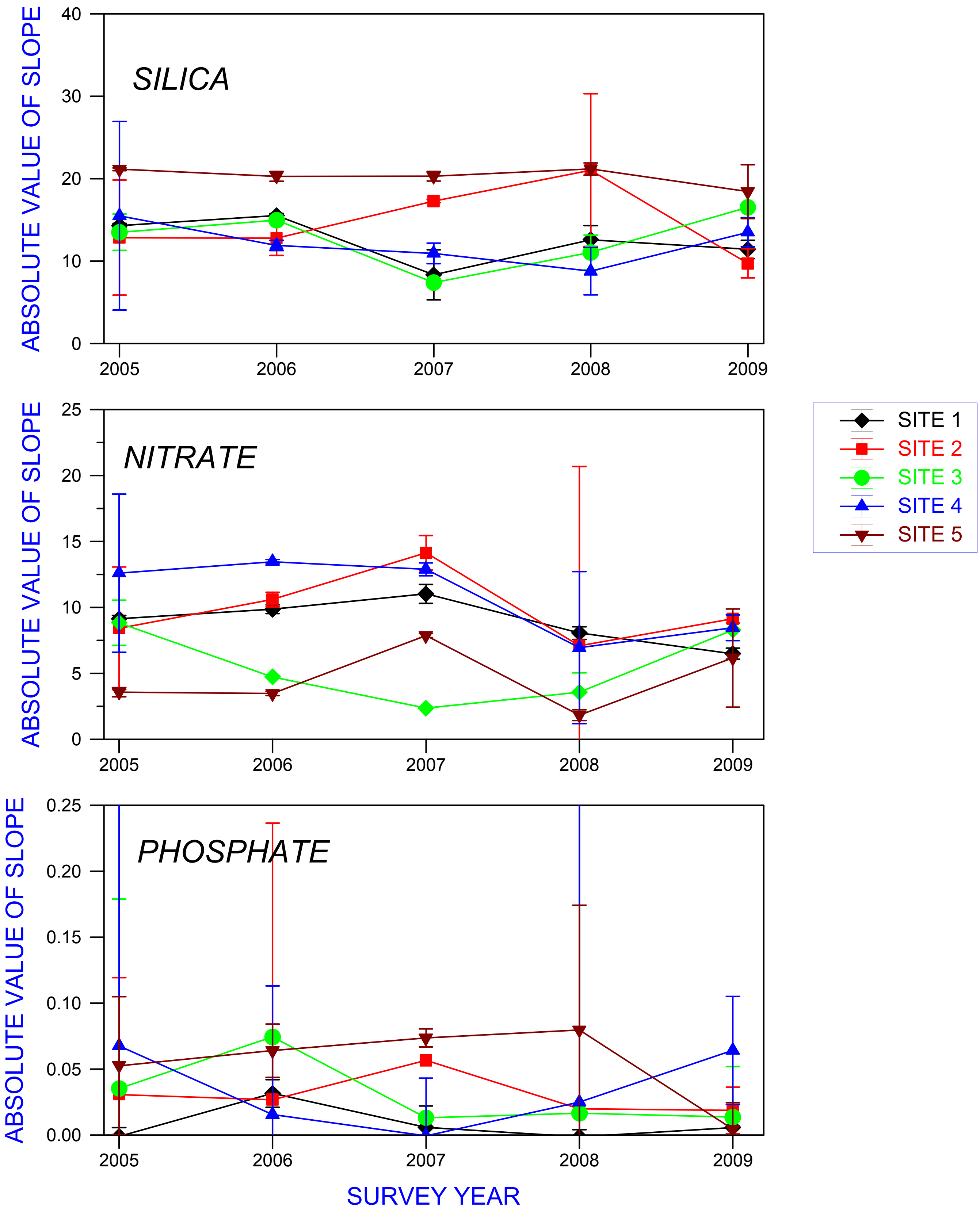

FIGURE 22. Time-course plots of absolute values of slopes of linear regressions of concentrations of silca, nitrate and phosphate as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations of sampling transect sites, see Figure 1.

