HONUA'ULA

October 1, 2020

Ms. Tamara Paltin, Chair
Planning and Sustainable Land Use Committee
Maui County Council
200 South High Street
Wailuku, HI 96793

Subject: Committee Request for Water Quality Reports, PSLU – 65

Dear Chair Paltin:

Please find attached to this letter copies of the water quality reports for the years 2008, 2009, 2010, 2011, and 2012 done in response to Condition 20 for the Honua`ula project for the establishment of baseline water quality data.

Please review the attached information and contact me should you have any questions regarding the attached documents. I can be reached via my email at charles@secondandpeck.com or cell phone at 808-250-3178.

Sincerely,

Charles Jencks
Owner Representative
Honua`ula Partners, LLC

Attachments

1300 N. Holopono Street, Suite 201 • P.O. Box 220 • Kihei, Hawaii 96753 • p: 808-879-5205 • f: 808-879-2557

MARINE ENVIRONMENTAL MONITORING PROGRAM: HONUA'ULA (WAILEA 670) WAILEA, MAUI

WATER CHEMISTRY

REPORT 1-2008

Prepared for

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by

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Submitted
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I. PURPOSE

The Honua'ula project (formerly known as Wailea 670) 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. The project area is also zoned Project District 9 in the Maui County code. Current zoning provides for the development of two golf courses comprising approximately 402 acres with accessory uses. The balance of the property is zoned agriculture/open space. 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 one mile of coastline.

The current development plan for the project includes residential units, commercial uses, one 18-hole golf course covering approximately 200 acres, affordable housing, as well as acreage for parks, and open space that will be utilized for landscape buffers and drainageways. 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 the Honua'ula project will cause any detrimental changes to the marine environment. Current project planning includes retention of surface drainage on the golf course, and a private waste 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 of 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, 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.

With the intention of evaluating these effects, one of the Conditions of Zoning for Honua'ula (No. 20) stipulated..."*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.*

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."*

This report represents the first monitoring effort to take place since the establishment of conditions of Zoning (Condition 20). However, prior to approval of the conditions three increments of monitoring to establish baseline conditions for Honua'ula have been conducted in 2005, 2006 and 2007. Hence, the following report conducted in June 2008 presents the results of the fourth phase of the monitoring program for the Honua'ula project.

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 two miles 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, or 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 Honua'ula. Further to the south, land development is less, but geologic structure consists of the 1790 lava flow, which is dissimilar with respect to hydrologic characteristics as the other survey sites off of Wailea.

All field work was conducted on June 29, 2008 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 seven 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.

Sample 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 golf course irrigation wells on July 10, 2008 shortly after the marine monitoring survey. Samples were collected from well #'s 2, 3, 4, 5, 7, 8, and 9) located on the Blue, Gold and Emerald courses and one reservoir located on the project site.

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 μM (0.14 μg/L) for NO_3^- and NH_4^+, 0.01 μM (0.31 μg/L) for PO_4^{3-}, 0.1 μM (1.4 μg/L) for TN and 0.1 μM (3.1 μg/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 μg/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 were acquired using an RBR Model XR-420 CTD calibrated to factory specifications. The CTD was a readability of 0.001°C, 0.001pH units, 0.001% oxygen saturation, and 0.001 parts per thousand (‰) salinity.

Analyses of nutrients, turbidity, 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 June 29, 2008 reported in micromolar units (μM). Table 2 shows similar results presented in units of micrograms per liter (μg/L). Tables 3 and 4 show geometric means of ocean samples collected at the same sampling stations from 1989 (Sites1-3; n=19), and 1995 (Sites 4-5; n=13). Table 5 shows water chemistry measurements (in units of μM and μg/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 the entire sampling program at Wailea Resort, as well as data from the most recent sampling, are plotted as functions of distance from the shoreline in Figures 4-18.

At all five transect sites there is a nearshore region extending from the highest wash of waves at the shoreline to a distance of up to at least 100 m offshore where the surface concentrations of dissolved Si, NO_3^-, and TN are elevated compared to bottom water (Figure 2, Tables 1 and 2). Horizontal profiles of PO_4^{3-} and TP are not evident in the same manner as Si NO_3^- and TN, and were only slightly evident near the shoreline at Site 5 ('Ahihi-kina'u).

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. 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 5, where surface concentrations of NO_3^-near the shoreline were an order 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 4.7‰ and 2.8‰ between the shoreline and offshore terminus of transects at Sites 1 and 5, respectively (Tables 1 and 2). Transects at Sites 2, 3 and 4 had elevated nutrient concentrations and depressed salinities near the shoreline, but were less pronounced compared to Transects 1 and 5. At all sites there was distinct horizontal stratification over the entire length of the transects.

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, and physical mixing condition (primarily by wind and wave stirring) at the sampling location.

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). The surface concentration of NH_4^+ was distinctly higher within 50 m of the shoreline at Site 5 compared to all other sites which displayed no distinct horizontal stratification (Figure 2, Tables 1 and 2). Concentrations of TP, TOP and TON were relatively constant at all sampling locations on all transect sites except Site 5 which displayed peak concentrations within 25 m of the shoreline (Figure 2)..

Surface concentrations of turbidity were slightly higher near the shoreline compared to offshore measurements at all transect sites (Figure 3 and Tables 1 and 2). Sites 3, 4 and 5 had the highest turbidity measurements (0.18- 0.22 NTU).Beyond the shoreline, turbidity was relatively constant across the transects, and was of the same magnitude among the five transect sites. Concentrations of Chl *a* displayed a similar trend to turbidity, with values measured within 10 m of the shoreline higher than measurements farther offshore (Figure 3, Tables 1 and 2). Chl *a* in the shoreline sample at Site 4 was nearly twice that of the other sites during June 2008. Surface temperature ranged between 25.1°C and 27.5°C and was cooler near the shoreline compared to the offshore samples at all sites except Site 3, where temperature did not vary across the length of the transect (Figure 3, Tables 1 and 2). Surface temperature at Site 5 was approximately 0.5°C cooler compared to the other four sites.

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 can persist for some distance from shore. Buoyant surface layers are generally found in areas with both distinct input of groundwater, and where turbulent processes (primarily wave action) are insufficient to completely mix the water column in the nearshore zone. During the June 2008 survey, vertical stratification was apparent in the concentrations of nutrients that occur in relatively high concentrations in groundwater (Si, NO_3^-, PO_4^{3-}, TN), as well as for salinity. Such stratification was evident at all sites with elevated concentrations of nutrients, and lower salinities, in surface samples relative to the corresponding bottom sample. Vertical stratification was also evident in temperature where deep water was consistently cooler than surface water at all transect sites (Figure 3).These temperature gradients suggest that the groundwater was not completely mixed within the water column in the nearshore zone.

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 June 2008 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.

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 monitoring program off the Wailea Golf Courses. Also plotted are the data for the most recent survey in June 2008. Figures 4-12 show data since the inception of sampling (December 1989) at Sites 1, 2 and 3 (N=19). Figures 13-15 show comparisons at Sites 4 since August 1995 (N = 13) and Figures 16 - 18 show the data at the Control site since December 1994) (N= 14).

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, but have been consistently highest at Site 1 and Control Site 5 (Figures 4-18)., In the most recent survey (June 2008) the concentrations of Si and NO_3^- were below the mean values, in sharp contrast to the December 2007 survey where many instances of Si, NO_3^- and PO_4^{3-} were higher than the mean values. The December 2007 survey 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). Salinity was generally higher in the nearshore zone in June 2008 compared to the mean values. At all five sites, measurements of TON, TP and TOP in June 2008 were higher than the long-term mean values (Figures 5, 8, 11, 14 and 17) while values of turbidity and Chl *a* were generally lower than the means, particularly in the nearshore samples.

These comparisons suggest that water chemistry of the nearshore zone influenced by groundwater efflux was not distinctly different during the June 2008 survey compared to the average values of the numerous 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 the Wailea Golf Courses. 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-}, NH_4^+) as functions of salinity for the samples collected at each site in June 2008. 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 Irrigation Well No. 3 located to the northwest of the project area, and bottom ocean water.

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 most of the data points from sites 2-5 fall in linear arrays very close to the conservative mixing line for Si, indicating that groundwater entering the ocean at these sites is a pure mix of groundwater similar to that of Well No. 3 and open coastal water. Data points collected from near the shoreline at Site 1 fall below 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 Site 1 has contributions from another groundwater source (possibly rainwater) that is contributing to input to the ocean. It can be seen in Figure 20 that the same deviation in concentrations of silica as functions of salinity has also occurred in previous surveys at Site 1. In fact in previous surveys, the deviation has been larger than occurred in June 2008.

The plots of NO_3^- versus salinity reveal a different pattern than Si (Figure 19). When plotted versus salinity, the two data points with the lowest salinity fall near the mixing line. Hence, there is no deviation of the linear array that was evident for Si. At Site 5, however, concentrations of NO_3^- versus salinity prescribe a different line than at all other transects. Data points for samples collected in June 2008 from Sites 1 - 4 prescribe linear arrays that fall on, or slightly below the mixing line while data points from Site 5 fall distinctly below the mixing line (Figure 19).

Linear regression of NO_3^- concentrations as a function of salinity for all transects over the sixteen surveys conducted between 1989 and 2006 had Y-intercepts ranging between 83 - 440 μM, with the lowest values from the first two surveys (1989 and 1991). Hence, the Y-intercept from the five transects in the 2008 survey (209 μM) is about midway within the range of intercepts over the sixteen-year duration of monitoring. Compared to NO_3^- concentrations measured in an upslope irrigation well above the golf courses during each surveys, there is a subsidy of NO_3^- to groundwater of about 44 - 200 μM at Site 1 (142 μM in 2007, 44 μM in 2008). The peak subsidies occurred during 1994 and again in April 1997. The subsidies have decreased since 1994 and were lowest in 2008. This pattern suggests that if the nutrient subsidies are from fertilizer used on the golf course that may leach to groundwater, such inputs have decreased in the years following the initial grow-in period, but remain higher than before the golf course was constructed. Alternatively, it is also possible that there is another source of nutrients in the vicinity of Site 1 that may be responsible for the noted subsidies. Residences in the area are not connected to the municipal sewage system, and rely on septic systems or cesspools. Leakage from such private sewage treatment systems, rather than leaching of golf course fertilizers, may be the cause of the consistent nutrient subsidy at Site 1.

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). Linear regressions of NO_3^- as a function of salinity have had R^2 values of at least 0.95 for all five transects during all surveys, indicating highly significant linearity. Lack of uptake indicates that the nutrients are not being detectably 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 the water with increased concentrations of NO_3^- are limited to the buoyant surface plume that does not mix through the entire water column. As a result, there is good evidence to indicate that the increased nutrients fluxes from land are not causing any 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 mid-range (31-33‰) salinity also displayed the highest concentrations of NH_4^+, particularly at Transect Site 5. 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 little correlation between PO_4^{3-} and salinity at sites 1 – 4 and weak correlation at Site 5. 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.

It is also possible to utilize the mixing models to detect changes in nutrient input to the nearshore ocean between surveys. Table 6 shows regression statistics for concentrations of NO_3^- as functions of salinity on each transect during each of the surveys in 2005, 2006, 2007 and 2008. In all cases, there are highly significant P-values and coefficients of regression (R^2) indicating that concentrations of NO_3^- are dependent on salinity. In 2008, the Y-intercepts at Sites 1, 2, 4 and 5 are the lowest of all survey years. When linear regressions of the Y-intercepts as functions of time are calculated ("Change" in Table 6) there is no significant change at any of the transect sites from 2005 to 2008. Hence, there is no indication of a recent increase in groundwater NO_3^- to the ocean at any of the study areas. Similar analyses of concentrations of PO_4^{3-} indicate that there are no consistent trends of either increasing or decreasing subsidies at any of the sampling sites over the last four years.

E. 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 twenty-four of the sixty samples collected were above the 10% criteria for NO_3^- under "dry" conditions in the June 2008 survey, while thirty-two of the sixty samples were above the 10% criteria under "wet" conditions (Table 1). Most of the previous surveys have also had a high percentage of the samples exceeding the 10% limit for NO_3^-. These results contrast to the results of the September 1991 survey, when all sample values were below DOH standards for NO_3^-. During the September 1991 survey, efflux of groundwater at the shoreline (based on decreased salinity) was greatly reduced compared to other surveys.

In addition to NO_3^-, thirty-four measurements of NH_4^+, fifteen measurements of TN, and six measurements of Chl *a* exceeded the 10% DOH criteria under "dry" conditions in June 2008. If "wet" criteria are applied, twenty-one measurements of NH_4^+, six measurements of TN, and one measurement of Chl *a* exceeded the DOH water quality standards. No measurements of TP or turbidity exceeded the DOH standards during the June 2008 survey.

Tables 4 and 5 show geometric means of samples collected at the same locations during the nineteen increments of the monitoring program at Sites 1, 2 and 3 and during thirteen increments of monitoring at Sites 4 and 5. 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^- within 50 m of the shoreline, and nearly all measurements of NH_4^+, TN and Chl *a* at all five sites, 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 are not completely a result of existing land use development.

IV. SUMMARY

1. The fourth phase of the water quality monitoring program for the planned Honua'ula project was carried out in June 2008. This study also comprised the nineteenth phase of water chemistry monitoring of the nearshore ocean off the Wailea Golf Courses (originated in 1989). Sixty ocean water samples were collected on four transects spaced along the projects ocean frontage and one transect located outside of the project area. 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-Kinau Natural Area Reserve approximately four km to the south of the Wailea golf courses. 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 from seven irrigation wells and a golf-course reservoir in the Wailea area upslope of the sampling area.

2. Water chemistry constituents that occur in high concentration in groundwater (Si, NO_3^- and TN, and to a much lesser degree PO_4^{3-}) displayed 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. The steep nearshore gradients were apparent at all five sites during June 2008, but had the greatest magnitude (i.e., highest concentrations at the shoreline) at Sites 1 and 5. 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.

3. 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 not sufficient to completely break down the density differences between the buoyant low salinity surface layer and denser underlying water.

4. 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

5. Scaling nutrient concentrations to salinity indicates that during the June 2008 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 these locations have been evident. The likely cause of the subsidies of NO_3^- in past surveys was likely either leaching of golf course or landscaping fertilizers to groundwater that flows under the golf courses, or possibly leakage from old septic systems or cesspools that served residences in the vicinity of Site 1. Linear regression of the concentrations of NO_3^- scaled to salinity indicate that continuous increases in input from 2005 through 2007 at Sites 1, 2 and 5 reversed in 2008. These results indicate that factors affecting NO_3^- flux from land to the ocean have not increased, and may be decreasing at sampling locations off of the existing Wailea Development. In addition, the lack of upward curvature of the lines prescribed by the data points as functions of salinity indicate that there is no detectable of uptake of nutrient in the nearshore zone by biotic processes.

6. 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.

7. The next phase of the Honua'ula monitoring program is scheduled for December 2008.

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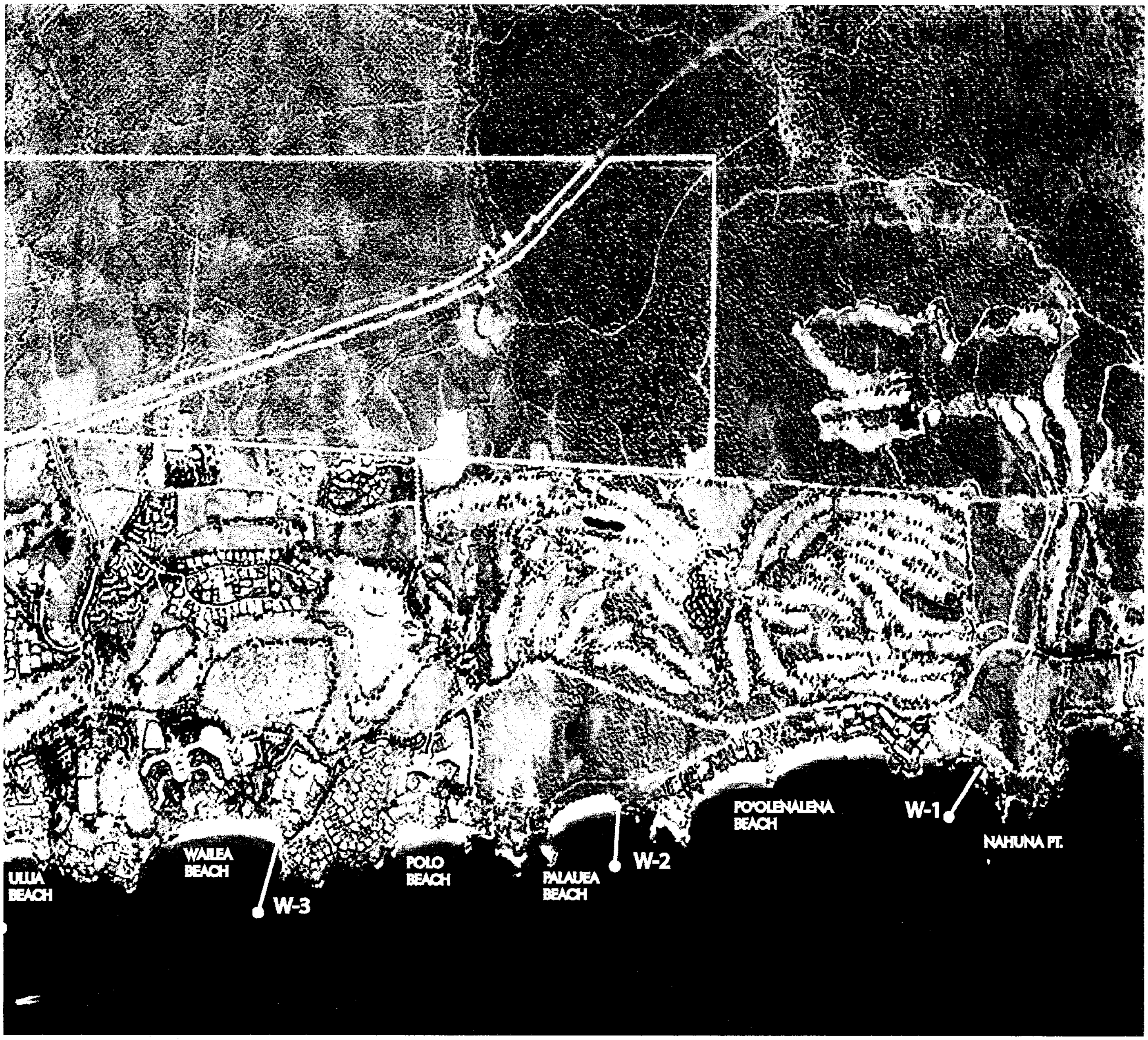

ı h of Wailea area showing boundaries of Honua'ula/Wailea 670 Project (in yellow) and locations of ng transects. Transect W-5 is considered a control and is located in the Ahihi-Kinau Natural Area Reserve ı of the Honua'ula/Wailea 670 Project site.

TABLE 1. Water chemistry measurements from ocean water samples collected in the vicinity off th e Honua'ula project site on June 29, 2008. 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	0.05	39.24	0.96	61.04	0.36	8.65	0.41	48.85	0.14	29.887	0.55	25.8	8.110	104.1
	2 S	0.1	0.05	31.34	0.23	57.61	0.35	9.02	0.40	40.59	0.13	30.874	0.58	25.8	8.136	108.7
	5 S	0.1	0.04	9.23	0.07	21.73	0.35	7.98	0.39	17.28	0.11	33.445	0.28	25.7	8.133	103.4
	5 D	1.0	0.04	5.66	0.92	16.62	0.31	6.90	0.35	13.48	0.06	33.816	0.18	25.8	8.117	100.4
	10 S	0.1	0.05	8.82	1.57	21.41	0.33	9.71	0.38	20.10	0.09	33.506	0.24	25.8	8.086	107.9
	10 D	1.7	0.06	2.56	1.07	7.78	0.38	8.63	0.44	12.26	0.11	34.410	0.24	25.8	8.082	109.3
	50 S	0.1	0.04	2.55	1.23	8.42	0.34	8.81	0.38	12.59	0.07	34.386	0.19	27.0	8.133	107.0
	50 D	4.4	0.05	0.11	1.20	1.66	0.38	9.70	0.43	11.01	0.12	34.849	0.25	26.1	8.100	98.4
	100 S	0.1	0.03	1.33	0.85	3.80	0.38	9.28	0.41	11.46	0.09	34.674	0.20	27.0	8.107	97.9
	100 D	6.2	0.04	0.03	1.19	1.46	0.38	9.83	0.42	11.05	0.08	34.848	0.13	25.9	8.102	95.2
	150 S	0.1	0.06	1.29	0.80	3.86	0.39	10.59	0.45	12.68	0.13	34.660	0.17	26.9	8.102	97.2
	150 D	11.7	0.07	0.05	0.97	1.44	0.41	10.38	0.48	11.40	0.08	34.827	0.16	25.9	8.107	95.3
WAILEA 2	0 S	0.1	0.11	2.82	0.45	8.17	0.39	11.07	0.50	14.34	0.12	34.632	0.42	26.3	8.145	99.6
	2 S	0.1	0.13	2.84	0.08	7.94	0.32	10.13	0.45	13.05	0.11	34.680	0.43	26.3	8.143	98.9
	5 S	0.1	0.13	2.55	0.25	6.57	0.35	10.27	0.48	13.07	0.08	34.724	0.27	26.3	8.132	100.5
	5 D	1.0	0.14	2.28	0.39	5.55	0.33	8.86	0.47	11.53	0.09	34.773	0.25	26.1	8.117	98.8
	10 S	0.1	0.10	2.49	0.35	5.47	0.32	8.89	0.42	11.73	0.09	34.773	0.25	26.3	8.105	100.4
	10 D	2.0	0.05	0.63	0.25	2.67	0.34	9.78	0.39	10.66	0.08	34.775	0.29	26.3	8.100	100.5
	50 S	0.1	0.12	2.32	0.50	7.09	0.29	9.38	0.41	12.20	0.08	34.673	0.16	27.0	8.084	96.2
	50 D	4.9	0.24	0.07	1.68	1.43	0.34	10.60	0.58	12.35	0.08	35.032	0.16	26.1	8.107	95.6
	100 S	0.2	0.22	1.67	0.42	5.83	0.30	9.41	0.52	11.50	0.08	34.725	0.15	26.7	8.097	96.9
	100 D	8.7	0.14	0.04	0.55	1.35	0.37	9.38	0.51	9.97	0.10	35.018	0.15	26.0	8.110	94.6
	150 S	0.1	0.10	1.02	0.16	5.70	0.32	10.68	0.42	11.86	0.10	34.747	0.14	27.0	8.092	97.8
	150 D	14.4	0.12	0.03	0.16	1.32	0.33	9.41	0.45	9.60	0.08	35.073	0.08	25.9	8.112	96.9
WAILEA 3	0 S	0.1	0.17	1.57	0.24	6.64	0.29	9.31	0.46	11.12	0.14	34.630	0.40	26.5	8.117	96.2
	2 S	0.1	0.11	0.86	0.28	5.04	0.33	10.43	0.44	11.57	0.18	34.801	0.26	26.5	8.117	96.2
	5 S	0.1	0.09	1.49	0.29	6.72	0.36	9.33	0.45	11.11	0.22	34.677	0.47	26.4	8.112	96.5
	5 D	1.0	0.15	1.70	0.39	6.71	0.36	13.27	0.51	15.36	0.17	34.654	0.30	26.5	8.114	96.3
	10 S	0.1	0.10	0.71	0.53	4.59	0.32	8.74	0.42	9.98	0.11	34.855	0.22	26.5	8.110	96.2
	10 D	1.0	0.10	0.46	0.42	4.97	0.35	8.52	0.45	9.40	0.10	34.855	0.22	26.4	8.110	96.4
	50 S	0.1	0.20	0.24	0.58	3.44	0.34	11.24	0.54	12.06	0.09	34.973	0.25	26.5	8.133	107.3
	50 D	4.0	0.15	0.19	1.15	2.98	0.35	10.36	0.50	11.70	0.14	34.990	0.31	26.4	8.135	107.0
	100 S	0.1	0.10	0.08	0.26	2.01	0.35	9.22	0.45	9.56	0.16	35.045	0.27	26.4	8.117	106.2
	100 D	6.1	0.10	BDL	0.29	1.93	0.33	8.49	0.43	8.78	0.16	35.022	0.17	26.2	8.118	95.9
	150 S	0.1	0.14	1.04	0.67	4.18	0.34	9.34	0.48	11.05	0.09	34.904	0.13	26.0	8.100	94.7
	150 D	11.2	0.14	0.02	0.49	1.53	0.34	8.62	0.48	9.13	0.15	35.056	0.15	26.0	8.110	94.8
WAILEA 4	0 S	0.1	0.09	2.05	0.25	5.28	0.30	9.13	0.39	11.43	0.22	34.773	1.04	26.6	8.135	99.2
	2 S	0.1	0.05	1.48	0.23	4.76	0.34	10.61	0.39	12.32	0.12	34.854	0.62	26.6	8.143	97.7
	5 S	0.1	0.09	0.44	0.29	3.52	0.35	8.44	0.44	9.17	0.10	34.925	0.70	26.7	8.153	106.9
	5 D	1.0	0.14	0.61	0.50	3.65	0.35	10.13	0.49	11.24	0.10	34.978	0.27	26.5	8.082	107.3
	10 S	0.1	0.11	0.13	0.15	3.09	0.35	13.96	0.46	14.24	0.13	35.045	0.19	26.4	8.136	107.0
	10 D	1.0	0.13	0.20	0.23	2.74	0.34	9.71	0.47	10.14	0.12	35.086	0.19	26.4	8.130	106.2
	50 S	0.1	0.05	1.12	0.41	3.35	0.32	11.35	0.37	12.88	0.15	35.006	0.51	27.5	8.140	102.3
	50 D	5.2	0.03	BDL	0.14	1.98	0.34	10.93	0.37	11.07	0.10	35.152	0.48	26.2	8.114	99.3
	100 S	0.1	0.12	2.09	0.17	4.30	0.33	9.57	0.45	11.83	0.14	34.881	0.35	26.7	8.123	100.0
	100 D	9.8	0.19	0.01	1.02	1.66	0.33	11.12	0.52	12.15	0.10	35.107	0.18	26.1	8.115	97.4
	150 S	0.1	0.07	2.17	0.20	5.06	0.32	8.70	0.39	11.07	0.08	34.833	0.15	27.0	8.100	97.4
	150 D	12.3	0.17	0.02	1.06	1.46	0.38	9.38	0.55	10.46	0.09	35.107	0.16	25.9	8.112	97.5
WAILEA 5	0 S	0.1	0.36	6.04	5.16	62.92	0.56	19.60	0.92	30.80	0.12	31.944	0.27	25.1	7.937	88.3
	2 S	0.1	0.24	3.48	5.28	44.32	0.60	22.12	0.84	30.88	0.13	32.833	0.22	25.6	7.961	90.6
	5 S	0.1	0.12	2.40	3.20	34.60	0.56	14.92	0.68	20.52	0.18	33.378	0.20	25.6	7.999	90.9
	5 D	1.0	0.01	1.86	1.02	19.93	0.38	7.68	0.39	10.56	0.08	33.917	0.17	25.6	8.045	90.4
	10 S	0.1	0.01	1.87	0.89	15.67	0.34	10.44	0.35	13.20	0.12	34.181	0.19	25.6	8.053	91.3
	10 D	2.0	0.14	2.07	1.00	17.42	0.37	7.36	0.51	10.43	0.10	34.109	0.19	25.7	8.053	90.6
	50 S	0.1	0.18	0.79	0.49	6.24	0.35	6.86	0.53	8.14	0.09	34.632	0.12	26.2	8.091	94.5
	50 D	4.4	0.03	0.05	0.31	1.93	0.35	6.83	0.38	7.19	0.13	34.811	0.12	25.9	8.086	92.8
	100 S	0.1	0.21	0.69	0.42	5.54	0.33	6.48	0.54	7.59	0.15	34.670	0.12	26.3	8.086	95.9
	100 D	6.4	0.04	0.01	0.29	2.07	0.35	7.64	0.39	7.94	0.10	34.817	0.09	25.9	8.096	95.1
	150 S	0.1	0.02	0.26	0.27	3.50	0.36	9.42	0.38	9.95	0.13	34.777	0.13	26.2	8.078	95.2
	150 D	7.7	BDL	BDL	0.21	1.70	0.37	8.92	0.37	9.13	0.18	34.841	0.22	25.9	8.109	96.0
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 $\mu g/L$) collected off the Honua 'ula project site on June 29, 2008. 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	1.55	549.60	13.45	1715.22	11.15	121.15	12.70	684.19	0.14	29.887	0.55	25.8	8.11	104.1
	2 S	0.1	1.55	438.95	3.22	1618.84	10.84	126.33	12.39	568.50	0.13	30.874	0.58	25.8	8.14	108.7
	5 S	0.1	1.24	129.28	0.98	610.61	10.84	111.77	12.08	242.02	0.11	33.445	0.28	25.7	8.13	103.4
	5 D	1.0	1.24	79.27	12.89	467.02	9.60	96.64	10.84	188.80	0.06	33.816	0.18	25.8	8.12	100.4
	10 S	0.1	1.55	123.53	21.99	601.62	10.22	136.00	11.77	281.52	0.09	33.506	0.24	25.8	8.09	107.9
	10 D	1.7	1.86	35.86	14.99	218.62	11.77	120.87	13.63	171.71	0.11	34.410	0.24	25.8	8.08	109.3
	50 S	0.1	1.24	35.72	17.23	236.60	10.53	123.39	11.77	176.34	0.07	34.386	0.19	27.0	8.13	107.0
	50 D	4.4	1.55	1.54	16.81	46.65	11.77	135.86	13.32	154.21	0.12	34.849	0.25	26.1	8.10	98.4
	100 S	0.1	0.93	18.63	11.91	106.78	11.77	129.98	12.70	160.51	0.09	34.674	0.20	27.0	8.11	97.9
	100 D	6.2	1.24	0.42	16.67	41.03	11.77	137.68	13.01	154.77	0.08	34.848	0.13	25.9	8.10	95.2
	150 S	0.1	1.86	18.07	11.20	108.47	12.08	148.32	13.94	177.60	0.13	34.660	0.17	26.9	8.10	97.2
	150 D	11.7	2.17	0.70	13.59	40.46	12.70	145.38	14.87	159.67	0.08	34.827	0.16	25.9	8.11	95.3
WAILEA 2	0 S	0.1	3.41	39.50	6.30	229.58	12.08	155.05	15.49	200.85	0.12	34.632	0.42	26.3	8.15	99.6
	2 S	0.1	4.03	39.78	1.12	223.11	9.91	141.88	13.94	182.78	0.11	34.680	0.43	26.3	8.14	98.9
	5 S	0.1	4.03	35.72	3.50	184.62	10.84	143.84	14.87	183.06	0.08	34.724	0.27	26.3	8.13	100.5
	5 D	1.0	4.34	31.93	5.46	155.96	10.22	124.09	14.56	161.49	0.09	34.773	0.25	26.1	8.12	98.8
	10 S	0.1	3.10	34.87	4.90	153.71	9.91	124.51	13.01	164.29	0.09	34.773	0.25	26.3	8.11	100.4
	10 D	2.0	1.55	8.82	3.50	75.03	10.53	136.98	12.08	149.30	0.08	34.775	0.29	26.3	8.10	100.5
	50 S	0.1	3.72	32.49	7.00	199.23	8.98	131.38	12.70	170.87	0.08	34.673	0.16	27.0	8.08	96.2
	50 D	4.9	7.43	0.98	23.53	40.18	10.53	148.46	17.96	172.97	0.08	35.032	0.16	26.1	8.11	95.6
	100 S	0.2	6.81	23.39	5.88	163.82	9.29	131.80	16.11	161.07	0.08	34.725	0.15	26.7	8.10	96.9
	100 D	8.7	4.34	0.56	7.70	37.94	11.46	131.38	15.80	139.64	0.10	35.018	0.15	26.0	8.11	94.6
	150 S	0.1	3.10	14.29	2.24	160.17	9.91	149.58	13.01	166.11	0.10	34.747	0.14	27.0	8.09	97.8
	150 D	14.4	3.72	0.42	2.24	37.09	10.22	131.80	13.94	134.46	0.08	35.073	0.08	25.9	8.11	96.9
WAILEA 3	0 S	0.1	5.27	21.99	3.36	186.58	8.98	130.40	14.25	155.75	0.14	34.630	0.40	26.5	8.12	96.2
	2 S	0.1	3.41	12.05	3.92	141.62	10.22	146.08	13.63	162.05	0.18	34.801	0.26	26.5	8.12	96.2
	5 S	0.1	2.79	20.87	4.06	188.83	11.15	130.68	13.94	155.61	0.22	34.677	0.47	26.4	8.11	96.5
	5 D	1.0	4.65	23.81	5.46	188.55	11.15	185.86	15.80	215.13	0.17	34.654	0.30	26.5	8.11	96.3
	10 S	0.1	3.10	9.94	7.42	128.98	9.91	122.41	13.01	139.78	0.11	34.855	0.22	26.5	8.11	96.2
	10 D	1.0	3.10	6.44	5.88	139.66	10.84	119.33	13.94	131.66	0.10	34.855	0.22	26.4	8.11	96.4
	50 S	0.1	6.19	3.36	8.12	96.66	10.53	157.43	16.73	168.91	0.09	34.973	0.25	26.5	8.13	107.3
	50 D	4.0	4.65	2.66	16.11	83.74	10.84	145.10	15.49	163.87	0.14	34.990	0.31	26.4	8.14	107.0
	100 S	0.1	3.10	1.12	3.64	56.48	10.84	129.14	13.94	133.90	0.16	35.045	0.27	26.4	8.12	106.2
	100 D	6.1	3.10	BDL	4.06	54.23	10.22	118.91	13.32	122.97	0.16	35.022	0.17	26.2	8.12	95.9
	150 S	0.1	4.34	14.57	9.38	117.46	10.53	130.82	14.87	154.77	0.09	34.904	0.13	26.0	8.10	94.7
	150 D	11.2	4.34	0.28	6.86	42.99	10.53	120.73	14.87	127.87	0.15	35.056	0.15	26.0	8.11	94.8
WAILEA 4	0 S	0.1	2.79	28.71	3.50	148.37	9.29	127.87	12.08	160.09	0.22	34.773	1.04	26.6	8.14	99.2
	2 S	0.1	1.55	20.73	3.22	133.76	10.53	148.60	12.08	172.55	0.12	34.854	0.62	26.6	8.14	97.7
	5 S	0.1	2.79	6.16	4.06	98.91	10.84	118.21	13.63	128.44	0.10	34.925	0.70	26.7	8.15	106.9
	5 D	1.0	4.34	8.54	7.00	102.57	10.84	141.88	15.18	157.43	0.10	34.978	0.27	26.5	8.08	107.3
	10 S	0.1	3.41	1.82	2.10	86.83	10.84	195.52	14.25	199.45	0.13	35.045	0.19	26.4	8.14	107.0
	10 D	1.0	4.03	2.80	3.22	76.99	10.53	136.00	14.56	142.02	0.12	35.086	0.19	26.4	8.13	106.2
	50 S	0.1	1.55	15.69	5.74	94.14	9.91	158.97	11.46	180.40	0.15	35.006	0.51	27.5	8.14	102.3
	50 D	5.2	0.93	BDL	1.96	55.64	10.53	153.09	11.46	155.05	0.10	35.152	0.48	26.2	8.11	99.3
	100 S	0.1	3.72	29.27	2.38	120.83	10.22	134.04	13.94	165.69	0.14	34.881	0.35	26.7	8.12	100.0
	100 D	9.8	5.88	0.14	14.29	46.65	10.22	155.75	16.11	170.17	0.10	35.107	0.18	26.1	8.12	97.4
	150 S	0.1	2.17	30.39	2.80	142.19	9.91	121.85	12.08	155.05	0.08	34.833	0.15	27.0	8.10	97.4
	150 D	12.3	5.27	0.28	14.85	41.03	11.77	131.38	17.04	146.50	0.09	35.107	0.16	25.9	8.11	97.5
WAILEA 5	0 S	0.1	11.15	84.60	72.27	1768.05	17.34	274.52	28.50	431.38	0.12	31.944	0.27	25.1	7.94	88.3
	2 S	0.1	7.43	48.74	73.95	1245.39	18.58	309.81	26.02	432.51	0.13	32.833	0.22	25.6	7.96	90.6
	5 S	0.1	3.72	33.61	44.82	972.26	17.34	208.97	21.06	287.40	0.18	33.378	0.20	25.6	8.00	90.9
	5 D	1.0	0.31	26.05	14.29	560.03	11.77	107.57	12.08	147.90	0.08	33.917	0.17	25.6	8.05	90.4
	10 S	0.1	0.31	26.19	12.47	440.33	10.53	146.22	10.84	184.88	0.12	34.181	0.19	25.6	8.05	91.3
	10 D	2.0	4.34	28.99	14.01	489.50	11.46	103.08	15.80	146.08	0.10	34.109	0.19	25.7	8.05	90.6
	50 S	0.1	5.58	11.06	6.86	175.34	10.84	96.08	16.42	114.01	0.09	34.632	0.12	26.2	8.09	94.5
	50 D	4.4	0.93	0.70	4.34	54.23	10.84	95.66	11.77	100.70	0.13	34.811	0.12	25.9	8.09	92.8
	100 S	0.1	6.50	9.66	5.88	155.67	10.22	90.76	16.73	106.31	0.15	34.670	0.12	26.3	8.09	95.9
	100 D	6.4	1.24	0.14	4.06	58.17	10.84	107.01	12.08	111.21	0.10	34.817	0.09	25.9	8.10	95.1
	150 S	0.1	0.62	3.64	3.78	98.35	11.15	131.94	11.77	139.36	0.13	34.777	0.13	26.2	8.08	95.2
	150 D	7.7	BDL	BDL	2.94	47.77	11.46	124.93	11.46	127.87	0.18	34.841	0.22	25.9	8.11	96.0
DOH WQS		DRY	10%	10.00	5.00				30.00	180.00	0.50	*	0.50	**	***	****
			2%	20.00	9.00				45.00	250.00	1.00		1.00			
		WET	10%	14.00	8.50				40.00	250.00	1.25	*	0.90	**	***	****
			2%	25.00	15.00				60.00	350.00	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 3. Geometric mean data from water chemistry measurements (in μM) collected at sites off the Honua'ula project site since the inception of monitoring for the Wailea Golf Courses in December 1989 at Sites 1, 2 and 3 (N=19) and since August 1995 at Sites 4 and 5 (N=13). 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)
WAILEA 1	0 S	1	0.20	31.63	0.22	56.38	0.21	6.69	0.49	47.42	0.26	28.656	0.68	25.11	8.15
	2 S	1	0.16	22.26	0.14	41.85	0.21	6.60	0.41	35.36	0.23	30.668	0.71	25.21	8.17
	5 S	1	0.12	9.52	0.14	21.26	0.23	6.90	0.38	21.50	0.21	32.911	0.46	25.35	8.18
	5 D	2.5	0.12	7.88	0.23	18.31	0.24	6.87	0.39	19.48	0.17	33.285	0.46	25.35	8.18
	10 S	1	0.10	4.44	0.21	11.88	0.23	6.84	0.35	14.02	0.16	33.947	0.36	25.42	8.17
	10 D	3	0.09	2.78	0.18	7.99	0.24	6.73	0.34	11.10	0.17	34.293	0.35	25.40	8.17
	50 S	1	0.08	2.55	0.20	7.32	0.24	6.67	0.34	10.59	0.15	34.338	0.26	25.54	8.17
	50 D	4.5	0.09	0.47	0.13	3.23	0.26	7.13	0.35	8.26	0.13	34.686	0.29	25.45	8.17
	100 S	1	0.09	2.04	0.14	6.52	0.25	6.97	0.36	10.62	0.13	34.392	0.25	25.54	8.16
	100 D	10	0.08	0.21	0.11	2.35	0.24	7.06	0.34	7.59	0.11	34.770	0.19	25.44	8.17
	150 S	1	0.09	0.70	0.19	3.60	0.25	7.27	0.35	8.97	0.13	34.613	0.20	25.59	8.17
	150 D	15	0.08	0.13	0.17	1.96	0.25	7.21	0.35	7.55	0.10	34.788	0.18	25.45	8.17
WAILEA 2	0 S	1	0.11	6.31	0.20	14.10	0.23	7.56	0.40	17.07	0.23	32.368	0.49	25.64	8.18
	2 S	1	0.13	5.21	0.19	12.51	0.25	6.96	0.41	14.79	0.20	33.515	0.38	25.67	8.18
	5 S	1	0.11	3.64	0.20	9.05	0.25	6.98	0.37	11.85	0.18	34.245	0.32	25.56	8.18
	5 D	2.5	0.11	2.76	0.24	7.81	0.25	6.75	0.38	10.58	0.20	34.441	0.37	25.57	8.18
	10 S	1	0.11	2.16	0.20	7.44	0.26	6.88	0.38	10.32	0.17	34.465	0.26	25.68	8.17
	10 D	3	0.10	1.12	0.17	4.63	0.26	6.80	0.37	8.71	0.16	34.608	0.30	25.69	8.17
	50 S	1	0.10	1.53	0.19	6.05	0.26	6.89	0.37	9.73	0.16	34.526	0.25	25.71	8.17
	50 D	4.5	0.10	0.37	0.21	2.76	0.24	6.89	0.36	7.82	0.14	34.735	0.27	25.62	8.17
	100 S	1	0.10	0.97	0.22	4.54	0.25	7.08	0.37	9.17	0.13	34.598	0.21	25.59	8.17
	100 D	10	0.09	0.18	0.13	2.41	0.24	6.67	0.35	7.19	0.13	34.770	0.24	25.59	8.17
	150 S	1	0.09	0.58	0.20	3.67	0.25	6.92	0.35	8.47	0.12	34.661	0.20	25.73	8.16
	150 D	15	0.09	0.12	0.18	1.98	0.25	6.84	0.36	7.28	0.11	34.798	0.20	25.48	8.17
WAILEA 3	0 S	1	0.21	6.16	0.27	20.41	0.27	7.26	0.52	17.89	0.33	31.879	0.47	25.79	8.12
	2 S	1	0.17	4.00	0.22	13.78	0.26	7.18	0.48	13.77	0.28	33.755	0.48	25.86	8.13
	5 S	1	0.14	2.50	0.25	10.01	0.26	6.71	0.44	10.91	0.20	34.214	0.48	25.82	8.15
	5 D	2.5	0.15	2.26	0.25	9.57	0.28	7.11	0.47	11.26	0.21	34.252	0.45	25.78	8.15
	10 S	1	0.14	1.73	0.19	8.44	0.28	6.92	0.47	10.60	0.18	34.286	0.34	25.79	8.15
	10 D	5	0.13	1.17	0.24	6.86	0.26	6.53	0.42	9.17	0.18	34.484	0.39	25.79	8.15
	50 S	1	0.10	0.74	0.26	4.54	0.26	6.97	0.38	8.39	0.13	34.601	0.33	25.76	8.14
	50 D	10	0.10	0.35	0.23	3.45	0.27	6.68	0.38	7.86	0.14	34.689	0.33	25.69	8.15
	100 S	1	0.10	0.57	0.22	4.17	0.26	6.89	0.39	8.82	0.14	34.646	0.33	25.80	8.14
	100 D	15	0.09	0.17	0.16	2.59	0.26	6.87	0.38	7.92	0.13	34.771	0.28	25.69	8.15
	150 S	1	0.10	0.25	0.19	2.64	0.25	6.74	0.37	7.92	0.13	34.759	0.22	25.82	8.15
	150 D	20	0.09	0.13	0.20	2.08	0.25	6.77	0.35	7.22	0.09	34.803	0.23	25.66	8.06
WAILEA 4	0 S	1	0.11	8.71	0.32	14.19	0.31	7.89	0.44	21.02	0.41	33.365	0.86	26.05	8.15
	2 S	1	0.08	6.04	0.37	11.16	0.29	8.11	0.39	17.10	0.26	34.013	0.82	26.00	8.18
	5 S	1	0.07	1.32	0.25	5.12	0.28	7.66	0.37	9.97	0.16	34.595	0.52	25.96	8.18
	5 D	2.5	0.11	1.16	0.33	4.94	0.28	8.62	0.43	10.99	0.15	34.603	0.44	25.93	8.17
	10 S	1	0.10	0.47	0.27	3.52	0.28	8.27	0.39	9.48	0.17	34.771	0.29	25.90	8.15
	10 D	3	0.13	0.39	0.30	3.23	0.28	7.62	0.47	8.64	0.15	34.793	0.30	25.89	8.15
	50 S	1	0.10	1.06	0.29	4.09	0.29	8.18	0.40	10.27	0.19	34.660	0.37	26.21	8.14
	50 D	10	0.08	0.13	0.15	2.37	0.26	7.81	0.38	8.33	0.13	34.853	0.34	25.77	8.14
	100 S	1	0.09	0.86	0.19	4.38	0.28	7.69	0.39	9.35	0.15	34.704	0.26	25.97	8.14
	100 D	15	0.10	0.09	0.24	2.21	0.28	7.47	0.40	8.11	0.10	34.863	0.22	25.77	8.14
	150 S	1	0.08	0.37	0.18	3.61	0.29	6.99	0.38	8.14	0.11	34.773	0.18	26.01	8.14
	150 D	25	0.08	0.07	0.18	1.93	0.29	6.95	0.39	7.37	0.11	34.865	0.22	25.53	8.15
WAILEA 5	0 S	1	0.42	10.58	0.57	80.52	0.22	6.50	0.74	26.11	0.32	28.160	0.65	24.97	8.03
	2 S	1	0.35	7.62	0.63	61.57	0.25	7.46	0.68	21.95	0.28	29.996	0.55	25.11	8.04
	5 S	1	0.16	1.87	0.42	21.02	0.27	8.44	0.46	12.49	0.21	33.498	0.34	25.19	8.07
	5 D	1.5	0.11	1.41	0.38	15.83	0.25	7.56	0.41	10.22	0.17	33.986	0.34	25.19	8.09
	10 S	1	0.09	0.99	0.35	11.13	0.26	7.82	0.40	9.54	0.17	34.328	0.22	25.25	8.08
	10 D	2.5	0.13	0.78	0.39	10.19	0.25	7.31	0.40	9.12	0.16	34.343	0.26	25.19	8.08
	50 S	1	0.12	0.55	0.36	7.16	0.27	7.88	0.41	9.13	0.14	34.547	0.19	25.21	8.11
	50 D	9	0.09	0.14	0.22	3.50	0.28	7.67	0.40	8.14	0.14	34.767	0.21	25.28	8.11
	100 S	1	0.12	0.26	0.27	4.94	0.27	7.21	0.41	7.96	0.12	34.709	0.16	25.43	8.12
	100 D	14	0.08	0.13	0.26	2.96	0.28	7.53	0.38	8.19	0.11	34.785	0.18	25.36	8.13
	150 S	1	0.06	0.13	0.16	2.54	0.28	7.35	0.37	7.95	0.10	34.803	0.14	25.54	8.14
	150 D	18	0.06	0.07	0.15	2.00	0.28	7.32	0.36	7.68	0.10	34.842	0.15	25.45	8.14
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 sites off the Honuaula project site since the inception of monitoring in for the Wailea Golf Courses in December 1989 at Sites 1, 2 and 3 (N=19) and since August 1995 at Sites 4 and 5 (N=13). 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)
WAILEA 1	0 S	1	6.19	443.00	3.08	1,583.71	6.50	93.70	15.17	664.16	0.26	28.66	0.68	25.11	8.15
	2 S	1	4.95	311.77	1.96	1,175.57	6.50	92.43	12.69	495.25	0.23	30.67	0.71	25.21	8.17
	5 S	1	3.71	133.33	1.96	597.19	7.12	96.64	11.76	301.12	0.21	32.91	0.46	25.35	8.18
	5 D	2.5	3.71	110.36	3.22	514.33	7.43	96.22	12.07	272.83	0.17	33.29	0.46	25.35	8.18
	10 S	1	3.09	62.18	2.94	333.71	7.12	95.80	10.84	196.36	0.16	33.95	0.36	25.42	8.17
	10 D	3	2.78	38.93	2.52	224.44	7.43	94.26	10.53	155.46	0.17	34.29	0.35	25.40	8.17
	50 S	1	2.47	35.71	2.80	205.62	7.43	93.42	10.53	148.32	0.15	34.34	0.26	25.54	8.17
	50 D	4.5	2.78	6.58	1.82	90.73	8.05	99.86	10.84	115.68	0.13	34.69	0.29	25.45	8.17
	100 S	1	2.78	28.57	1.96	183.15	7.74	97.62	11.15	148.74	0.13	34.39	0.25	25.54	8.16
	100 D	10	2.47	2.94	1.54	66.01	7.43	98.88	10.53	106.30	0.11	34.77	0.19	25.44	8.17
	150 S	1	2.78	9.80	2.66	101.12	7.74	101.82	10.84	125.63	0.13	34.61	0.20	25.59	8.17
	150 D	15	2.47	1.82	2.38	55.06	7.74	100.98	10.84	105.74	0.10	34.79	0.18	25.45	8.17
WAILEA 2	0 S	1	3.40	88.37	2.80	396.07	7.12	105.88	12.38	239.08	0.23	32.37	0.49	25.64	8.18
	2 S	1	4.02	72.97	2.66	351.41	7.74	97.48	12.69	207.14	0.20	33.52	0.38	25.67	8.18
	5 S	1	3.40	50.98	2.80	254.21	7.74	97.76	11.46	165.97	0.18	34.25	0.32	25.56	8.18
	5 D	2.5	3.40	38.65	3.36	219.38	7.74	94.54	11.76	148.18	0.20	34.44	0.37	25.57	8.18
	10 S	1	3.40	30.25	2.80	208.99	8.05	96.36	11.76	144.54	0.17	34.47	0.26	25.68	8.17
	10 D	3	3.09	15.68	2.38	130.06	8.05	95.24	11.46	121.99	0.16	34.61	0.30	25.69	8.17
	50 S	1	3.09	21.42	2.66	169.94	8.05	96.50	11.46	136.27	0.16	34.53	0.25	25.71	8.17
	50 D	4.5	3.09	5.18	2.94	77.53	7.43	96.50	11.15	109.52	0.14	34.74	0.27	25.62	8.17
	100 S	1	3.09	13.58	3.08	127.53	7.74	99.16	11.46	128.43	0.13	34.60	0.21	25.59	8.17
	100 D	10	2.78	2.52	1.82	67.70	7.43	93.42	10.84	100.70	0.13	34.77	0.24	25.59	8.17
	150 S	1	2.78	8.12	2.80	103.09	7.74	96.92	10.84	118.63	0.12	34.66	0.20	25.73	8.16
	150 D	15	2.78	1.68	2.52	55.62	7.74	95.80	11.15	101.96	0.11	34.80	0.20	25.48	8.17
WAILEA 3	0 S	1	6.50	86.27	3.78	573.32	8.36	101.68	16.10	250.56	0.33	31.88	0.47	25.79	8.12
	2 S	1	5.26	56.02	3.08	387.08	8.05	100.56	14.86	192.86	0.28	33.76	0.48	25.86	8.13
	5 S	1	4.33	35.01	3.50	281.18	8.05	93.98	13.62	152.80	0.20	34.21	0.48	25.82	8.15
	5 D	2.5	4.64	31.65	3.50	268.82	8.67	99.58	14.55	157.70	0.21	34.25	0.45	25.78	8.15
	10 S	1	4.33	24.23	2.66	237.08	8.67	96.92	14.55	148.46	0.18	34.29	0.34	25.79	8.15
	10 D	5	4.02	16.38	3.36	192.70	8.05	91.45	13.00	128.43	0.18	34.48	0.39	25.79	8.15
	50 S	1	3.09	10.36	3.64	127.53	8.05	97.62	11.76	117.51	0.13	34.60	0.33	25.76	8.14
	50 D	10	3.09	4.90	3.22	96.91	8.36	93.56	11.76	110.08	0.14	34.69	0.33	25.69	8.15
	100 S	1	3.09	7.98	3.08	117.14	8.05	96.50	12.07	123.53	0.14	34.65	0.33	25.80	8.14
	100 D	15	2.78	2.38	2.24	72.75	8.05	96.22	11.76	110.92	0.13	34.77	0.28	25.69	8.15
	150 S	1	3.09	3.50	2.66	74.16	7.74	94.40	11.46	110.92	0.13	34.76	0.22	25.82	8.15
	150 D	20	2.78	1.82	2.80	58.43	7.74	94.82	10.84	101.12	0.09	34.80	0.23	25.66	8.06
WAILEA 4	0 S	1	3.40	121.99	4.48	398.60	9.60	110.50	13.62	294.40	0.41	33.37	0.86	26.05	8.15
	2 S	1	2.47	84.59	5.18	313.48	8.98	113.58	12.07	239.50	0.26	34.01	0.82	26.00	8.18
	5 S	1	2.16	18.48	3.50	143.82	8.67	107.28	11.46	139.63	0.16	34.60	0.52	25.96	8.18
	5 D	2.5	3.40	16.24	4.62	138.76	8.67	120.73	13.31	153.92	0.15	34.60	0.44	25.93	8.17
	10 S	1	3.09	6.58	3.78	98.88	8.67	115.82	12.07	132.77	0.17	34.77	0.29	25.90	8.15
	10 D	3	4.02	5.46	4.20	90.73	8.67	106.72	14.55	121.01	0.15	34.79	0.30	25.89	8.15
	50 S	1	3.09	14.84	4.06	114.89	8.98	114.56	12.38	143.84	0.19	34.66	0.37	26.21	8.14
	50 D	10	2.47	1.82	2.10	66.57	8.05	109.38	11.76	116.66	0.13	34.85	0.34	25.77	8.14
	100 S	1	2.78	12.04	2.66	123.03	8.67	107.70	12.07	130.95	0.15	34.70	0.26	25.97	8.14
	100 D	15	3.09	1.26	3.36	62.08	8.67	104.62	12.38	113.58	0.10	34.86	0.22	25.77	8.14
	150 S	1	2.47	5.18	2.52	101.40	8.98	97.90	11.76	114.00	0.11	34.77	0.18	26.01	8.14
	150 D	25	2.47	0.98	2.52	54.21	8.98	97.34	12.07	103.22	0.11	34.87	0.22	25.53	8.15
WAILEA 5	0 S	1	13.00	148.18	7.98	2,261.81	6.81	91.03	22.92	365.69	0.32	28.16	0.65	24.97	8.03
	2 S	1	10.84	106.72	8.82	1,729.50	7.74	104.48	21.06	307.43	0.28	30.00	0.55	25.11	8.04
	5 S	1	4.95	26.19	5.88	590.45	8.36	118.21	14.24	174.93	0.21	33.50	0.34	25.19	8.07
	5 D	1.5	3.40	19.74	5.32	444.66	7.74	105.88	12.69	143.14	0.17	33.99	0.34	25.19	8.09
	10 S	1	2.78	13.86	4.90	312.64	8.05	109.52	12.38	133.61	0.17	34.33	0.22	25.25	8.08
	10 D	2.5	4.02	10.92	5.46	286.24	7.74	102.38	12.38	127.73	0.16	34.34	0.26	25.19	8.08
	50 S	1	3.71	7.70	5.04	201.12	8.36	110.36	12.69	127.87	0.14	34.55	0.19	25.21	8.11
	50 D	9	2.78	1.96	3.08	98.32	8.67	107.42	12.38	114.00	0.14	34.77	0.21	25.28	8.11
	100 S	1	3.71	3.64	3.78	138.76	8.36	100.98	12.69	111.48	0.12	34.71	0.16	25.43	8.12
	100 D	14	2.47	1.82	3.64	83.15	8.67	105.46	11.76	114.70	0.11	34.79	0.18	25.36	8.13
	150 S	1	1.85	1.82	2.24	71.35	8.67	102.94	11.46	111.34	0.10	34.80	0.14	25.54	8.14
	150 D	18	1.85	0.98	2.10	56.18	8.67	102.52	11.15	107.56	0.10	34.84	0.15	25.45	8.14
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.