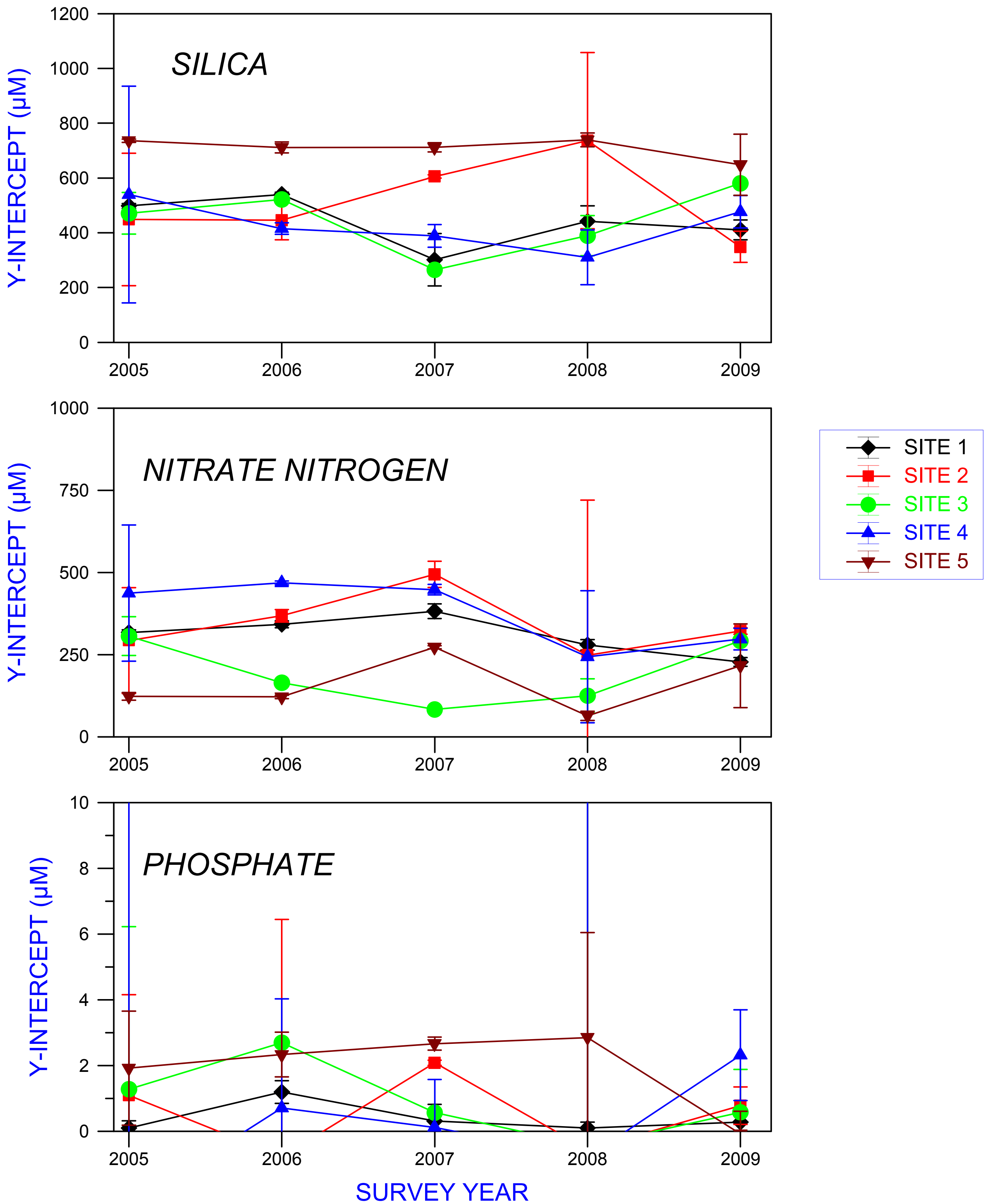

FIGURE 23. Time-course plots of Y-intercepts of linear regressions of concentrations of silca, nitrate and phosphorus as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations of sampling transect sites, see Figure 1.

PRELIMINARY ASSESSEMENT OF MARINE COMMUNITY STRUCTURE
HONUA'ULA PROJECT

WAILEA, MAUI

Prepared for:

Honua'ula Partners LLC
P.O. Box 220
Kihei, Maui, Hawaii 96753

Prepared by:

Marine Research Consultants, Inc.
1039 Waakaua Pl.
Honolulu, HI 96822

February 2010

INTRODUCTION

The Honua'ula project is situated on the slopes of Haleakala directly mauka of the Wailea Resort in South Maui, Hawaii. The project area is comprised of two parcels totaling 670 acres and is designated Project District 9 in the Kihei/Makena Community Plan (Figure 1). The project area is also zoned Project District 9 in the Maui County code. Current zoning includes provisions for 1,400 homes (including affordable workforce homes in conformance with the County's Residential Workforce Housing Policy (Chapter 2.96, MCC), village mixed uses, a homeowner's golf course, and other recreational amenities as well as acreage for parks, and open space that will be utilized for landscape buffers and drainage ways. The project is immediately above three 18-hole golf courses (Blue, Gold and Emerald) within the southern area of Wailea Resort. The composite Wailea Resort/ Honua'ula encompasses approximately 1.9 mile of coastline. No aspect of the project involves direct alteration of the shoreline or nearshore marine environment. At the time of submission of this report, development of the project EIS and Phase II submittal is in progress. No construction activities associated with the project have commenced.

While all planning and construction activities will place a high priority on maintaining the existing nature of the marine environment, it is nevertheless important to address any potential impacts that may be associated with the planned community. The potential exists, however, for the project to affect the composition and volume of groundwater that flows beneath the property, as well as surface runoff. As all groundwater and runoff that could be affected by the project could potentially reach the ocean, it is recognized that there is potential for effects to the marine environment. As the shoreline downslope from the planned project is a recreational area and is utilized for surfing, swimming, and fishing, evaluating the potential for alterations to water quality and marine life from material input from the community constitutes an important factor in the planning process.

In the interest of addressing these concerns and assuring maintenance of environmental quality, a marine water quality assessment and potential impact analysis of the nearshore areas downslope from Honua'ula are being conducted. The foundation of these assessments are based on a monitoring program that was stipulated as one condition of zoning (No. 20) which states …" *That marine monitoring programs shall be conducted which include monitoring and assessment of coastal water resources (groundwater and surface water) that receive surface water or groundwater discharges from the hydrologic unit where the project is located Monitoring programs shall include both water quality and ecological monitoring."* With respect to ecological monitoring, surveys will be conducted in accordance with the Coral Reef Assessment and Monitoring Program protocols used by the Department of Land and Natural Resources. The initial assessment shall use the full protocol. Subsequent annual assessments can use the Rapid Assessment Techniques. Results shall be reported annually to the Aquatic Resources Division, Department of Land and Natural Resources.

At this time, field surveys for the initial assessment have been conducted. This report describes the results of the baseline survey of the nearshore marine communities. Such a characterization of biotic assemblages can provide a basis for estimating alteration of community structure as a result of modifying land uses mauka of the shoreline. This baseline will also serve to identify any specific biotic communities that may be especially susceptible (or resistant), to the potential alterations that may result from the planned development.

An important part of this investigation is to provide an evaluation of the degree of natural stresses (sedimentation, wave scour, freshwater input, etc.) that influence the nearshore marine environment in the area that could be potentially influenced by the proposed project. Typically, water quality and the composition of nearshore marine communities are intimately associated with the magnitude and frequency of these stresses, and any impacts caused by the proposed project may either be mitigated in large part, or amplified, by natural environmental factors. Therefore, evaluating the range of natural stress is a prerequisite for assessing the potential for additional change to the marine environment owing to shoreline modification. It is also important to note that while no work has been initiated for the Honua`ula project, the project site is separated from the ocean by the Wailea Resort, which has been in place for several decades. Hence, the marine communities downslope from the proposed project have been influenced by land uses of the Wailea Resort, and do not represent "pristine" conditions.

Marine community structure can be defined as the abundance, diversity, and distribution of stony and soft corals, motile benthos such as echinoderms, and pelagic species such as reef fish. In the context of time-series surveys, a most useful biological assemblage for direct evaluation of environmental impacts to the offshore marine environment are benthic (bottom-dwelling) communities. Because benthos are generally long-lived, immobile, and can be significantly affected by exogenous input of sediments and other potential pollutants, these organisms must either tolerate the surrounding conditions within the limits of adaptability or die.

As members of the benthos, stony corals are of particular importance in nearshore Hawaiian environments. Corals compose a large portion of the reef biomass and their skeletal structures are vital in providing a complex of habitat space, shelter, and food for other species. Since corals serve in such a keystone function, coral community structure is considered the most "relevant" group in the use of reef community structure as a means of evaluating past and potential impacts associated with land development. For this reason, and because alterations in coral communities are easy to identify, observable change in coral population parameters is a practical and direct method for obtaining the information for determining the effects of stress in the marine environment. In addition, because they comprise a very visible component of the nearshore environment, investigations of reef fish assemblages are presented.