μM and μg/L (shaded) from irrigation wells and an irrigation lake (Res) collected at the Wailea Golf Courses on July 10, 2008. For sampling site locations,

)3 /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)
3468	0.96	13.44	556.76	15645	0.32	9.92	2.40	33.60	2.36	73.16	251.0	3515	1.33
3255	1.88	26.32	559.36	15718	0.36	11.16	11.96	167.44	2.68	83.08	246.3	3448	1.08
2530	1.56	21.84	571.12	16048	0.44	13.64	8.04	112.56	2.24	69.44	190.3	2664	1.74
5042	0.96	13.44	556.36	15634	0.00	0.00	13.20	184.80	2.32	71.92	374.3	5240	1.62
4366	0.32	4.48	546.68	15362	0.36	11.16	12.76	178.64	2.56	79.36	325.0	4549	1.85
2911	0.00	0.00	542.92	15256	0.28	8.68	8.48	118.72	2.24	69.44	216.4	3030	1.91
2230	0.28	3.92	511.96	14386	0.48	14.88	8.24	115.36	2.60	80.60	167.8	2350	2.10
3157	12.52	175.28	432.88	12164	1.08	33.48	28.32	396.48	1.96	60.76	266.4	3729	1.96

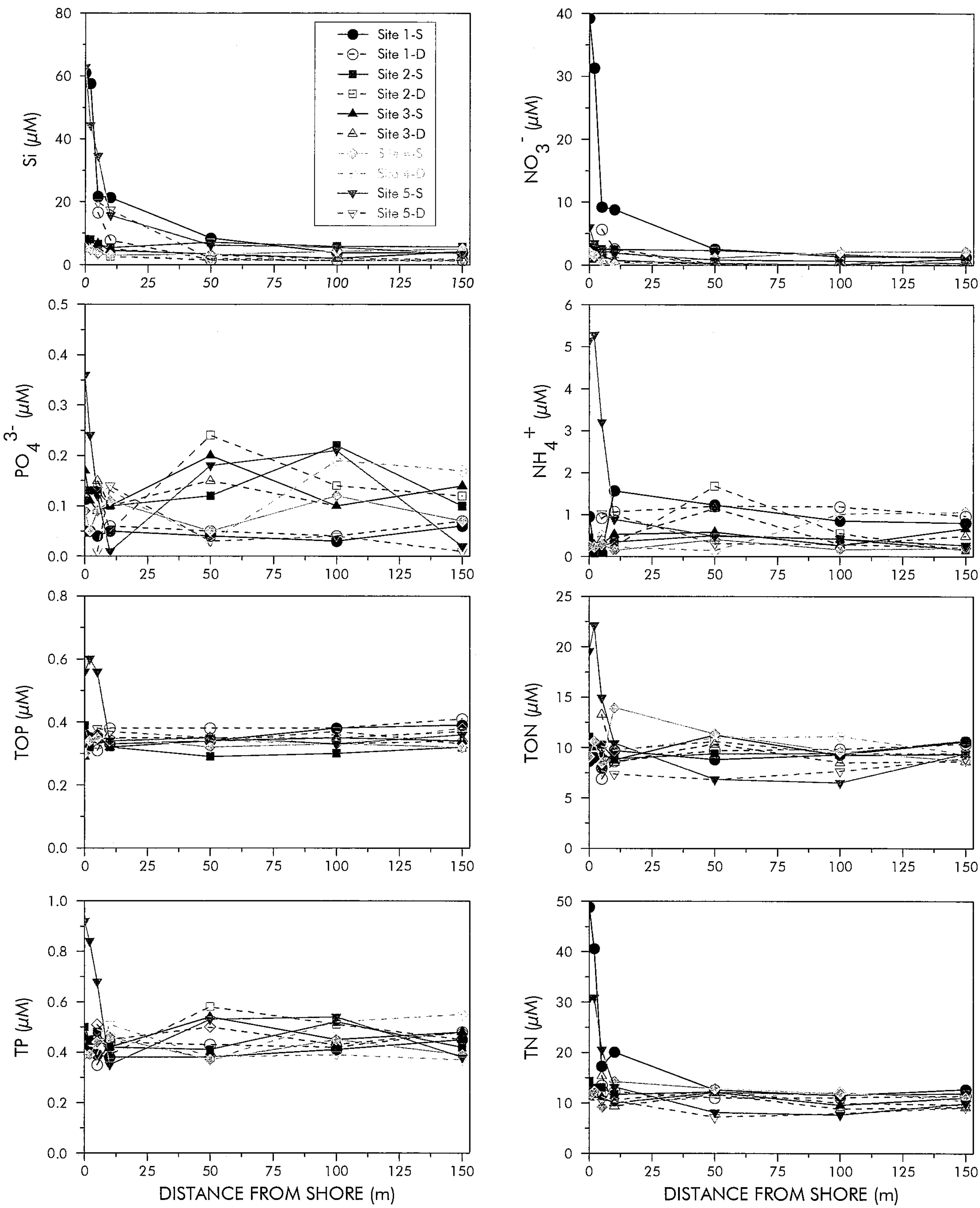

FIGURE 2. Plots of dissolved nutrients in surface (S) and deep (D) samples collected on June 29, 2008 as a function of distance from the shoreline off Honua`ula, Wailea, Maui. For site locations, see Figure 1.

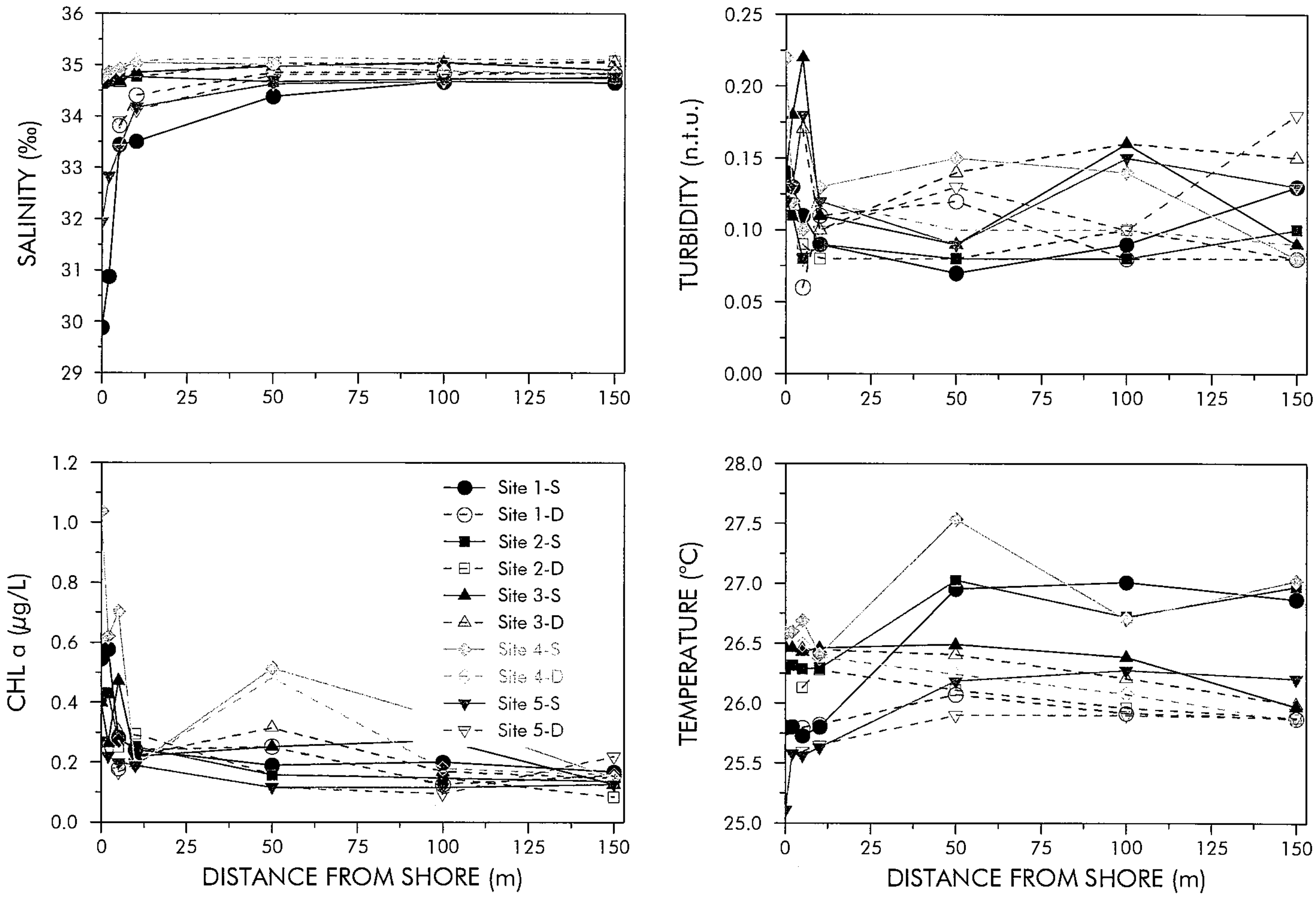

FIGURE 3. Plots of water chemistry constituents in surface (S) and deep (D) samples collected on June 29, 2008 as a function of distance from the shoreline off Honua`ula, Wailea, Maui. For site locations, see Figure 1.

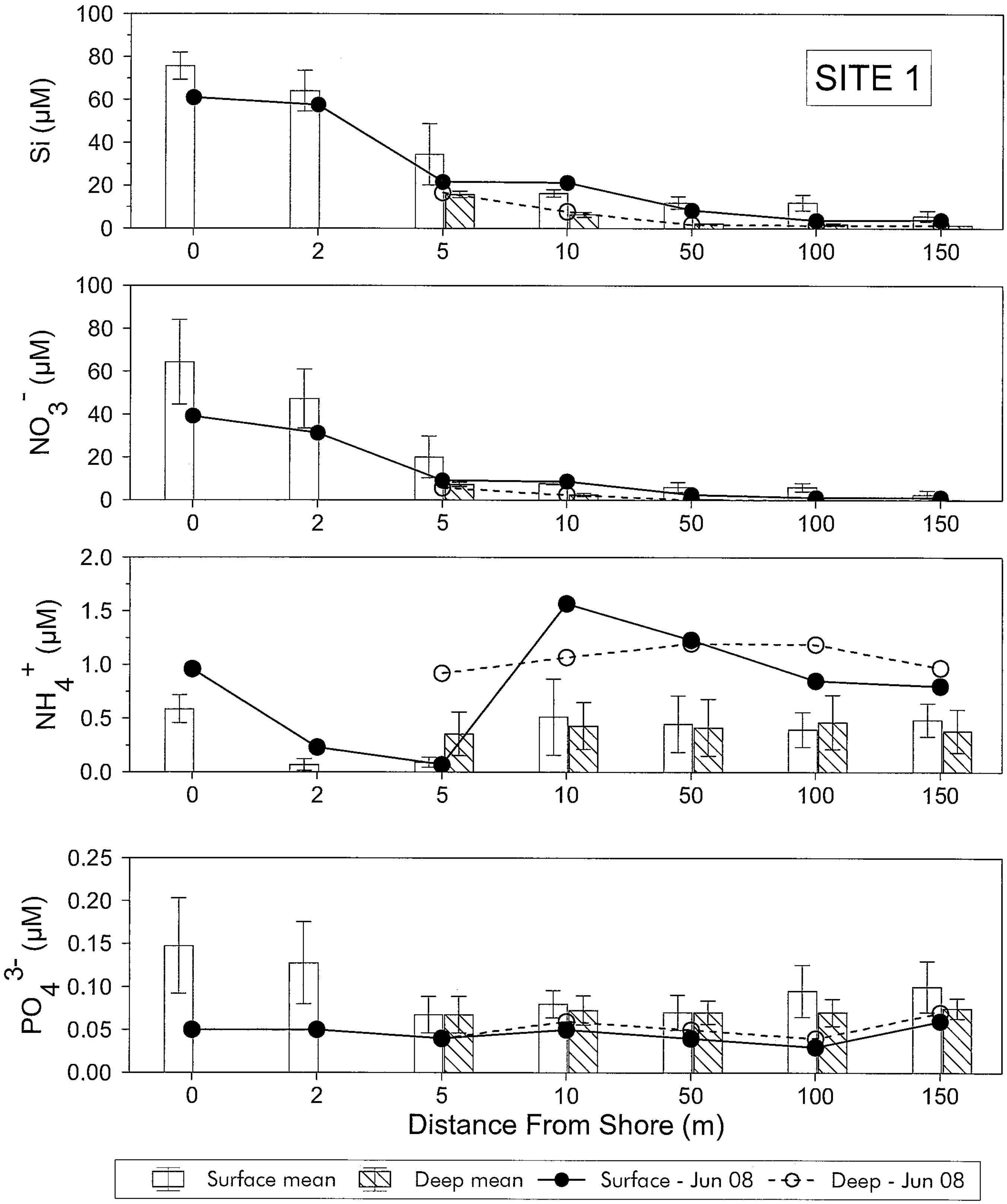

FIGURE 4. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean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

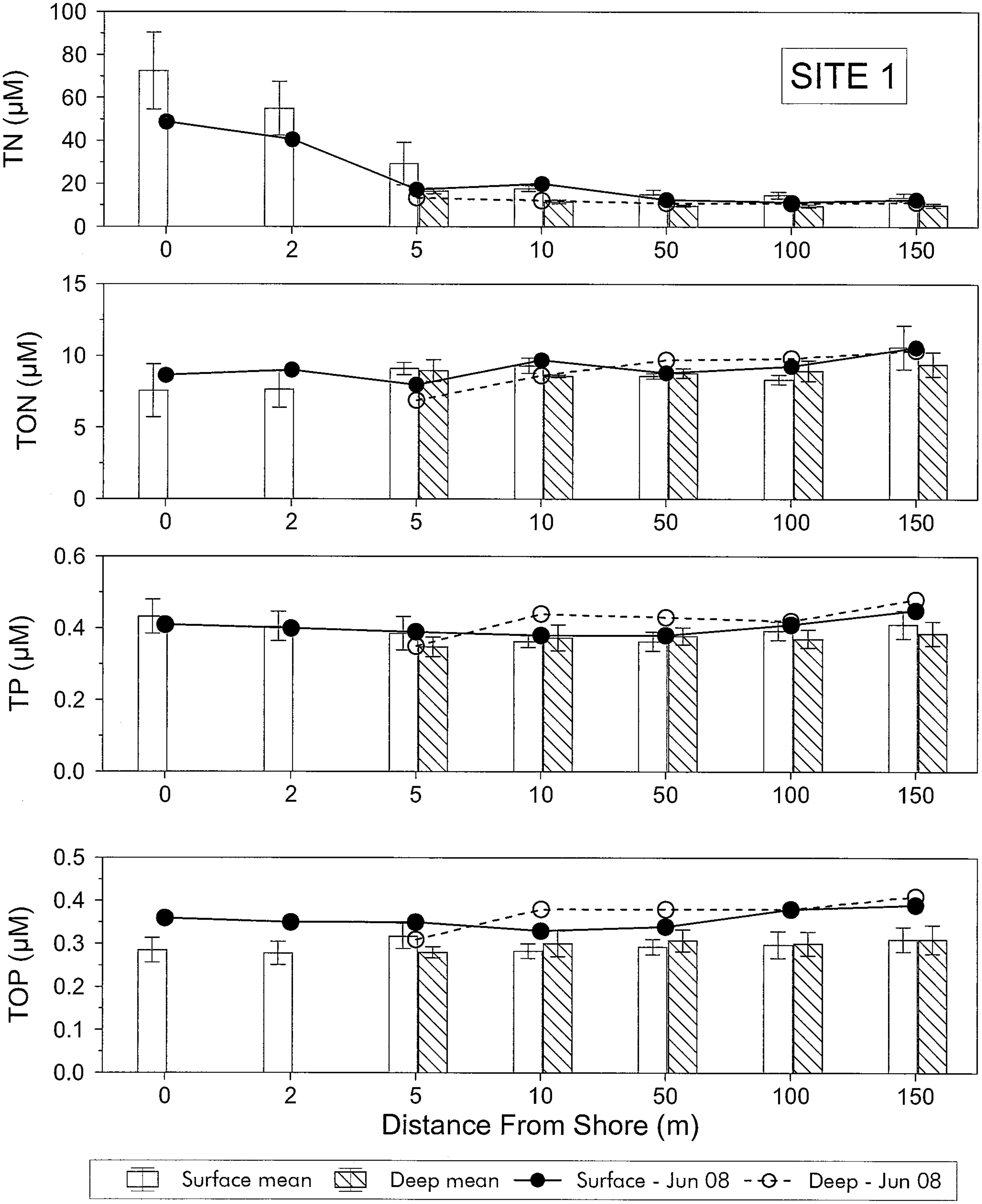

FIGURE 5. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

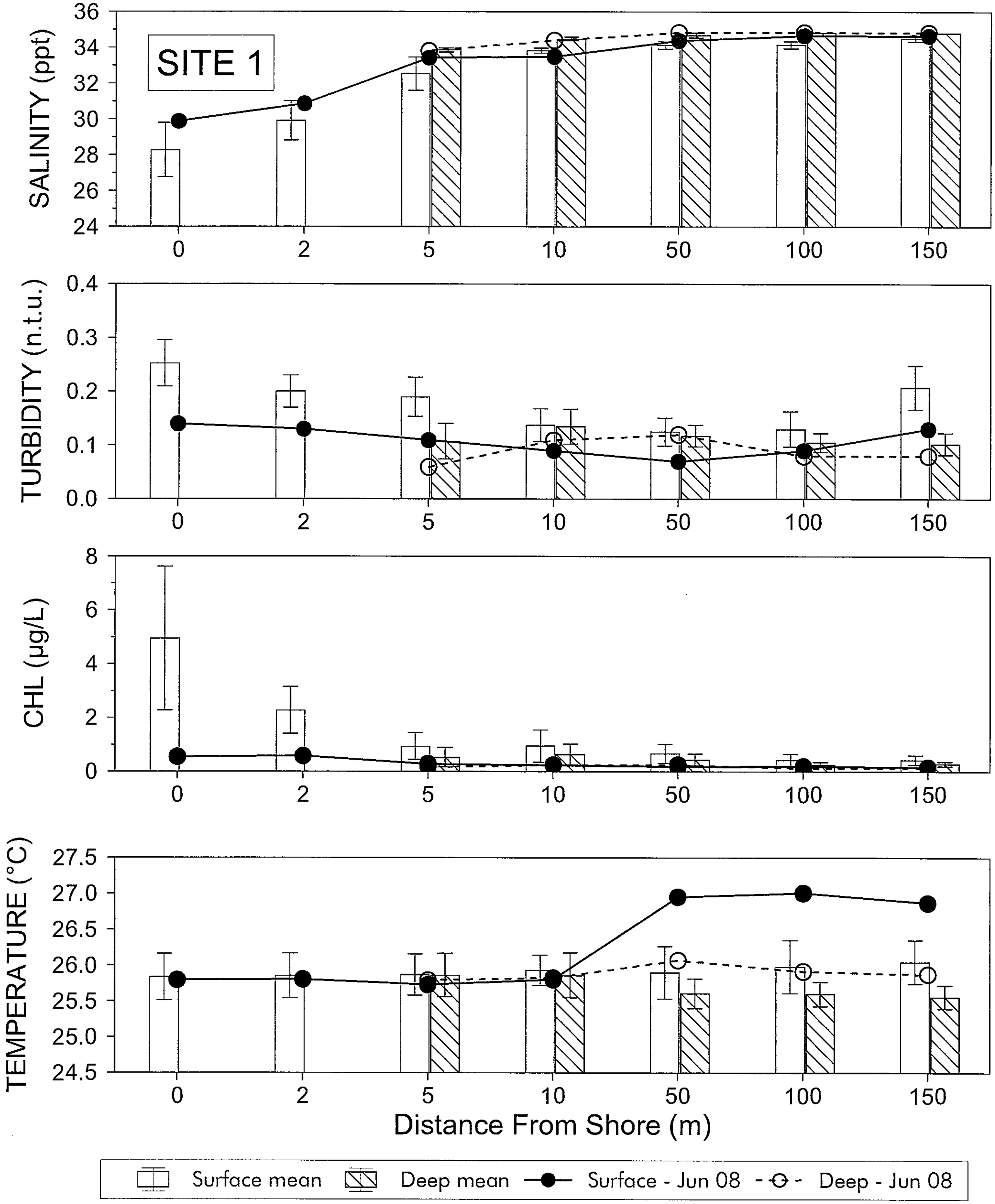

FIGURE 6. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent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