METHODS

All fieldwork was carried out on February 20, 2010 conducted from a 22-foot boat. Biotic structure of benthic (bottom dwelling) communities inhabiting the reef environment was evaluated by establishing a descriptive and quantitative baseline between the shoreline and the 20 meter (m) (~60 foot) depth contour. Initial qualitative reconnaissance surveys were conducted that covered the area off the Honua'ula property from the shoreline out to the limits of coral reef formation. These reconnaissance surveys were useful in making relative comparisons between areas, identifying any unique or unusual biotic resources, and providing a general picture of the physiographic structure and benthic assemblages occurring throughout the region of study.

Following the preliminary survey, two quantitative transect sites were selected offshore of the development area, while a third site was selected as a control within the `Ahihi-Kina'u Natural Area Reserve (Figure 1). Site 1 was located near the northern property boundary between Polo and Palauea Beaches, while Site 2 was located between Ulua and Wailea Beaches. At each site, transect surveys were conducted, one in each of the dominant reef zones. Each transect was oriented parallel to depth contours so as to bisect a single reef zone. Care was taken to place transects in random locations that were not biased toward either peak or low coral cover. In total, twelve quantitative transects were conducted.

Quantitative benthic surveys were conducted at each site by evaluating reef community composition using methods described in the Coral Reef Assessment and Monitoring Program. For the purposes of the present report, qualitative descriptions of physical and biotic composition of the nearshore marine habitats are presented.

DESCRIPTION OF THE NEARSHORE MARINE ENVIRONMENT

Physical Structure

The main structural feature of the shoreline and nearshore areas off Honua`ula are a series of crescent shaped white sand beaches separated by basaltic rocky headlands that extend up to several hundred meters offshore (Figure 1). Sand plains extend from the beach shorelines continuously to the depth limit of the survey (60 ft). The rocky headlands generally consist of extended fingers of exposed rock with sharply angled edges that form the shorelines of these features. Owing to the vertical faces, there are essentially no well-defined intertidal platforms, or extensive tide pools along the shoreline.

The seaward extensions of the rocky headlands that separate the beaches provide the major habitats for marine biota. The intertidal range of the submerged headlands are colonized by bands of the seaweeds *Anhfeltia concinna* and *Ulva fasciata*. The submerged portions of the rock surfaces are lined with various forms of encrusting red algae, and contain numerous urchins of the species *Echinometra matheai, Echinostrephus aciculatus*, and *Colobocentrotus atratus*, as well as numerous juvenile reef fish. As the headlands extend seaward, the top surfaces flatten out into dome-shaped fingers. At the seaward termini, the headlands grade into the sandy bottom, often with a distinct boundary between the rock-rubble platform and the sand bottom, generally at a depth of about 25-30 feet. The exception to this pattern of composition occurred of the `Ahihi-Kina`u Natural Area Reserve. In this area, the shoreline area is comprised of a rocky platform with intermittent cobble beaches.

Biotic Community Structure

The coral reef communities that occur on the hard-bottom areas off the Wailea/Honua'ula properties consist of abundant and diverse assemblages of common Hawaiian marine life. The predominant taxon of macrobenthos (bottom-dwellers) throughout the reef zones are Scleractinian (reef-building) corals. Corals, primarily of the species *Pocillopora meandrina* and *Porites lobata* were by far the two most abundant forms. Other common corals observed were *Montipora capitata, M. flabellata*, and *M. patula, Porites compressa* and *Pavona varians.* Of note is that the richest communities in terms of both species number and bottom cover occur on the rocky outcrops that are elevated above the sand bottom. This is likely in response to lessened stress from abrasion from sand scour during periods when wave action is sufficient to resuspend sand off the bottom. At Survey site 1, the basaltic extension the rock headland was relatively narrow and steep-sided. Coral cover was greatest on the sloping sides of the rock finger, with total coral cover in the range of 50-75% of bottom cover. In addition to substantial coral cover, the top of the finger was also occupied by abundant slate-pencil sea urchins (*Heterocentrotus mammilatus*) (Figure 2). Of note is that throughout the rocky finger reefs, there were no observations of any species of frondose macro-algae. This observation is of interest as extensive growth of several species of macro-algae in several shoreline areas of Maui have been the subject of considerable concern, particularly with respect to interactions between algal abundance and human activities.

At the seaward end of the rock outcrop finger, coral abundance is reduced considerably, with the reef consisting primarily of a rock-rubble surface that ends at the juncture of the sand flats (Figure 3). While no macro-algae were observed in this zone, most of the rock/rubble bottom was covered with a thin veneer of micro-algal turf. Numerous boulders at the base of the finger outcrop were colonized by numerous small colonies of *Pocillopora meandrina* (Figure 4). This coral has been recognized as a "pioneering" species, in that it is often the first to colonize newly cleared substrata. In addition, it also has "determinate" growth, in that colonies grow to a certain size, or age, and then die. As a result, colonies of this species never reach a size larger than approximately one foot in diameter. Such a growth form does not occur for the other major genera found on Hawaiian reefs (Porites) which has an "indeterminate" growth form where colony life span is are not limited by either size or age. The significance of the abundant small colonies of *P. meandrina* at the deeper regions of Site 1 may be that it is indication that a new year class is taking hold, or that recolonization is beginning in an area where corals were removed by some factor. In either case, the occurrence of abundant recruiting colonies indicates that the present conditions are suitable for coral growth.

The physical structure of the reef at Site 2 is slightly different than at Site 1 in that the top of the outcrop is flatter and wider. Coral cover, consisting of the same common species listed above, was someone greater on the flat reef of Site 2, with nearly complete coverage of the rocky substratum (Figures 5 and 6). As at Site 1, there were no observations of frondose macro-algae. The deeper seaward extension of the rocky headland at Site 2 was also different than at Site 1. While a relatively barren rock/rubble shelf occurred at the terminus of the reef at Site 1, corals, particularly mats of the branching finger coral *Porites compressa* extended to the sand floor at Site 2 (Figure 7). Numerous large coral-covered boulders also extended onto the sand flats at the seaward end of the reef at Site 2.

Reef structure and composition at the control site off of `Ahihi-Kina`u differed than off of the Wailea area. As mentioned above, the shoreline at `Ahihi-Kina`u is not composed of the distinct cusp beaches separated by rocky headlands which extend a substantial distance offshore. Rather the bottom in this area consists primarily of a solid limestone pavement with interspersed pockets of sand. Scattered throughout the pavement are areas where corals are concentrated into patches between areas of essentially barren bottom. The predominant growth form of coral in this region is large helmet-shaped head of *Porites lobata*, some of which extend up to several feet off the pavement (Figure 8). The highly valued edible algae *Asparagopsis taxiformis* (limu kohu) was abundant throughout the survey area, although no other algae were observed prevalent (Figure 8)

Other than corals, the dominant group of macroinvertebrates inhabiting the reef surface off the Honua'ula study sites are sea urchins. The most common urchins are the small species that bore into the rock surface (*Echinometra matheai*, *Echinostrephus aciculatus*) which occurred in all reef zones. The larger species, including the collector urchin *Tripneustes gratilla* and *Heterocentrotus mammillatus* were also abundant on the tops and sides of the rocky finger reefs. On the other hand, sea cucumbers (Holothurians) or starfish (Asteroidea) were not commonly observed during the survey. No crown-of-thorns starfish (*Acanthaster planci*) were observed feeding on coral colonies, nor were there observations of recently bleached coral skeletons as a result of Acanthaster predation. The green conical-shaped sponge *Iotrocha protea* was observed on the sandy flats at the seaward ends of the reefs. The only commonly occurring mollusk was the oyster *Pinctata* spp.