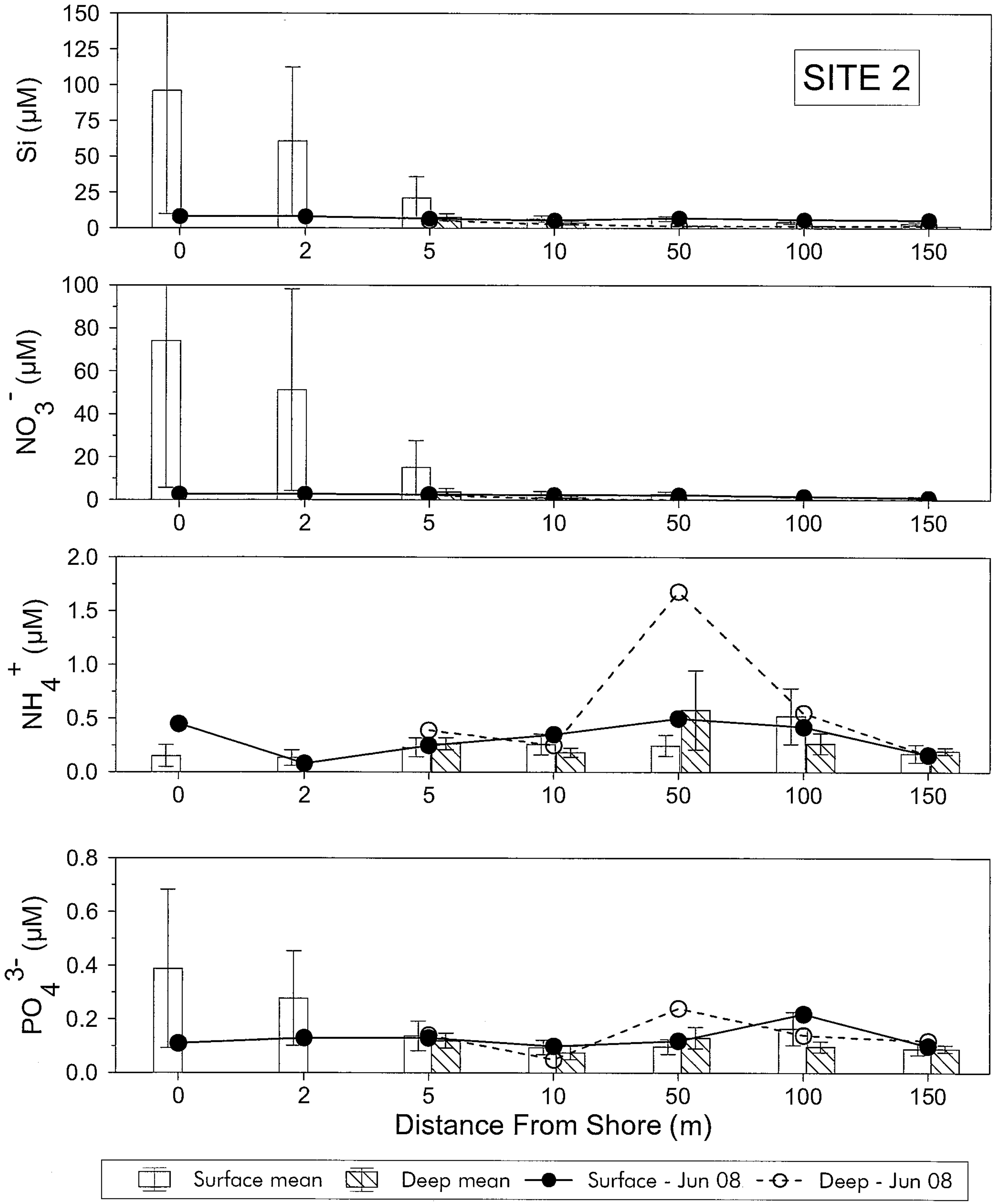

FIGURE 7. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

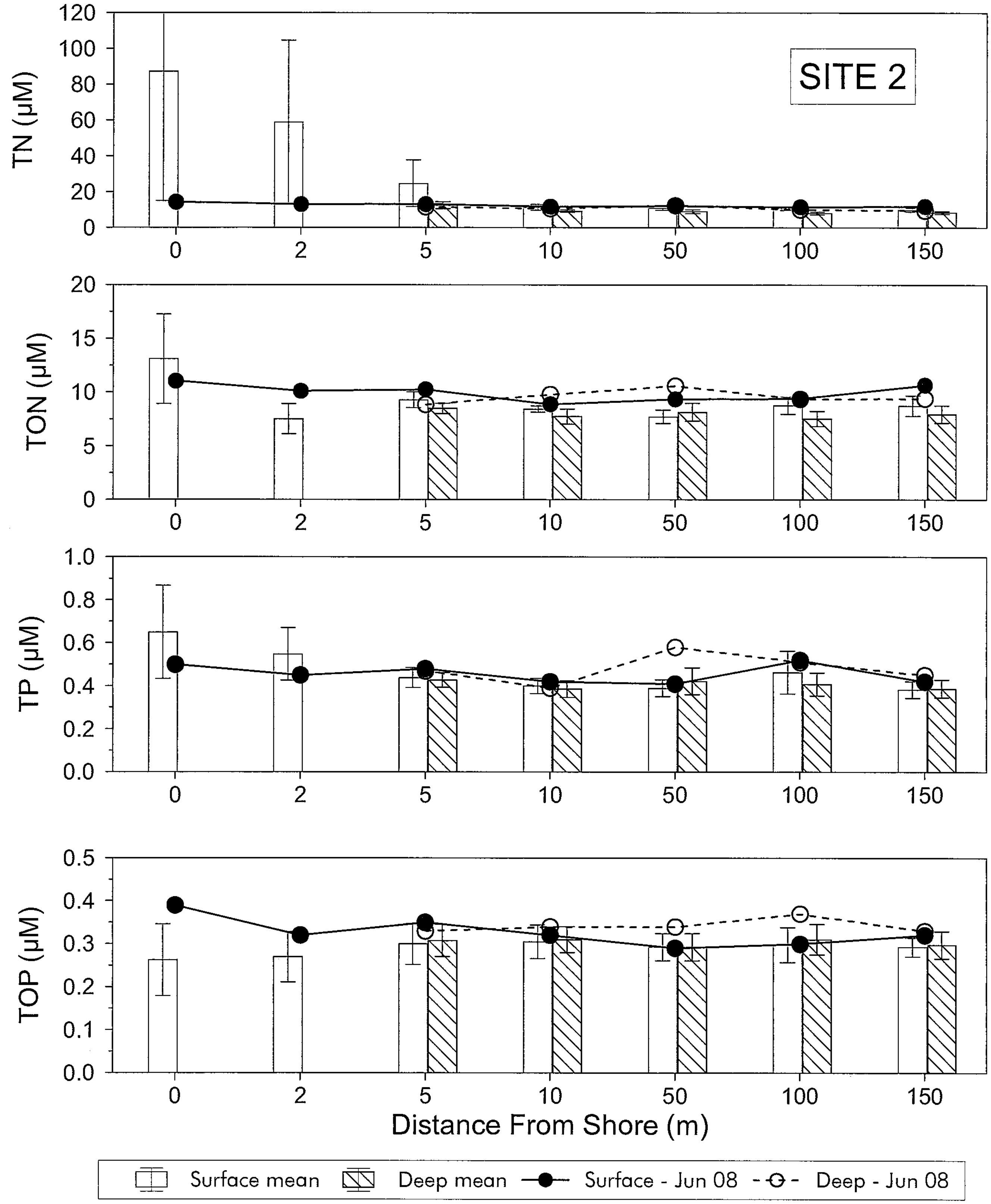

FIGURE 8. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

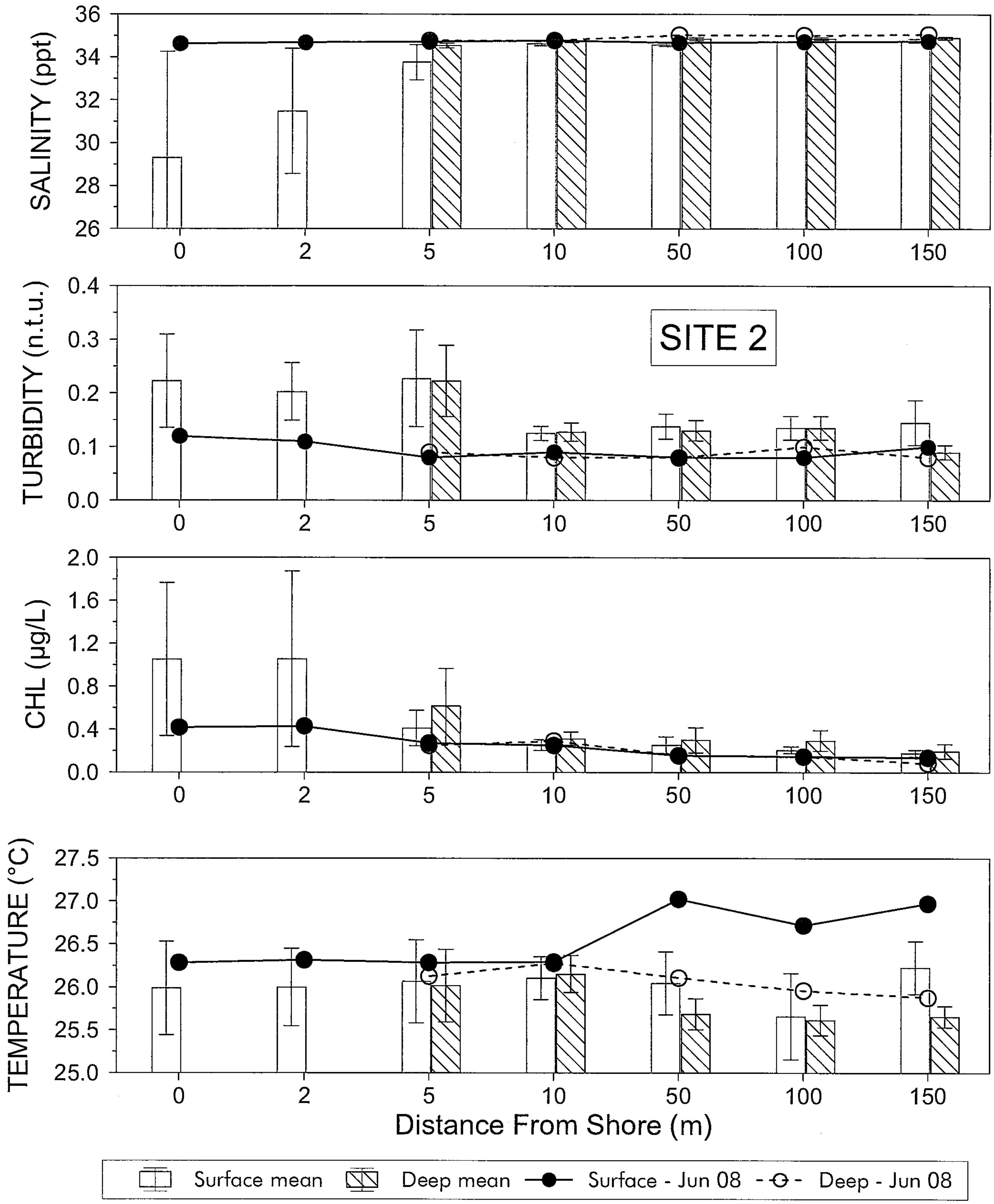

FIGURE 9. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

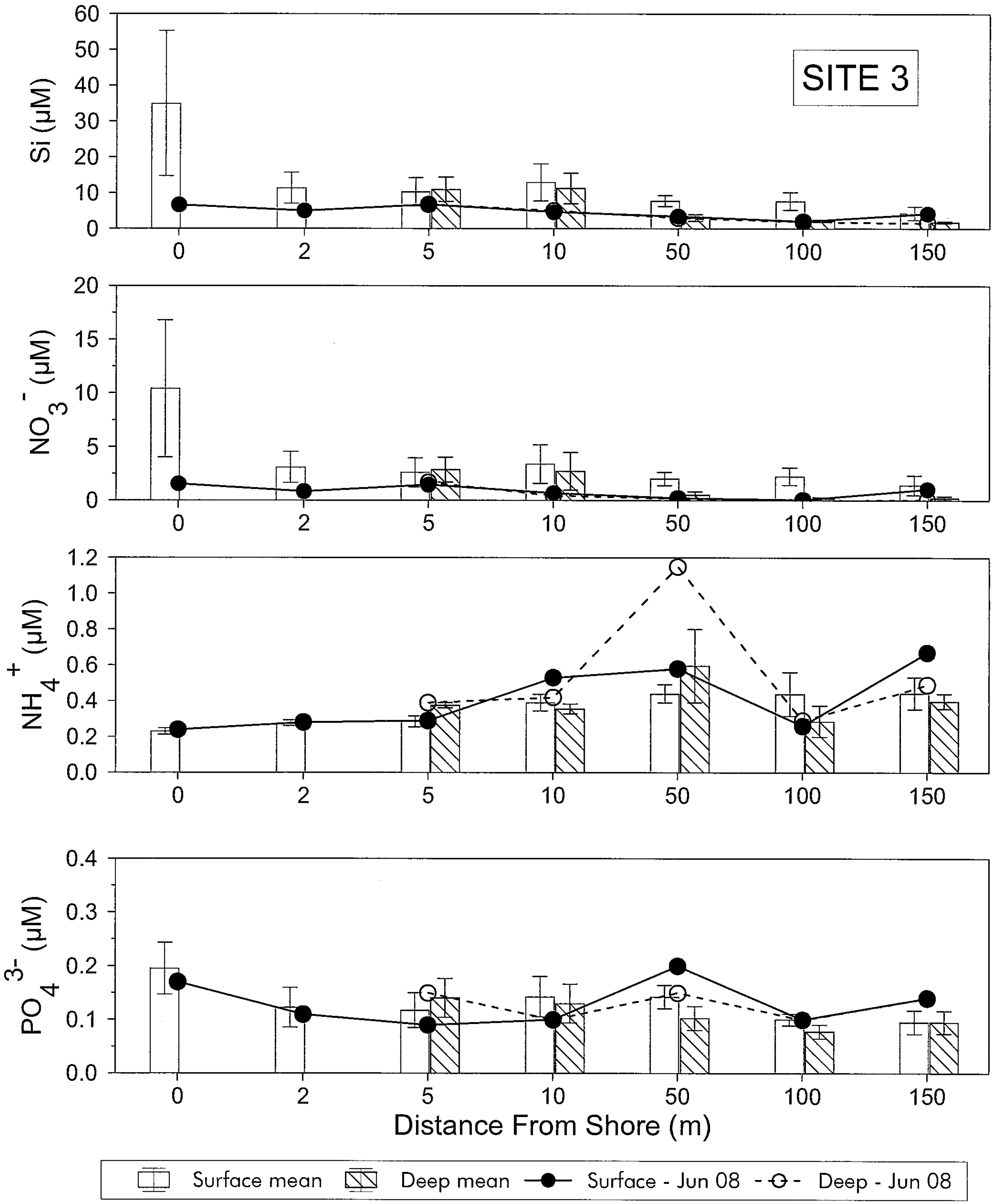

FIGURE 10. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

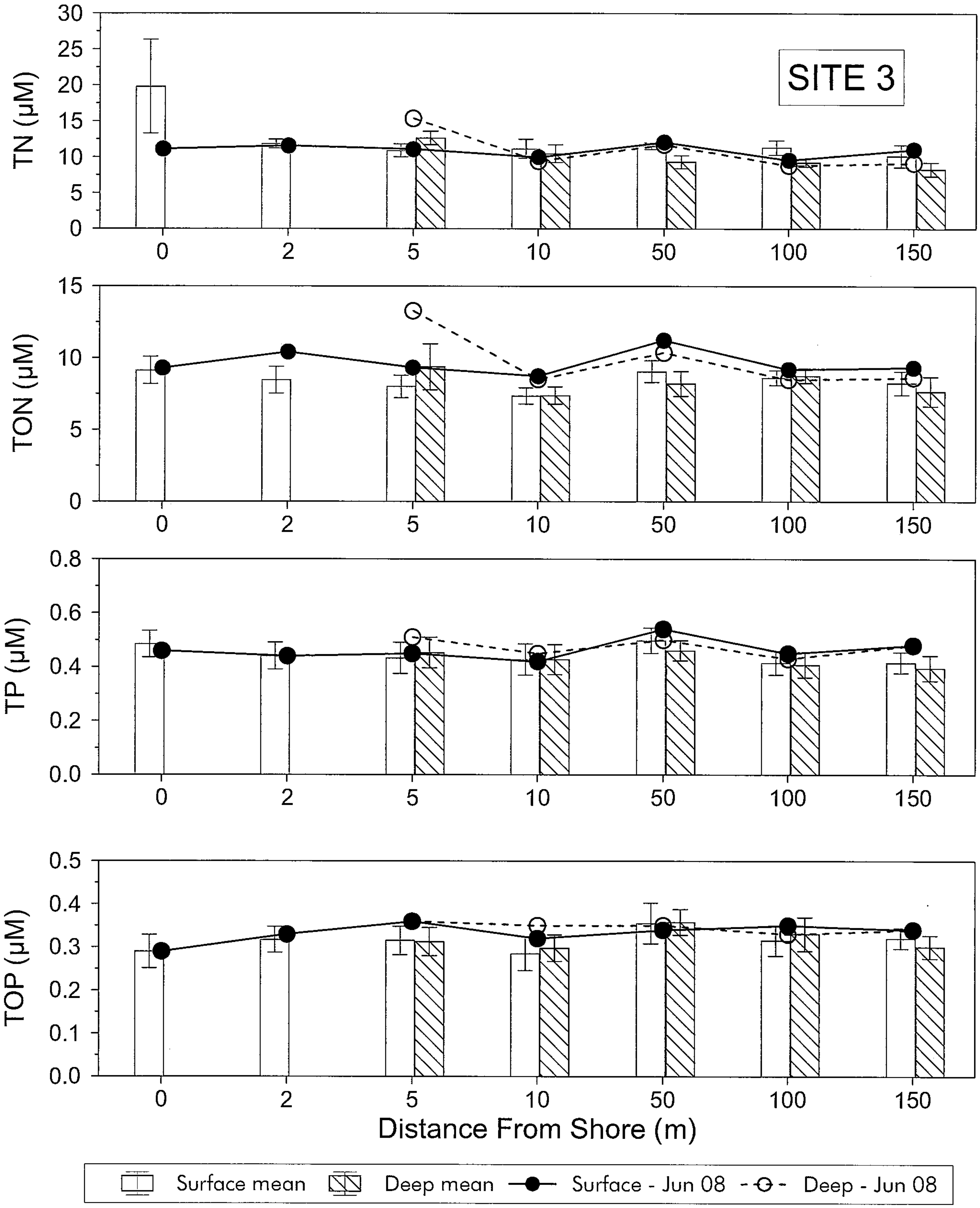

FIGURE 11. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

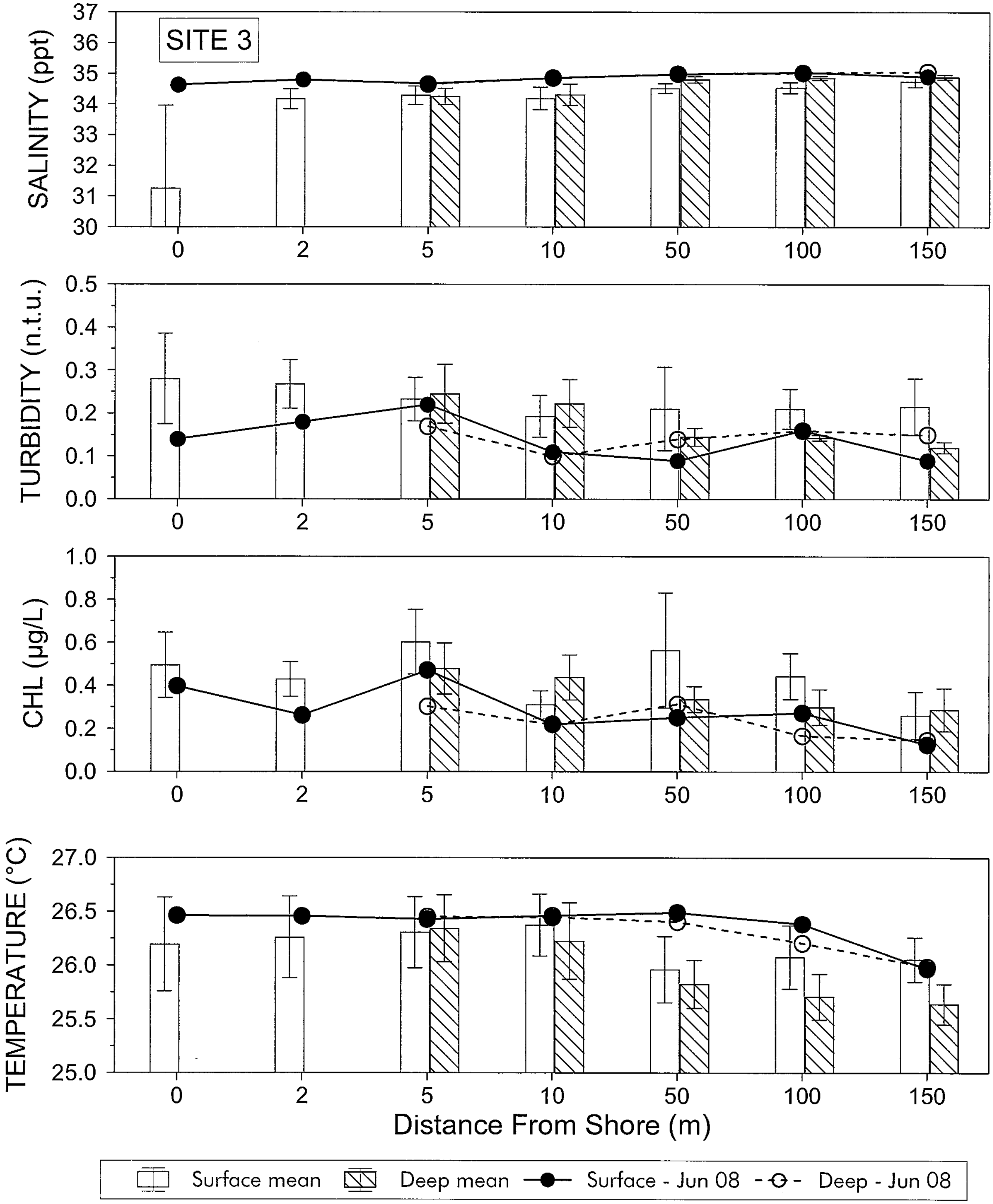

FIGURE 12. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

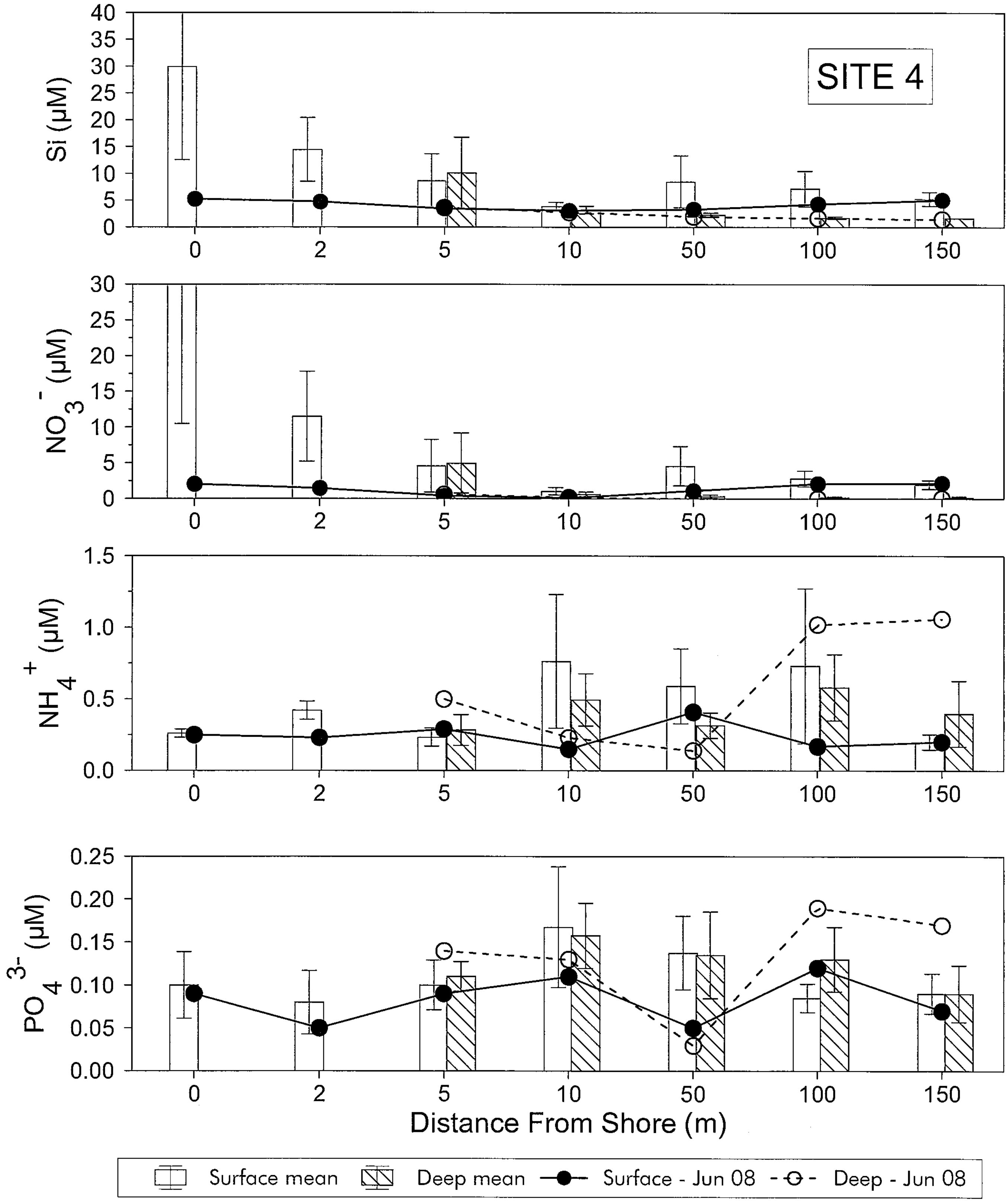

FIGURE 13. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean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

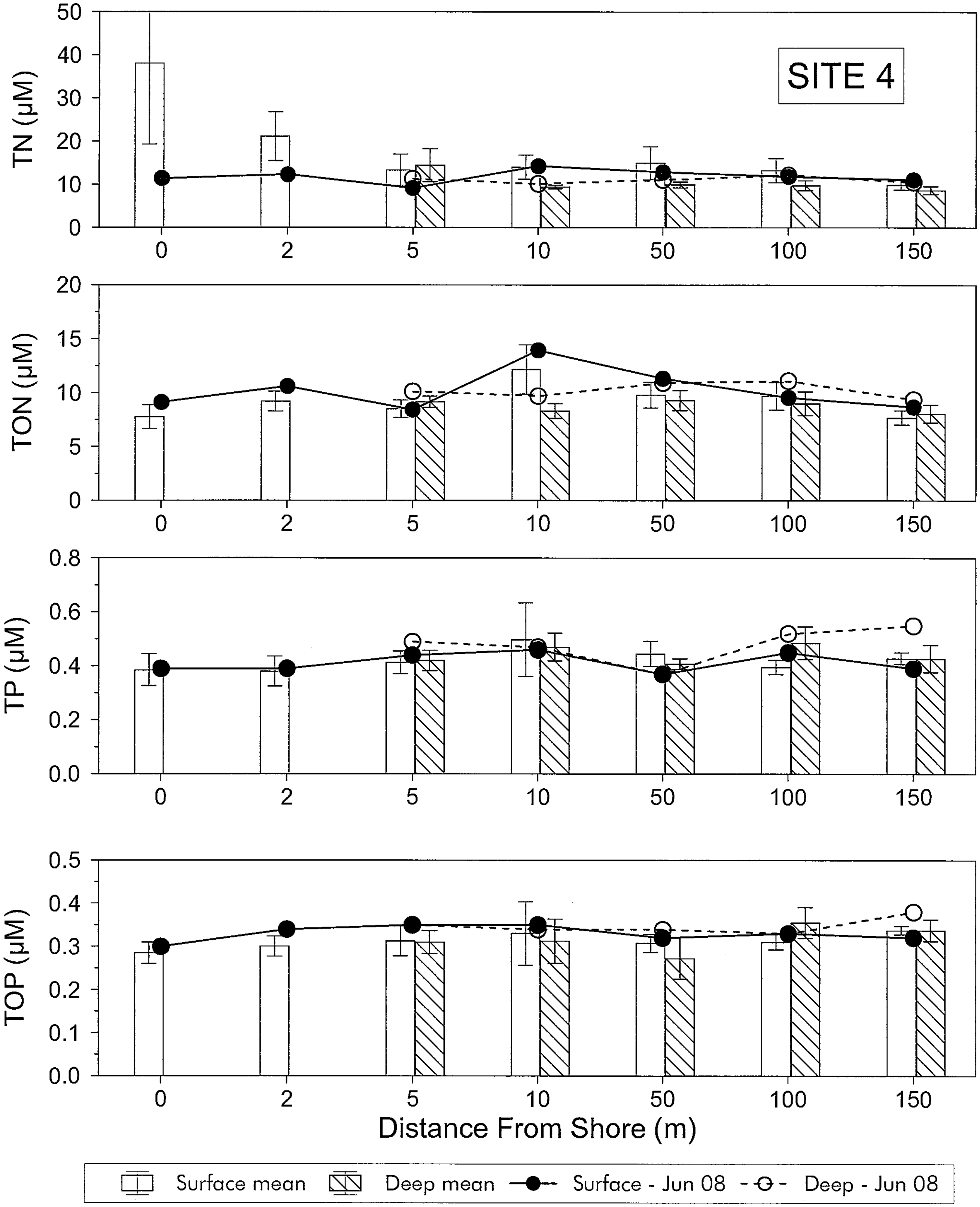

FIGURE 14. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent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

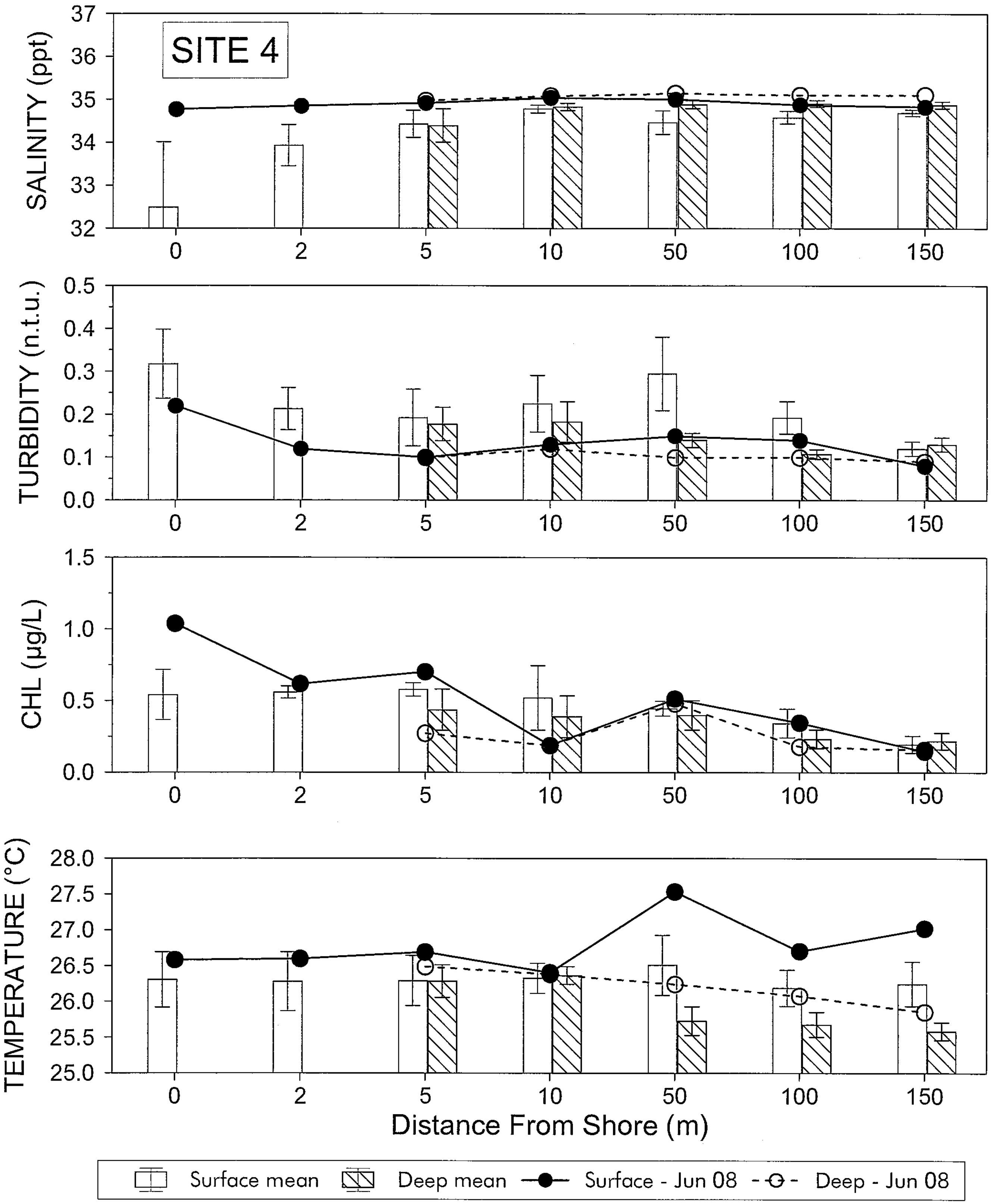

FIGURE 15. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent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

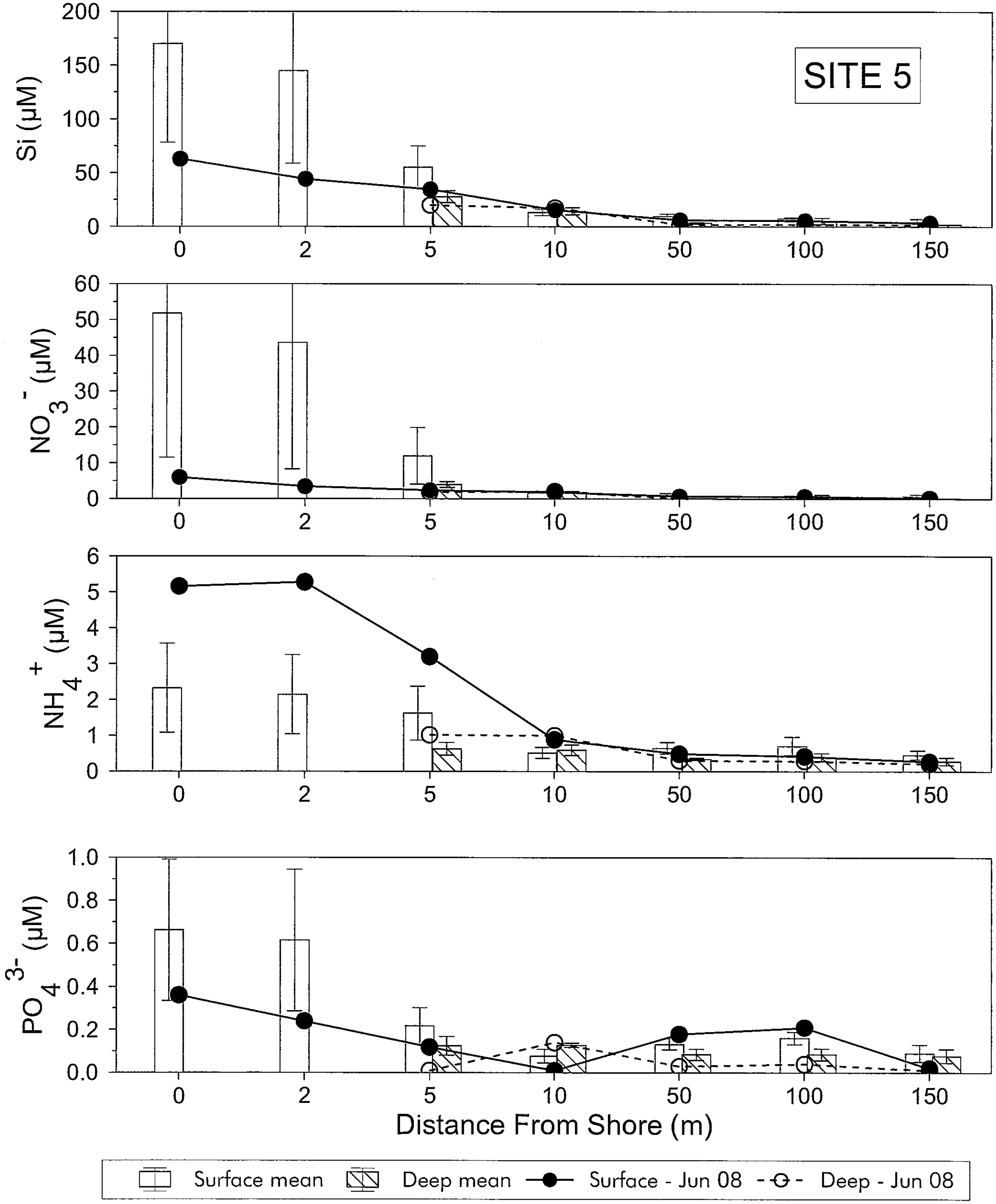

FIGURE 16. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

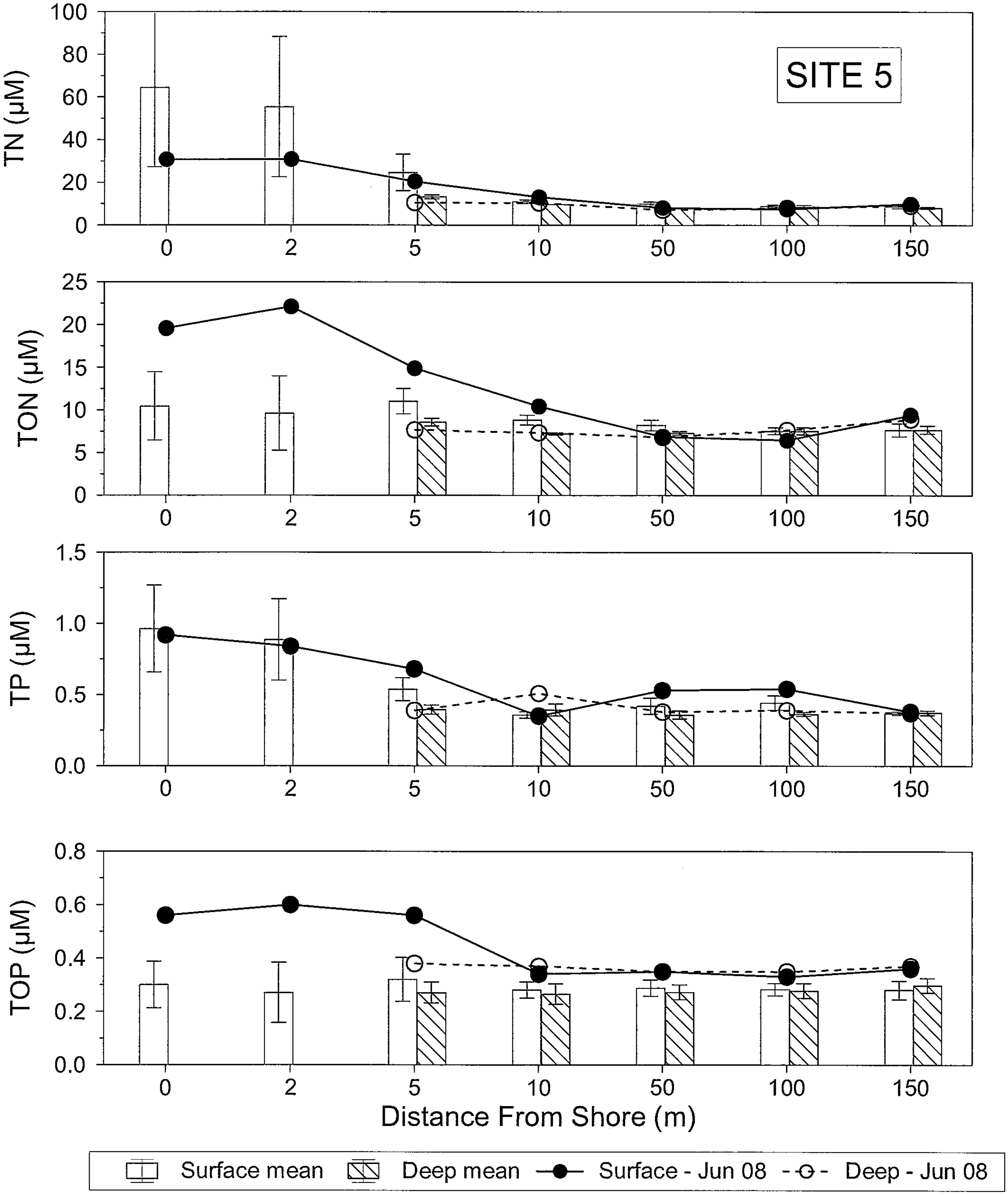

FIGURE 17. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

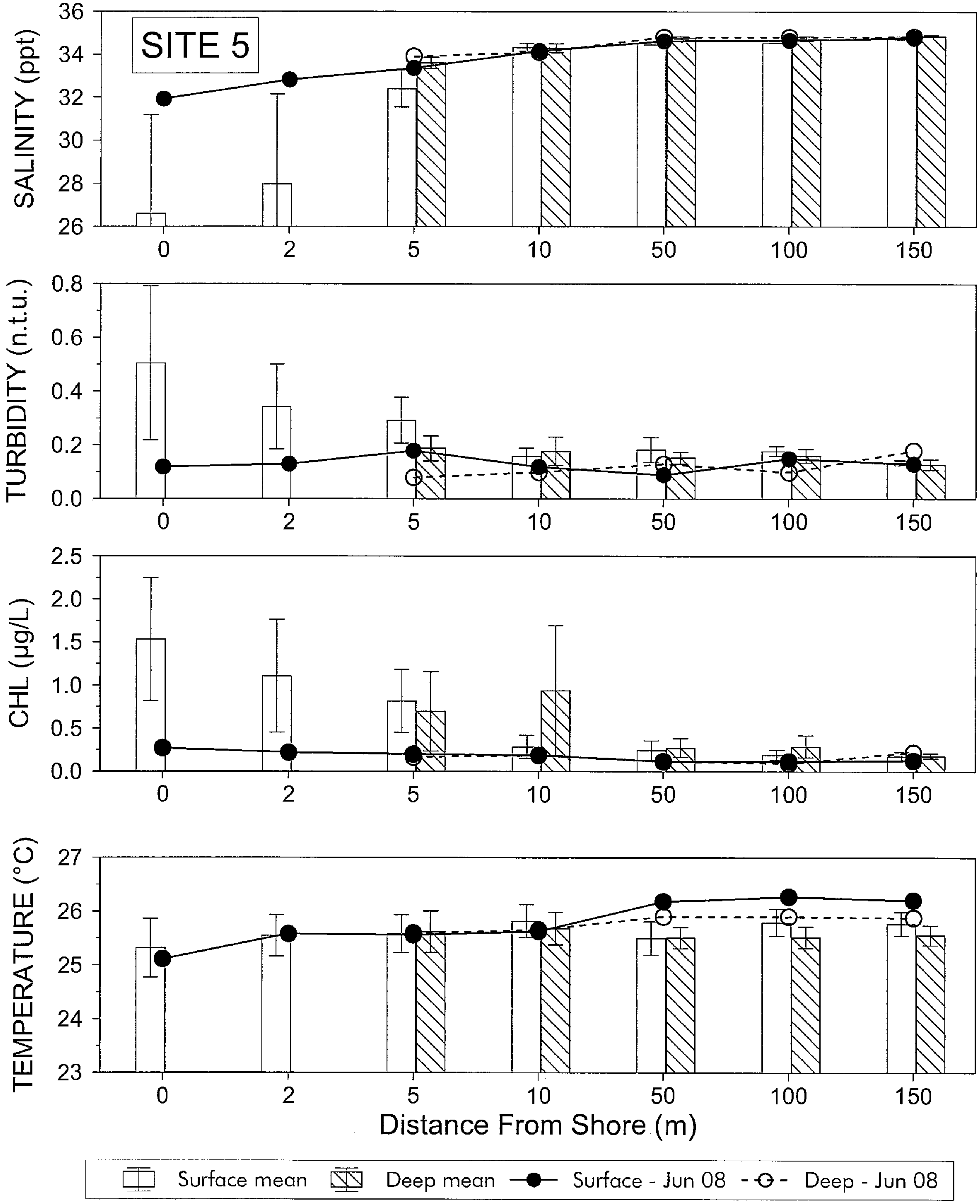

FIGURE 18. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=4). Error bars represent standard error of the mean. For site location, see Figure 1.

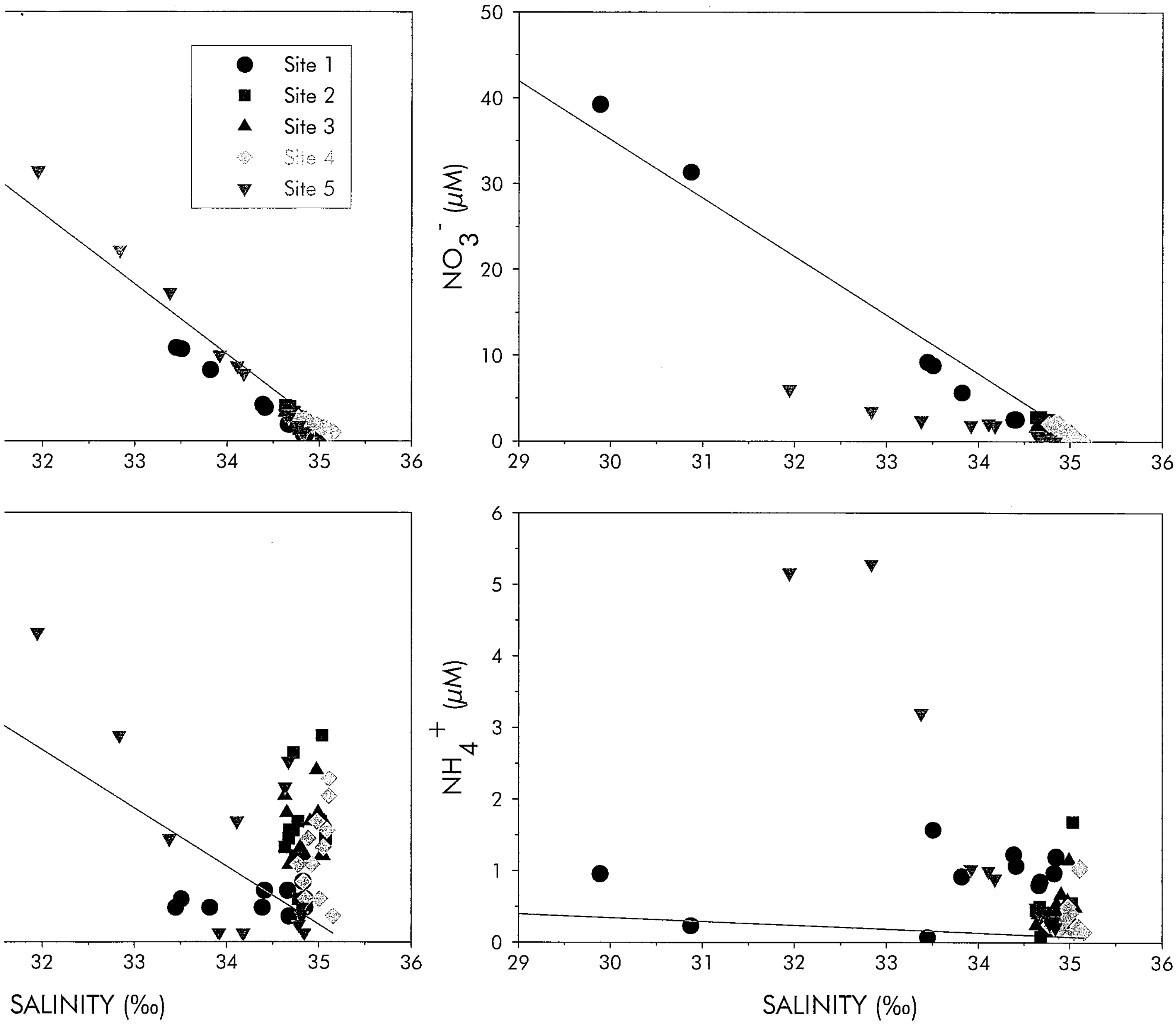

diagram showing concentration of dissolved nutrients from samples collected at five transect sites offshore
:a, Maui on June 29, 2008 as functions of salinity. Straight line in each plot is conservative mixing line
:cting the concentrations in open coastal water with water from a golf course irrigation well. For transect
jure 1.

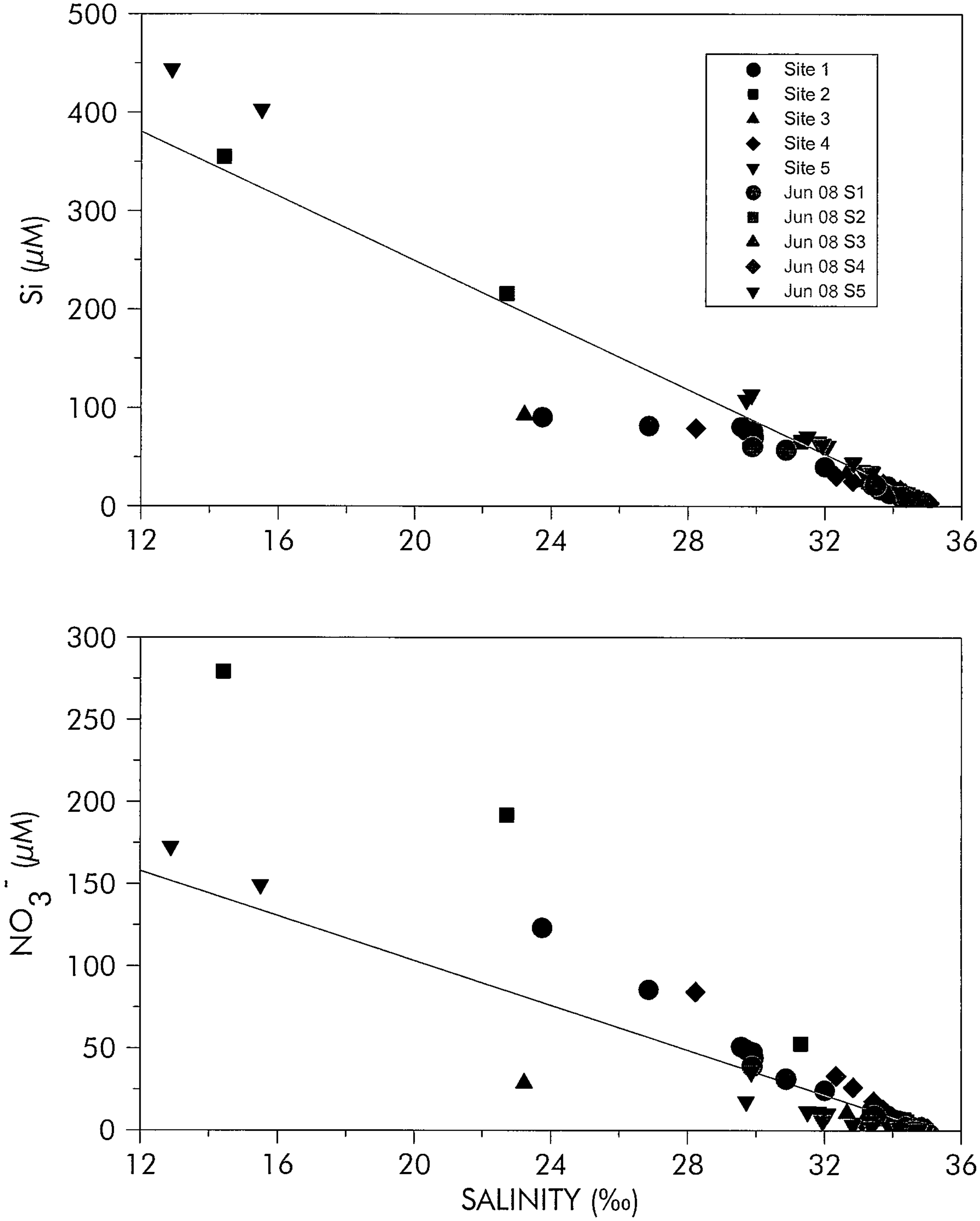

FIGURE 20. Silicate and nitrate, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Hawaii. Black symbols represent data from surveys conducted in June 2005, June 2006 and December 2007. Red symbols are data from the most recent survey in June 2008. 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.