While frondose benthic algae were conspicuously absent on the survey reefs, encrusting red calcareous algae (*Porolithon* spp., *Peysonellia rubra, Hydrolithon* spp.) were abundant of rocky surfaces throughout the study area. These algae were abundant on bared limestone surfaces, and on the nonliving parts of coral colonies.

The design of the reef survey was such that no cryptic organisms or species living within interstitial spaces of the reef surface were enumerated. Since this is the habitat of the majority of mollusks and crustacea, detailed species counts were not included in the transecting scheme.

Reef fish community structure was largely determined by the topography and composition of reef structure. Fish were most abundant on the edges of the rocky outcrops and in areas of highest relief. Fish were abundant, but were small in size. Overall, fish community structure at Honua`ula is fairly typical of the assemblages found in undisturbed Hawaiian reef environments. The lack of abundance of food fish indicates that the area has been subjected to moderate amounts of fishing pressure.

Several species of marine animals that occur in Hawaiian waters have been declared threatened or endangered by Federal jurisdiction. The threatened green sea turtle (*Chelonia mydas*) occurs commonly along the South Maui Coast, and turtles are frequently observed on beaches throughout the area. The endangered hawksbill turtle (*Eretmochelys imbricata*) is also known to occur in the study area, with hatching grounds nearly at Maalaea.

Populations of the endangered humpback whale (*Megaptera novaeangliae*) winter in the Hawaiian Islands from December to April, and were commonly observed off the survey sites. . The Hawaiian Monk Seal, (*Monachus schauinslandi)*, is an endangered earless seal that is endemic to the waters off of the Hawaiian Islands. Monk seals commonly haul out of the water onto sandy beaches to rest. Hence, while there is no greater potential for haul out to the beaches fronting the Honua`ula site than any other area, there is a probability that seals will haul out on these beaches. No individuals were observed on the beach or in the water during the course of the present survey. As there are no plans for any modification of the shoreline, and with established of the shoreline preservation area, there are no physical factors that will result in modification of seal behavior. The major factor that could affect seal behavior is interaction with humans. Typically when seals haul out, authorized Federal or State agencies may establish a safety zone by placement of temporary fencing and signs indicating proper treatment of the animals. At present, the shoreline below Honua`ula is heavily used for recreational purposes, which is not likely to change. Any additional activity by people using the beach area as a result of the project will not qualitatively change usage of the shoreline by humans. Hence, the best management protocol to ensure the absence of negative effects to seals is establishment of a protocol to notify the appropriate authorities as soon as possible to establish buffer zones with appropriate signage.

CONCLUSIONS

Biotic composition of the nearshore marine environment downslope from the proposed Honua'ula project is characterized by rich coral reef assemblages that occupy hard bottom primarily on submerged extensions of rocky headlands that occur between sandy shorelines. Results of the present assessment do no reveal any substantial effects to marine community structure from human activities along the shoreline (with the possible exception of overfishing). Aggregations of nuisance algae do not occur in the subject area.

Implementation of the proposed Honua`ula project will not involve alteration of the shoreline, or offshore environments in any manner. In fact, the project is separated from the shoreline by the existing Wailea Resort. Considerations of the changes to water chemistry as a result of alteration of groundwater flow and composition will not change the existing character of the marine environment to an extent that will alter biotic community structure (see Reports by Tom Nance Water Resources Engineering, and Marine Research Consultants). In summary, the proposed project does not appear to present the potential for alteration of the offshore environments. None of the proposed development activities has the potential to induce large changes in physico-chemical properties that could affect biotic community structure.

FIGURE 1. Aerial photograph of Wailea Maui coastline showing locations of beaches downslope from Wailea Golf Couses and Honua`ula project site (outlined in yellow). Locations of representative marine biota sampling sites are shown as red ovals. Site 3, which is considered a control station, is located within the `Ahihi-Kina`u Natural Area Reserve, approximately 4 km south of the Honua`ula project site.