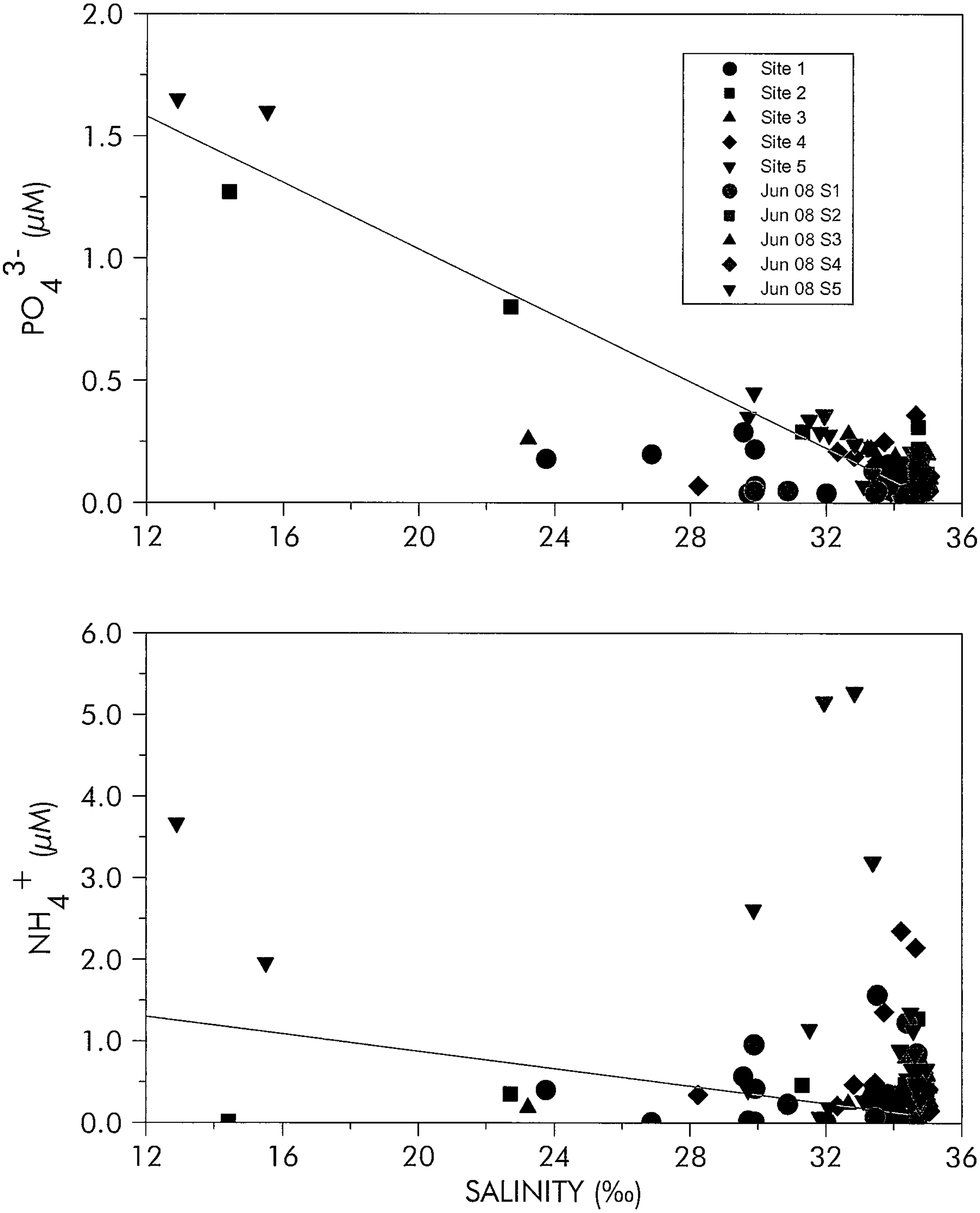

FIGURE 21. Phosphate and ammonium, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted in June 2005, June 2006 and December 2007. Red symbols are data from the most recent 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.

TABLE 6. Linear regression statistics for Y-intercepts of concentrations of NO_3^- as functions of salinity for samples collected along Transects at five sites off the Wailea Golf Courses during surveys in June 2005, June 2006, December 2007 and June 2008. Column labeled "Change" indicates if there is a significant (P=0.05) increase (INC), decrease (DEC), or no change (NC) of the Y-intercepts over the four year period of sampling. For location of Transect sites, see Figure 1.

	Y-INT	*STD ERR*	*P-value*	*Lower 95%*	*Upper 95%*	*R^2*	*CHANGE*
SITE 1							
2005	312.67	3.89	0.00000	304.00	321.34	0.998	
2006	342.43	6.03	0.00000	328.98	355.87	0.997	NC
2007	378.85	6.04	0.00000	365.39	392.32	0.997	
2008	276.02	5.92	0.00000	262.83	289.22	0.995	
SITE 2							
2005	275.91	29.92	0.00000	209.25	342.57	0.894	
2006	362.44	7.71	0.00000	345.25	379.63	0.995	NC
2007	495.18	10.73	0.00000	471.26	519.09	0.995	
2008	228.07	41.57	0.00027	135.44	320.70	0.748	
SITE 3							
2005	242.16	21.75	0.00000	193.70	290.63	0.925	
2006	166.23	4.54	0.00000	156.13	176.34	0.991	NC
2007	84.19	2.06	0.00000	79.60	88.79	0.994	
2008	137.12	13.26	0.00000	107.57	166.66	0.914	
SITE 4							
2005	324.87	46.65	0.00004	220.93	428.81	0.828	
2006	468.11	2.44	0.00000	462.68	473.54	1.000	NC
2007	440.57	7.28	0.00000	424.35	456.78	0.997	
2008	222.98	33.34	0.00005	148.68	297.27	0.816	
SITE 5							
2005	120.65	3.68	0.00000	112.45	128.86	0.990	
2006	120.24	1.39	0.00000	117.15	123.34	0.999	NC
2007	272.00	1.49	0.00000	268.69	275.31	1.000	
2008	65.94	4.06	0.00000	56.90	74.99	0.962	

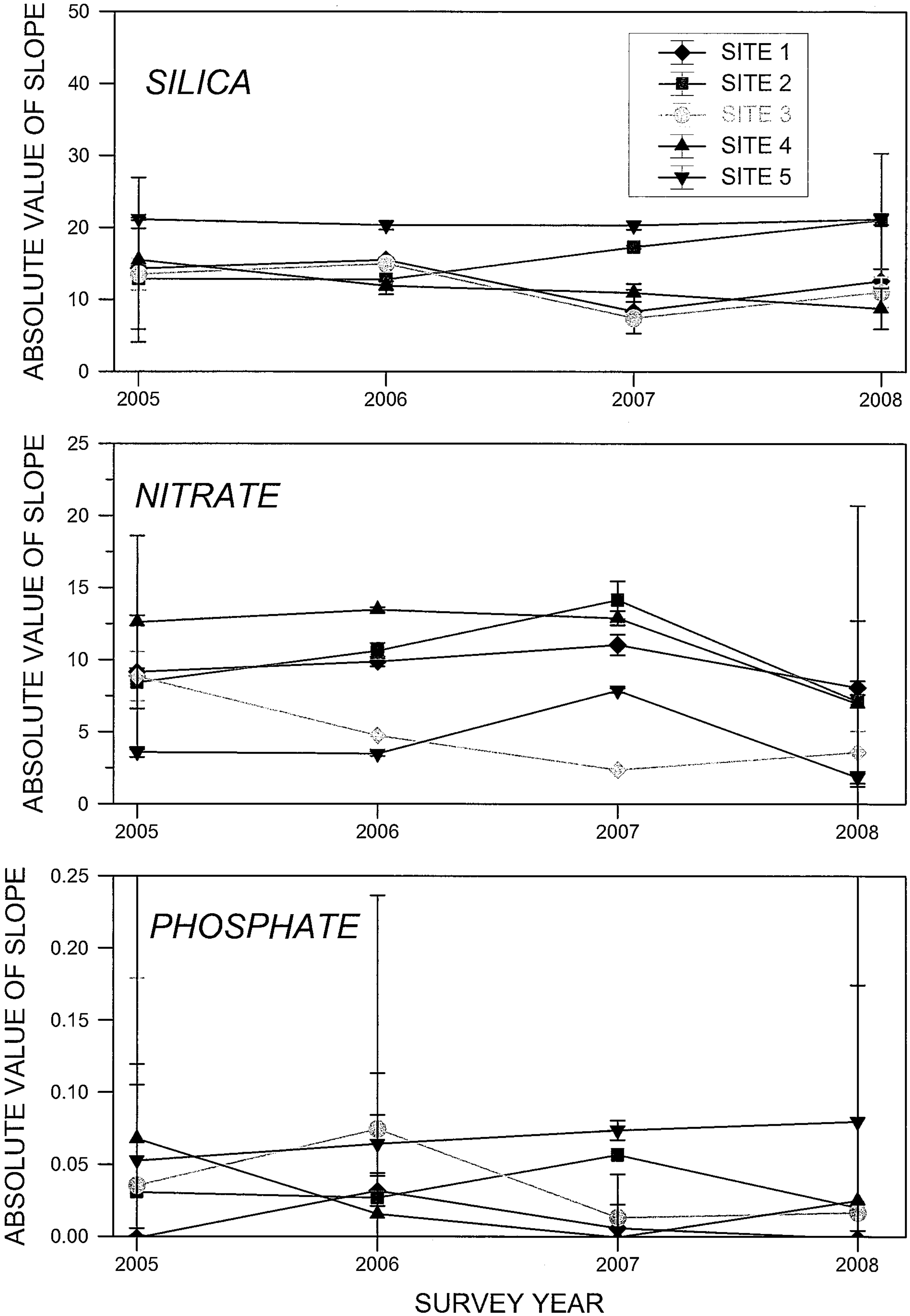

FIGURE 22. Time-course plots of absolute values of slopes of linear regressions of concentrations of silca, nitrate and phosphate as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations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

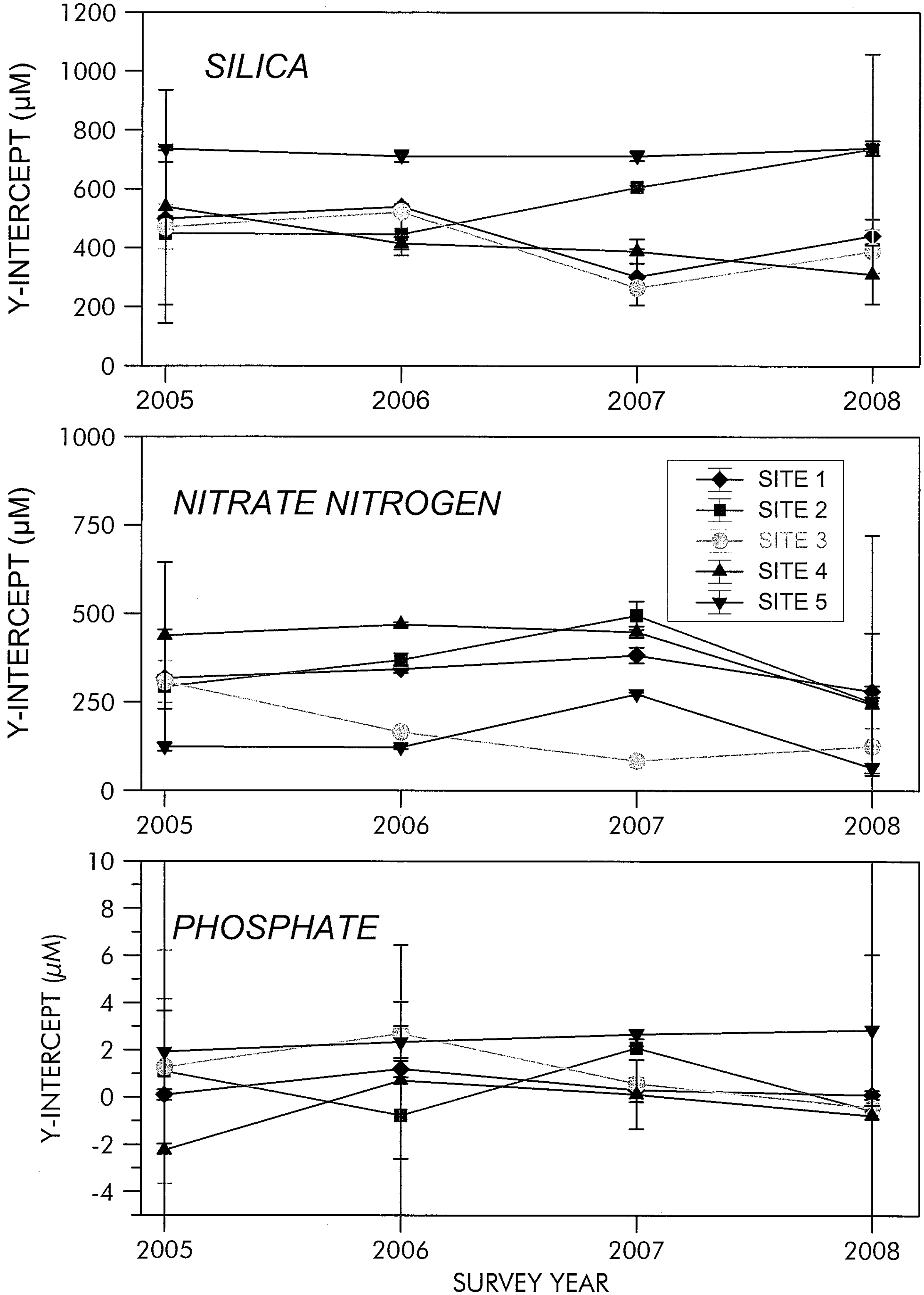

FIGURE 23. Time-course plots of Y-intercepts of linear regressions of concentrations of silca, nitrate and phosphorus as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations of sampling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

MARINE ENVIRONMENTAL

MONITORING PROGRAM:

HONUA'ULA

WAILEA, MAUI

<u>WATER CHEMISTRY</u>

<u>REPORT 1-2009</u>

Prepared for

Wailea 670 Associates
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by

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Honolulu, HI 96722

Submitted
June 2009

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. 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, 250 of which will be provided off-site, thus reducing the total number of homes on-site to 1,150), village mixed uses, a single homeowners golf course, and other recreational amenities. 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 one mile of coastline.

The Honua'ula development plan includes residential units, commercial uses, one 18-hole golf course covering approximately 200 acres, affordable housing, as well as acreage for parks, and open space that will be utilized for landscape buffers and drainage ways. 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 retention of surface drainage on the golf course, and a private waste 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.

With the intention of evaluating these effects, one of the Conditions of Zoning for Honua'ula (No. 20) stipulated..."*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.*

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." To date, HIDOH, which is the agency responsible for developing TMDL's (rather than property owners) has not performed this action for any marine areas off Maui.

This report represents the second monitoring effort to take place since the establishment of conditions of Zoning (Condition 20). However, prior to approval of the conditions three increments of monitoring to establish baseline conditions for Honua'ula have been conducted in 2005, 2006 and 2008. Hence, the following report conducted in January 2009 presents the results of the fifth phase of the monitoring program for the Honua'ula project.

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 Honua'ula. 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 was conducted on January 24, 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 seven 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 shortly after the marine monitoring survey. 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 μM (0.14 μg/L) for NO_3^- and NH_4^+, 0.01 μM (0.31 μg/L) for PO_4^{3-}, 0.1 μM (1.4 μg/L) for TN and 0.1 μM (3.1 μg/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 μg/L). Salinity was determined using an AGE Model 2100 laboratory salinometer with a precision of 0.0003‰.

In situ field measurements normally include water temperature, pH, dissolved oxygen and salinity which are acquired using an RBR Model XR-420 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. During the January 2009 survey, however, meter malfunction precluded the recording of temperature and dissolved oxygen.

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 January 24, 2009 reported in micromolar units (μM). Table 2 shows similar results presented in units of micrograms per liter (μg/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 μM and μg/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^-, TN, PO_4^{3-} and TP 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 much decreased 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 2 and 4, 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 17.3‰ and 4.9‰ between the shoreline and offshore terminus of transects at Sites 2 and 4, respectively (Tables 1 and 2). Transects at Sites 1, 3 and 5 had elevated nutrient concentrations and depressed salinities near the shoreline, but the horizontal gradients were far less pronounced compared to Transects 2 and 4.

The pattern of elevated Si, NO_3^-, TN, PO_4^{3-} and TP 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, and physical mixing condition (primarily by wind and wave stirring) at the sampling location.

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). The surface concentration of NH_4^+ was distinctly higher within 50 m of the shoreline at all sites (Figure 2, Tables 1 and 2). Concentrations of TOP were relatively constant at all sampling locations on all transect sites with Site 2 having slightly higher concentrations compared to the other four sites (Figure 2). At Site 2, TON increased by an order of magnitude between the shoreline and 25 m offshore (Figure 2), while at the other four sites patterns of horizontal distribution were absent.

Surface concentrations of turbidity were nearly double in magnitude near the shoreline compared to offshore measurements at transect Sites 1, 4 and 5 (Figure 3 and Tables 1 and 2). These sites also had the highest turbidity measurements (0.19- 0.23 NTU) compared to the other two sites. Beyond the shoreline, turbidity was relatively constant across the transects, and was of the same magnitude among the five transect sites. Concentrations of Chl *a* displayed a similar trend to turbidity, with values measured within 10 m of the shoreline higher than measurements farther offshore (Figure 3, Tables 1 and 2). Chl *a* in the shoreline samples at Sites 3 and 5 were more than twice that of the other sites during January 2009. Surface temperature was not recorded during this survey and thus are not reported.

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 can persist for some distance from shore. Buoyant surface layers are generally found in areas with both distinct input of groundwater, and where turbulent processes (primarily wave action) are insufficient to completely mix the water column in the nearshore zone. During the January 2009 survey, vertical stratification was apparent in the concentrations of nutrients that occur in relatively high concentrations in groundwater (Si, NO_3^-, PO_4^{3-}, TN), as well as for salinity. Such stratification was evident at all sites with elevated concentrations of nutrients, and lower salinities, in surface samples relative to the corresponding bottom sample. Such gradients suggest that the groundwater was not completely mixed within the water column in the nearshore zone.

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 January 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.

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 are the data for the most recent survey in January 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, but have been consistently highest at Site 1 and Control Site 5 (Figures 4-18). In the most recent survey (January 2009) the concentrations of Si, NO_3^-, TN, and PO_4^{3-}were slightly higher than the mean values at Sites 2, 3 and 4. 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 influenced by groundwater efflux was not distinctly different during the January 2009 survey compared to the average values of the numerous surveys conducted in past years. Elevated concentrations near the shorelines of some stations are reflected by depressed salinity, indicating increased groundwater input as a result of tidal and sea conditions. 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 the Wailea Golf Courses. 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-}, NH_4^+) as functions of salinity for the samples collected at each site in January 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 Irrigation Well No. 5 located to the northwest of the project area, and bottom ocean water.

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 a single data point 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 pure mix of groundwater similar to that from Well No. 5, and open coastal water. The single anomalous data point collected from the shoreline at Site 2 fell off the linear array below the conservative mixing line. The deviation of this nearshore point suggest that groundwater entering the ocean at the shoreline at Site 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 at Site 1. In fact, in previous surveys, the deviation has been larger than occurred in January 2009. 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 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). When plotted versus salinity, the shoreline sample from Site 2 also falls below the mixing line, although by a smaller margin than was evident for Si.

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). With the exception of Sites 2 and 4 during the June 2008 survey, linear regressions of the surface concentrations of NO_3^- as a function of salinity have had R^2 values of at least 0.95 for all five transects during all surveys, indicating highly significant linearity. 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 are not causing any 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 Site 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 only the concentrations of samples collected during multiple samplings at different stages of tide and weather 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 originating from land based activities to groundwater 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 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 annual nutrient concentrations when 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). 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 twenty-seven of the sixty samples collected were above the 10% criteria for NO_3^- under "dry" or "wet" conditions in the January 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^-. These results contrast to the results of the September 1991 survey, when all sample values were below DOH standards for NO_3^-. During the September 1991 survey, efflux of groundwater at the shoreline (based on decreased salinity) was greatly reduced compared to other surveys.

In addition to NO_3^-, eighteen measurements of NH_4^+, two measurements of TP, nine measurements of TN, and nine measurements of Chl *a* exceeded the 10% DOH criteria under "dry" conditions in January 2009. If "wet" criteria are applied, thirty-eight measurements of NH_4^+, twenty-two measurements of TN, and fifteen measurement of Chl *a* exceeded the DOH water quality standards. No measurements of TP exceeded the "wet" criteria. During the January 2009 survey, no measurements of turbidity exceeded either the "dry" or "wet" DOH standards.

Tables 4 and 5 show geometric means of samples collected at the same locations during the five 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 but one surface water measurements of NO_3^-, 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. SUMMARY

- The fifth phase of the water quality monitoring program for the planned Honua'ula project was carried out in January 2009. Sixty ocean water samples were collected on four transects spaced along the projects ocean frontage and one transect located outside of the project area. 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-Kinau Natural Area Reserve approximately four km to the south of the Wailea golf courses. 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 from seven irrigation wells and a golf-course reservoir in the Wailea area upslope of the sampling area.

- Water chemistry constituents that occur in high concentration in groundwater (Si, NO_3^- and TN, and PO_4^{3-}) displayed 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 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 2 and 4. 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 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 January 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 likely either leaching of golf course or landscaping fertilizers to groundwater that flows under the 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.

- The next phase of the Honua'ula monitoring program is scheduled for the second half of 2009.

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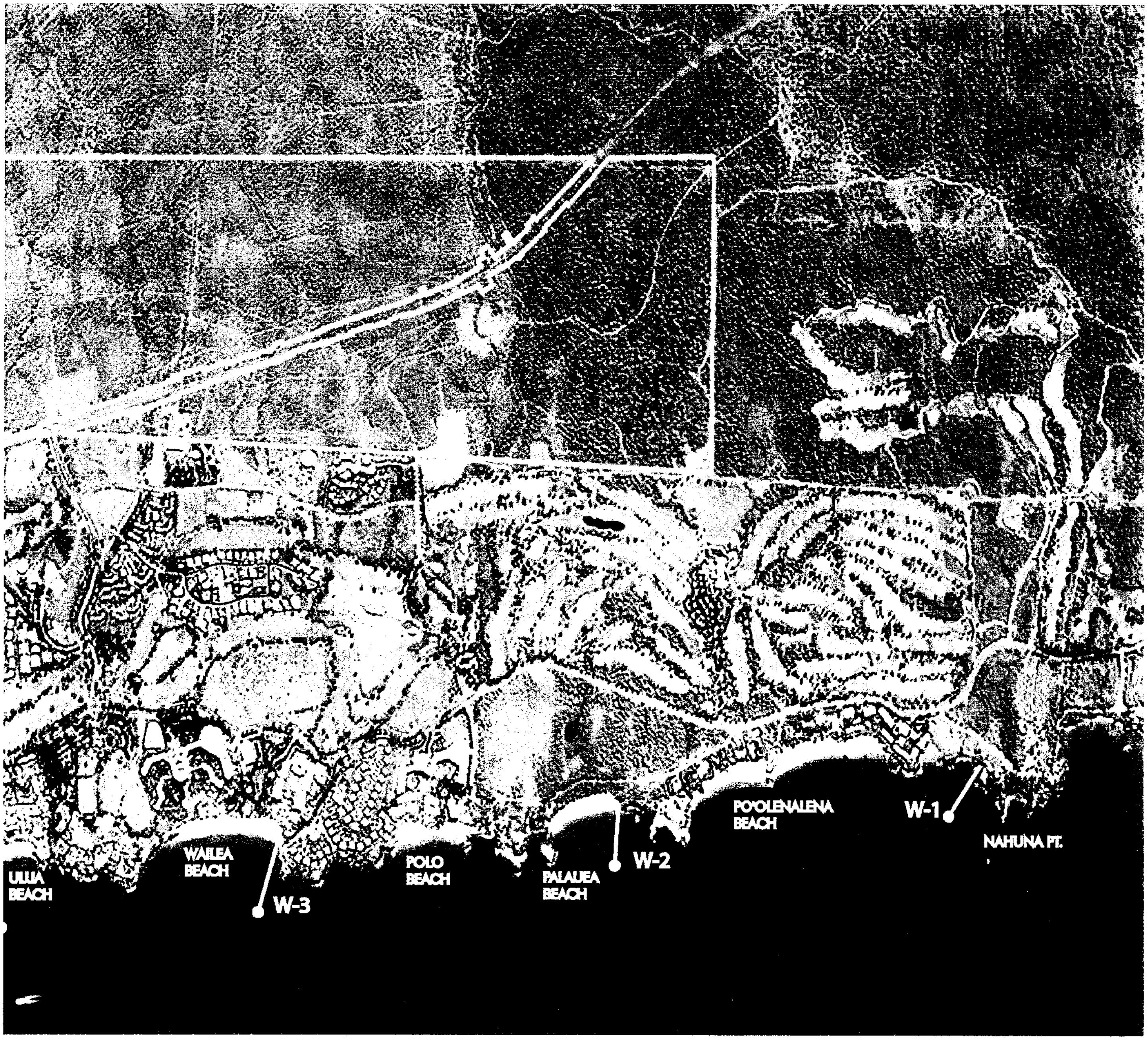

ıh of Wailea area showing boundaries of Honua'ula Project (in yellow) and locations of marine water
'ransect W-5 is considered a control and is located in the Ahihi-Kinau Natural Area Reserve approximately
'ula Project site.

TABLE 1. Water chemistry measurements from ocean water samples collected in the vicinity of the Honua'ula project site on January 24, 2009. Abbreviations as follows: DFS=distance from shore; S=surface; D=deep, BDL=below detection limit (Note: temperature and O2 data not measured during this survey). 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)	pH (std.units)
WAILEA 1	0 S	0.1	0.23	12.12	0.12	62.08	0.30	10.37	0.53	22.61	0.10	32.277	0.34	8.168
	2 S	0.1	0.20	11.00	1.11	62.73	0.34	9.63	0.54	21.74	0.09	32.296	0.72	8.211
	5 S	0.1	0.05	3.81	BDL	19.80	0.29	9.48	0.34	13.29	0.08	34.200	0.54	8.018
	5 D	1.0	0.15	3.86	0.51	20.41	0.35	B.59	0.50	12.96	0.09	34.188	0.39	8.020
	10 S	0.1	0.07	0.60	0.16	5.26	0.32	6.33	0.39	7.09	0.07	34.859	0.16	8.046
	10 D	1.7	0.08	0.43	0.17	4.62	0.32	8.61	0.40	9.21	0.10	34.895	0.22	8.046
	50 S	0.1	0.02	0.26	0.67	2.58	0.32	8.81	0.34	9.74	0.08	34.945	0.15	8.050
	50 D	4.4	0.09	0.20	0.08	2.64	0.31	B.88	0.40	9.16	0.09	34.928	0.15	8.046
	100 S	0.1	0.03	0.26	0.12	2.38	0.30	8.24	0.33	8.62	0.10	34.967	0.10	8.078
	100 D	6.2	0.01	0.19	0.12	2.43	0.31	7.60	0.32	7.91	0.14	34.957	0.09	8.080
	150 S	0.1	0.02	0.07	0.19	1.41	0.32	9.44	0.34	9.70	0.11	35.010	0.10	8.119
	150 D	11.7	0.07	0.06	0.13	1.40	0.35	10.66	0.42	10.85	0.14	34.992	0.08	8.121
WAILEA 2	0 S	0.1	0.72	155.7	2.36	192.8	0.40	0.60	1.12	158.7	0.11	17.745	0.28	8.173
	2 S	0.1	0.60	76.48	2.72	136.8	0.48	7.68	1.0B	86.88	0.10	26.736	0.71	8.133
	5 S	0.1	0.18	12.10	0.32	25.21	0.29	7.25	0.47	19.67	0.10	33.651	0.30	8.026
	5 D	1.0	0.18	10.55	0.25	22.71	0.25	9.80	0.43	20.60	0.09	33.816	0.27	8.031
	10 S	0.1	0.09	3.78	0.46	8.83	0.28	8.72	0.37	12.96	0.11	34.576	0.17	8.036
	10 D	2.0	0.16	3.21	0.49	8.22	0.26	6.78	0.42	10.48	0.12	34.657	0.21	8.038
	50 S	0.1	0.15	4.60	0.58	9.57	0.28	9.06	0.43	14.24	0.10	34.572	0.15	8.051
	50 D	4.9	0.25	1.02	0.52	3.11	0.26	5.98	0.51	7.52	0.09	34.920	0.16	8.051
	100 S	0.2	0.12	0.25	0.54	1.49	0.29	7.68	0.41	8.47	0.10	35.010	0.12	8.114
	100 D	8.7	0.08	0.19	0.33	1.89	0.29	6.25	0.37	6.77	0.09	34.997	0.10	8.113
	150 S	0.1	0.07	0.12	0.26	1.39	0.32	8.00	0.39	8.38	0.09	35.027	0.07	8.126
	150 D	14.4	0.06	0.05	0.39	1.27	0.31	10.55	0.37	10.99	0.09	35.032	0.08	8.129
WAILEA 3	0 S	0.1	0.12	18.30	5.28	22.36	0.40	6.31	0.52	29.89	0.14	33.677	2.45	8.123
	2 S	0.1	0.14	14.90	1.58	20.27	0.32	7.36	0.46	23.84	0.10	33.900	1.66	8.139
	5 S	0.1	0.10	6.23	0.49	10.74	0.27	4.43	0.37	11.15	0.09	34.518	0.20	8.083
	5 D	1.0	0.10	6.27	0.71	10.80	0.31	7.32	0.41	14.30	0.14	34.509	0.23	8.080
	10 S	0.1	0.08	3.43	0.68	6.61	0.29	8.14	0.37	12.25	0.11	34.732	0.13	8.085
	10 D	1.0	0.06	1.26	0.87	3.33	0.27	6.26	0.33	8.39	0.10	34.924	0.19	8.091
	50 S	0.1	0.37	0.33	2.73	1.90	0.27	9.89	0.64	12.95	0.10	34.983	0.35	8.118
	50 D	4.0	0.07	0.19	0.67	1.68	0.29	8.85	0.36	9.71	0.10	34.991	0.21	8.126
	100 S	0.1	0.12	0.19	0.70	1.51	0.30	8.88	0.42	9.77	0.09	34.984	0.15	8.126
	100 D	6.1	0.11	0.13	0.43	1.53	0.33	11.18	0.44	11.74	0.09	34.977	0.12	8.128
	150 S	0.1	0.06	0.22	0.60	1.92	0.27	6.70	0.33	7.52	0.07	34.983	0.10	8.129
	150 D	11.2	0.05	0.27	0.61	1.81	0.29	8.10	0.34	8.98	0.08	34.975	0.09	8.129
WAILEA 4	0 S	0.1	0.44	40.19	0.56	70.87	0.24	4.67	0.68	45.42	0.19	30.131	0.53	8.068
	2 S	0.1	0.36	30.80	1.30	52.47	0.23	4.28	0.59	36.38	0.23	31.418	0.50	8.086
	5 S	0.1	0.23	6.24	0.70	13.03	0.28	7.44	0.51	14.38	0.14	34.356	0.35	8.081
	5 D	1.0	0.08	4.91	0.65	11.88	0.29	9.13	0.37	14.69	0.10	34.447	0.23	8.083
	10 S	0.1	0.16	5.09	0.40	12.25	0.26	7.96	0.42	13.45	0.10	34.403	0.31	8.080
	10 D	1.0	0.19	3.53	0.08	9.18	0.30	6.17	0.49	9.78	0.10	34.584	0.36	8.081
	50 S	0.1	0.14	5.52	0.05	13.05	0.29	7.23	0.43	12.80	0.09	34.355	0.36	8.068
	50 D	5.2	0.05	1.27	0.03	4.78	0.29	7.98	0.34	9.28	0.09	34.843	0.41	8.085
	100 S	0.1	0.34	20.19	0.36	39.89	0.20	6.10	0.54	26.65	0.09	32.798	0.25	8.060
	100 D	9.8	0.14	0.59	BDL	2.47	0.30	11.22	0.44	11.81	0.09	34.947	0.20	8.090
	150 S	0.1	0.10	0.14	0.26	1.56	0.33	9.43	0.43	9.83	0.07	34.986	0.14	8.131
	150 D	12.3	0.14	0.11	0.02	1.67	0.34	7.15	0.48	7.28	0.08	34.979	0.17	8.133
WAILEA 5	0 S	0.1	0.12	28.48	1.34	36.62	0.36	3.72	0.48	33.54	0.10	32.756	1.47	8.123
	2 S	0.1	0.08	21.28	3.70	23.06	0.41	6.24	0.49	31.22	0.19	33.373	2.34	8.126
	5 S	0.1	0.09	3.85	0.40	6.98	0.35	5.19	0.44	9.44	0.09	34.716	0.40	8.118
	5 D	1.0	0.05	2.96	0.28	6.50	0.48	7.65	0.53	10.89	0.09	34.762	0.58	8.114
	10 S	0.1	0.05	1.45	0.72	3.68	0.36	7.05	0.41	9.22	0.08	34.906	0.64	8.098
	10 D	2.0	0.12	1.31	0.92	3.33	0.32	5.92	0.44	8.15	0.08	34.918	2.29	8.101
	50 S	0.1	0.05	0.62	0.61	2.47	0.41	7.48	0.46	8.71	0.08	34.960	1.45	8.123
	50 D	4.4	0.05	0.56	0.83	2.39	0.50	7.10	0.55	8.49	0.09	34.968	0.80	8.123
	100 S	0.1	0.06	0.09	0.35	1.37	0.44	5.92	0.50	6.36	0.07	34.995	0.19	8.131
	100 D	6.4	0.04	0.07	0.37	1.35	0.42	4.67	0.46	5.11	0.09	34.999	0.26	8.129
	150 S	0.1	0.07	0.09	0.29	1.67	0.36	8.45	0.43	8.83	0.09	35.026	0.33	8.131
	150 D	7.7	0.06	0.08	0.28	1.69	0.34	7.71	0.40	8.07	0.10	34.995	0.63	8.128
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 $\mu g/L$) collected off the Honua'ula project site on January 24, 2009. Abbreviations as follows: DFS=distance from shore; S=surface; D=deep, BDL=below detection limit (Note: temperature and O2 data not measured during this survey). 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 ($\mu g/L$)	NO3 ($\mu g/L$)	NH4 ($\mu g/L$)	Si ($\mu g/L$)	TOP ($\mu g/L$)	TON ($\mu g/L$)	TP ($\mu g/L$)	TN ($\mu g/L$)	TURB (NTU)	SALINITY (ppt)	CHL a ($\mu g/L$)	pH (std.units)
WAILEA 1	0 S	0.1	7.12	169.8	1.68	1744	9.29	145.2	16.42	316.7	0.10	32.277	0.34	8.17
	2 S	0.1	6.19	154.1	15.55	1763	10.53	134.9	16.73	304.5	0.09	32.296	0.72	8.21
	5 S	0.1	1.55	53.36	BDL	556.4	8.98	132.8	10.53	186.1	0.08	34.200	0.54	8.02
	5 D	1.0	4.65	54.06	7.14	573.5	10.84	120.3	15.49	181.5	0.09	34.188	0.39	8.02
	10 S	0.1	2.17	8.40	2.24	147.8	9.91	88.66	12.08	99.3	0.07	34.859	0.16	8.05
	10 D	1.7	2.48	6.02	2.38	129.8	9.91	120.6	12.39	129.0	0.10	34.895	0.22	8.05
	50 S	0.1	0.62	3.64	9.38	72.50	9.91	123.4	10.53	136.4	0.08	34.945	0.15	8.05
	50 D	4.4	2.79	2.80	1.12	74.18	9.60	124.4	12.39	128.3	0.09	34.928	0.15	8.05
	100 S	0.1	0.93	3.64	1.68	66.88	9.29	115.4	10.22	120.7	0.10	34.967	0.10	8.08
	100 D	6.2	0.31	2.66	1.68	68.28	9.60	106.4	9.91	110.8	0.14	34.957	0.09	8.08
	150 S	0.1	0.62	0.98	2.66	39.62	9.91	132.2	10.53	135.9	0.11	35.010	0.10	8.12
	150 D	11.7	2.17	0.84	1.82	39.34	10.84	149.3	13.01	152.0	0.14	34.992	0.08	8.12
WAILEA 2	0 S	0.1	22.30	2181	33.05	5417	12.39	8.40	34.69	2222	0.11	17.745	0.28	8.17
	2 S	0.1	18.58	1071	38.10	3845	14.87	107.6	33.45	1217	0.10	26.736	0.71	8.13
	5 S	0.1	5.58	169.5	4.48	708.4	8.98	101.5	14.56	275.5	0.10	33.651	0.30	8.03
	5 D	1.0	5.58	147.8	3.50	638.2	7.74	137.3	13.32	288.5	0.09	33.816	0.27	8.03
	10 S	0.1	2.79	52.94	6.44	248.1	8.67	122.1	11.46	181.5	0.11	34.576	0.17	8.04
	10 D	2.0	4.96	44.96	6.86	231.0	8.05	94.96	13.01	146.8	0.12	34.657	0.21	8.04
	50 S	0.1	4.65	64.43	8.12	268.9	8.67	126.9	13.32	199.4	0.10	34.572	0.15	8.05
	50 D	4.9	7.74	14.29	7.28	87.39	8.05	83.76	15.80	105.3	0.09	34.920	0.16	8.05
	100 S	0.2	3.72	3.50	7.56	41.87	8.98	107.6	12.70	118.6	0.10	35.010	0.12	8.11
	100 D	8.7	2.48	2.66	4.62	53.11	8.98	87.54	11.46	94.8	0.09	34.997	0.10	8.11
	150 S	0.1	2.17	1.68	3.64	39.06	9.91	112.0	12.08	117.4	0.09	35.027	0.07	8.13
	150 D	14.4	1.86	0.70	5.46	35.69	9.60	147.8	11.46	153.9	0.09	35.032	0.08	8.13
WAILEA 3	0 S	0.1	3.72	256.3	73.95	628.3	12.39	88.38	16.11	418.6	0.14	33.677	2.45	8.12
	2 S	0.1	4.34	208.7	22.13	569.6	9.91	103.1	14.25	333.9	0.10	33.900	1.66	8.14
	5 S	0.1	3.10	87.26	6.86	301.8	8.36	62.05	11.46	156.2	0.09	34.518	0.20	8.08
	5 D	1.0	3.10	87.82	9.94	303.5	9.60	102.5	12.70	200.3	0.14	34.509	0.23	8.08
	10 S	0.1	2.48	48.04	9.52	185.7	8.98	114.0	11.46	171.6	0.11	34.732	0.13	8.09
	10 D	1.0	1.86	17.65	12.19	93.57	8.36	87.68	10.22	117.5	0.10	34.924	0.19	8.09
	50 S	0.1	11.46	4.62	38.24	53.39	8.36	138.5	19.82	181.4	0.10	34.983	0.35	8.12
	50 D	4.0	2.17	2.66	9.38	47.21	8.98	124.0	11.15	136.0	0.10	34.991	0.21	8.13
	100 S	0.1	3.72	2.66	9.80	42.43	9.29	124.4	13.01	136.8	0.09	34.984	0.15	8.13
	100 D	6.1	3.41	1.82	6.02	42.99	10.22	156.6	13.63	164.4	0.09	34.977	0.12	8.13
	150 S	0.1	1.86	3.08	8.40	53.95	8.36	93.84	10.22	105.3	0.07	34.983	0.10	8.13
	150 D	11.2	1.55	3.78	8.54	50.86	8.98	113.4	10.53	125.8	0.08	34.975	0.09	8.13
WAILEA 4	0 S	0.1	13.63	562.9	7.84	1991	7.43	65.41	21.06	636.2	0.19	30.131	0.53	8.07
	2 S	0.1	11.15	431.4	18.21	1474	7.12	59.95	18.27	509.5	0.23	31.418	0.50	8.09
	5 S	0.1	7.12	87.40	9.80	366.1	8.67	104.2	15.80	201.4	0.14	34.356	0.35	8.08
	5 D	1.0	2.48	68.77	9.10	333.8	8.98	127.9	11.46	205.7	0.10	34.447	0.23	8.08
	10 S	0.1	4.96	71.29	5.60	344.2	8.05	111.5	13.01	188.4	0.10	34.403	0.31	8.08
	10 D	1.0	5.88	49.44	1.12	258.0	9.29	86.42	15.18	137.0	0.10	34.584	0.36	8.08
	50 S	0.1	4.34	77.31	0.70	366.7	8.98	101.3	13.32	179.3	0.09	34.355	0.36	8.07
	50 D	5.2	1.55	17.79	0.42	134.3	8.98	111.8	10.53	130.0	0.09	34.843	0.41	8.09
	100 S	0.1	10.53	282.8	5.04	1121	6.19	85.44	16.73	373.3	0.09	32.798	0.25	8.06
	100 D	9.8	4.34	8.26	BDL	69.41	9.29	157.1	13.63	165.4	0.09	34.947	0.20	8.09
	150 S	0.1	3.10	1.96	3.64	43.84	10.22	132.1	13.32	137.7	0.07	34.986	0.14	8.13
	150 D	12.3	4.34	1.54	0.28	46.93	10.53	100.1	14.87	102.0	0.08	34.979	0.17	8.13
WAILEA 5	0 S	0.1	3.72	398.9	18.77	1029	10.53	52.10	14.87	469.8	0.10	32.756	1.47	8.12
	2 S	0.1	2.48	298.0	51.82	648.0	10.53	87.40	15.18	437.3	0.19	33.373	2.34	8.13
	5 S	0.1	2.79	53.92	5.60	196.1	10.53	72.69	13.63	132.2	0.09	34.716	0.40	8.12
	5 D	1.0	1.55	41.46	3.92	182.7	10.53	107.1	16.42	152.5	0.09	34.762	0.58	8.11
	10 S	0.1	1.55	20.31	10.08	103.4	10.53	98.74	12.70	129.1	0.08	34.906	0.64	8.10
	10 D	2.0	3.72	18.35	12.89	93.57	10.53	82.92	13.63	114.1	0.08	34.918	2.29	8.10
	50 S	0.1	1.55	8.68	8.54	69.41	10.53	104.8	14.25	122.0	0.08	34.960	1.45	8.12
	50 D	4.4	1.55	7.84	11.62	67.16	10.53	99.44	17.04	118.9	0.09	34.968	0.80	8.12
	100 S	0.1	1.86	1.26	4.90	38.50	10.53	82.92	15.49	89.1	0.07	34.995	0.19	8.13
	100 D	6.4	1.24	0.98	5.18	37.94	10.53	65.41	14.25	71.6	0.09	34.999	0.26	8.13
	150 S	0.1	2.17	1.26	4.06	46.93	10.53	118.4	13.32	123.7	0.09	35.026	0.33	8.13
	150 D	7.7	1.86	1.12	3.92	47.49	10.53	108.0	12.39	113.0	0.10	34.995	0.63	8.13
DOH WQS		DRY	10%	10.00	5.00				30.00	180.00	0.50	*	0.50	***
			2%	20.00	9.00				45.00	250.00	1.00		1.00	
		WET	10%	14.00	8.50				40.00	250.00	1.25	*	0.90	***
			2%	25.00	15.00				60.00	350.00	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 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=5). 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	42.05	0.40	72.13	0.28	7.05	0.44	54.06	0.20	28.930	1.16	25.83	8.15	101.73
	2 S	1	0.11	32.12	0.05	61.90	0.28	7.63	0.42	43.04	0.16	30.321	1.43	25.84	8.17	104.49
	5 S	1	0.05	11.59	0.04	26.18	0.30	9.15	0.36	22.44	0.15	32.827	0.57	25.86	8.12	102.36
	5 D	2.5	0.07	6.30	0.22	16.39	0.29	8.80	0.37	15.70	0.09	33.926	0.30	25.85	8.13	101.38
	10 S	1	0.07	4.66	0.22	12.84	0.28	8.58	0.36	14.63	0.11	34.033	0.40	25.92	8.12	107.68
	10 D	3	0.06	1.63	0.26	5.69	0.30	8.57	0.37	10.96	0.11	34.564	0.34	25.85	8.11	106.72
	50 S	1	0.04	2.77	0.33	8.29	0.29	8.62	0.35	13.55	0.10	34.290	0.33	25.88	8.13	101.83
	50 D	4.5	0.07	0.27	0.18	2.31	0.30	8.78	0.38	9.56	0.10	34.732	0.28	25.60	8.12	94.34
	100 S	1	0.06	2.63	0.25	7.54	0.29	8.29	0.37	13.06	0.11	34.304	0.24	25.97	8.12	97.14
	100 D	10	0.04	0.13	0.23	1.83	0.29	8.59	0.35	9.20	0.10	34.845	0.18	25.59	8.13	93.56
	150 S	1	0.06	0.68	0.33	3.31	0.30	10.11	0.39	12.41	0.17	34.611	0.24	26.04	8.12	96.12
	150 D	15	0.07	0.08	0.21	1.44	0.31	9.54	0.38	10.00	0.10	34.845	0.20	25.55	8.13	92.65
WAILEA 2	0 S	1	0.21	20.33	0.13	34.80	0.19	6.37	0.64	43.20	0.16	25.260	0.43	25.97	8.08	94.93
	2 S	1	0.20	15.16	0.17	28.01	0.27	7.14	0.59	32.91	0.16	30.100	0.46	25.98	8.11	98.65
	5 S	1	0.11	6.56	0.19	13.25	0.28	8.77	0.43	18.14	0.16	33.715	0.32	26.05	8.12	99.90
	5 D	2.5	0.12	3.73	0.24	8.45	0.28	8.70	0.42	13.38	0.16	34.393	0.38	26.00	8.13	99.55
	10 S	1	0.08	1.28	0.19	6.17	0.29	8.47	0.38	11.32	0.12	34.616	0.22	26.10	8.13	99.31
	10 D	3	0.07	1.13	0.20	3.72	0.29	7.46	0.38	9.27	0.12	34.703	0.27	26.14	8.13	100.10
	50 S	1	0.08	2.88	0.22	6.20	0.28	7.91	0.39	11.30	0.12	34.577	0.20	26.03	8.13	96.44
	50 D	4.5	0.13	0.23	0.36	1.86	0.28	7.56	0.42	8.46	0.11	34.860	0.22	25.68	8.13	91.58
	100 S	1	0.11	0.88	0.39	3.05	0.28	8.45	0.42	10.07	0.12	34.756	0.17	25.64	8.13	94.27
	100 D	10	0.08	0.09	0.24	1.45	0.30	7.17	0.39	7.63	0.12	34.888	0.21	25.61	8.14	91.63
	150 S	1	0.07	0.20	0.21	2.28	0.29	8.45	0.37	9.34	0.12	34.814	0.14	26.21	8.14	96.17
	150 D	15	0.08	0.06	0.21	1.24	0.29	8.29	0.37	8.68	0.08	34.921	0.14	25.65	8.14	92.02
WAILEA 3	0 S	1	0.15	6.36	0.42	19.72	0.30	8.35	0.48	19.24	0.20	31.395	0.58	26.18	8.12	98.28
	2 S	1	0.11	3.20	0.39	10.66	0.31	8.09	0.43	13.56	0.20	34.112	0.53	26.25	8.13	97.70
	5 S	1	0.10	2.32	0.31	8.80	0.30	7.02	0.41	10.85	0.17	34.327	0.44	26.30	8.13	98.49
	5 D	2.5	0.11	2.70	0.42	9.67	0.30	8.58	0.43	12.85	0.20	34.297	0.38	26.33	8.13	98.77
	10 S	1	0.11	2.24	0.42	8.88	0.27	7.45	0.40	11.17	0.15	34.287	0.24	26.36	8.13	98.14
	10 D	5	0.09	1.40	0.42	7.49	0.28	7.08	0.39	9.85	0.17	34.422	0.34	26.21	8.13	99.34
	50 S	1	0.16	1.05	0.62	5.45	0.32	9.14	0.51	11.75	0.14	34.609	0.38	25.95	8.14	97.25
	50 D	10	0.08	0.21	0.51	2.33	0.33	8.22	0.43	9.28	0.13	34.836	0.29	25.82	8.15	94.54
	100 S	1	0.10	0.81	0.44	4.66	0.30	8.63	0.41	10.87	0.16	34.625	0.33	26.07	8.14	96.35
	100 D	15	0.07	0.05	0.24	1.93	0.32	9.15	0.40	9.61	0.12	34.874	0.22	25.70	8.14	92.14
	150 S	1	0.07	0.34	0.44	2.87	0.30	7.80	0.39	9.24	0.15	34.780	0.18	26.04	8.13	92.60
	150 D	20	0.07	0.08	0.42	1.75	0.29	7.57	0.37	8.27	0.10	34.902	0.19	25.63	8.14	89.90
WAILEA 4	0 S	1	0.11	11.05	0.29	21.21	0.27	6.84	0.42	28.94	0.26	31.915	0.47	26.29	8.12	99.83
	2 S	1	0.08	6.56	0.50	13.99	0.28	7.78	0.40	21.38	0.20	33.402	0.54	26.27	8.15	99.05
	5 S	1	0.10	1.94	0.26	6.69	0.30	8.19	0.42	12.56	0.15	34.414	0.51	26.28	8.15	104.03
	5 D	2.5	0.09	1.83	0.25	6.64	0.30	9.11	0.40	13.52	0.14	34.399	0.34	26.28	8.15	103.72
	10 S	1	0.12	0.84	0.44	4.58	0.29	10.67	0.44	13.24	0.17	34.706	0.37	26.32	8.14	104.57
	10 D	3	0.15	0.51	0.29	3.64	0.29	7.76	0.46	9.47	0.15	34.778	0.33	26.36	8.13	103.13
	50 S	1	0.12	3.25	0.29	6.80	0.30	9.04	0.43	13.54	0.20	34.444	0.41	26.49	8.12	95.08
	50 D	10	0.08	0.18	0.17	2.51	0.26	8.90	0.39	9.72	0.12	34.880	0.36	25.72	8.12	91.55
	100 S	1	0.10	3.24	0.34	7.77	0.28	8.65	0.41	14.44	0.15	34.217	0.26	26.18	8.11	94.81
	100 D	15	0.10	0.11	0.15	1.80	0.33	9.22	0.46	9.93	0.10	34.912	0.20	25.67	8.13	90.66
	150 S	1	0.08	0.95	0.19	3.69	0.33	7.92	0.42	9.65	0.10	34.751	0.16	26.23	8.12	93.03
	150 D	25	0.07	0.07	0.14	1.63	0.33	7.75	0.43	8.22	0.11	34.896	0.19	25.58	8.14	90.73
WAILEA 5	0 S	1	0.37	22.56	0.93	93.75	0.28	4.83	0.75	40.90	0.25	26.369	0.99	25.30	8.05	88.87
	2 S	1	0.31	16.61	1.52	70.91	0.24	6.77	0.70	34.77	0.24	27.984	0.72	25.53	8.06	90.41
	5 S	1	0.15	6.00	0.82	32.46	0.30	9.28	0.50	18.00	0.21	32.836	0.49	25.57	8.08	95.56
	5 D	1.5	0.07	3.49	0.46	19.74	0.29	8.34	0.41	12.59	0.14	33.839	0.43	25.61	8.10	95.66
	10 S	1	0.05	1.58	0.49	9.58	0.28	8.39	0.36	10.55	0.13	34.454	0.26	25.81	8.09	96.64
	10 D	2.5	0.12	1.65	0.60	9.95	0.26	6.93	0.39	9.31	0.13	34.419	0.48	25.67	8.09	96.19
	50 S	1	0.10	0.86	0.60	6.81	0.30	8.00	0.41	9.66	0.14	34.604	0.28	25.49	8.12	92.82
	50 D	9	0.06	0.16	0.40	2.81	0.30	7.24	0.38	7.91	0.13	34.816	0.28	25.50	8.11	91.25
	100 S	1	0.12	0.29	0.51	5.33	0.30	7.16	0.44	8.23	0.14	34.658	0.17	25.78	8.11	93.76
	100 D	14	0.06	0.14	0.36	2.84	0.29	6.81	0.37	7.64	0.13	34.785	0.21	25.51	8.13	91.09
	150 S	1	0.06	0.28	0.37	2.67	0.28	7.73	0.38	8.68	0.12	34.811	0.18	25.76	8.13	93.51
	150 D	18	0.05	0.05	0.21	1.65	0.30	7.64	0.37	8.03	0.11	34.885	0.22	25.54	8.14	92.01
DOH WQS	DRY			0.25	0.14				0.52	7.86	0.20	*	0.15	**	***	
GEOMETRIC MEAN	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=5). 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	588.95	5.60	2,026.13	8.67	98.74	13.62	757.16	0.20	28.93	1.16	25.83	8.15	101.73
	2 S	1	3.40	449.87	0.70	1,738.77	8.67	106.86	13.00	602.81	0.16	30.32	1.43	25.84	8.17	104.49
	5 S	1	1.54	162.32	0.56	735.40	9.29	128.15	11.15	314.29	0.15	32.83	0.57	25.86	8.12	102.36
	5 D	2.5	2.16	88.23	3.08	460.40	8.98	123.25	11.46	219.89	0.09	33.93	0.30	25.85	8.13	101.38
	10 S	1	2.16	65.26	3.08	360.68	8.67	120.17	11.15	204.90	0.11	34.03	0.40	25.92	8.12	107.68
	10 D	3	1.85	22.82	3.64	159.83	9.29	120.03	11.46	153.50	0.11	34.56	0.34	25.85	8.11	106.72
	50 S	1	1.23	38.79	4.62	232.87	8.98	120.73	10.84	189.78	0.10	34.29	0.33	25.88	8.13	101.83
	50 D	4.5	2.16	3.78	2.52	64.89	9.29	122.97	11.76	133.89	0.10	34.73	0.28	25.60	8.12	94.34
	100 S	1	1.85	36.83	3.50	211.80	8.98	116.10	11.46	182.91	0.11	34.30	0.24	25.97	8.12	97.14
	100 D	10	1.23	1.82	3.22	51.40	B.98	120.31	10.84	128.85	0.10	34.85	0.18	25.59	8.13	93.56
	150 S	1	1.85	9.52	4.62	92.98	9.29	141.60	12.07	173.81	0.17	34.61	0.24	26.04	8.12	96.12
	150 D	15	2.16	1.12	2.94	40.45	9.60	133.61	11.76	140.06	0.10	34.85	0.20	25.55	8.13	92.65
WAILEA 2	0 S	1	6.50	284.74	1.82	977.53	5.88	89.21	19.82	605.05	0.16	25.26	0.43	25.97	8.08	94.93
	2 S	1	6.19	212.33	2.38	786.80	8.36	100.00	18.27	460.93	0.16	30.10	0.46	25.98	B.11	98.65
	5 S	1	3.40	91.87	2.66	372.19	8.67	122.83	13.31	254.06	0.16	33.72	0.32	26.05	8.12	99.90
	5 D	2.5	3.71	52.24	3.36	237.36	8.67	121.85	13.00	187.40	0.16	34.39	0.38	26.00	8.13	99.55
	10 S	1	2.47	17.92	2.66	173.32	8.98	118.63	11.76	158.54	0.12	34.62	0.22	26.10	8.13	99.31
	10 D	3	2.16	15.82	2.80	104.49	8.98	104.48	11.76	129.83	0.12	34.70	0.27	26.14	8.13	100.10
	50 S	1	2.47	40.33	3.08	174.16	8.67	110.78	12.07	158.26	0.12	34.58	0.20	26.03	8.13	96.44
	50 D	4.5	4.02	3.22	5.04	52.25	8.67	105.88	13.00	118.49	0.11	34.86	0.22	25.68	8.13	91.58
	100 S	1	3.40	12.32	5.46	85.67	8.67	118.35	13.00	141.04	0.12	34.76	0.17	25.64	8.13	94.27
	100 D	10	2.47	1.26	3.36	40.73	9.29	100.42	12.07	106.86	0.12	34.89	0.21	25.61	8.14	91.63
	150 S	1	2.16	2.80	2.94	64.05	8.98	118.35	11.46	130.81	0.12	34.81	0.14	26.21	8.14	96.17
	150 D	15	2.47	0.84	2.94	34.83	8.98	116.10	11.46	121.57	0.08	34.92	0.14	25.65	8.14	92.02
WAILEA 3	0 S	1	4.64	89.07	5.88	553.93	9.29	116.95	14.86	269.47	0.20	31.40	0.58	26.18	8.12	98.28
	2 S	1	3.40	44.81	5.46	299.44	9.60	113.30	13.31	189.92	0.20	34.11	0.53	26.25	8.13	97.70
	5 S	1	3.09	32.49	4.34	247.19	9.29	98.32	12.69	151.96	0.17	34.33	0.44	26.30	8.13	98.49
	5 D	2.5	3.40	37.81	5.88	271.63	9.29	120.17	13.31	179.97	0.20	34.30	0.38	26.33	8.13	98.77
	10 S	1	3.40	31.37	5.88	249.44	8.36	104.34	12.38	156.44	0.15	34.29	0.24	26.36	8.13	98.14
	10 D	5	2.78	19.60	5.88	210.39	8.67	99.16	12.07	137.95	0.17	34.42	0.34	26.21	8.13	99.34
	50 S	1	4.95	14.70	8.68	153.09	9.91	128.01	15.79	164.57	0.14	34.61	0.38	25.95	8.14	97.25
	50 D	10	2.47	2.94	7.14	65.45	10.22	115.12	13.31	129.97	0.13	34.84	0.29	25.82	8.15	94.54
	100 S	1	3.09	11.34	6.16	130.90	9.29	120.87	12.69	152.24	0.16	34.63	0.33	26.07	8.14	96.35
	100 D	15	2.16	0.70	3.36	54.21	9.91	128.15	12.38	134.59	0.12	34.87	0.22	25.70	8.14	92.14
	150 S	1	2.16	4.76	6.16	80.62	9.29	109.24	12.07	129.41	0.15	34.78	0.18	26.04	8.13	92.60
	150 D	20	2.16	1.12	5.8B	49.16	8.98	106.02	11.46	115.82	0.10	34.90	0.19	25.63	8.14	89.90
WAILEA 4	0 S	1	3.40	154.76	4.06	595.79	8.36	95.80	13.00	405.33	0.26	31.92	0.47	26.29	8.12	99.83
	2 S	1	2.47	91.87	7.00	392.98	8.67	108.96	12.38	299.44	0.20	33.40	0.54	26.27	8.15	99.05
	5 S	1	3.09	27.17	3.64	187.92	9.29	114.70	13.00	175.91	0.15	34.41	0.51	26.28	8.15	104.03
	5 D	2.5	2.78	25.63	3.50	186.52	9.29	127.59	12.38	189.36	0.14	34.40	0.34	26.28	8.15	103.72
	10 S	1	3.71	11.76	6.16	128.65	8.98	149.44	13.62	185.43	0.17	34.71	0.37	26.32	8.14	104.57
	10 D	3	4.64	7.14	4.06	102.25	8.98	108.68	14.24	132.63	0.15	34.78	0.33	26.36	8.13	103.13
	50 S	1	3.71	45.51	4.06	191.01	9.29	126.61	13.31	189.64	0.20	34.44	0.41	26.49	8.12	95.08
	50 D	10	2.47	2.52	2.38	70.51	8.05	124.65	12.07	136.13	0.12	34.88	0.36	25.72	8.12	91.55
	100 S	1	3.09	45.37	4.76	218.26	8.67	121.15	12.69	202.24	0.15	34.22	0.26	26.18	8.11	94.81
	100 D	15	3.09	1.54	2.10	50.56	10.22	129.13	14.24	139.07	0.10	34.91	0.20	25.67	8.13	90.66
	150 S	1	2.47	13.30	2.66	103.65	10.22	110.92	13.00	135.15	0.10	34.75	0.16	26.23	8.12	93.03
	150 D	25	2.16	0.98	1.96	45.79	10.22	108.54	13.31	115.12	0.11	34.90	0.19	25.58	8.14	90.73
WAILEA 5	0 S	1	11.46	315.97	13.02	2,633.44	8.67	67.64	23.22	572.84	0.25	26.37	0.99	25.30	8.05	88.87
	2 S	1	9.60	232.63	21.28	1,991.86	7.43	94.82	21.68	486.98	0.24	27.98	0.72	25.53	8.06	90.41
	5 S	1	4.64	84.03	11.48	911.80	9.29	129.97	15.48	252.10	0.21	32.84	0.49	25.57	8.0B	95.56
	5 D	1.5	2.16	48.88	6.44	554.50	8.98	116.81	12.69	176.33	0.14	33.84	0.43	25.61	8.10	95.66
	10 S	1	1.54	22.12	6.86	269.10	8.67	117.51	11.15	147.76	0.13	34.45	0.26	25.81	8.09	96.64
	10 D	2.5	3.71	23.10	8.40	279.50	8.05	97.06	12.07	130.39	0.13	34.42	0.48	25.67	8.09	96.19
	50 S	1	3.09	12.04	8.40	191.29	9.29	112.04	12.69	135.29	0.14	34.60	0.28	25.49	8.12	92.B2
	50 D	9	1.85	2.24	5.60	78.93	9.29	101.40	11.76	110.78	0.13	34.82	0.28	25.50	8.11	91.25
	100 S	1	3.71	4.06	7.14	149.72	9.29	100.28	13.62	115.26	0.14	34.66	0.17	25.78	8.11	93.76
	100 D	14	1.85	1.96	5.04	79.78	8.98	95.38	11.46	107.00	0.13	34.79	0.21	25.51	8.13	91.09
	150 S	1	1.85	3.92	5.18	75.00	8.67	108.26	11.76	121.57	0.12	34.81	0.18	25.76	8.13	93.51
	150 D	18	1.54	0.70	2.94	46.35	9.29	107.00	11.46	112.46	0.11	34.89	0.22	25.54	8.14	92.01
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.