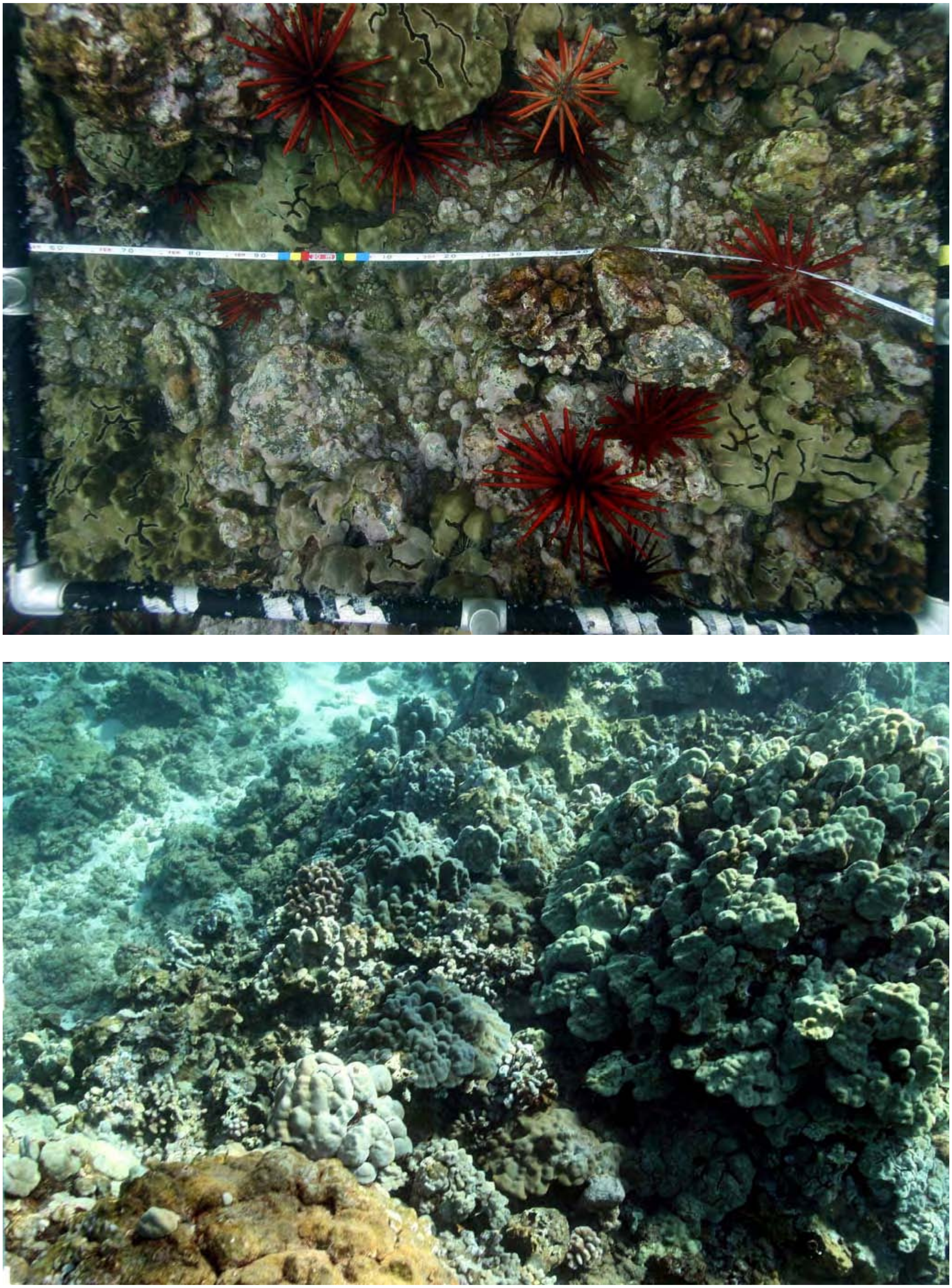

FIGURE 2. Typical views of reef on rocky outcrop at Survey site 1 between Palauea and Polo Beaches. Upper photo shows photo-quadrat used for quantifying reef community structure. Red slate-pencil sea urchins (*Heterocentrotus mammilatus*) were common throughout the survey area.

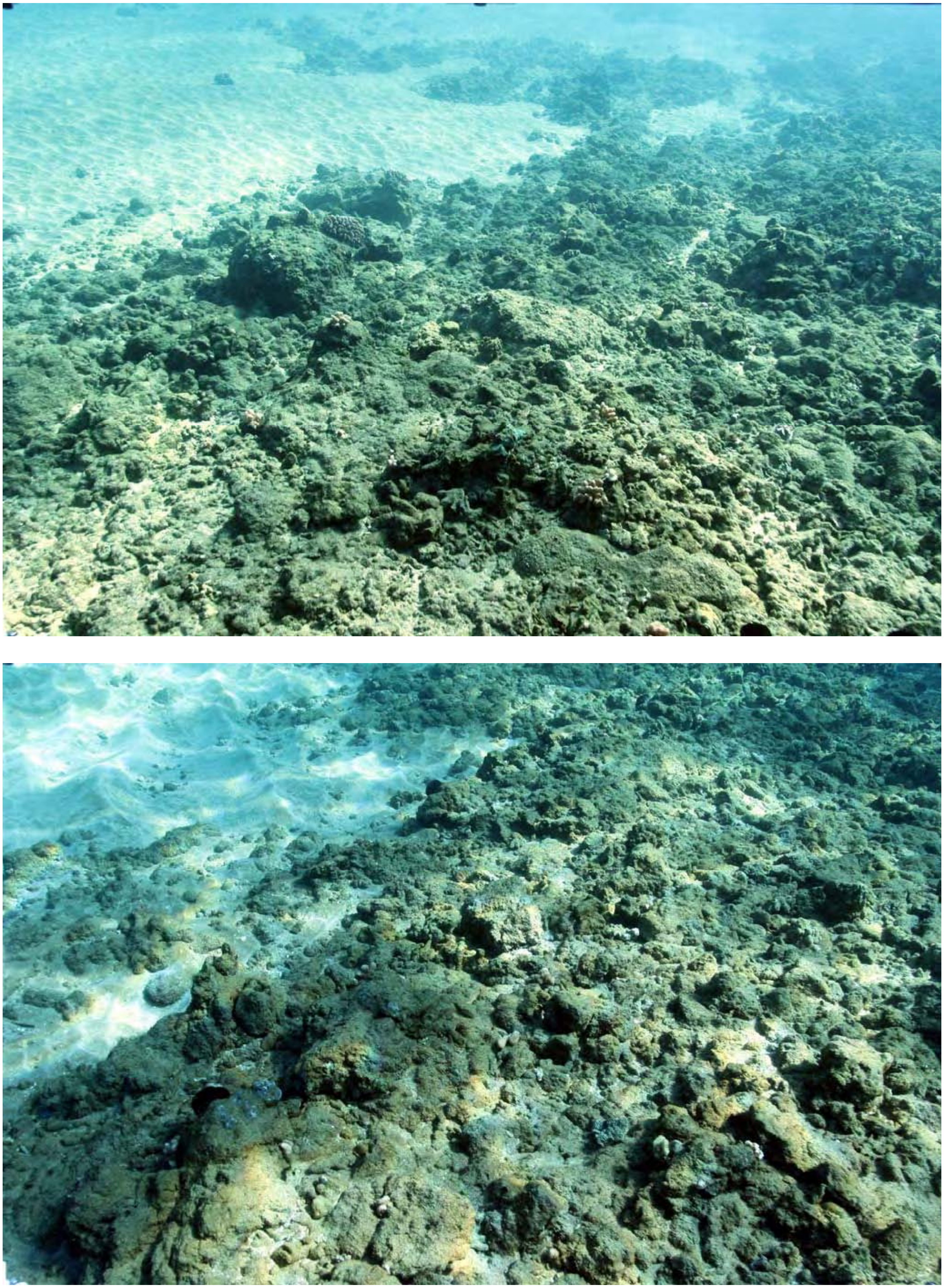

FIGURE 3. Seaward edge of reef at juncture of sand flats and seaward extension of rock headlands off Survey site 1 between Polo and Palauea Beaches. Water depth is approximately 25 feet.