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
pling site locations, see Figure 1.

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)
3159	bdl	bdl	524.2	14729	0.16	4.96	9.36	131.0	2.16	66.96	235.0	3290	1.48
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
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
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
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
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
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
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 January 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.

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	784.96	4.73	772.79	797.13
REGSLOPE	47.62	58.33	-138.00	233.23
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	415.06	33.32	329.41	500.72
REGSLOPE	22.35	48.38	-131.62	176.32
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	568.64	20.06	517.06	620.22
REGSLOPE	6.27	43.62	-132.55	145.08
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	493.68	20.20	441.76	545.61
REGSLOPE	-19.70	30.82	-117.77	78.38
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	515.08	23.39	454.95	575.22
REGSLOPE	-41.39	24.96	-120.84	38.05

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	-22.38	0.14	-22.74	-22.02
REGSLOPE	-1.33	1.70	-6.75	4.10
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	-11.64	1.05	-14.35	-8.93
REGSLOPE	-0.59	1.40	-5.05	3.87
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	-16.19	0.58	-17.69	-14.70
REGSLOPE	-0.15	1.27	-4.20	3.90
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	-13.99	0.61	-15.55	-12.43
REGSLOPE	0.61	0.89	-2.22	3.44
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	-14.66	0.68	-16.41	-12.91
REGSLOPE	1.21	0.72	-1.08	3.49

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 January 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	148.22	4.03	137.87	158.57
REGSLOPE	-40.03	23.12	-113.60	33.54
SITE 2				
2005	292.69	62.62	453.65	131.73
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	316.70	1.50	312.86	320.54
REGSLOPE	-7.19	34.23	-116.12	101.74
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	480.51	5.45	466.49	494.53
REGSLOPE	30.91	56.53	-148.98	210.81
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	292.04	6.14	276.25	307.82
REGSLOPE	-51.47	22.69	-123.68	20.74
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	444.99	3.73	435.41	454.57
REGSLOPE	58.65	45.25	-85.35	202.65

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	-4.23	0.12	-4.54	-3.93
REGSLOPE	1.16	0.67	-0.98	3.30
SITE 2				
2005	-8.40	1.81	-3.75	-13.06
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	-9.04	0.05	-9.16	-8.92
REGSLOPE	-0.86	1.62	-6.03	4.30
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	-13.73	0.16	-14.14	-13.33
REGSLOPE	-0.86	1.62	-6.03	4.30
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	-8.33	0.18	-8.80	-7.85
REGSLOPE	-0.86	1.62	-6.03	4.30
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	-12.71	0.11	-12.99	-12.43
REGSLOPE	-1.67	1.30	-5.79	2.46

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 January 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	2.42	0.26	1.76	3.08
REGSLOPE	0.35	0.31	-0.63	1.34
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	1.49	0.16	1.06	1.91
REGSLOPE	0.10	0.46	-1.36	1.56
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	-1.10	2.90	-8.57	6.36
REGSLOPE	-0.79	0.29	-1.73	0.15
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	2.47	0.33	1.64	3.31
REGSLOPE	0.80	0.45	-0.62	2.22
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	0.83	0.24	0.20	1.45
REGSLOPE	-0.17	0.28	-1.05	0.72

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	-0.07	0.01	-0.09	-0.05
REGSLOPE	-0.01	0.01	-0.04	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	-0.04	0.01	-0.05	-0.03
REGSLOPE	0.00	0.01	-0.05	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	0.04	0.08	-0.18	0.25
REGSLOPE	0.02	0.01	0.00	0.05
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	-0.07	0.01	-0.09	-0.04
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	-0.02	0.01	-0.04	0.00
REGSLOPE	0.00	0.01	-0.02	0.03

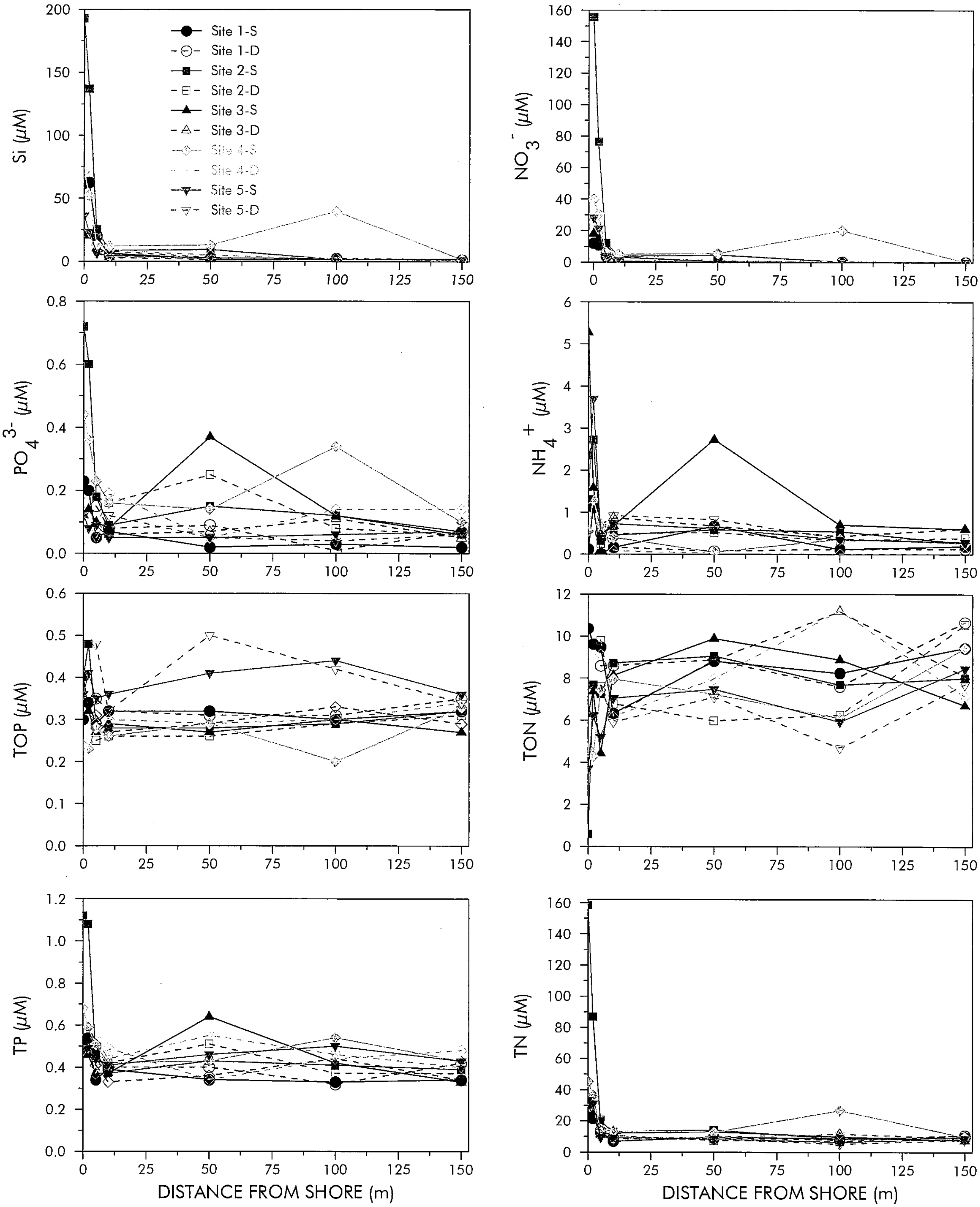

FIGURE 2. Plots of dissolved nutrients in surface (S) and deep (D) samples collected on January 24, 2009 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. For site locations, see Figure 1.

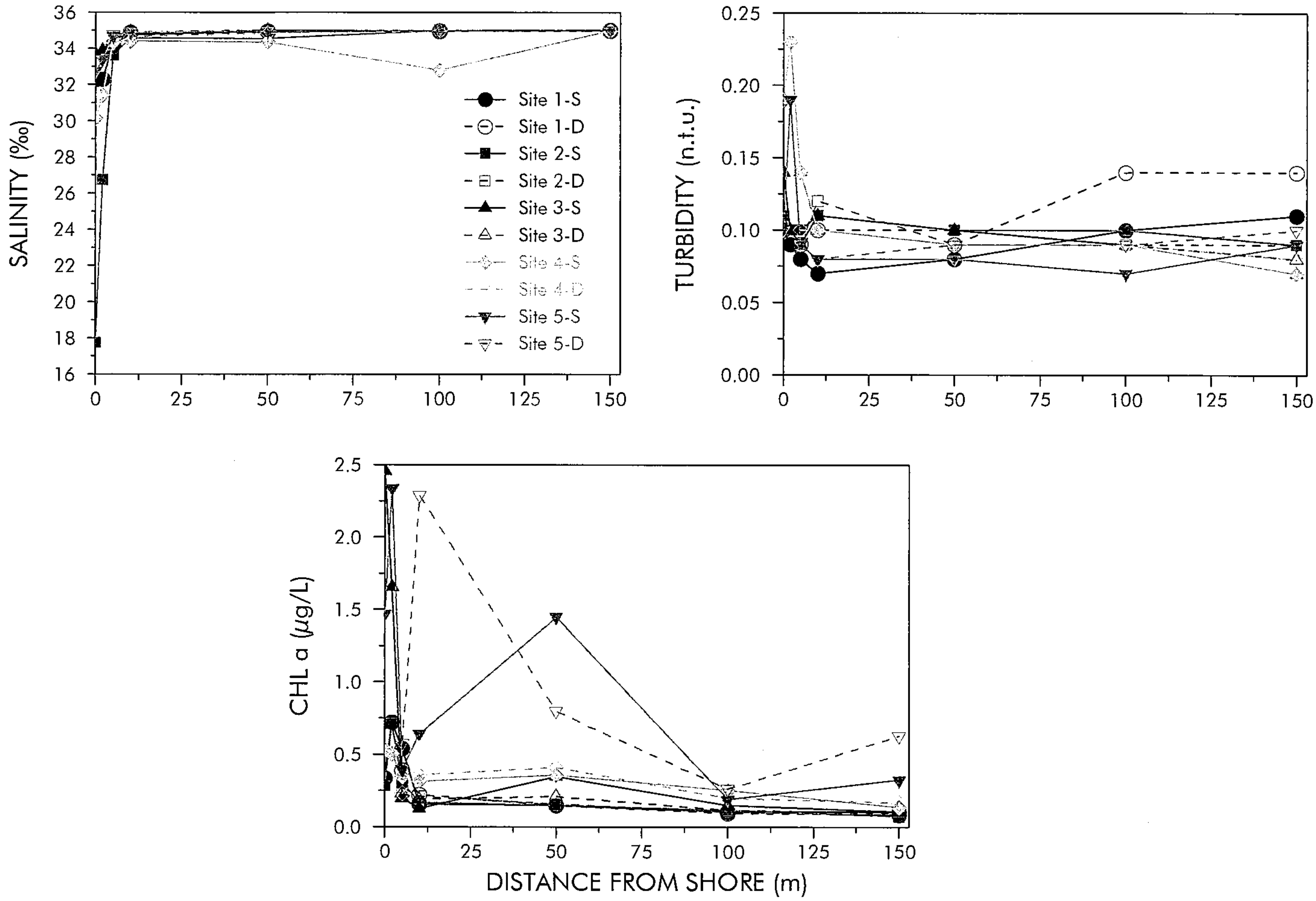

FIGURE 3. Plots of water chemistry constituents in surface (S) and deep (D) samples collected on January 24, 2009 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. Note: Temperatures not measured during this survey. For site locations, see Figure 1.

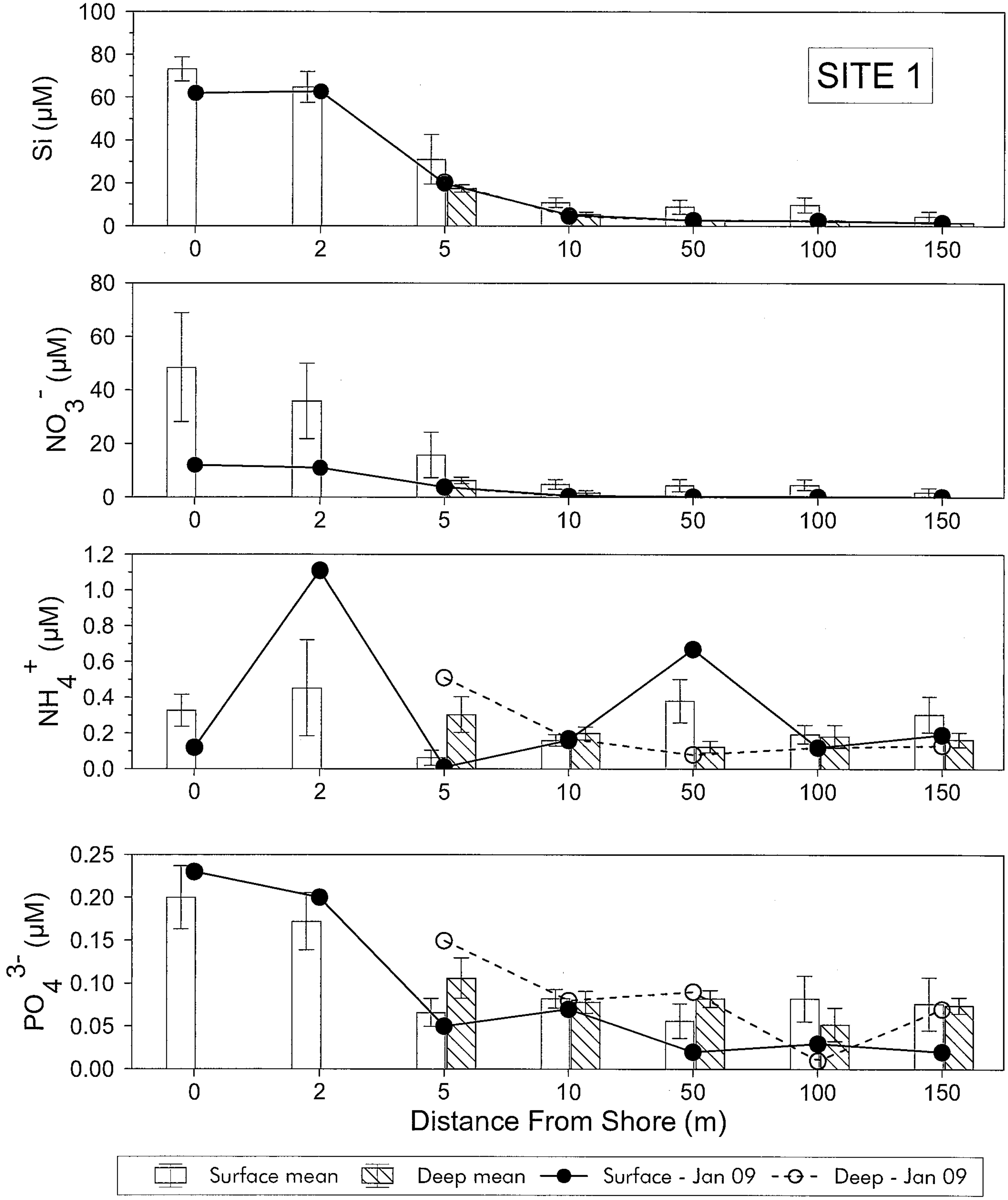

FIGURE 4. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

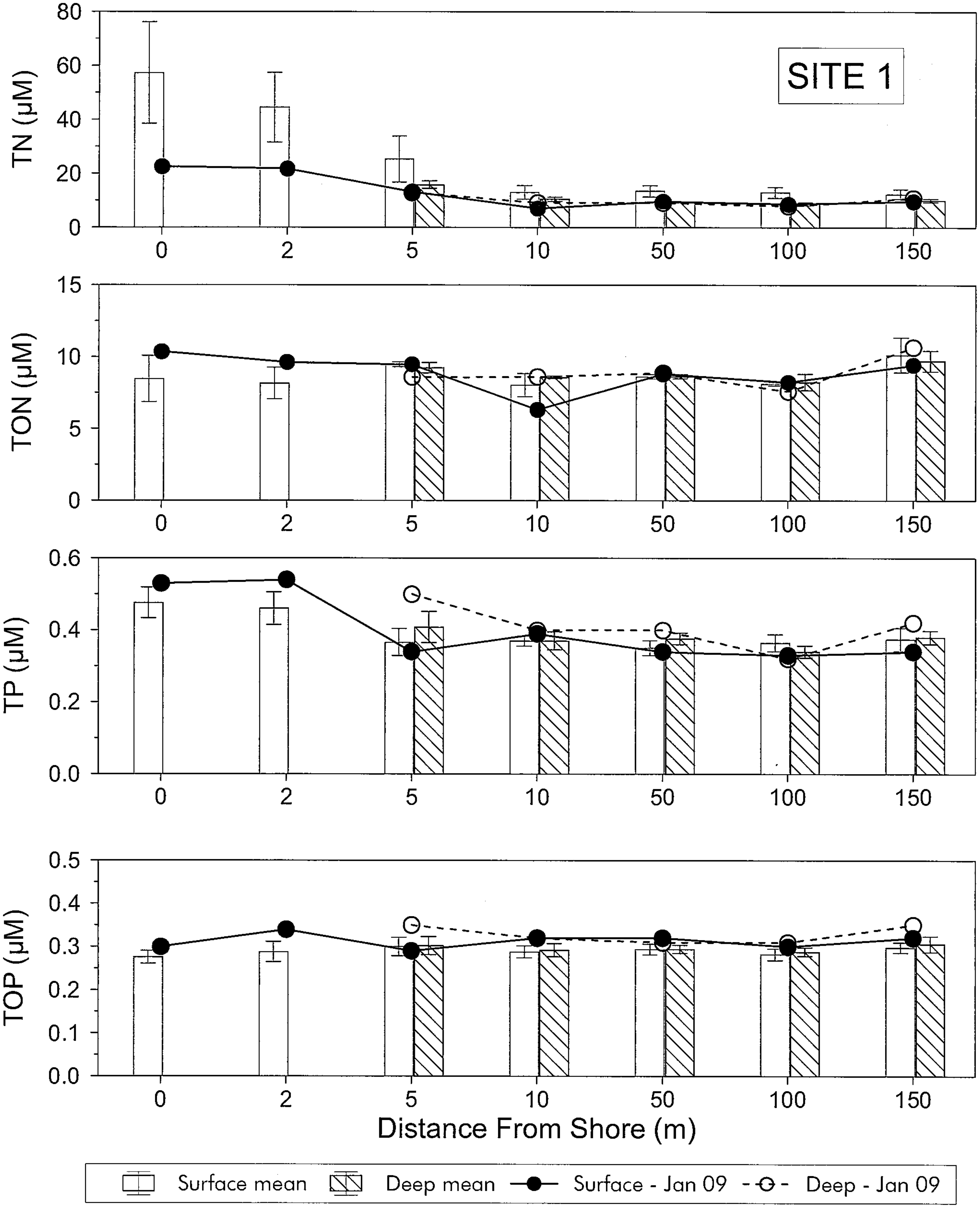

FIGURE 5. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent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

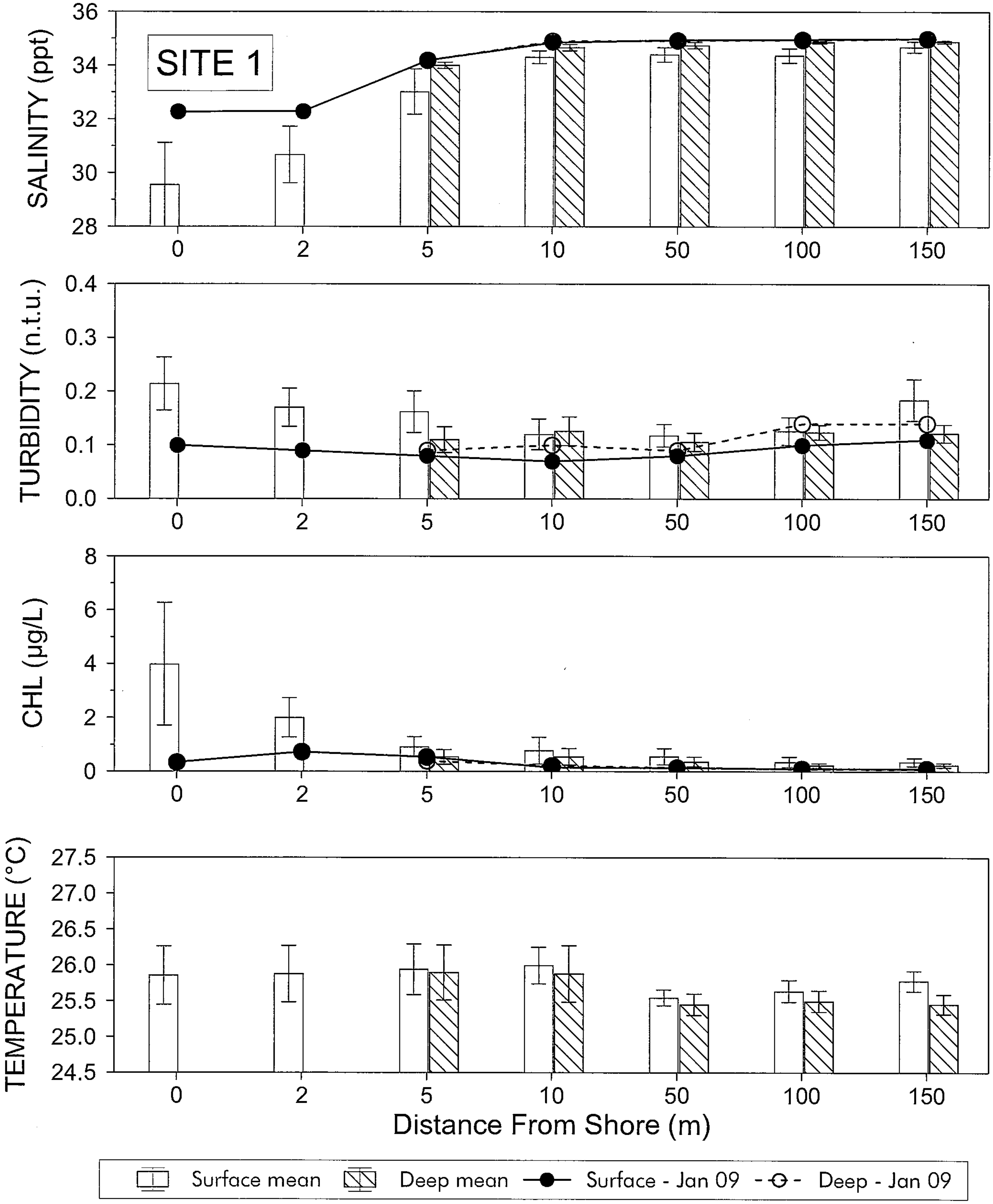

FIGURE 6. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey (Note: temperatures not measured in January 2009). Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