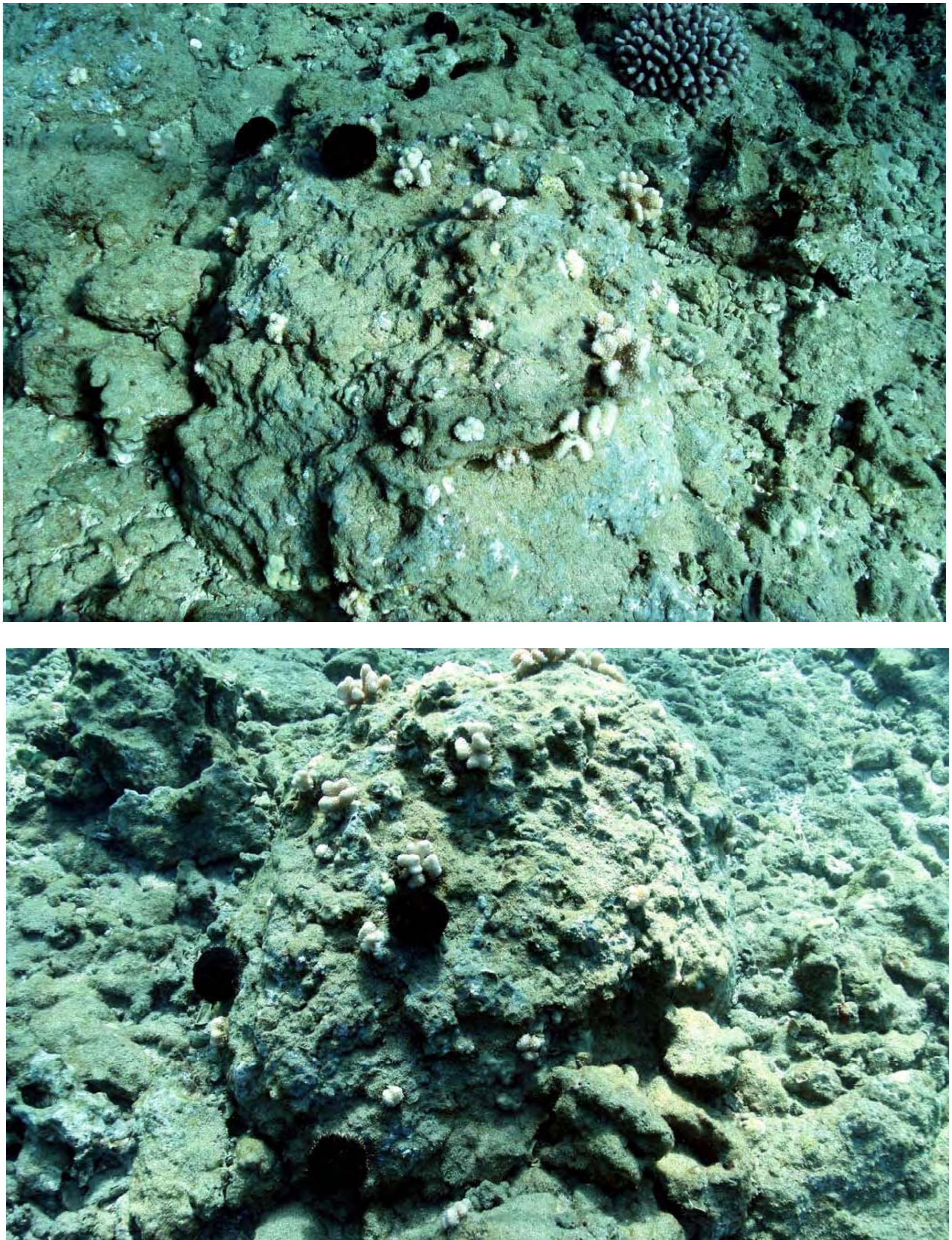

FIGURE 4. Boulders at base of reef at Survey site 1 settled by numerous small branching colonies of *Pocillopora meandrina*. Water depth is approximately 25 feet.

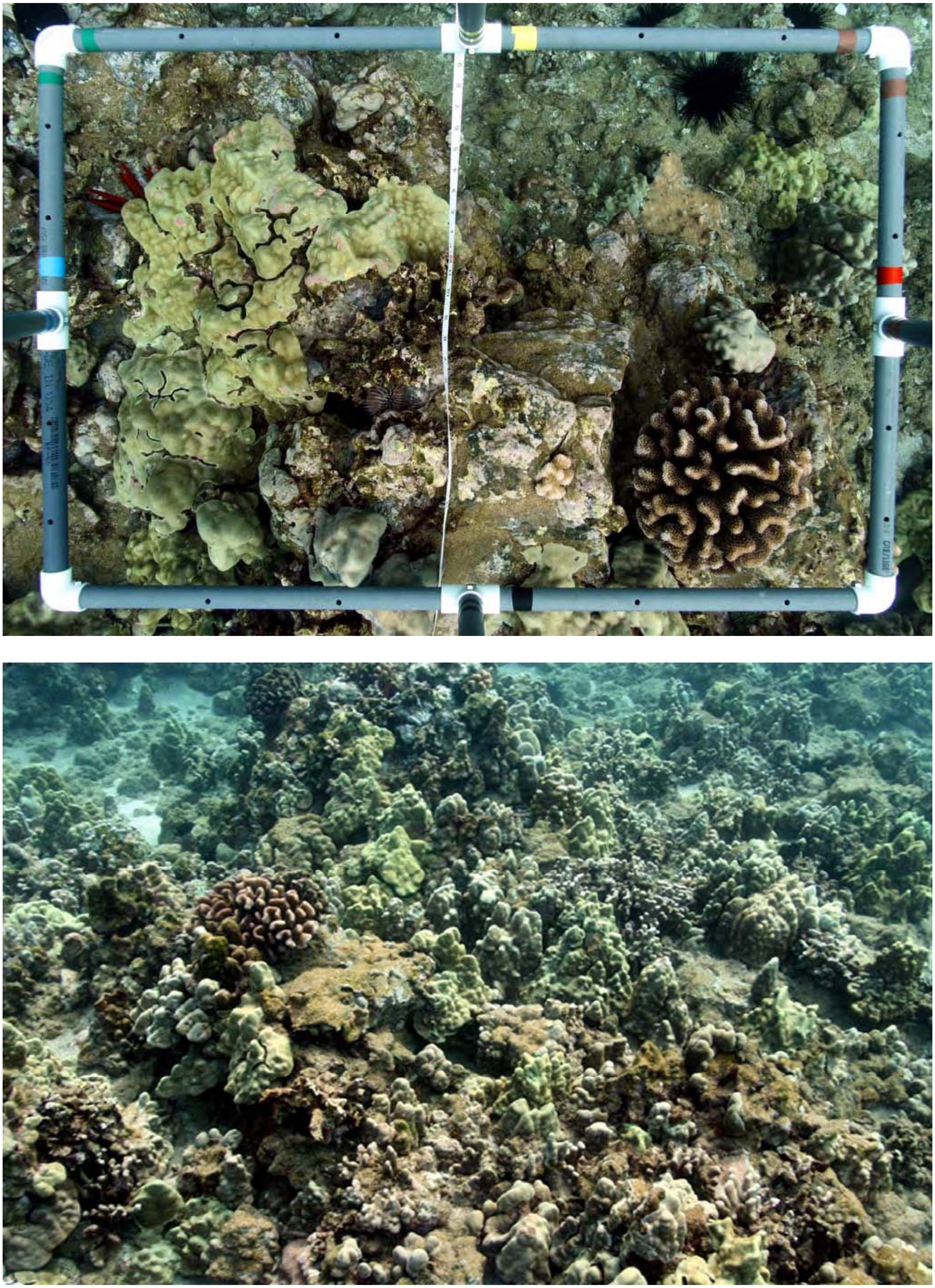

FIGURE 5. Typical vies of reef surface on top of rocky outcrop at Site 2 between Ulua and Wailea beaches. Upper photo shows typical photo-quadrat used for determining quantitative estimates of coral abundance. Water depth is approximately 12 feet.