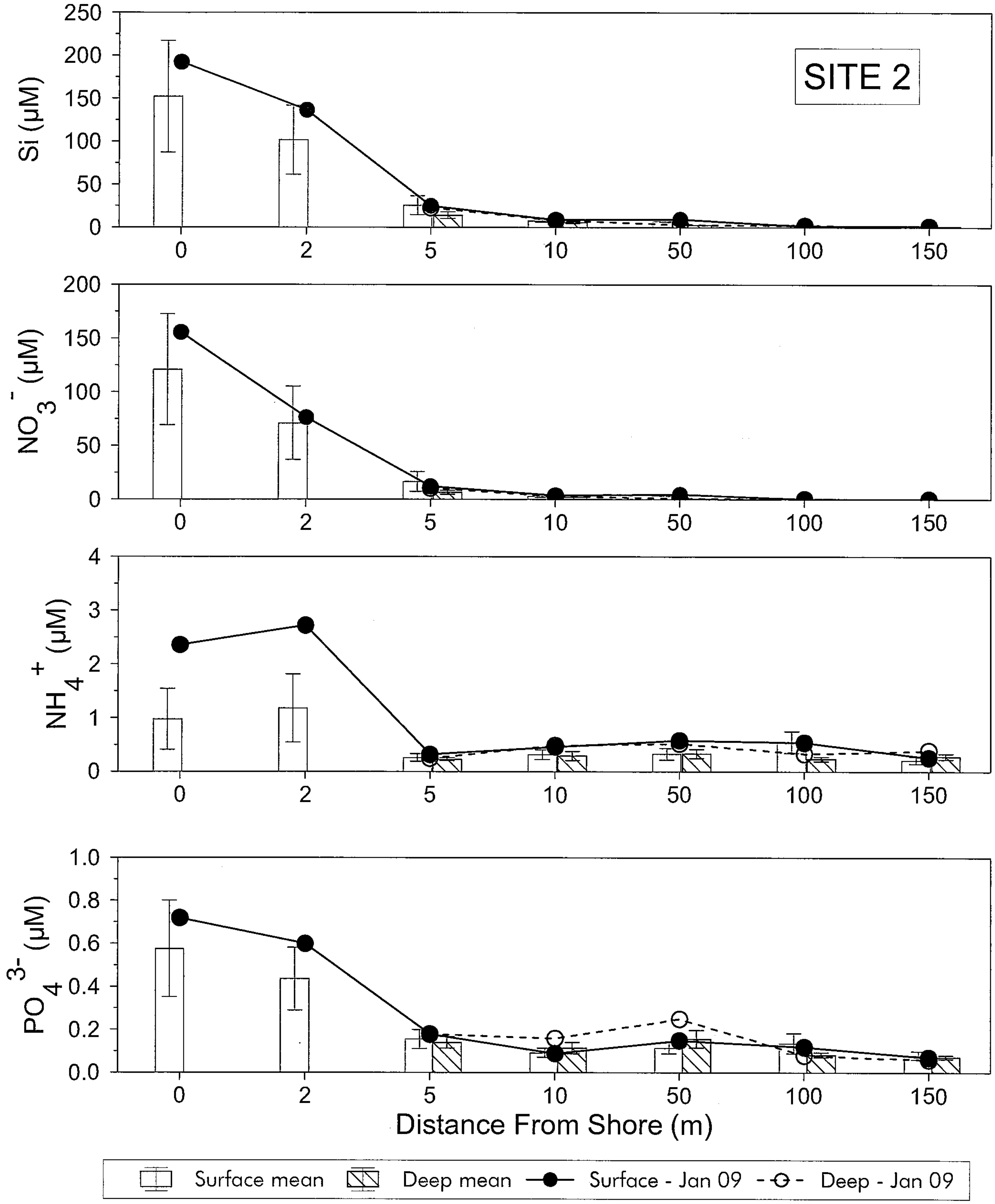

FIGURE 7. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

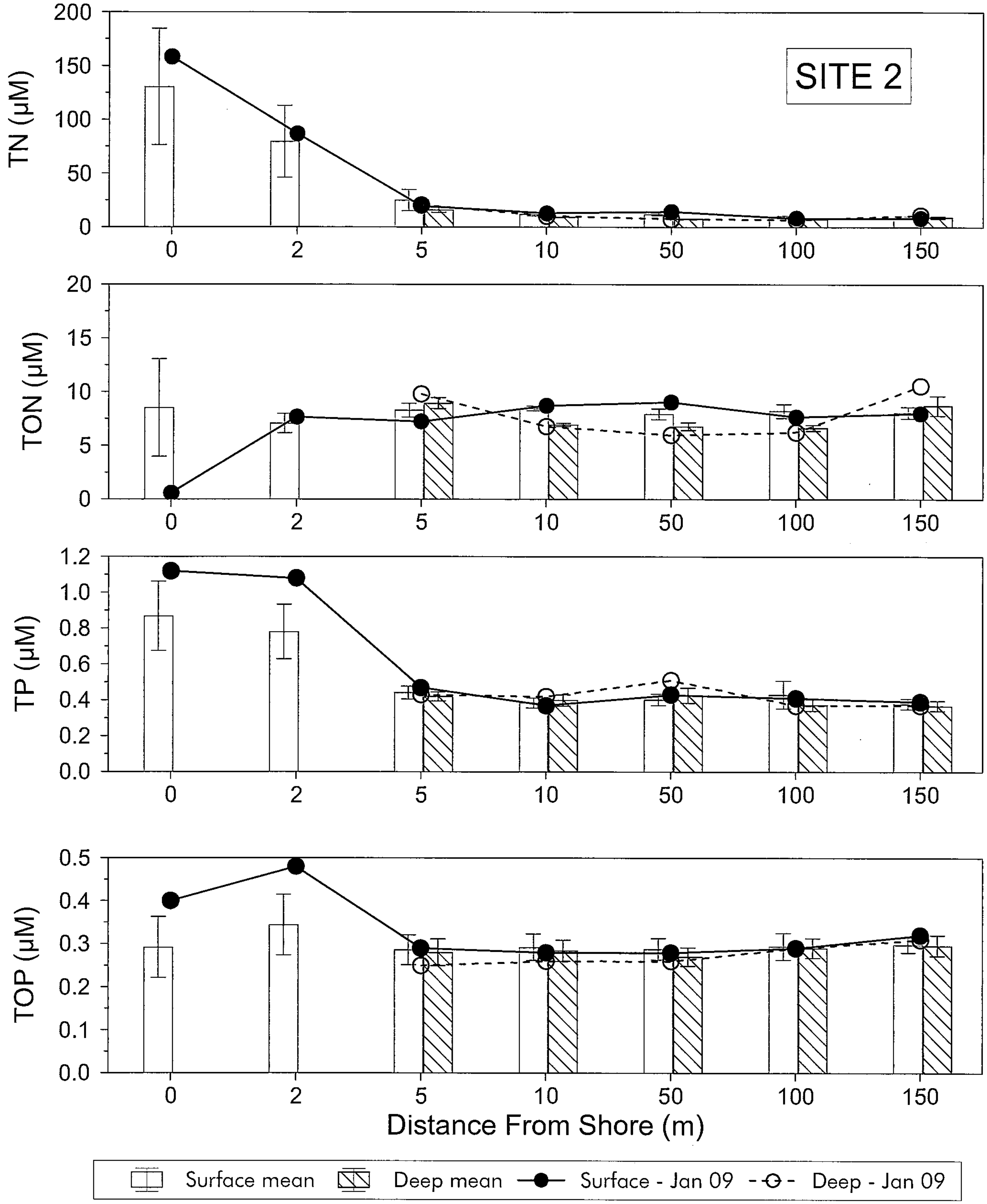

FIGURE 8. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

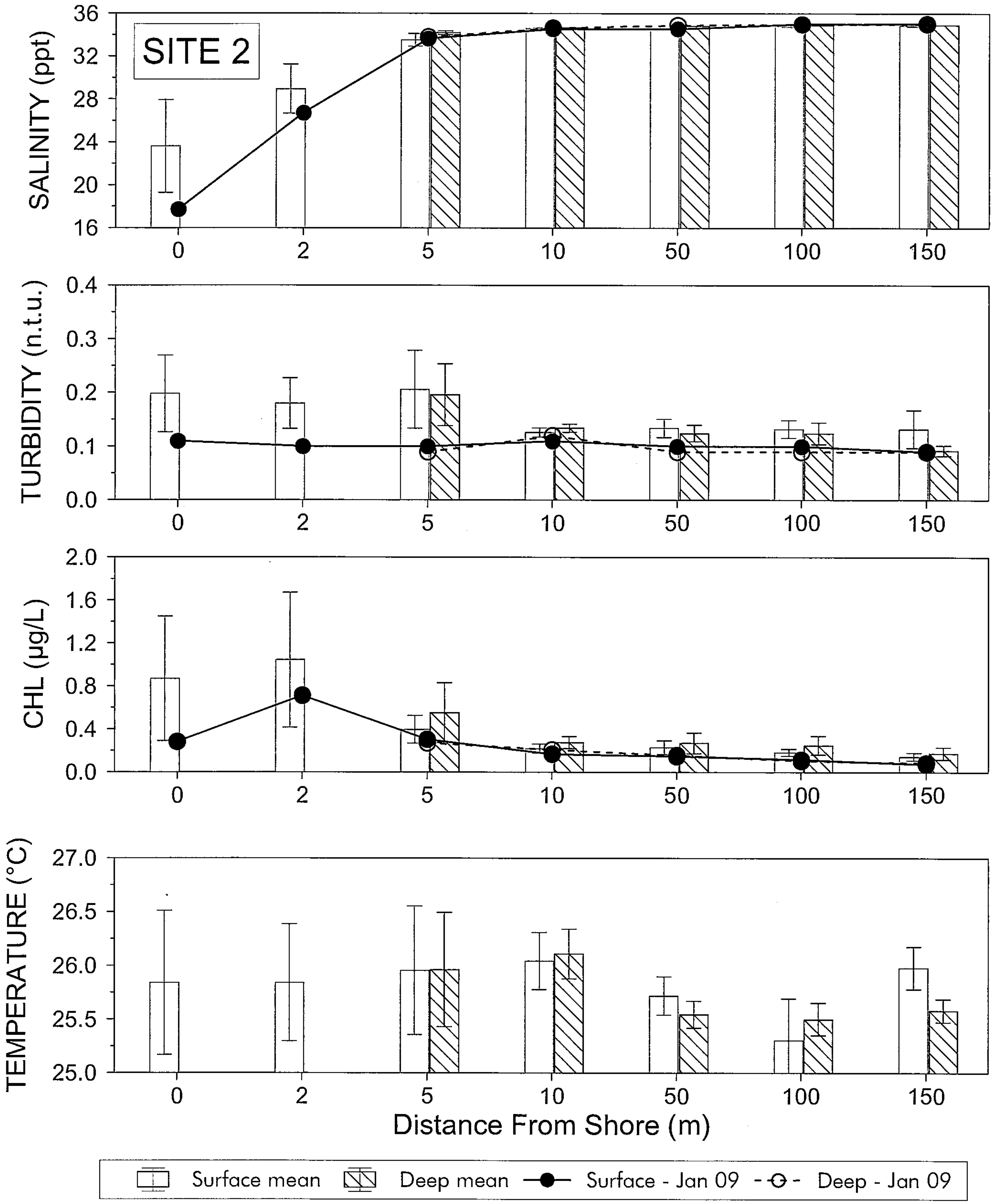

FIGURE 9. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey (Note: temperatures not measured in January 2009). Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

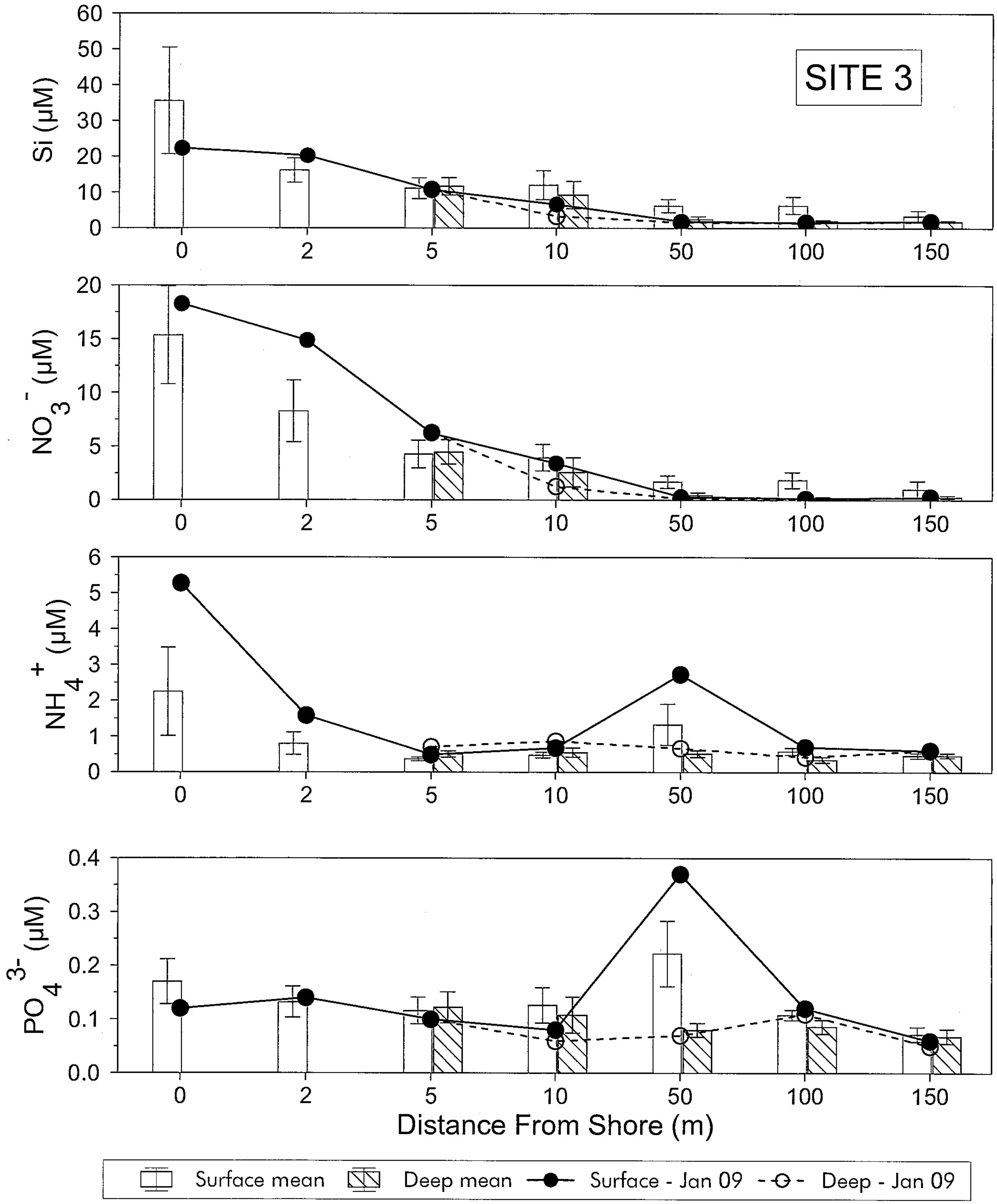

FIGURE 10. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

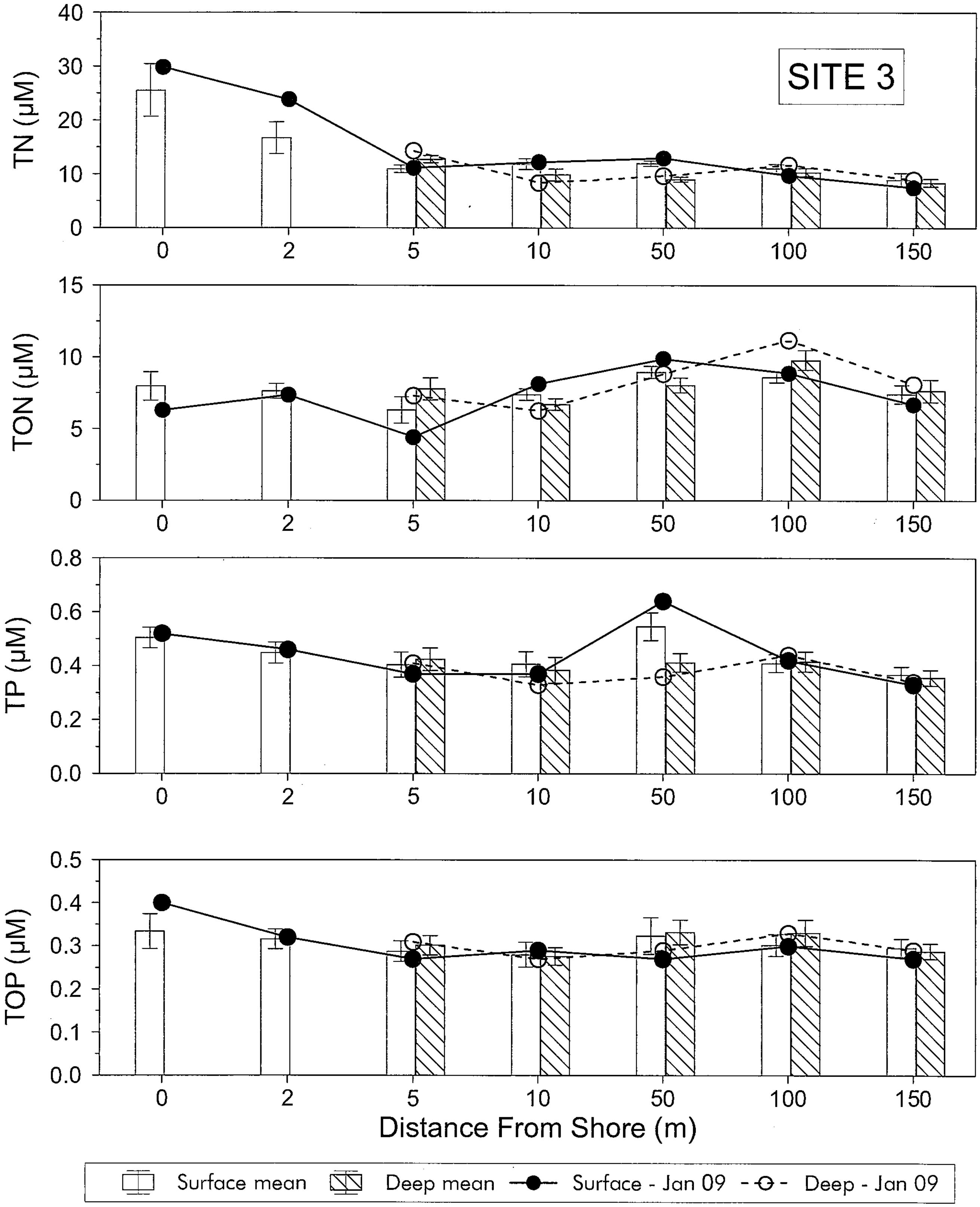

FIGURE 11. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

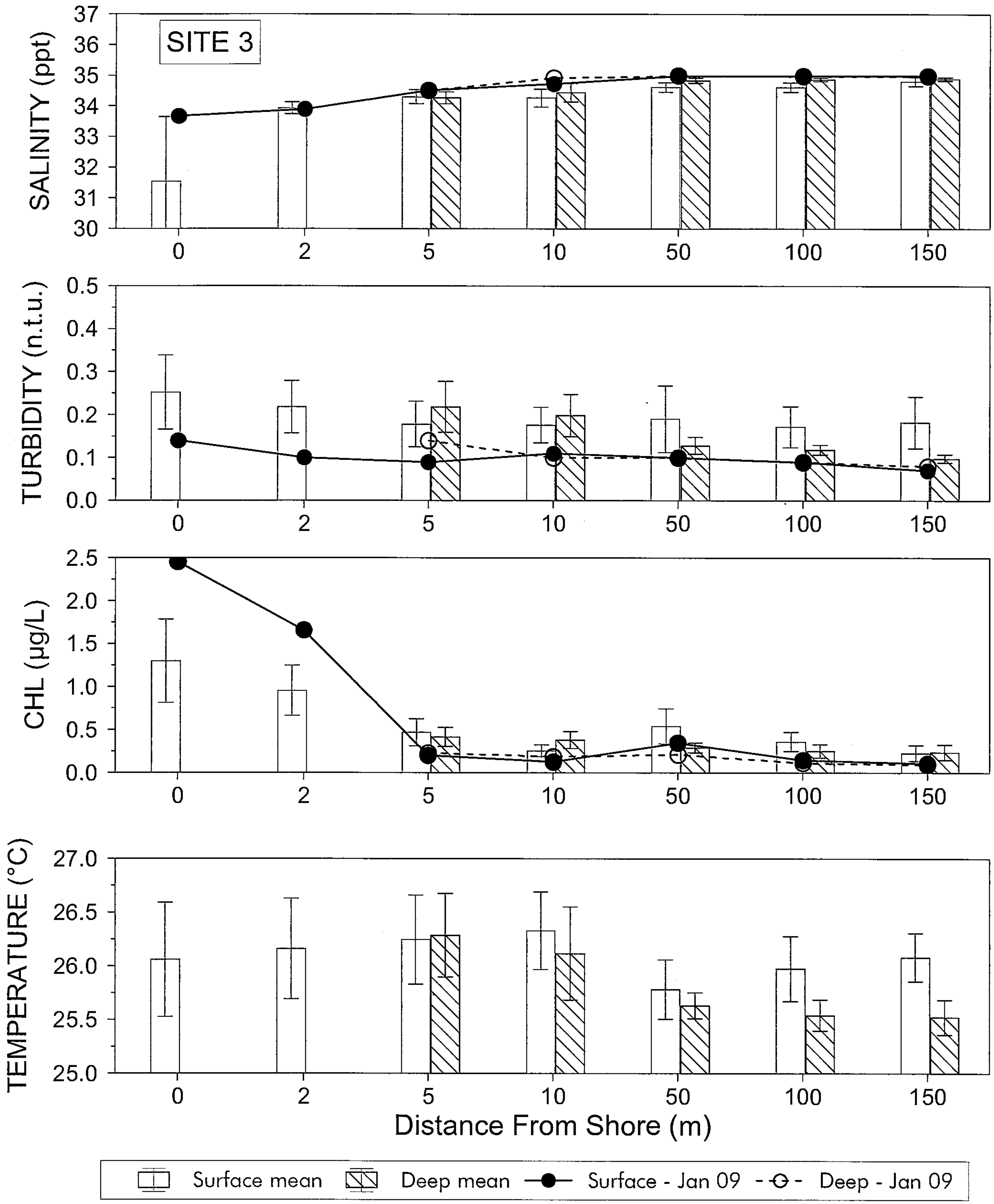

FIGURE 12. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey (Note: temperatures not measured in January 2009). Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

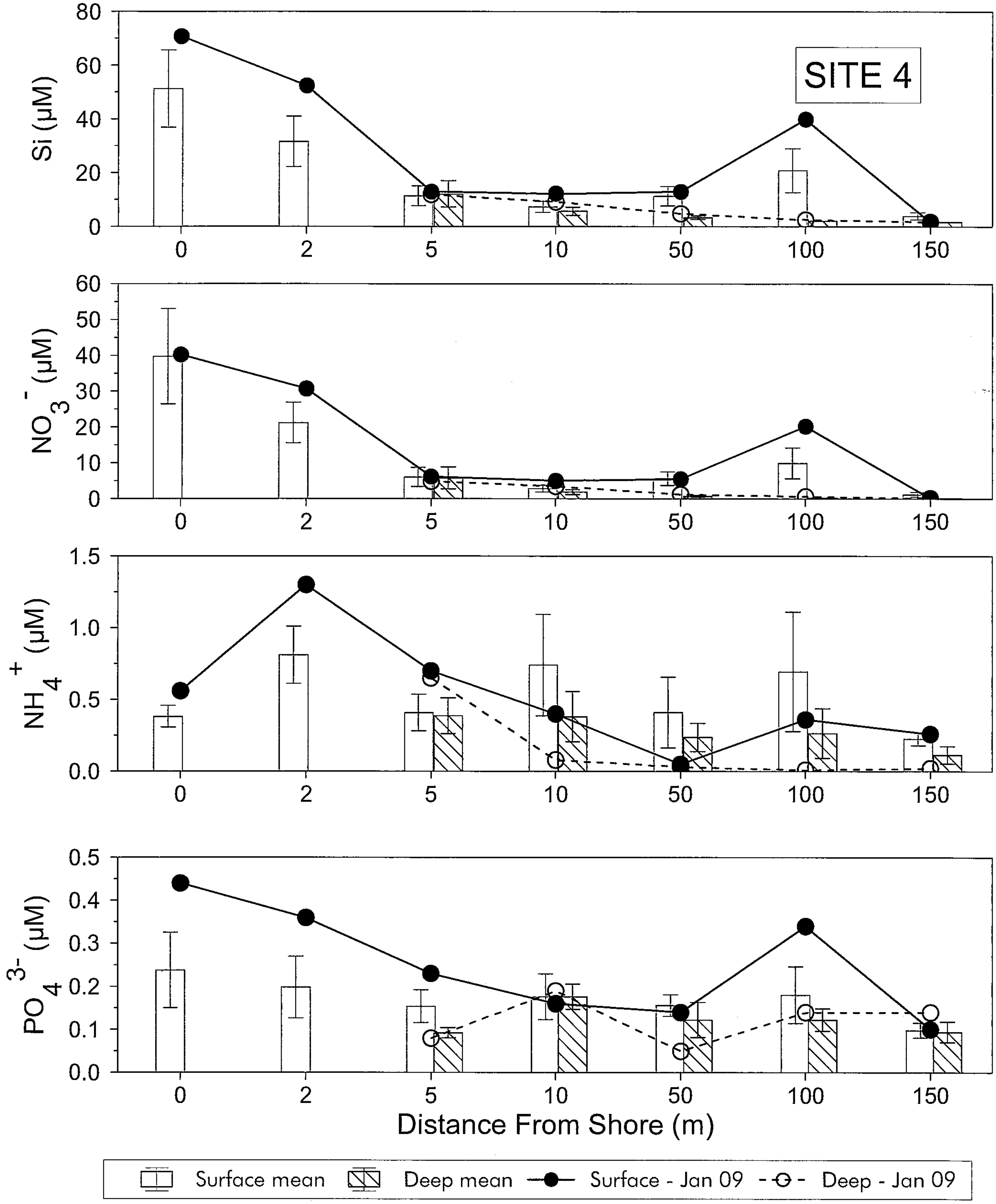

FIGURE 13. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

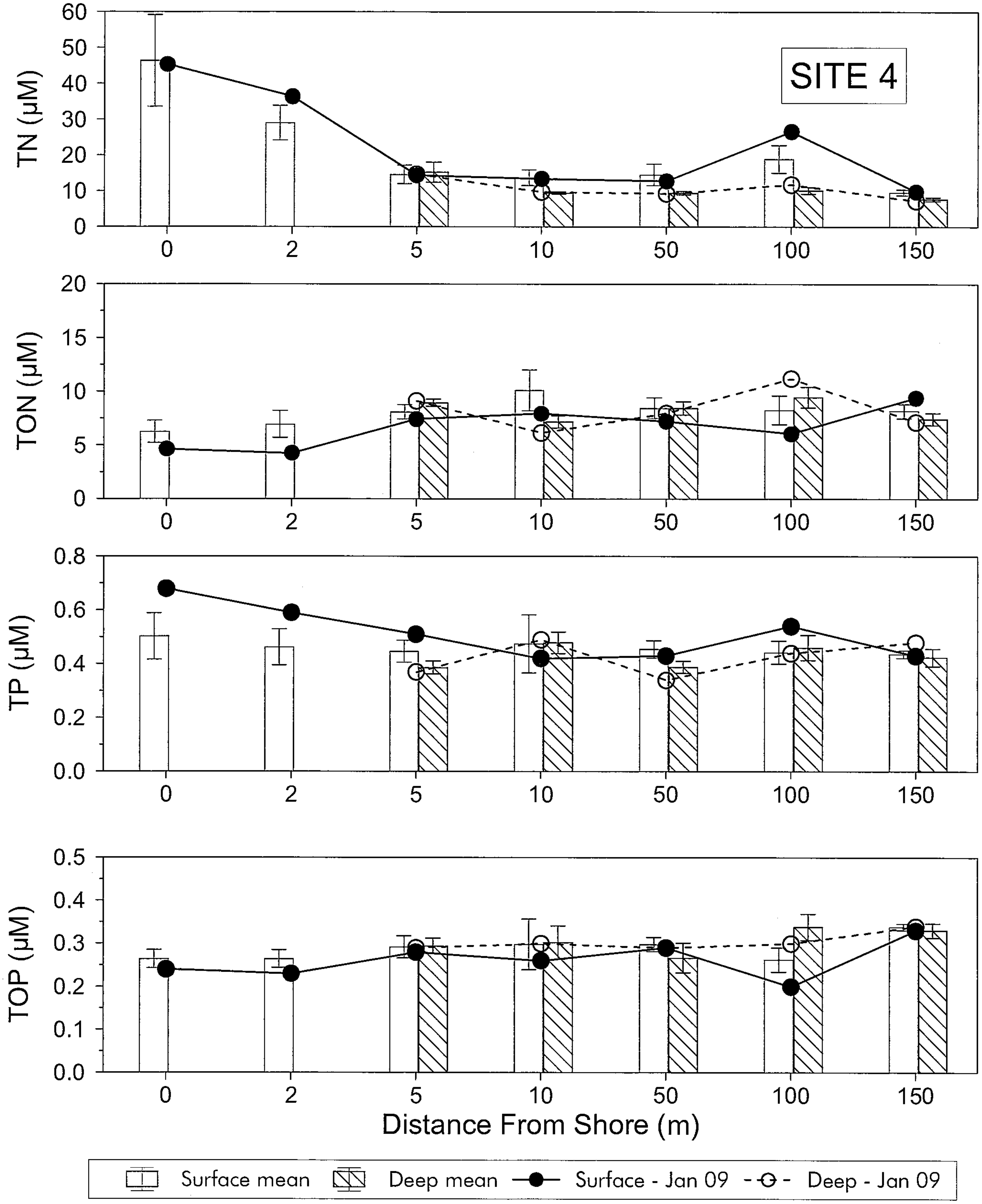

FIGURE 14. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

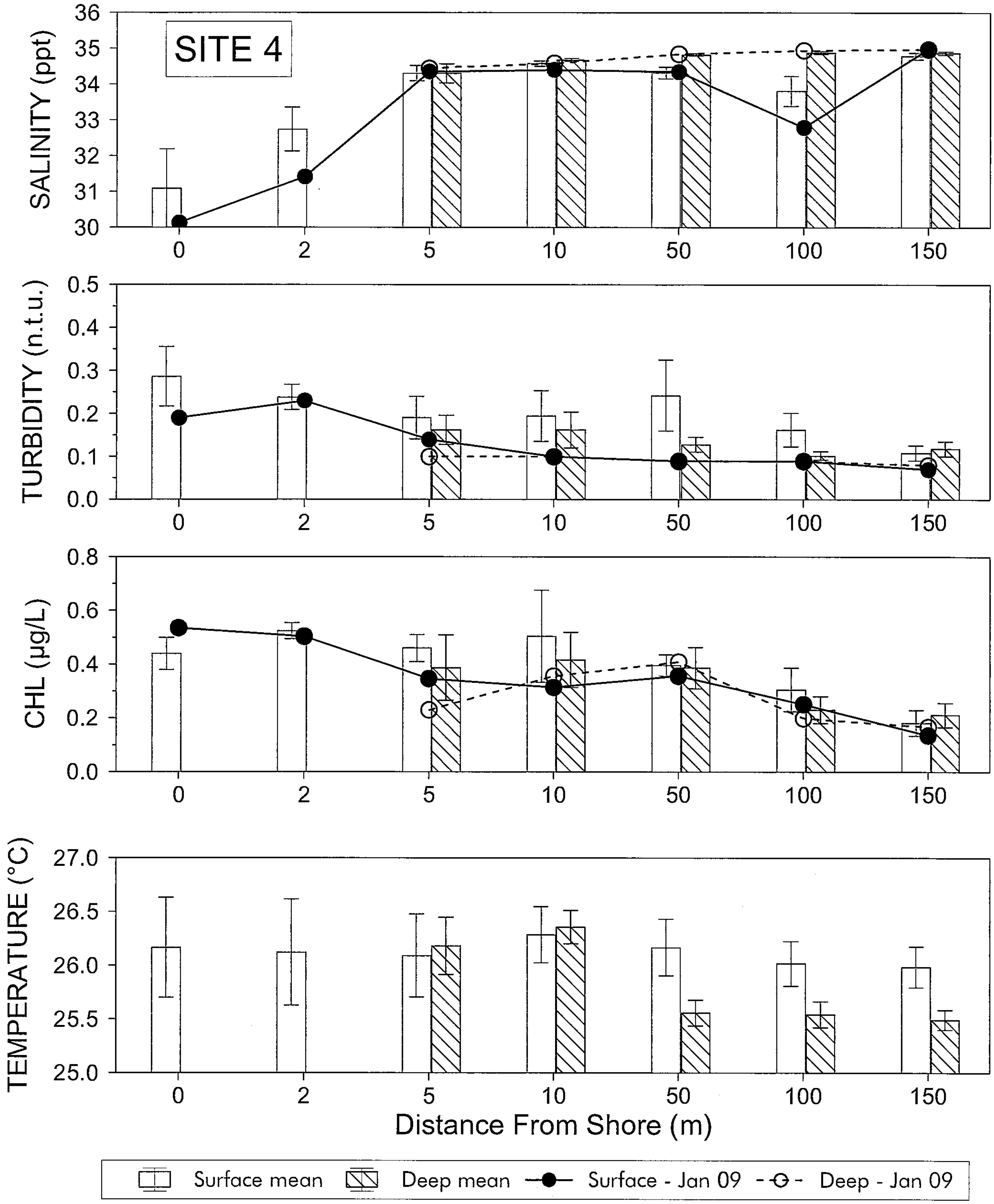

FIGURE 15. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey (Note: temperatures not measured in January 2009). Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

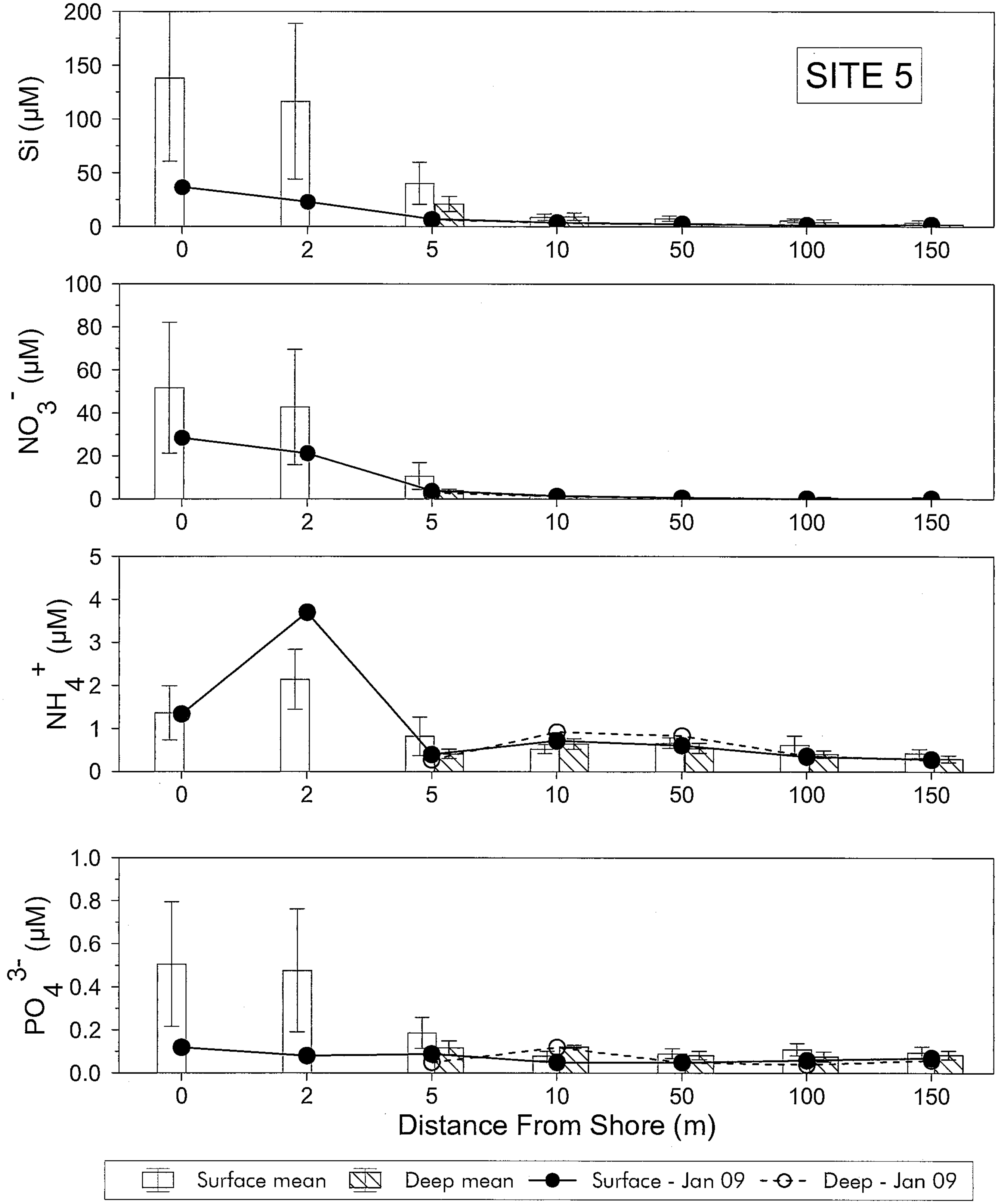

FIGURE 16. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean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

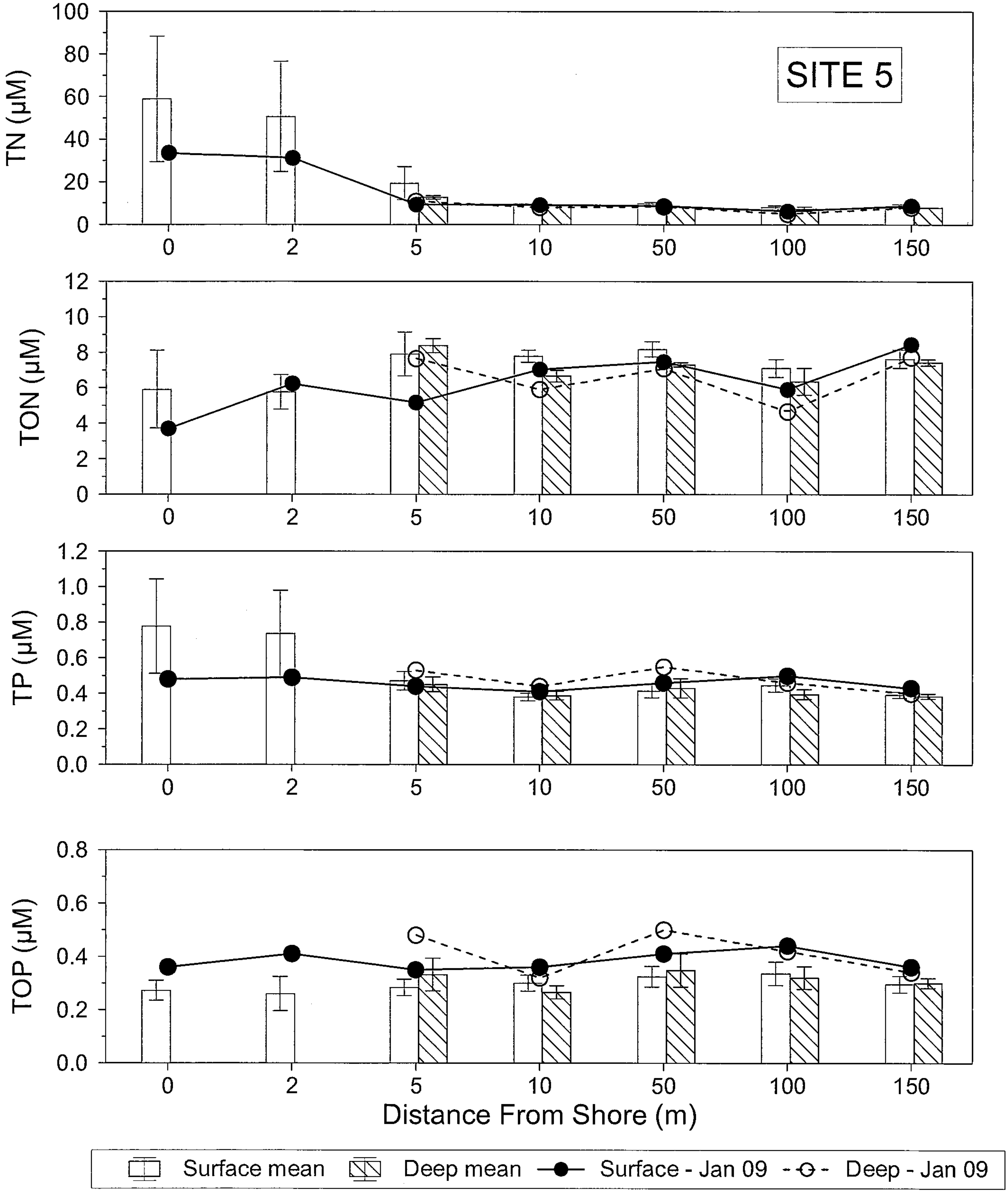

FIGURE 17. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent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

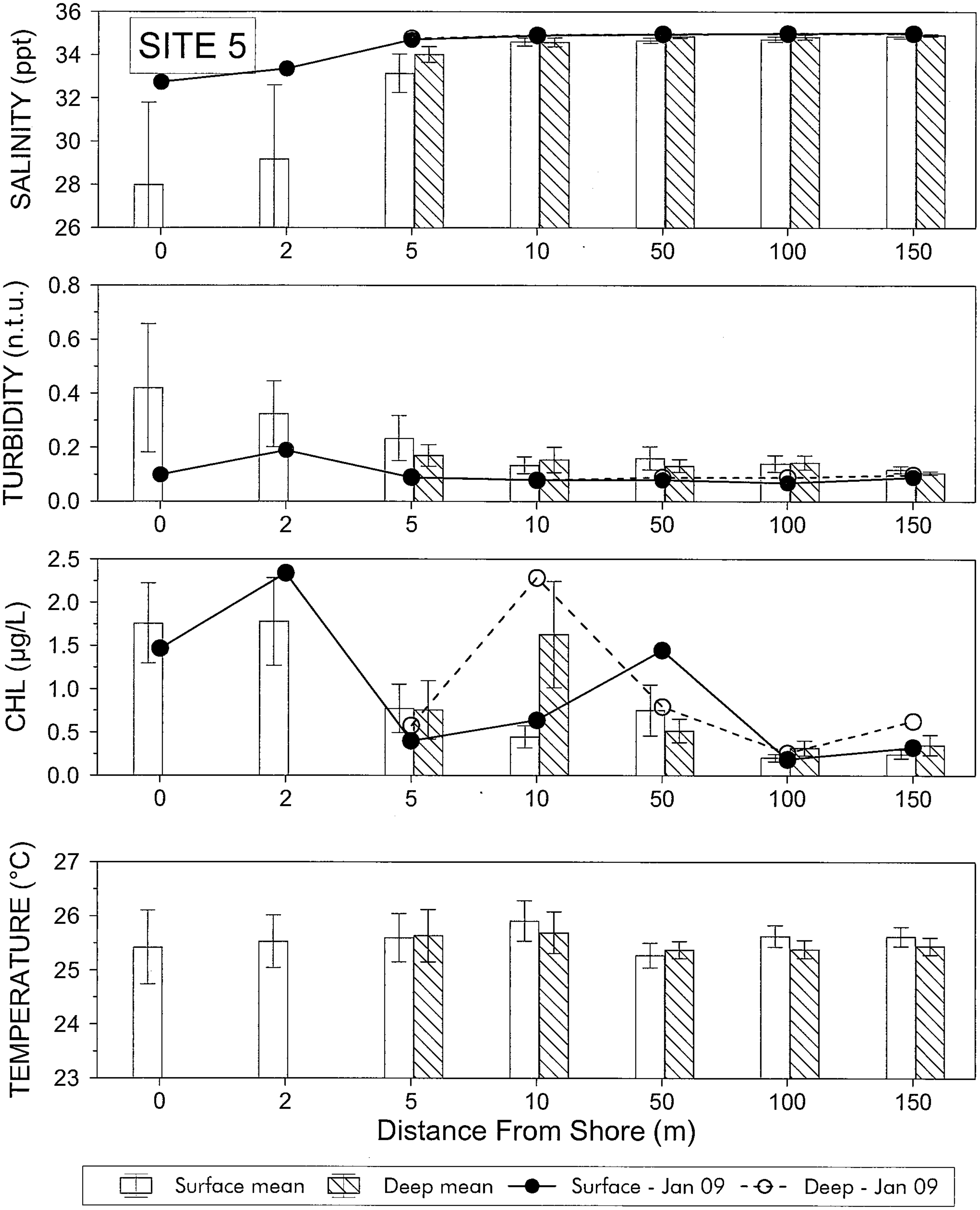

FIGURE 18. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey (Note: temperatures not measured in January 2009). Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=5). Error bars represent standard error of the mean. For site location, see Figure 1.

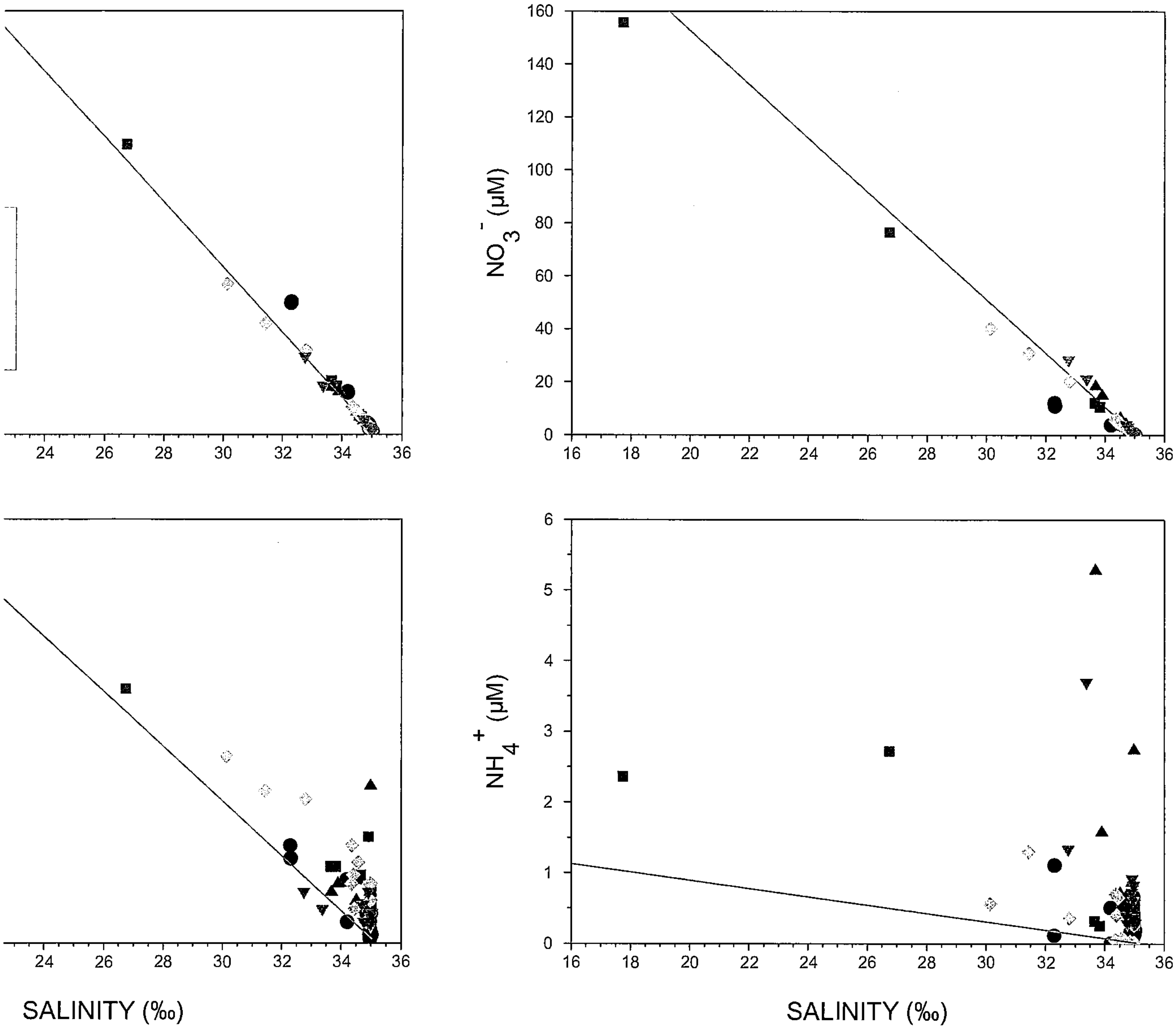

diagram showing concentration of dissolved nutrients from samples collected at five transect sites offshore
a, Maui on January 24, 2009 as functions of salinity. Straight line in each plot is conservative mixing line
ecting the concentrations in open coastal water with water from a golf course irrigation well. For transect
jure 1.

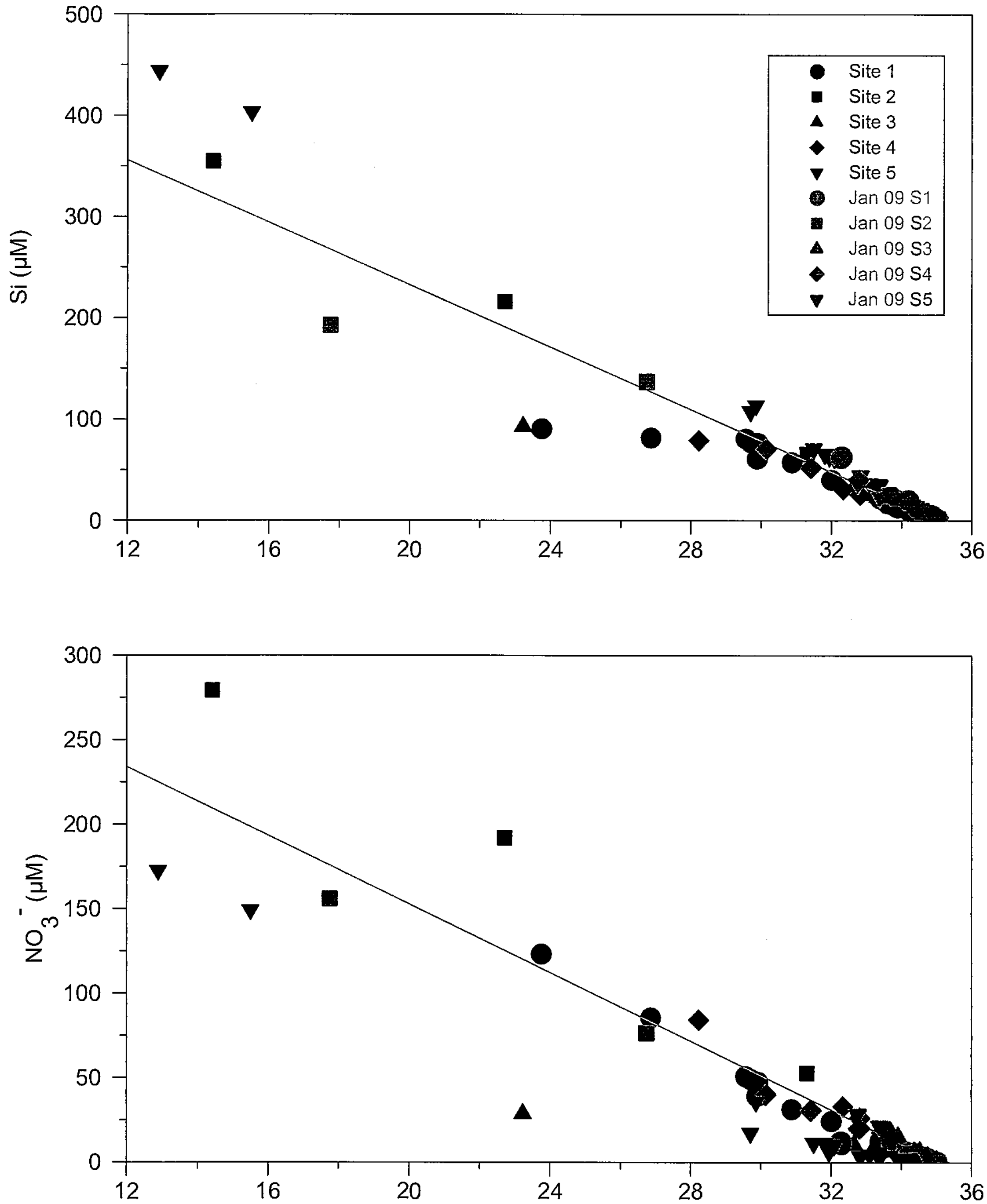

FIGURE 20. Silicate and nitrate, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and June 2008 (N=4). Red symbols are data from the most recent survey. 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.

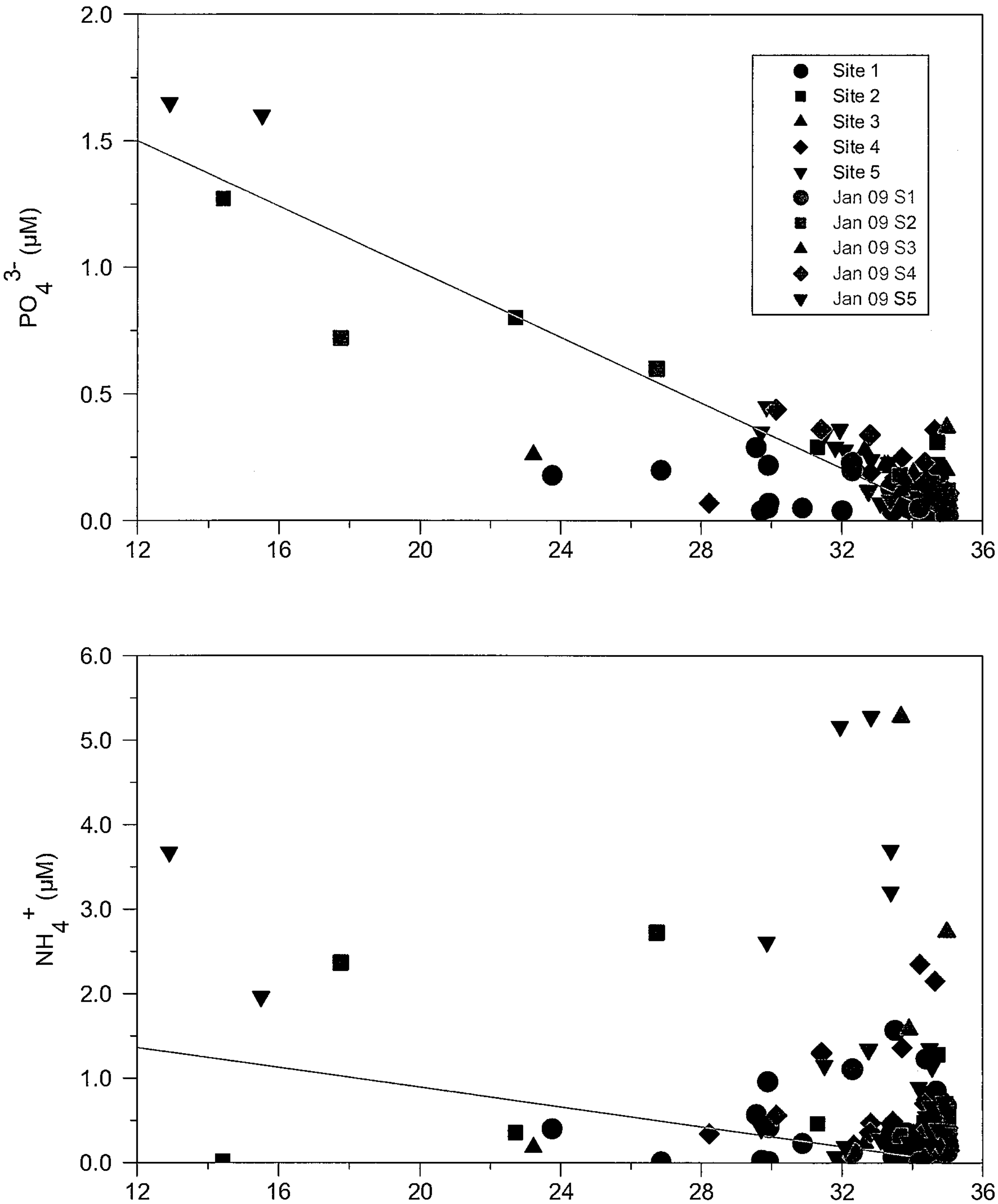

FIGURE 21. Phosphate and ammonium, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and June 2008 (N=4). Red symbols are data from the most recent survey. 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.

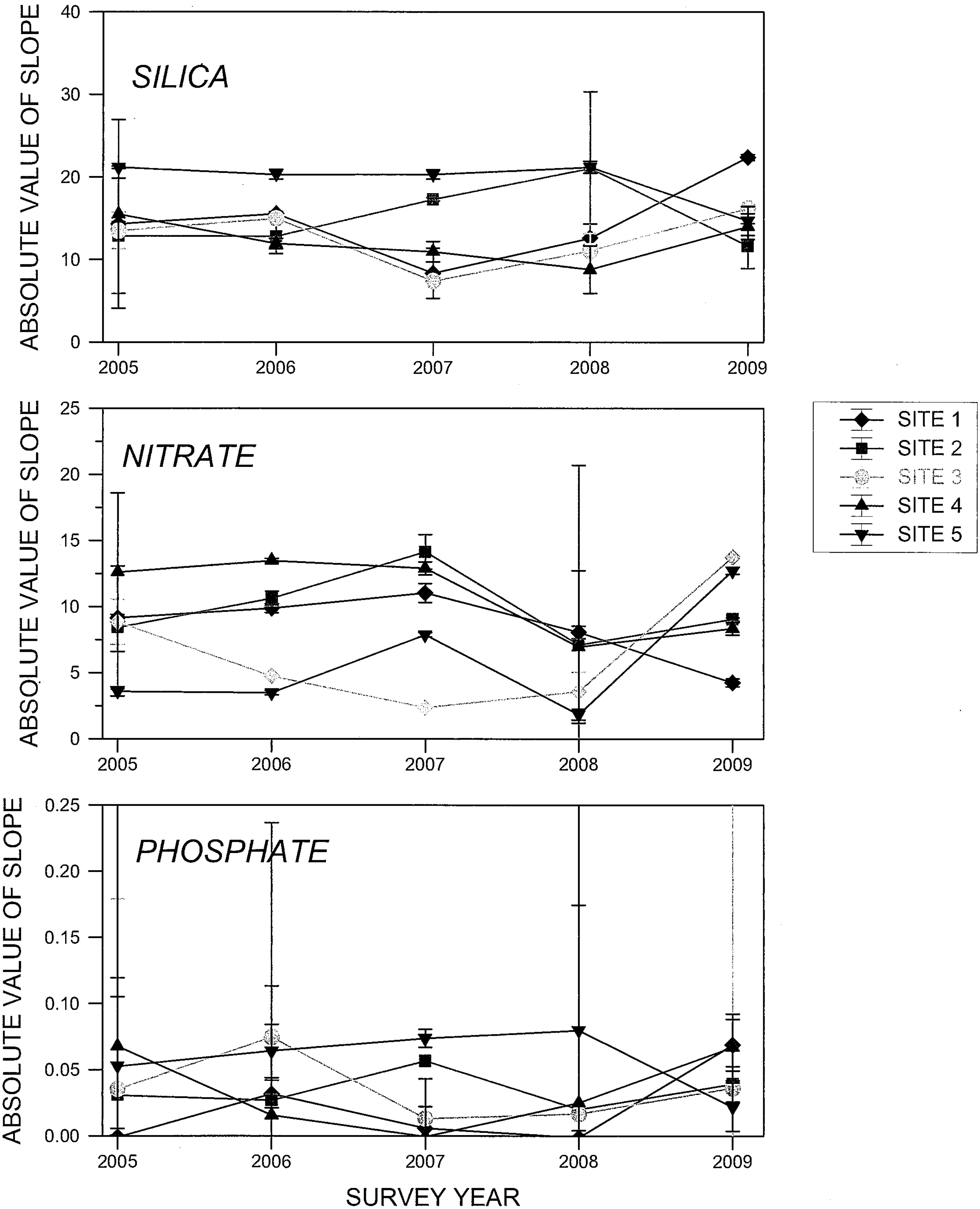

FIGURE 22. Time-course plots of absolute values of slopes of linear regressions of concentrations of silca, nitrate and phosphate as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations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

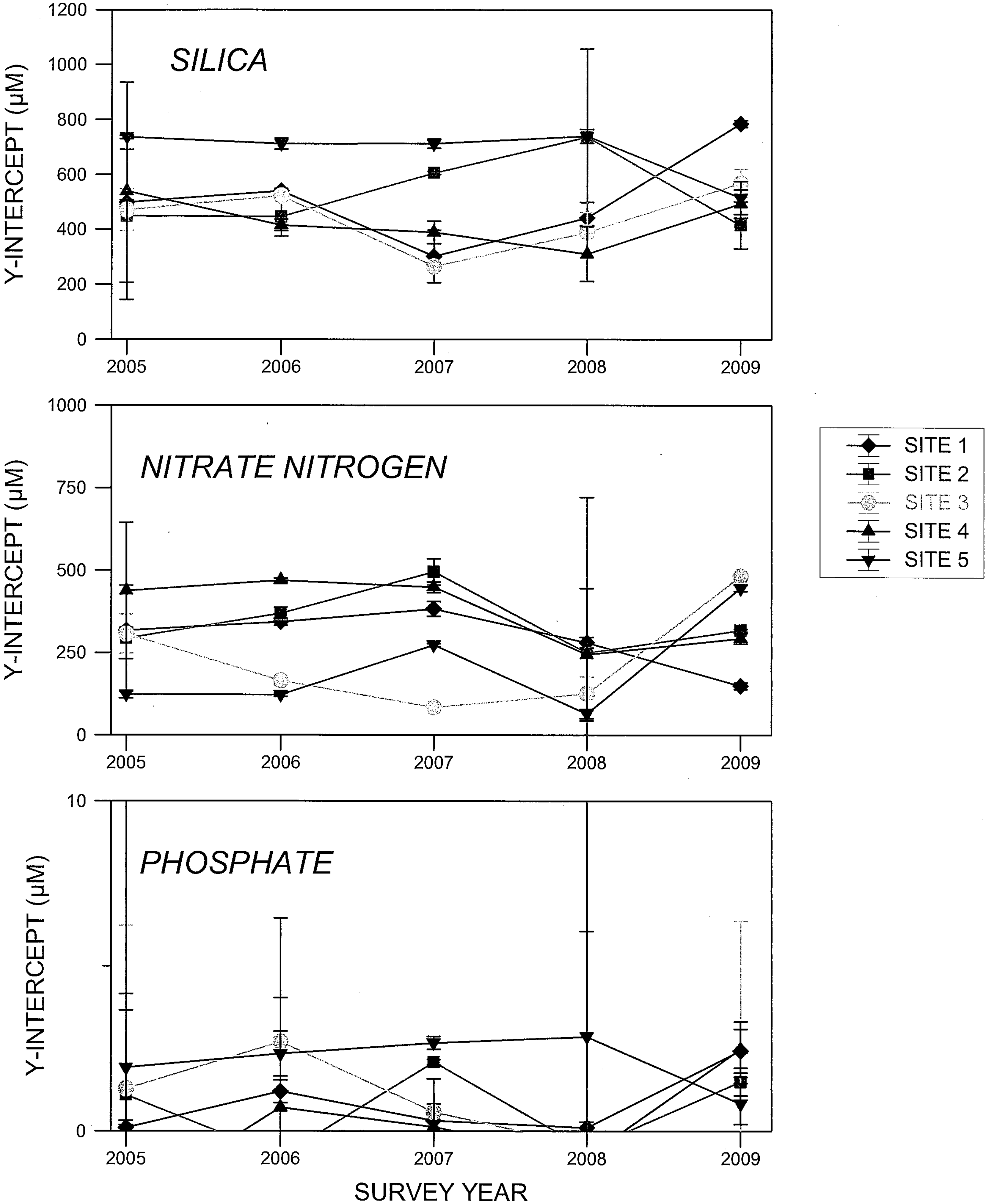

FIGURE 23. Time-course plots of Y-intercepts of linear regressions of concentrations of silca, nitrate and phosphorus as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations of sampling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

MARINE ENVIRONMENTAL

MONITORING PROGRAM:

HONUA'ULA

WAILEA, MAUI

WATER CHEMISTRY

REPORT 1-2010

Prepared for

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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. 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, 250 of which will be provided off-site, thus reducing the total number of homes on-site to 1,150), 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 one 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.

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 retention of surface drainage on the golf course, and a private waste 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.

With the intention of evaluating these effects, one of the Conditions of Zoning for Honua'ula (No. 20) stipulated..."*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.*

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."* To date, HIDOH, which is the agency responsible for developing TMDL's (rather than property owners) has not performed this action for any marine areas off Maui.

This report represents the fourth monitoring effort to take place since the establishment of conditions of Zoning (Condition 20). 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. The following report conducted in July 2010 presents the results of the overall seventh phase of the monitoring program for the Honua'ula project.

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 Palau'ea 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 Honua'ula. 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 was conducted on July 11, 2010 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.

Typically, part of the monitoring program includes collection of water samples from irrigation wells on the Wailea golf course. Sampling of wells was not conducted during this phase of monitoring owing to logistic constraints. Data from the previous well sampling conducted on February 11, 2009 is used for evaluation of groundwater mixing with ocean water in the Results section below. 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 μM (0.14 μg/L) for NO_3^- and NH_4^+, 0.01 μM (0.31 μg/L) for PO_4^{3-}, 0.1 μM (1.4 μg/L) for TN and 0.1 μM (3.1 μg/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 μg/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 July 11, 2010 reported in micromolar units (μM). Table 2 shows similar results presented in units of micrograms per liter (μg/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 μM and μg/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 ($\pm$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 10 m of the shoreline at all five transect sites. Beyond 10 m from the shoreline, concentrations of nutrients decreased progressively with distance from shore but at a substantially reduced gradient compared with the zone within 10 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 Site 1(Five Graves) , where surface concentrations of NO_3^- near the shoreline was more than two orders of magnitude higher than samples collected at the seaward end of the transect. Salinity was correspondingly lower near the shoreline compared to offshore samples, with values differing by 59.4‰ between the shoreline and offshore terminus of the transect at Site 1 (Tables 1 and 2). Transects at Site 4 (Ulua Beach) also had distinctly elevated nutrient concentrations and correspondingly lower salinities near the shoreline. Similar patterns were evident at Sites 2, 3 and 5, but the horizontal gradients were far less pronounced compared to the patterns at Transects 1, and 4.

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 distinct horizontal patterns with distance offshore that was evident Si, NO_3^-, and TN. (Figure 2, Tables 1 and 2). While there was a weak pattern of decreasing values with distance from shore at Site 1, there were no consistent gradients of decline of PO_4^{3-} and TP at the other sites.

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 and among the five sites (Figure 2). With the exception of the shoreline samples at Site 1,the surface concentrations of NH_4^+ were relatively constant along the length of each transect, with values ranging from 0.04 – 0.64 μM (Figure 2, Tables 1 and 2). With the exception of the shoreline samples at Sites 1 and 4, surface concentrations of TOP and TON were relatively constant at all sampling locations on transect sites during the July 2010 survey (Figure 2).

Turbidity was slightly elevated at the shoreline and decreased with distance from shore at all five transect sites during the July 2010 survey (Figure 3 and Tables 1 and 2). Site 1 (Five Graves) had distinctly higher turbidity levels compared to the other four sites, reaching a maximum of 0.99 NTU in the sample collected 10 m from the shoreline (Table 1). Similar to turbidity, Chl *a* values were distinctly higher at Site 1 compared to the other fives sites. Surface temperature ranged between a low of 23.4°C near the shoreline to 25.9°C in the offshore waters at Sites 1 and 4 during July 2010 (Tables 1 and 2, Figure 3). At the other three sites, temperature averaged 25.4°C and varied by no more than 0.9°C along the transect.

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 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 July 2010 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 July 2010 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 at Sites 1 and 4, 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 ($\pm$ 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 July 2010.

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 (Palau'ea), and Control Site 5 (Figures 4-18). In the most recent survey (July 2010) the concentrations of Si, NO_3^-, TN, PO_4^{3-} and TP were higher than the mean values at Sites 1 and 4 (Figures 4,5, 13 and 14). Salinity during the July 2010 survey was distinctly lower than the mean values at Sites 1 and 4, while at Sites 2, 3 and 5 salinity in the nearshore was higher than the mean values (Figures 6, 9, 12, 15 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).

With two exceptions (Site 1 at 10 m from shore and Site 5 at 2 m from shore), turbidity measurements during July 2010 were of the same magnitude or slightly lower than the mean values. Measurements of Chl *a* and temperature during July 2010 were all less than the mean values at all stations and across the entire length of each transect (Figures 6, 9, 12, 15 and 18).

These comparisons suggest that while there are some differences between surveys; water chemistry of the nearshore zone at Sites 1 and 4 was influenced by greater groundwater efflux during the July 2010 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 July 2010. 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 Irrigation Well No. 5 located to the northwest of the project area (sampled on February 11, 2009), and from the average concentrations of ocean water collected from near the bottom at the sampling locations 150 m offshore.

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 data points from Sites 1-5 fall in a linear array on, or very close to the conservative mixing line for Si. Such linearity indicates that groundwater (as defined by the concentration of SI) entering the ocean at these sites is a nearly pure mix of groundwater similar to that from Well No. 5, and open coastal water. It can be seen in Figure 20 that while data points from the present survey in July 2010 lie close to the conservative mixing line, deviations in concentrations of silica as functions of salinity have occurred in previous surveys. Such deviations above the suggest input of other sources of groundwater enriched in Si relative to groundwater from Well No. 5.

The plots of NO_3^- versus salinity reveal a generally similar pattern as Si, with most of the data points from three of the five sites falling on, or very close to the mixing line (Figure 19). At Site 1 and 5, plots of NO_3^- vs. salinity reveal a linear array, however several data points fall below the mixing line. A similar pattern is evident over the course of sampling in Figure 20, where many of the NO_3^- data points from previous surveys fell below the mixing line. The reduced slope of the line prescribed by the data points from Site 1 suggest the possibility of removal of NO_3^- by turfgrass on the golf course following irrigation, and subsequent leaching to the groundwater.

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 high concentrations of NH_4^+, particularly at Transect Sites 1, 2 and 5. 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 correlation between PO_4^{3-} and salinity, although the linearity is weaker than evident 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 2010 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 in the confidence limits for Sites 2 and 4 occurred during 2005 and 2008 (Tables 6 and 7) (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 (2005-2010).

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 twenty-one of the sixty samples collected were above the 10% criteria for NO_3^- under "dry" or "wet" conditions in the July 2010 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^-, seven measurements of NH_4^+, two measurements of TP, seventeen measurements of TN, three measurements of turbidity and two measurements of Chl *a* exceeded the 10% DOH criteria under "dry" conditions in July 2010. If "wet" criteria are applied, three measurements of NH_4^+, two measurements of TP, eight measurements of TN, and one measurement of Chl *a* exceeded the DOH water quality standards. During the July 2010 survey, no measurements of turbidity exceeded the "wet" DOH standards.

Tables 3 and 4 show geometric means of samples collected at the same locations during the seven 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 but one surface water measurements of NO_3^-, 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. SUMMARY

- The seventh phase of the water quality monitoring program for the planned Honua'ula project was carried out in July 2010. Sixty ocean water samples were collected on four transects spaced along the projects ocean frontage and one transect located outside of the project area. 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 (Palau'ea Beach), Site 3 was located off Palau'ea Beach downslope from the juncture of the Emerald and Blue Courses, and Site 4 was located off Ulua Beach 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 Wailea golf courses. 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 sample data collected in February 2009 from seven irrigation wells and a golf-course reservoir in the Wailea area upslope of the sampling area are given for comparison.

- Water chemistry constituents that occur in high concentration in groundwater (Si, NO_3^-, TN and PO_4^{3-}) displayed 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 continued across the entire length of all transects. The steepest nearshore gradients, indicating the highest input of groundwater at the shoreline occurred at Sites 1 (Five Graves) and 4 (Ulua Beach). 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 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 July 2010 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 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 six 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 2010. 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.

- The next phase of the Honua'ula monitoring program is scheduled for the winter months during the first quarter of 2011.

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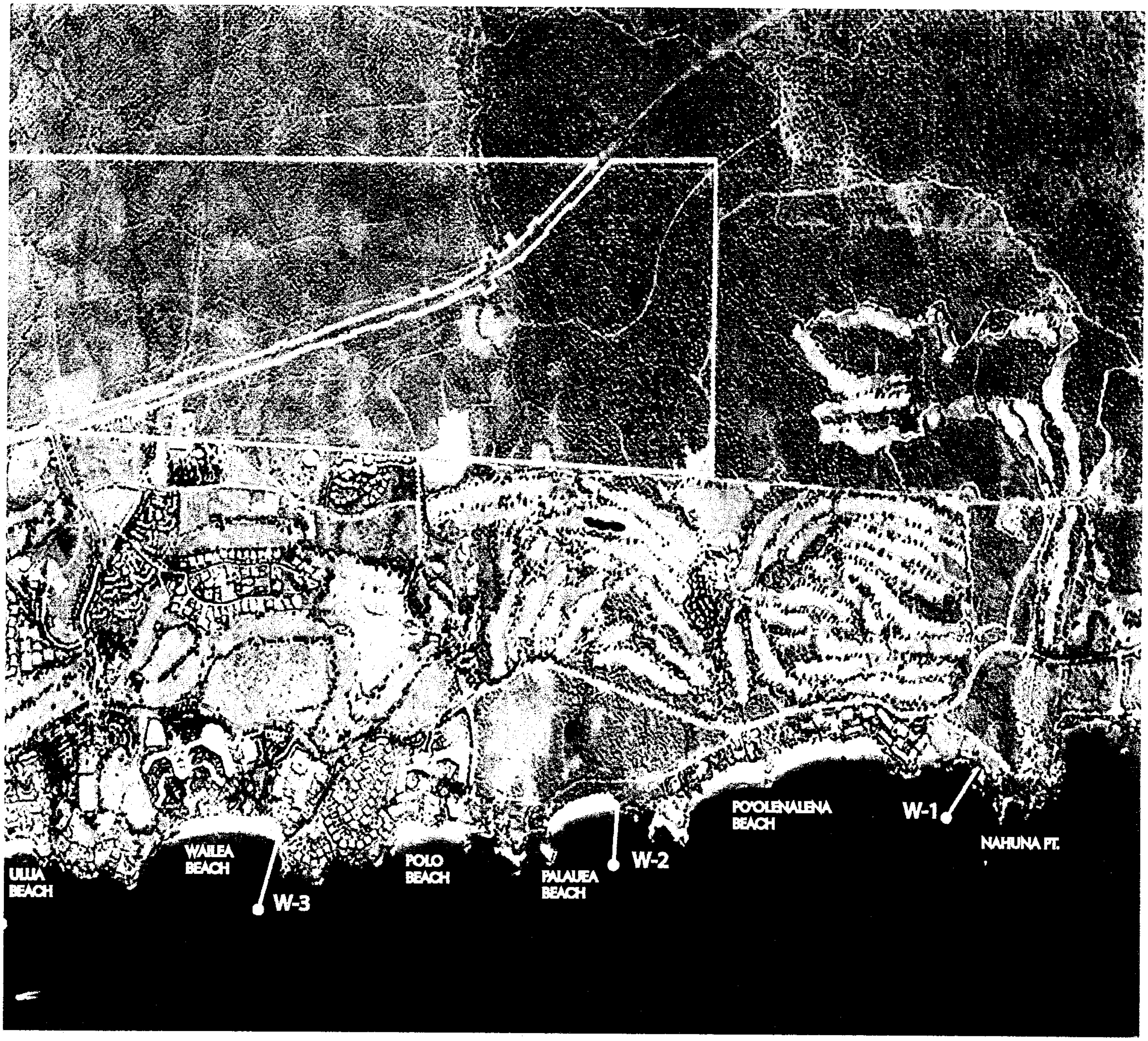

ıh of Wailea area showing boundaries of Honua'ula Project (in yellow) and locations of marine water ˈransect W-5 is considered a control and is located in the 'Ahihi-kina'u Natural Area Reserve approximately 'ula Project site.