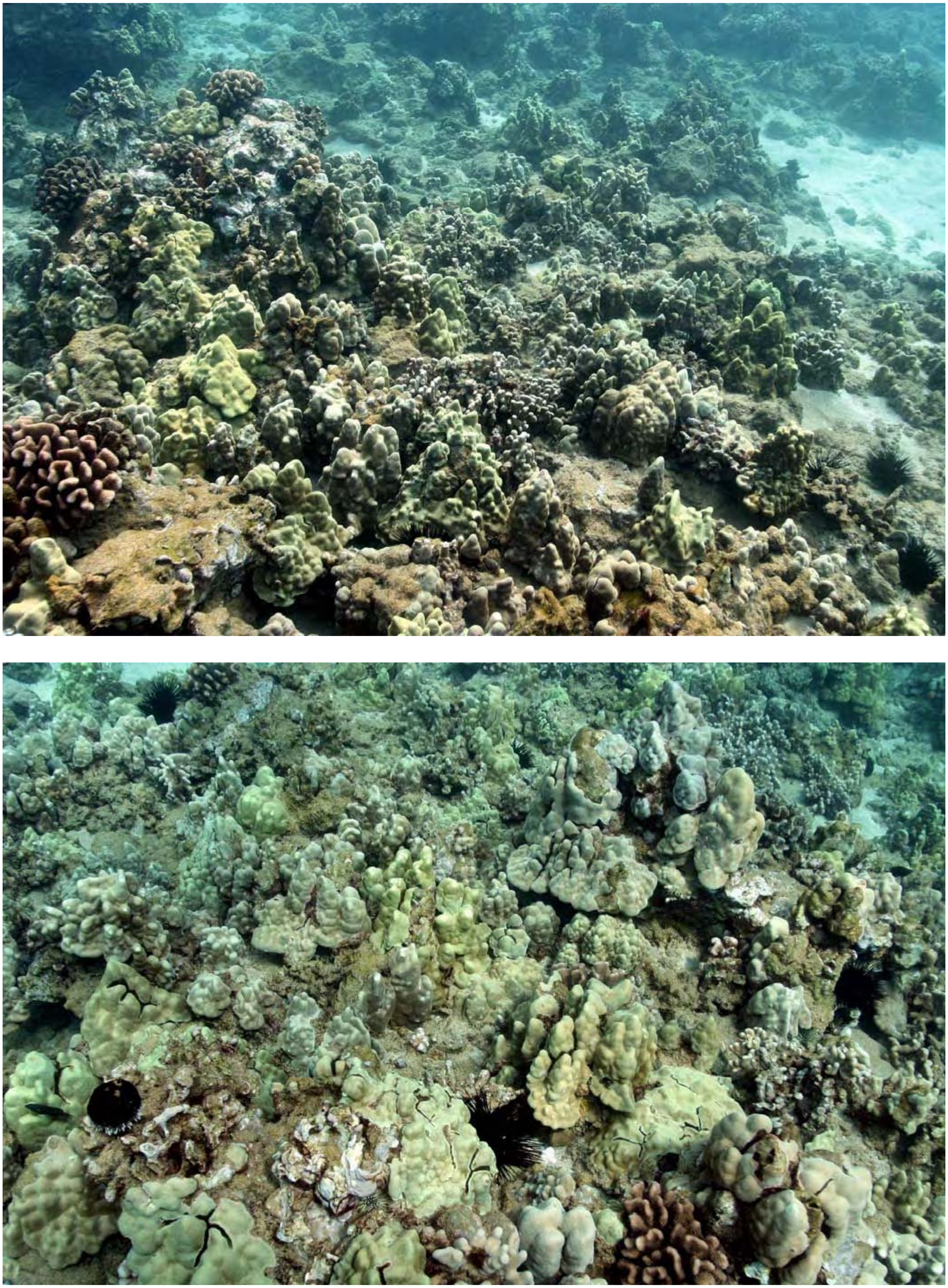

FIGURE 6. Surface of reef on extension of rocky headland at Survey site 2 between Wailea and Ulua Beaches. Dominant coral in both photos is *Porites lobata*. Water depth is approximately 12 feet.

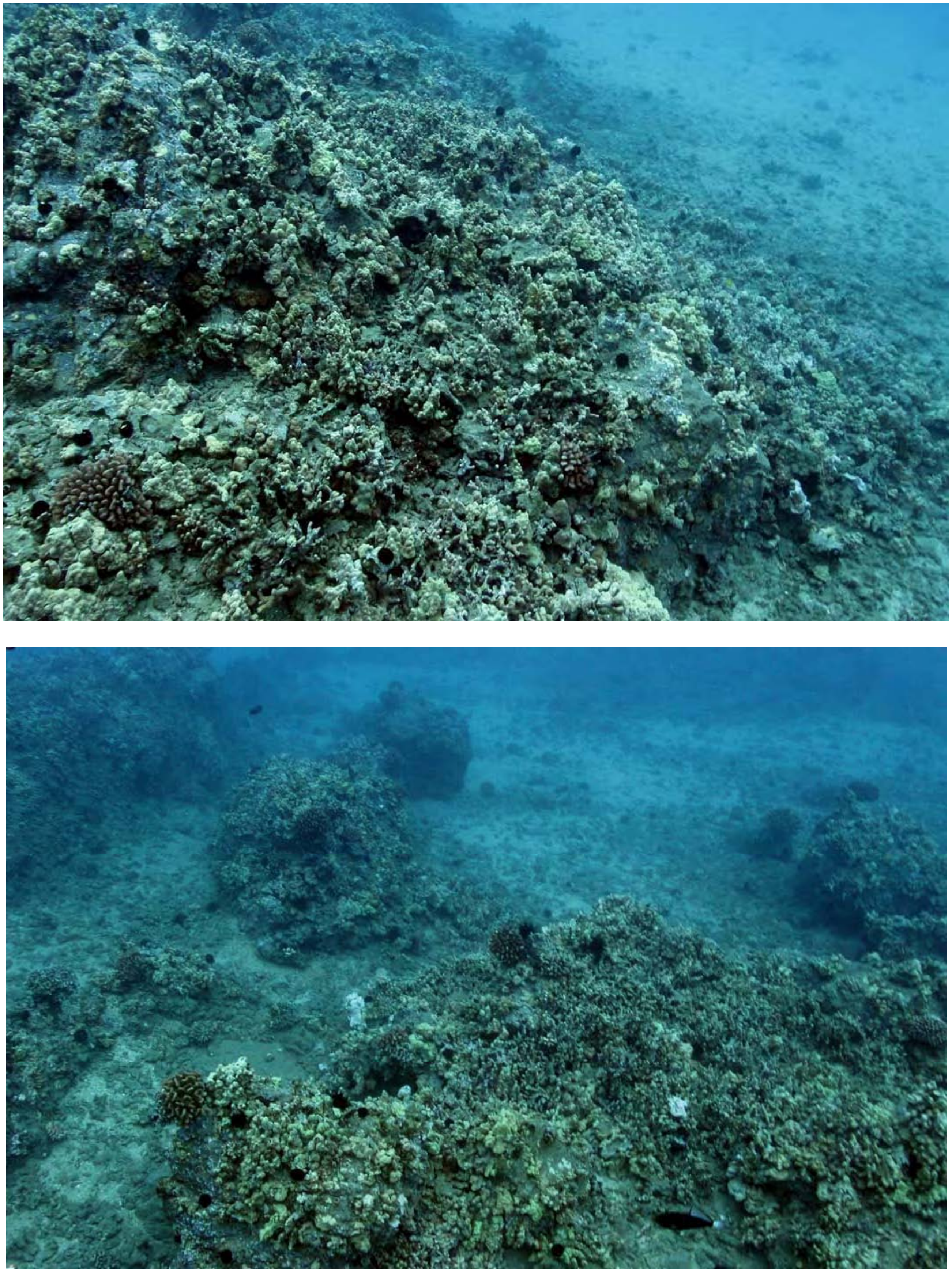

FIGURE 7. Outer, boundaries of reef at Survey site 2 between Ulua and Wailea Beaches. Boundaries between hard bottom colonized by high densities of coral and sandy bottom are clearly seen in both top and bottom photos.

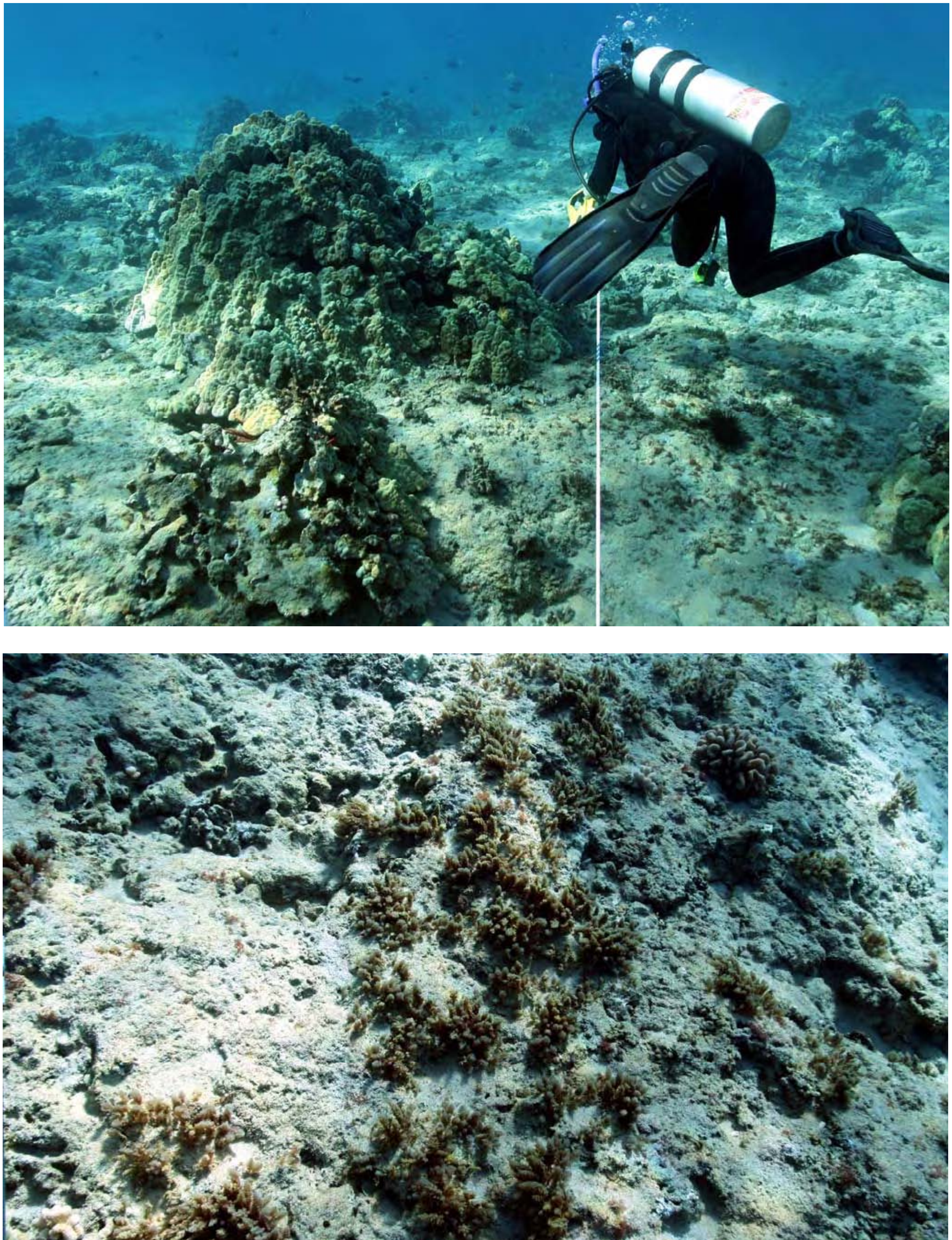

FIGURE 8. Typical "patch reef" off `Ahihi-Kina`u Natural Area Reserve characterized by large dome-shaped colonies of *Porites lobata* (top). Dense patches of the edible seaweed *Asparagopsis taxiformis* (bottom) occurred throughout this area, but was not observed on the reefs offshore of Honua`ula/Wailea.