TABLE 1.Water chemistry measurements from ocean water samples collected in the vicinity of the Honua'ula project site on July 11, 2010. 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)	PO_4^{3-} (µM)	NO_3^- (µM)	NH_4^+ (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 - Five Graves	0 S	0.1	1.56	182.72	0.88	389.40	0.48	23.92	2.04	207.52	0.28	9.171	0.53	25.0	7.97	108.4
	2 S	0.1	0.92	146.84	2.68	275.60	0.84	20.92	1.76	170.44	0.36	15.610	1.32	24.8	7.99	103.6
	5 S	0.1	0.39	68.57	0.11	141.34	0.26	7.66	0.65	76.34	0.32	24.768	0.41	23.7	8.05	105.0
	5 D	1.0	0.29	33.63	0.16	75.25	0.28	8.25	0.57	42.04	0.34	29.872	0.27	25.2	8.03	108.6
	10 S	0.1	0.22	11.10	0.11	26.55	0.30	8.81	0.52	20.02	0.99	33.247	0.17	25.3	8.00	105.8
	10 D	1.7	0.09	4.85	0.41	14.01	0.30	6.65	0.39	11.91	0.23	34.064	0.21	25.5	8.05	105.2
	50 S	0.1	0.05	2.37	0.17	9.12	0.31	7.11	0.36	9.65	0.47	34.327	0.20	25.8	8.12	98.3
	50 D	4.4	0.11	0.16	0.04	1.57	0.33	7.15	0.44	7.35	0.20	34.834	0.27	25.6	8.09	100.0
	100 S	0.1	0.27	2.12	0.57	8.31	0.23	6.75	0.50	9.44	0.15	34.400	0.13	25.9	8.10	98.5
	100 D	6.2	0.08	0.06	0.10	1.23	0.31	7.16	0.39	7.32	0.12	34.861	0.08	25.5	8.08	97.2
	150 S	0.1	0.05	1.91	0.42	7.11	0.37	7.22	0.42	9.55	0.23	34.550	0.12	25.8	8.06	96.0
	150 D	11.7	0.07	0.05	0.28	1.42	0.32	6.00	0.39	6.33	0.11	34.862	0.08	25.4	8.09	95.9
WAILEA 2 - Palau'ea	0 S	0.1	0.12	10.09	0.11	19.66	0.33	6.34	0.45	16.54	0.23	34.017	0.31	25.4	8.14	93.8
	2 S	0.1	0.09	10.80	0.06	19.06	0.33	7.00	0.42	17.86	0.25	34.046	0.19	25.4	8.14	93.7
	5 S	0.1	0.10	6.76	0.20	12.77	0.33	7.31	0.43	14.27	0.22	34.352	0.18	25.4	8.14	95.1
	5 D	1.0	0.08	5.69	0.22	11.25	0.32	6.64	0.40	12.55	0.18	34.428	0.13	25.4	8.14	93.4
	10 S	0.1	0.03	6.92	0.20	13.42	0.33	9.30	0.36	16.42	0.23	34.352	0.13	25.4	8.14	93.8
	10 D	2.0	0.03	2.97	0.15	6.90	0.32	8.05	0.35	11.17	0.20	34.673	0.21	25.4	8.14	93.5
	50 S	0.1	0.15	4.18	0.33	9.49	0.18	8.52	0.33	13.03	0.19	34.512	0.16	25.4	8.17	93.5
	50 D	4.9	0.04	0.01	0.20	1.51	0.28	6.94	0.32	7.15	0.16	34.922	0.19	25.4	8.17	93.6
	100 S	0.2	0.06	1.01	0.20	4.98	0.36	9.43	0.42	10.64	0.14	34.742	0.09	25.9	8.18	97.1
	100 D	8.7	0.05	BDL	0.24	1.32	0.39	7.39	0.44	7.63	0.11	34.939	0.07	25.5	8.18	98.0
	150 S	0.1	0.08	0.56	0.14	3.45	0.33	6.55	0.41	7.25	0.18	34.821	0.07	25.9	8.16	93.9
	150 D	14.4	0.03	0.01	0.25	1.81	0.31	9.21	0.34	9.47	0.11	34.941	0.14	25.4	8.17	95.9
WAILEA 3 - Wailea Beach	0 S	0.1	0.09	8.87	0.09	21.50	0.30	7.24	0.39	16.20	0.16	33.465	0.17	25.3	8.16	94.5
	2 S	0.1	0.10	4.58	0.19	11.92	0.31	6.32	0.41	11.09	0.17	34.191	0.19	25.3	8.14	95.8
	5 S	0.1	0.11	2.87	0.18	7.85	0.36	7.25	0.47	10.30	0.12	34.447	0.13	25.4	8.15	94.6
	5 D	1.0	0.06	1.59	0.20	5.23	0.30	6.78	0.36	8.57	0.15	34.616	0.16	25.4	8.15	92.8
	10 S	0.1	0.06	3.85	0.06	10.55	0.33	7.52	0.39	11.43	0.13	34.298	0.15	25.4	8.15	92.4
	10 D	1.0	0.09	2.64	0.12	7.92	0.31	8.84	0.40	11.60	0.18	34.499	0.24	25.4	8.15	92.7
	50 S	0.1	0.03	0.08	0.24	2.44	0.29	7.98	0.32	8.30	0.11	34.895	0.10	25.4	8.15	93.4
	50 D	4.0	0.02	0.09	0.18	2.57	0.30	8.64	0.32	8.91	0.10	34.896	0.12	25.4	8.15	94.1
	100 S	0.1	0.03	0.72	0.15	6.08	0.31	7.50	0.34	8.37	0.13	34.709	0.08	25.9	8.17	95.4
	100 D	6.1	0.02	0.05	0.09	1.29	0.29	6.81	0.31	6.95	0.10	34.920	0.08	25.5	8.18	96.4
	150 S	0.1	0.09	0.14	0.15	2.22	0.31	7.60	0.40	7.89	0.13	34.866	0.08	25.8	8.17	94.5
	150 D	11.2	0.03	0.08	0.18	1.17	0.29	6.20	0.32	6.46	0.12	34.913	0.15	25.4	8.17	96.0
WAILEA 4 - Ulua Beach	0 S	0.1	0.20	66.64	0.64	83.88	0.48	15.56	0.68	82.84	0.16	28.356	0.09	23.4	7.99	89.2
	2 S	0.1	0.12	47.64	0.04	74.20	0.64	18.24	0.76	65.92	0.16	30.259	0.09	24.6	7.98	94.3
	5 S	0.1	0.05	9.01	0.11	16.39	0.29	7.37	0.34	16.49	0.16	33.951	0.12	24.6	8.07	91.8
	5 D	1.0	0.07	4.98	0.09	10.26	0.31	8.11	0.38	13.18	0.17	34.337	0.08	24.9	8.09	88.3
	10 S	0.1	0.09	1.43	0.14	3.97	0.31	6.86	0.40	8.43	0.18	34.754	0.12	24.9	8.11	90.8
	10 D	1.0	0.09	0.69	0.18	2.89	0.33	8.11	0.42	8.98	0.12	34.795	0.14	25.1	8.11	92.3
	50 S	0.1	0.04	2.24	0.11	3.12	0.34	7.63	0.38	9.98	0.16	34.697	0.07	25.2	8.14	94.7
	50 D	5.2	0.10	0.08	0.19	1.57	0.29	7.86	0.39	8.13	0.11	34.865	0.07	23.5	8.15	88.9
	100 S	0.1	0.07	3.79	0.05	8.26	0.31	7.41	0.38	11.25	0.12	34.508	0.07	25.7	8.15	96.0
	100 D	9.8	0.11	0.05	0.19	1.60	0.29	7.17	0.40	7.41	0.09	34.890	0.05	25.6	8.16	96.6
	150 S	0.1	0.12	0.54	0.06	2.75	0.32	6.76	0.44	7.36	0.13	34.771	0.09	25.8	8.16	95.1
	150 D	12.3	0.04	0.02	0.11	1.60	0.33	6.87	0.37	7.00	0.10	34.826	0.07	25.4	8.17	95.9
WAILEA 5 - Ahihi-kina'u	0 S	0.1	0.13	9.26	0.12	57.16	0.33	8.00	0.46	17.38	0.30	32.149	0.10	25.0	8.16	95.2
	2 S	0.1	0.12	12.12	0.13	54.91	0.31	3.10	0.43	15.35	0.66	32.329	0.06	25.0	8.14	95.3
	5 S	0.1	0.16	5.00	0.25	35.49	0.30	7.22	0.46	12.47	0.15	33.324	0.20	25.0	8.14	95.2
	5 D	1.0	0.16	5.26	0.11	37.73	0.31	7.52	0.47	12.89	0.16	33.231	0.21	25.0	8.14	96.4
	10 S	0.1	0.08	1.11	0.13	13.23	0.33	8.07	0.41	9.31	0.16	34.493	0.09	25.0	8.12	96.7
	10 D	2.0	0.12	0.89	0.14	12.55	0.36	8.60	0.48	9.63	0.13	34.511	0.16	25.0	8.12	94.9
	50 S	0.1	0.10	1.72	0.15	17.60	0.32	6.55	0.42	8.42	0.12	34.228	0.07	25.1	8.14	95.0
	50 D	4.4	0.08	BDL	0.17	4.19	0.32	7.08	0.40	7.25	0.12	34.854	0.12	25.1	8.13	93.9
	100 S	0.1	0.05	1.62	0.05	17.53	0.33	7.39	0.38	9.06	0.16	34.248	0.09	25.2	8.14	95.4
	100 D	6.4	0.04	0.02	0.11	2.39	0.32	8.10	0.36	8.23	0.13	34.910	0.08	25.2	8.15	96.6
	150 S	0.1	0.13	1.65	0.13	16.43	0.32	6.26	0.45	8.04	0.12	34.302	0.07	25.2	8.14	96.0
	150 D	7.7	0.08	0.15	0.75	4.61	0.32	5.95	0.40	6.85	0.17	34.788	0.12	25.3	8.16	95.2
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 $\mu g/L$) collected off the Honua'ula project site on July 11, 2010. 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)	PO_4^{3-} (μM)	NO_3^- (μM)	NH_4^+ (μM)	Si ($\mu g/L$)	TOP ($\mu g/L$)	TON ($\mu g/L$)	TP ($\mu g/L$)	TN ($\mu g/L$)	TURB (NTU)	SALINITY (ppt)	CHL a ($\mu g/L$)	TEMP (deg.C)	pH (std.units)	O2 % Sat
WAILEA 1 - Five Graves	0 S	0.1	48.32	2559	12.33	10942	14.87	335.0	63.18	2907	0.28	9.171	0.53	25.0	7.97	108.4
	2 S	0.1	28.50	2057	37.54	7744	26.02	293.0	54.51	2387	0.36	15.610	1.32	24.8	7.99	103.6
	5 S	0.1	12.08	960.4	1.54	3972	8.05	107.3	20.13	1069	0.32	24.768	0.41	23.7	8.05	105.0
	5 D	1.0	8.98	471.0	2.24	2115	8.67	115.5	17.65	588.8	0.34	29.872	0.27	25.2	8.03	108.6
	10 S	0.1	6.81	155.5	1.54	746.1	9.29	123.4	16.11	280.4	0.99	33.247	0.17	25.3	8.00	105.8
	10 D	1.7	2.79	67.93	5.74	393.7	9.29	93.1	12.08	166.8	0.23	34.064	0.21	25.5	8.05	105.2
	50 S	0.1	1.55	33.19	2.38	256.3	9.60	99.6	11.15	135.2	0.47	34.327	0.20	25.8	8.12	98.3
	50 D	4.4	3.41	2.24	0.56	44.12	10.22	100.1	13.63	102.9	0.20	34.834	0.27	25.6	8.09	100.0
	100 S	0.1	8.37	29.69	7.98	233.5	7.12	94.5	15.49	132.2	0.15	34.400	0.13	25.9	8.10	98.5
	100 D	6.2	2.48	0.84	1.40	34.56	9.60	100.3	12.08	102.5	0.12	34.861	0.08	25.5	8.08	97.2
	150 S	0.1	1.55	26.75	5.88	199.8	11.46	101.1	13.01	133.8	0.23	34.550	0.12	25.8	8.06	96.0
	150 D	11.7	2.17	0.70	3.92	39.90	9.91	84.0	12.08	88.7	0.11	34.862	0.08	25.4	8.09	95.9
WAILEA 2 - Palau'ea	0 S	0.1	3.72	141.3	1.54	552.4	10.22	88.8	13.94	231.7	0.23	34.017	0.31	25.4	8.14	93.8
	2 S	0.1	2.79	151.3	0.84	535.6	10.22	98.0	13.01	250.1	0.25	34.046	0.19	25.4	8.14	93.7
	5 S	0.1	3.10	94.68	2.80	358.8	10.22	102.4	13.32	199.9	0.22	34.352	0.18	25.4	8.14	95.1
	5 D	1.0	2.48	79.69	3.08	316.1	9.91	93.0	12.39	175.8	0.18	34.428	0.13	25.4	8.14	93.4
	10 S	0.1	0.93	96.92	2.80	377.1	10.22	130.3	11.15	230.0	0.23	34.352	0.13	25.4	8.14	93.8
	10 D	2.0	0.93	41.60	2.10	193.9	9.91	112.7	10.84	156.4	0.20	34.673	0.21	25.4	8.14	93.5
	50 S	0.1	4.65	58.55	4.62	266.7	5.58	119.3	10.22	182.5	0.19	34.512	0.16	25.4	8.17	93.5
	50 D	4.9	1.24	0.14	2.80	42.43	8.67	97.2	9.91	100.1	0.16	34.922	0.19	25.4	8.17	93.6
	100 S	0.2	1.86	14.15	2.80	139.9	11.15	132.1	13.01	149.0	0.14	34.742	0.09	25.9	8.18	97.1
	100 D	8.7	1.55	BDL	3.36	37.09	12.08	103.5	13.63	106.9	0.11	34.939	0.07	25.5	8.18	98.0
	150 S	0.1	2.48	7.84	1.96	96.95	10.22	91.7	12.70	101.5	0.18	34.821	0.07	25.9	8.16	93.9
	150 D	14.4	0.93	0.14	3.50	50.86	9.60	129.0	10.53	132.6	0.11	34.941	0.14	25.4	8.17	95.9
WAILEA 3 - Wailea Beach	0 S	0.1	2.79	124.2	1.26	604.2	9.29	101.4	12.08	226.9	0.16	33.465	0.17	25.3	8.16	94.5
	2 S	0.1	3.10	64.15	2.66	335.0	9.60	88.5	12.70	155.3	0.17	34.191	0.19	25.3	8.14	95.8
	5 S	0.1	3.41	40.20	2.52	220.6	11.15	101.5	14.56	144.3	0.12	34.447	0.13	25.4	8.15	94.6
	5 D	1.0	1.86	22.27	2.80	147.0	9.29	95.0	11.15	120.0	0.15	34.616	0.16	25.4	8.15	92.8
	10 S	0.1	1.86	53.92	0.84	296.5	10.22	105.3	12.08	160.1	0.13	34.298	0.15	25.4	8.15	92.4
	10 D	1.0	2.79	36.98	1.68	222.6	9.60	123.8	12.39	162.5	0.18	34.499	0.24	25.4	8.15	92.7
	50 S	0.1	0.93	1.12	3.36	68.56	8.98	111.8	9.91	116.2	0.11	34.895	0.10	25.4	8.15	93.4
	50 D	4.0	0.62	1.26	2.52	72.22	9.29	121.0	9.91	124.8	0.10	34.896	0.12	25.4	8.15	94.1
	100 S	0.1	0.93	10.08	2.10	170.8	9.60	105.0	10.53	117.2	0.13	34.709	0.08	25.9	8.17	95.4
	100 D	6.1	0.62	0.70	1.26	36.25	8.98	95.4	9.60	97.3	0.10	34.920	0.08	25.5	8.18	96.4
	150 S	0.1	2.79	1.96	2.10	62.38	9.60	106.4	12.39	110.5	0.13	34.866	0.08	25.8	8.17	94.5
	150 D	11.2	0.93	1.12	2.52	32.88	8.98	86.8	9.91	90.5	0.12	34.913	0.15	25.4	8.17	96.0
WAILEA 4 - Ulua Beach	0 S	0.1	6.19	933.4	8.96	2357	14.87	217.9	21.06	1160	0.16	28.356	0.09	23.4	7.99	89.2
	2 S	0.1	3.72	667.2	0.56	2085	19.82	255.5	23.54	923.3	0.16	30.259	0.09	24.6	7.98	94.3
	5 S	0.1	1.55	126.2	1.54	460.6	8.98	103.2	10.53	231.0	0.16	33.951	0.12	24.6	8.07	91.8
	5 D	1.0	2.17	69.75	1.26	288.3	9.60	113.6	11.77	184.6	0.17	34.337	0.08	24.9	8.09	88.3
	10 S	0.1	2.79	20.03	1.96	111.6	9.60	96.1	12.39	118.1	0.18	34.754	0.12	24.9	8.11	90.8
	10 D	1.0	2.79	9.66	2.52	81.21	10.22	113.6	13.01	125.8	0.12	34.795	0.14	25.1	8.11	92.3
	50 S	0.1	1.24	31.37	1.54	87.67	10.53	106.9	11.77	139.8	0.16	34.697	0.07	25.2	8.14	94.7
	50 D	5.2	3.10	1.12	2.66	44.12	8.98	110.1	12.08	113.9	0.11	34.865	0.07	23.5	8.15	88.9
	100 S	0.1	2.17	53.08	0.70	232.1	9.60	103.8	11.77	157.6	0.12	34.508	0.07	25.7	8.15	96.0
	100 D	9.8	3.41	0.70	2.66	44.96	8.98	100.4	12.39	103.8	0.09	34.890	0.05	25.6	8.16	96.6
	150 S	0.1	3.72	7.56	0.84	77.28	9.91	94.7	13.63	103.1	0.13	34.771	0.09	25.8	8.16	95.1
	150 D	12.3	1.24	0.28	1.54	44.96	10.22	96.2	11.46	98.0	0.10	34.826	0.07	25.4	8.17	95.9
WAILEA 5 - Ahihi-kina'u	0 S	0.1	4.03	129.7	1.68	1606	10.22	112.0	14.25	243.4	0.30	32.149	0.10	25.0	8.16	95.2
	2 S	0.1	3.72	169.8	1.82	1543	9.60	43.4	13.32	215.0	0.66	32.329	0.06	25.0	8.14	95.3
	5 S	0.1	4.96	70.03	3.50	997.3	9.29	101.1	14.25	174.7	0.15	33.324	0.20	25.0	8.14	95.2
	5 D	1.0	4.96	73.67	1.54	1060	9.60	105.3	14.56	180.5	0.16	33.231	0.21	25.0	8.14	96.4
	10 S	0.1	2.48	15.55	1.82	371.8	10.22	113.0	12.70	130.4	0.16	34.493	0.09	25.0	8.12	96.7
	10 D	2.0	3.72	12.47	1.96	352.7	11.15	120.5	14.87	134.9	0.13	34.511	0.16	25.0	8.12	94.9
	50 S	0.1	3.10	24.09	2.10	494.6	9.91	91.7	13.01	117.9	0.12	34.228	0.07	25.1	8.14	95.0
	50 D	4.4	2.48	BDL	2.38	117.7	9.91	99.2	12.39	101.5	0.12	34.854	0.12	25.1	8.13	93.9
	100 S	0.1	1.55	22.69	0.70	492.6	10.22	103.5	11.77	126.9	0.16	34.248	0.09	25.2	8.14	95.4
	100 D	6.4	1.24	0.28	1.54	67.16	9.91	113.4	11.15	115.3	0.13	34.910	0.08	25.2	8.15	96.6
	150 S	0.1	4.03	23.11	1.82	461.7	9.91	87.7	13.94	112.6	0.12	34.302	0.07	25.2	8.14	96.0
	150 D	7.7	2.48	2.10	10.50	129.54	9.91	83.3	12.39	95.9	0.17	34.788	0.12	25.3	8.16	95.2
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=7). 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)	PO_4^{3-} (μM)	NO_3^- (μM)	NH_4^+ (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 - Five Graves	0 S	1	0.18	61.78	0.31	109.9	0.30	6.82	0.53	75.40	0.21	21.856	0.92	25.98	8.11	106.20
	2 S	1	0.17	43.36	0.10	82.99	0.33	8.12	0.54	55.18	0.20	27.180	1.38	25.97	8.14	105.91
	5 S	1	0.07	15.63	0.05	34.45	0.29	8.54	0.39	26.78	0.18	31.558	0.51	25.73	8.12	104.94
	5 D	2.5	0.11	8.61	0.30	21.65	0.29	9.01	0.44	19.23	0.12	33.267	0.31	26.03	8.12	105.07
	10 S	1	0.08	6.48	0.19	16.77	0.29	8.30	0.38	16.64	0.17	33.712	0.32	26.10	8.11	107.66
	10 D	3	0.07	2.23	0.22	7.22	0.30	8.07	0.37	11.26	0.13	34.477	0.30	26.00	8.11	106.88
	50 S	1	0.05	3.28	0.29	9.47	0.30	8.47	0.36	13.67	0.14	34.253	0.28	26.00	8.13	102.23
	50 D	4.5	0.08	0.30	0.13	2.32	0.31	8.29	0.40	9.01	0.11	34.798	0.32	25.77	8.12	96.94
	100 S	1	0.08	3.14	0.25	8.77	0	7.85	0.38	13.08	0.12	34.268	0.22	26.08	8.13	99.06
	100 D	10	0.04	0.11	0.16	1.84	0.30	8.18	0.35	8.64	0.11	34.888	0.15	25.76	8.13	96.11
	150 S	1	0.05	0.84	0.28	3.70	0.31	9.34	0.38	11.48	0.18	34.669	0.18	26.14	8.12	97.14
	150 D	15	0.06	0.07	0.18	1.51	0.31	8.54	0.38	8.92	0.10	34.900	0.15	25.72	8.13	95.16
WAILEA 2 - Palau'ea	0 S	1	0.15	24.92	0.10	39.36	0.22	6.03	0.54	45.99	0.18	24.903	0.43	26.10	8.11	98.40
	2 S	1	0.18	15.70	0.15	25.76	0.28	7.30	0.54	30.55	0.17	31.060	0.46	26.12	8.12	100.29
	5 S	1	0.10	6.42	0.16	12.53	0.29	8.24	0.42	16.59	0.17	33.957	0.28	26.16	8.12	100.67
	5 D	2.5	0.12	3.77	0.19	8.31	0.29	8.15	0.43	12.70	0.16	34.479	0.30	26.13	8.13	100.64
	10 S	1	0.08	1.78	0.21	6.86	0.30	9.12	0.41	12.52	0.14	34.632	0.19	26.15	8.13	100.10
	10 D	3	0.05	1.26	0.19	4.04	0.30	7.54	0.37	9.42	0.13	34.752	0.29	26.15	8.13	100.34
	50 S	1	0.08	3.38	0.15	7.25	0.27	8.14	0.37	12.02	0.13	34.582	0.19	26.06	8.14	97.37
	50 D	4.5	0.09	0.14	0.27	1.86	0.28	7.44	0.39	8.13	0.13	34.920	0.22	25.81	8.14	93.63
	100 S	1	0.09	1.14	0.24	3.87	0.30	8.41	0.41	10.44	0.12	34.778	0.16	25.87	8.14	96.15
	100 D	10	0.06	0.05	0.19	1.47	0.31	7.32	0.38	7.70	0.12	34.947	0.17	25.78	8.15	94.66
	150 S	1	0.06	0.36	0.16	2.95	0.29	8.03	0.37	9.35	0.13	34.802	0.12	26.31	8.14	96.35
	150 D	15	0.06	0.05	0.20	1.44	0.29	8.29	0.36	8.66	0.09	34.970	0.16	25.76	8.15	94.65
WAILEA 3 - Wailea Beach	0 S	1	0.13	8.23	0.40	23.35	0.31	8.71	0.47	20.99	0.24	31.719	0.56	26.23	8.15	98.91
	2 S	1	0.11	4.69	0.30	14.04	0.30	7.36	0.43	15.27	0.21	33.681	0.44	26.26	8.14	98.69
	5 S	1	0.09	2.63	0.24	8.77	0.30	7.17	0.40	10.99	0.16	34.386	0.34	26.51	8.13	98.69
	5 D	2.5	0.10	2.65	0.32	8.89	0.30	8.08	0.42	11.91	0.19	34.389	0.31	26.49	8.14	98.56
	10 S	1	0.10	3.46	0.27	11.83	0.28	7.18	0.41	13.07	0.15	33.942	0.22	26.50	8.13	97.96
	10 D	5	0.08	1.99	0.29	8.66	0.28	7.49	0.38	10.93	0.18	34.384	0.31	26.30	8.13	98.37
	50 S	1	0.11	0.81	0.46	4.93	0.33	8.88	0.47	11.08	0.15	34.703	0.28	26.06	8.14	97.24
	50 D	10	0.07	0.12	0.43	2.23	0.33	8.32	0.42	9.18	0.12	34.891	0.24	25.96	8.15	95.50
	100 S	1	0.07	0.80	0.33	4.62	0.31	8.33	0.39	10.16	0.16	34.699	0.23	26.19	8.14	96.91
	100 D	15	0.06	0.04	0.19	1.73	0.32	8.66	0.39	9.01	0.12	34.926	0.19	25.84	8.15	94.64
	150 S	1	0.07	0.36	0.31	2.93	0.30	7.56	0.38	8.81	0.14	34.832	0.15	26.16	8.14	94.37
	150 D	20	0.07	0.07	0.32	1.54	0.29	7.34	0.37	7.89	0.10	34.946	0.17	25.77	8.15	93.55
WAILEA 4 - Ulua Beach	0 S	1	0.10	16.02	0.25	27.95	0.30	7.71	0.43	34.06	0.26	31.426	0.39	26.09	8.12	101.27
	2 S	1	0.07	10.49	0.20	19.28	0.32	8.54	0.43	26.41	0.22	32.835	0.53	26.34	8.14	101.26
	5 S	1	0.08	2.49	0.18	7.35	0.30	8.07	0.40	12.75	0.17	34.406	0.43	26.34	8.14	103.71
	5 D	2.5	0.08	2.11	0.18	6.73	0.30	8.61	0.39	12.68	0.16	34.466	0.31	26.40	8.14	100.90
	10 S	1	0.10	0.87	0.30	4.48	0.30	9.64	0.42	11.72	0.19	34.767	0.28	26.38	8.15	101.38
	10 D	3	0.11	0.49	0.19	3.49	0.30	7.73	0.44	9.11	0.15	34.836	0.26	26.32	8.13	100.82
	50 S	1	0.11	4.13	0.25	7.82	0.31	8.52	0.44	14.71	0.18	34.271	0.27	26.35	8.12	96.46
	50 D	10	0.09	0.18	0.18	2.28	0.27	8.59	0.39	9.30	0.12	34.914	0.23	25.50	8.13	92.62
	100 S	1	0.08	3.71	0.23	8.18	0.29	8.10	0.40	13.83	0.15	34.305	0.21	26.29	8.12	96.03
	100 D	15	0.08	0.09	0.18	1.80	0.32	8.53	0.43	9.11	0.10	34.945	0.16	25.82	8.14	94.23
	150 S	1	0.07	0.45	0.12	3.17	0.33	7.65	0.41	8.92	0.10	34.818	0.14	26.41	8.13	94.87
	150 D	25	0.06	0.04	0.09	1.60	0.33	7.44	0.41	7.78	0.11	34.926	0.17	25.74	8.15	94.84
WAILEA 5 - Ahihi-kina'u	0 S	1	0.22	17.29	0.51	81.09	0.29	5.45	0.63	31.49	0.27	27.937	0.66	25.40	8.08	95.98
	2 S	1	0.16	14.05	0.81	64.93	0.26	6.14	0.58	27.36	0.28	29.232	0.47	25.66	8.08	97.42
	5 S	1	0.13	5.73	0.60	33.87	0.30	8.67	0.47	16.31	0.20	32.972	0.43	25.70	8.10	99.25
	5 D	1.5	0.06	3.87	0.36	23.72	0.30	8.35	0.41	12.88	0.15	33.702	0.39	25.71	8.11	99.87
	10 S	1	0.05	1.64	0.37	11.46	0.29	8.17	0.36	10.35	0.14	34.426	0.22	25.78	8.10	98.88
	10 D	2.5	0.11	1.60	0.40	11.40	0.28	7.10	0.40	9.35	0.14	34.481	0.34	25.65	8.10	96.88
	50 S	1	0.08	0.95	0.34	7.96	0.30	7.66	0.40	9.24	0.15	34.593	0.21	25.56	8.12	94.18
	50 D	9	0.07	0.10	0.25	3.23	0.30	7.18	0.39	7.71	0.13	34.867	0.32	25.56	8.11	93.53
	100 S	1	0.11	0.48	0.27	6.98	0.31	7.16	0.43	8.42	0.15	34.615	0.17	25.79	8.11	95.15
	100 D	14	0.05	0.09	0.20	2.75	0.30	7.01	0.37	7.64	0.14	34.855	0.19	25.64	8.13	93.85
	150 S	1	0.07	0.25	0.28	3.27	0.29	7.49	0.39	8.46	0.12	34.804	0.14	25.81	8.13	95.38
	150 D	18	0.05	0.04	0.18	1.98	0.31	7.39	0.38	7.81	0.12	34.914	0.17	25.68	8.14	94.53
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 $\mu g/L$) collected at five sites off of Honua'ula, Wailea, Maui since the inception of monitoring in June 2005 (N=7). 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)	PO_4^{3-} ($\mu g/L$)	NO_3^- ($\mu g/L$)	NH_4^+ ($\mu g/L$)	Si ($\mu g/L$)	TOP ($\mu g/L$)	TON ($\mu g/L$)	TP ($\mu g/L$)	TN ($\mu g/L$)	TURB (NTU)	SALINITY (ppt)	CHL a ($\mu g/L$)	TEMP (deg.C)	pH (std.units)	O2 % Sat
WAILEA 1 - Five Graves	0 S	1	5.57	865.3	4.34	3,088	9.29	95.52	16.41	1,056	0.21	21.86	0.92	25.98	8.11	106.20
	2 S	1	5.26	607.3	1.40	2,331	10.22	113.72	16.72	772.9	0.20	27.18	1.38	25.97	8.14	105.91
	5 S	1	2.16	218.9	0.70	967.7	8.98	119.61	12.07	375.1	0.18	31.56	0.51	25.73	8.12	104.94
	5 D	2.5	3.40	120.6	4.20	608.1	8.98	126.19	13.62	269.3	0.12	33.27	0.31	26.03	8.12	105.07
	10 S	1	2.47	90.75	2.66	471.1	8.98	116.24	11.76	233.1	0.17	33.71	0.32	26.10	8.11	107.66
	10 D	3	2.16	31.23	3.08	202.8	9.29	113.02	11.46	157.7	0.13	34.48	0.30	26.00	8.11	106.88
	50 S	1	1.54	45.93	4.06	266.0	9.29	118.63	11.15	191.5	0.14	34.25	0.28	26.00	8.13	102.23
	50 D	4.5	2.47	4.20	1.82	65.17	9.60	116.10	12.38	126.2	0.11	34.80	0.32	25.77	8.12	96.94
	100 S	1	2.47	43.97	3.50	246.3	5.57	109.94	11.76	183.2	0.12	34.27	0.22	26.08	8.13	99.06
	100 D	10	1.23	1.54	2.24	51.69	9.29	114.56	10.84	121.0	0.11	34.89	0.15	25.76	8.13	96.11
	150 S	1	1.54	11.76	3.92	103.9	9.60	130.81	11.76	160.8	0.18	34.67	0.18	26.14	8.12	97.14
	150 D	15	1.85	0.98	2.52	42.42	9.60	119.61	11.76	124.9	0.10	34.90	0.15	25.72	8.13	95.16
WAILEA 2 - Palau'ea	0 S	1	4.64	349.0	1.40	1,106	6.81	84.45	16.72	644.1	0.18	24.90	0.43	26.10	8.11	98.40
	2 S	1	5.57	219.9	2.10	723.6	8.67	102.24	16.72	427.9	0.17	31.06	0.46	26.12	8.12	100.29
	5 S	1	3.09	89.91	2.24	352.0	8.98	115.40	13.00	232.4	0.17	33.96	0.28	26.16	8.12	100.67
	5 D	2.5	3.71	52.80	2.66	233.4	8.98	114.14	13.31	177.9	0.16	34.48	0.30	26.13	8.13	100.64
	10 S	1	2.47	24.93	2.94	192.7	9.29	127.73	12.69	175.4	0.14	34.63	0.19	26.15	8.13	100.10
	10 D	3	1.54	17.64	2.66	113.5	9.29	105.60	11.46	131.9	0.13	34.75	0.29	26.15	8.13	100.34
	50 S	1	2.47	47.34	2.10	203.7	8.36	114.00	11.46	168.4	0.13	34.58	0.19	26.06	8.14	97.37
	50 D	4.5	2.78	1.96	3.78	52.25	8.67	104.20	12.07	113.9	0.13	34.92	0.22	25.81	8.14	93.63
	100 S	1	2.78	15.96	3.36	108.7	9.29	117.79	12.69	146.2	0.12	34.78	0.16	25.87	8.14	96.15
	100 D	10	1.85	0.70	2.66	41.29	9.60	102.52	11.76	107.8	0.12	34.95	0.17	25.78	8.15	94.66
	150 S	1	1.85	5.04	2.24	82.87	8.98	112.46	11.46	131.0	0.13	34.80	0.12	26.31	8.14	96.35
	150 D	15	1.85	0.70	2.80	40.45	8.98	116.10	11.15	121.3	0.09	34.97	0.16	25.76	8.15	94.65
WAILEA 3 - Wailea Beach	0 S	1	4.02	115.3	5.60	655.9	9.60	121.99	14.55	294.0	0.24	31.72	0.56	26.23	8.15	98.91
	2 S	1	3.40	65.68	4.20	394.4	9.29	103.08	13.31	213.9	0.21	33.68	0.44	26.26	8.14	98.69
	5 S	1	2.78	36.83	3.36	246.3	9.29	100.42	12.38	153.9	0.16	34.39	0.34	26.51	8.13	98.69
	5 D	2.5	3.09	37.11	4.48	249.7	9.29	113.16	13.00	166.8	0.19	34.39	0.31	26.49	8.14	98.56
	10 S	1	3.09	48.46	3.78	332.3	8.67	100.56	12.69	183.1	0.15	33.94	0.22	26.50	8.13	97.96
	10 D	5	2.47	27.87	4.06	243.3	8.67	104.90	11.76	153.1	0.18	34.38	0.31	26.30	8.13	98.37
	50 S	1	3.40	11.34	6.44	138.5	10.22	124.37	14.55	155.2	0.15	34.70	0.28	26.06	8.14	97.24
	50 D	10	2.16	1.68	6.02	62.64	10.22	116.52	13.00	128.6	0.12	34.89	0.24	25.96	8.15	95.50
	100 S	1	2.16	11.20	4.62	129.8	9.60	116.66	12.07	142.3	0.16	34.70	0.23	26.19	8.14	96.91
	100 D	15	1.85	0.56	2.66	48.60	9.91	121.29	12.07	126.2	0.12	34.93	0.19	25.84	8.15	94.64
	150 S	1	2.16	5.04	4.34	82.30	9.29	105.88	11.76	123.4	0.14	34.83	0.15	26.16	8.14	94.37
	150 D	20	2.16	0.98	4.48	43.26	8.98	102.80	11.46	110.5	0.10	34.95	0.17	25.77	8.15	93.55
WAILEA 4 - Ulua Beach	0 S	1	3.09	224.4	3.50	785.1	9.29	107.98	13.31	477.0	0.26	31.43	0.39	26.09	8.12	101.27
	2 S	1	2.16	146.9	2.80	541.6	9.91	119.61	13.31	369.9	0.22	32.84	0.53	26.34	8.14	101.26
	5 S	1	2.47	34.87	2.52	206.5	9.29	113.02	12.38	178.6	0.17	34.41	0.43	26.34	8.14	103.71
	5 D	2.5	2.47	29.55	2.52	189.0	9.29	120.59	12.07	177.6	0.16	34.47	0.31	26.40	8.14	100.90
	10 S	1	3.09	12.18	4.20	125.8	9.29	135.01	13.00	164.2	0.19	34.77	0.28	26.38	8.15	101.38
	10 D	3	3.40	6.86	2.66	98.03	9.29	108.26	13.62	127.6	0.15	34.84	0.26	26.32	8.13	100.82
	50 S	1	3.40	57.84	3.50	219.7	9.60	119.33	13.62	206.0	0.18	34.27	0.27	26.35	8.12	96.46
	50 D	10	2.78	2.52	2.52	64.05	8.36	120.31	12.07	130.3	0.12	34.91	0.23	25.50	8.13	92.62
	100 S	1	2.47	51.96	3.22	229.8	8.98	113.44	12.38	193.7	0.15	34.31	0.21	26.29	8.12	96.03
	100 D	15	2.47	1.26	2.52	50.56	9.91	119.47	13.31	127.6	0.10	34.95	0.16	25.82	8.14	94.23
	150 S	1	2.16	6.30	1.68	89.05	10.22	107.14	12.69	124.9	0.10	34.82	0.14	26.41	8.13	94.87
	150 D	25	1.85	0.56	1.26	44.94	10.22	104.20	12.69	109.0	0.11	34.93	0.17	25.74	8.15	94.84
WAILEA 5 - Ahihi-kina'u	0 S	1	6.81	242.2	7.14	2,278	8.98	76.33	19.51	441.0	0.27	27.94	0.66	25.40	8.08	95.98
	2 S	1	4.95	196.8	11.34	1,824	8.05	85.99	17.96	383.2	0.28	29.23	0.47	25.66	8.08	97.42
	5 S	1	4.02	80.25	8.40	951.4	9.29	121.43	14.55	228.4	0.20	32.97	0.43	25.70	8.10	99.25
	5 D	1.5	1.85	54.20	5.04	666.3	9.29	116.95	12.69	180.4	0.15	33.70	0.39	25.71	8.11	99.87
	10 S	1	1.54	22.96	5.18	321.9	8.98	114.42	11.15	145.0	0.14	34.43	0.22	25.78	8.10	98.88
	10 D	2.5	3.40	22.40	5.60	320.2	8.67	99.44	12.38	131.0	0.14	34.48	0.34	25.65	8.10	96.88
	50 S	1	2.47	13.30	4.76	223.6	9.29	107.28	12.38	129.4	0.15	34.59	0.21	25.56	8.12	94.18
	50 D	9	2.16	1.40	3.50	90.73	9.29	100.56	12.07	108.0	0.13	34.87	0.32	25.56	8.11	93.53
	100 S	1	3.40	6.72	3.78	196.1	9.60	100.28	13.31	117.9	0.15	34.62	0.17	25.79	8.11	95.15
	100 D	14	1.54	1.26	2.80	77.25	9.29	98.18	11.46	107.0	0.14	34.86	0.19	25.64	8.13	93.85
	150 S	1	2.16	3.50	3.92	91.85	8.98	104.90	12.07	118.5	0.12	34.80	0.14	25.81	8.13	95.38
	150 D	18	1.54	0.56	2.52	55.62	9.60	103.50	11.76	109.4	0.12	34.91	0.17	25.68	8.14	94.53
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.

M 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
ns, see Figure 1.

NO_3^- (μg/L)	NO_3^- (μM)	NO_3^- (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)
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
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
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
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
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
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
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
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 July 2010. 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 in 2009 (N=14) and once, to date for 2010 (N=7). 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
2010	515.27	7.85	495.09	535.45
REGSLOPE	-4.60	23.28	-69.24	60.04
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
2010	708.83	11.33	679.71	737.94
REGSLOPE	32.57	38.96	-75.62	140.75
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
2010	467.31	18.09	420.82	513.81
REGSLOPE	8.10	29.26	-73.14	89.34
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
2010	471.84	27.13	402.11	541.57
REGSLOPE	-6.66	21.17	-65.45	52.13
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
2010	673.09	6.27	656.98	689.21
REGSLOPE	-13.61	6.75	-32.36	5.14

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
2010	-14.78	0.00	-0.04	-0.02
REGSLOPE	0.16	0.71	-1.80	2.12
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
2010	-20.26	0.00	-0.18	0.24
REGSLOPE	-0.90	1.13	-4.05	2.24
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
2010	-13.32	0.00	-0.08	-0.06
REGSLOPE	-0.21	0.85	-2.58	2.15
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
2010	-13.45	0.00	-0.11	0.08
REGSLOPE	0.21	0.62	-1.50	1.92
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
2010	-19.14	0.00	-0.08	-0.04
REGSLOPE	0.42	0.20	-0.15	0.99

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 July 2010. 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 in 2009 (N=14) and once, to date for 2010 (N=7). 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
2010	253.63	4.57	241.88	265.38
REGSLOPE	-21.80	10.87	-51.98	8.37
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
2010	450.47	21.87	394.24	506.69
REGSLOPE	11.53	24.60	-56.78	79.84
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
2010	220.36	6.33	204.08	236.64
REGSLOPE	-0.18	24.08	-67.02	66.67
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
2010	357.71	2.10	352.32	363.10
REGSLOPE	-31.82	18.41	-82.93	19.30
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
2010	148.96	16.96	105.35	192.57
REGSLOPE	5.89	19.79	-49.05	60.83

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
2010	-7.31	0.16	-7.72	-6.89
REGSLOPE	0.63	0.32	-0.25	1.52
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
2010	-12.93	0.64	-14.56	-11.29
REGSLOPE	-0.32	0.71	-2.29	1.65
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
2010	-6.32	0.18	-6.79	-5.84
REGSLOPE	0.02	0.69	-1.90	1.94
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
2010	-10.26	0.06	-10.42	-10.10
REGSLOPE	0.93	0.54	-0.56	2.42
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
2010	-4.30	0.50	-5.60	-3.00
REGSLOPE	-0.16	0.57	-1.75	1.42

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 July 2010. 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 in 2009 (N=14) and once, to date for 2010 (N=7). 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
2010	1.80	0.27	1.11	2.50
REGSLOPE	0.16	0.17	-0.32	0.64
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
2010	1.08	1.88	-3.75	5.92
REGSLOPE	0.06	0.29	-0.75	0.86
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
2010	1.12	0.91	-1.22	3.45
REGSLOPE	-0.23	0.25	-0.93	0.47
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
2010	0.65	0.18	0.19	1.12
REGSLOPE	0.53	0.32	-0.35	1.41
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
2010	0.76	0.47	-0.46	1.97
REGSLOPE	-0.37	0.25	-1.06	0.33

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
2010	-0.05	0.01	-0.07	-0.02
REGSLOPE	0.00	0.00	-0.02	0.01
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
2010	-0.03	0.05	-0.17	0.11
REGSLOPE	0.00	0.01	-0.03	0.02
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
2010	-0.03	0.03	-0.10	0.04
REGSLOPE	0.01	0.01	-0.01	0.03
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
2010	-0.02	0.01	-0.03	0.00
REGSLOPE	-0.02	0.01	-0.04	0.01
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
2010	-0.02	0.01	-0.06	0.02
REGSLOPE	0.01	0.01	-0.01	0.03

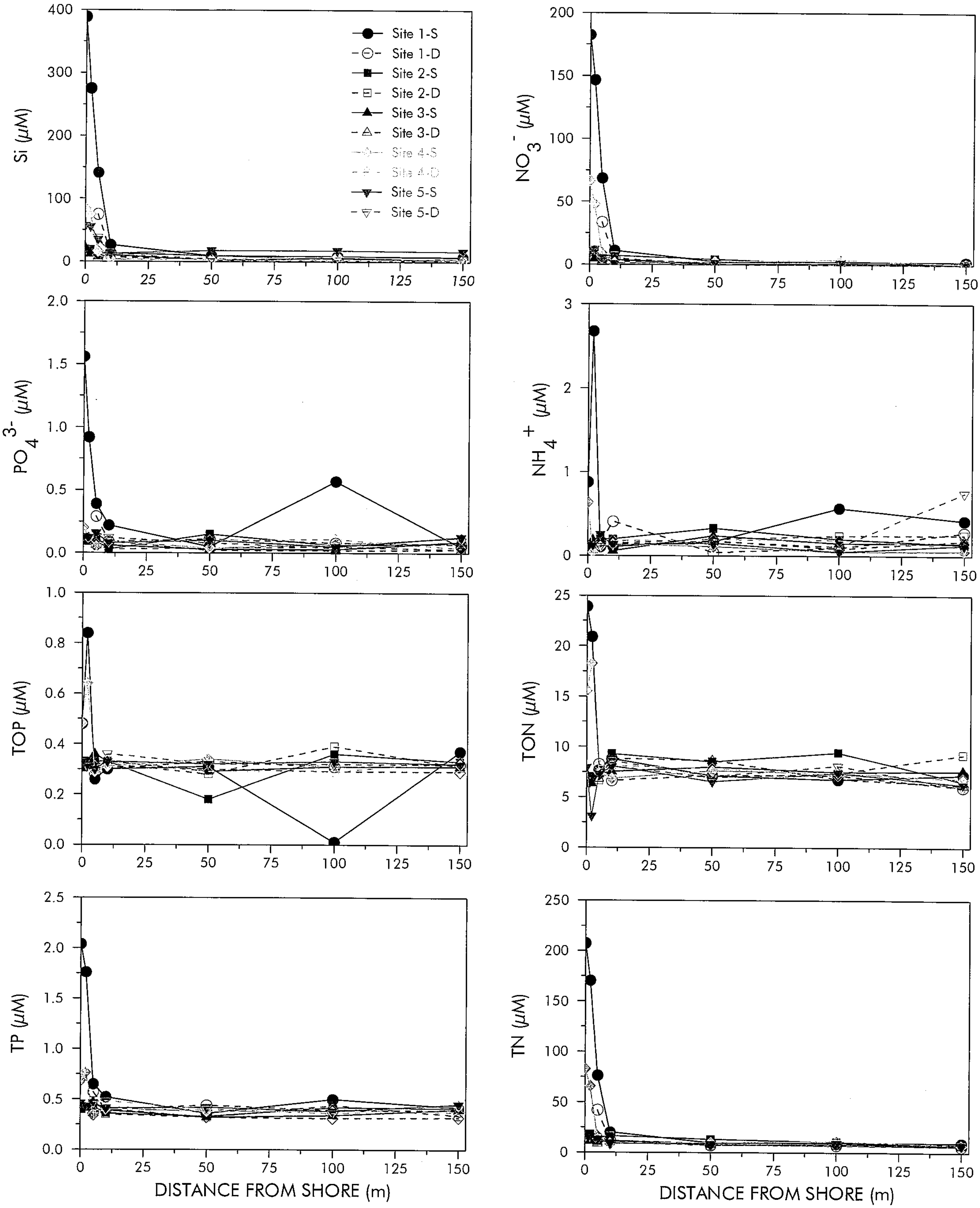

FIGURE 2. Plots of dissolved nutrients in surface (S) and deep (D) samples collected on July 11, 2010 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. For site locations, see Figure 1.

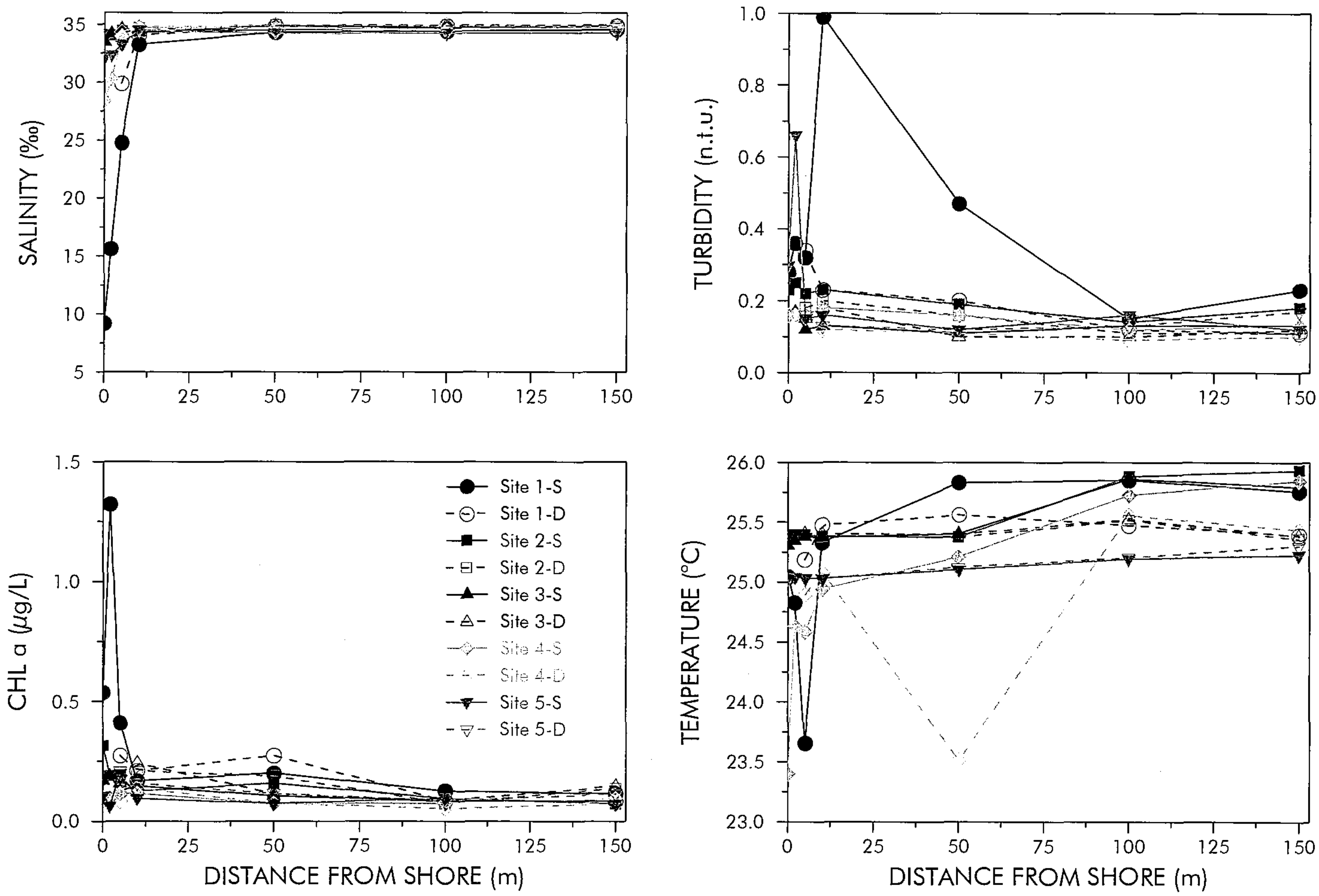

FIGURE 3. Plots of water chemistry constituents in surface (S) and deep (D) samples collected on July 11, 2010 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. For site locations, see Figure 1.

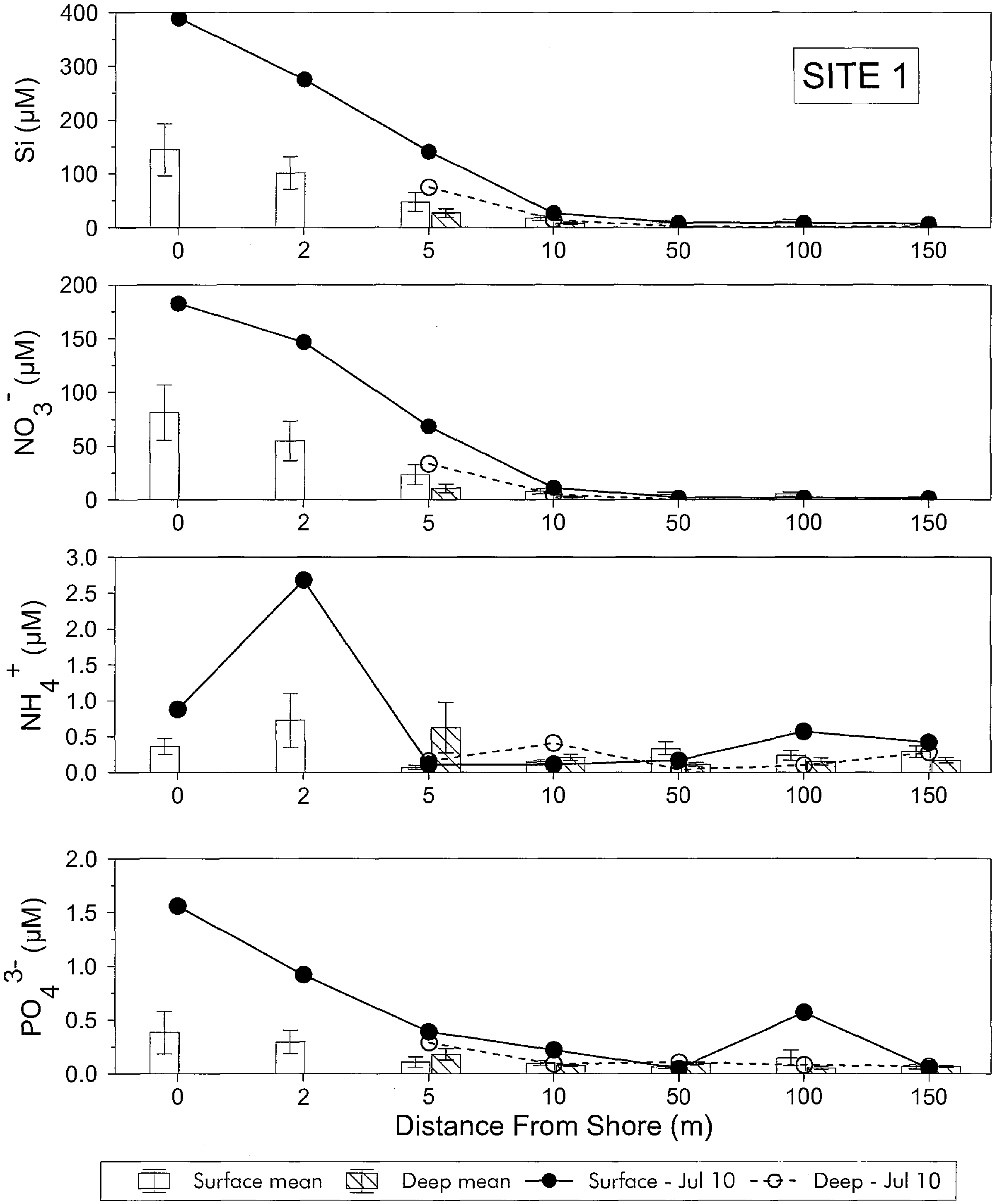

FIGURE 4. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

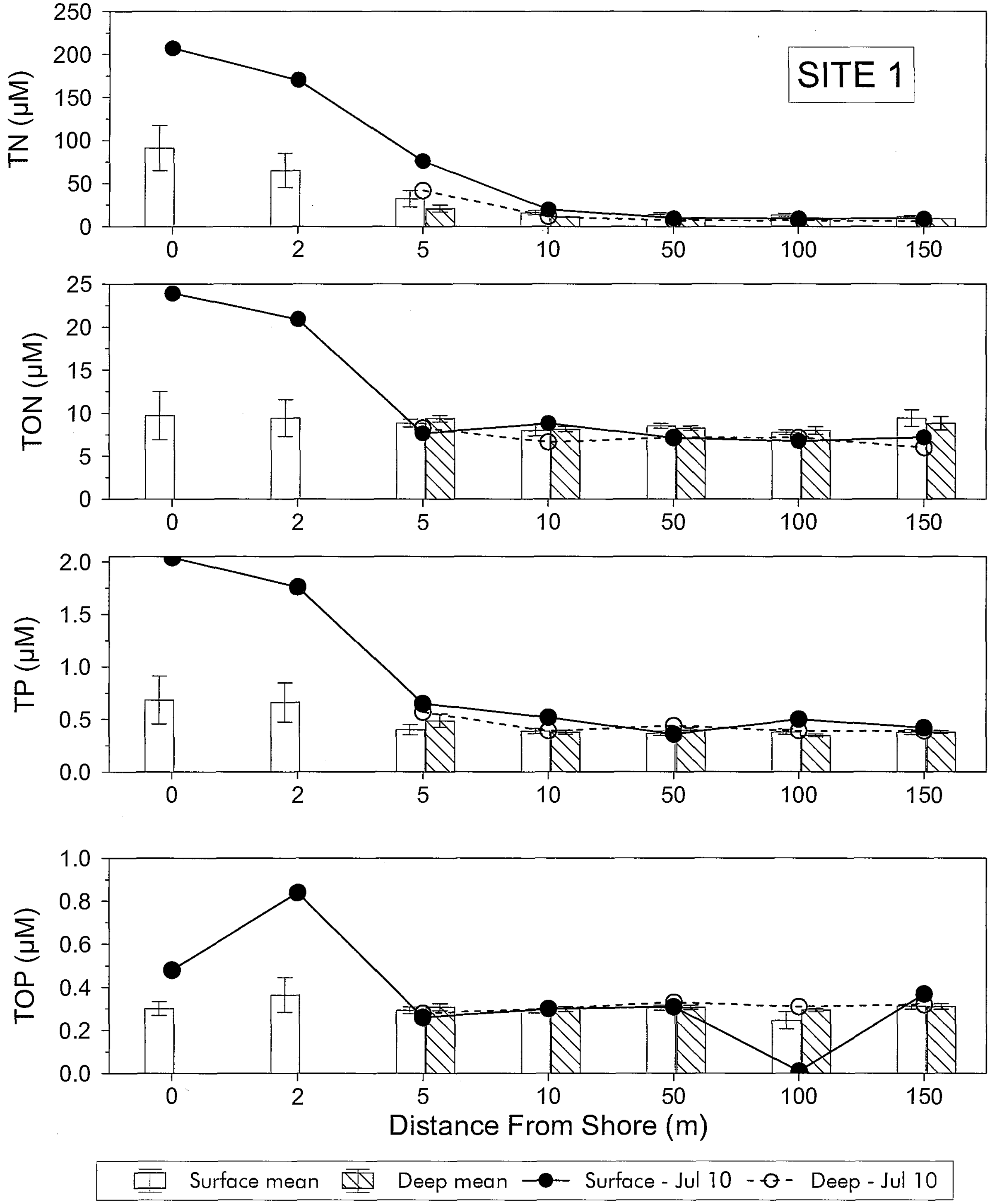

FIGURE 5. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

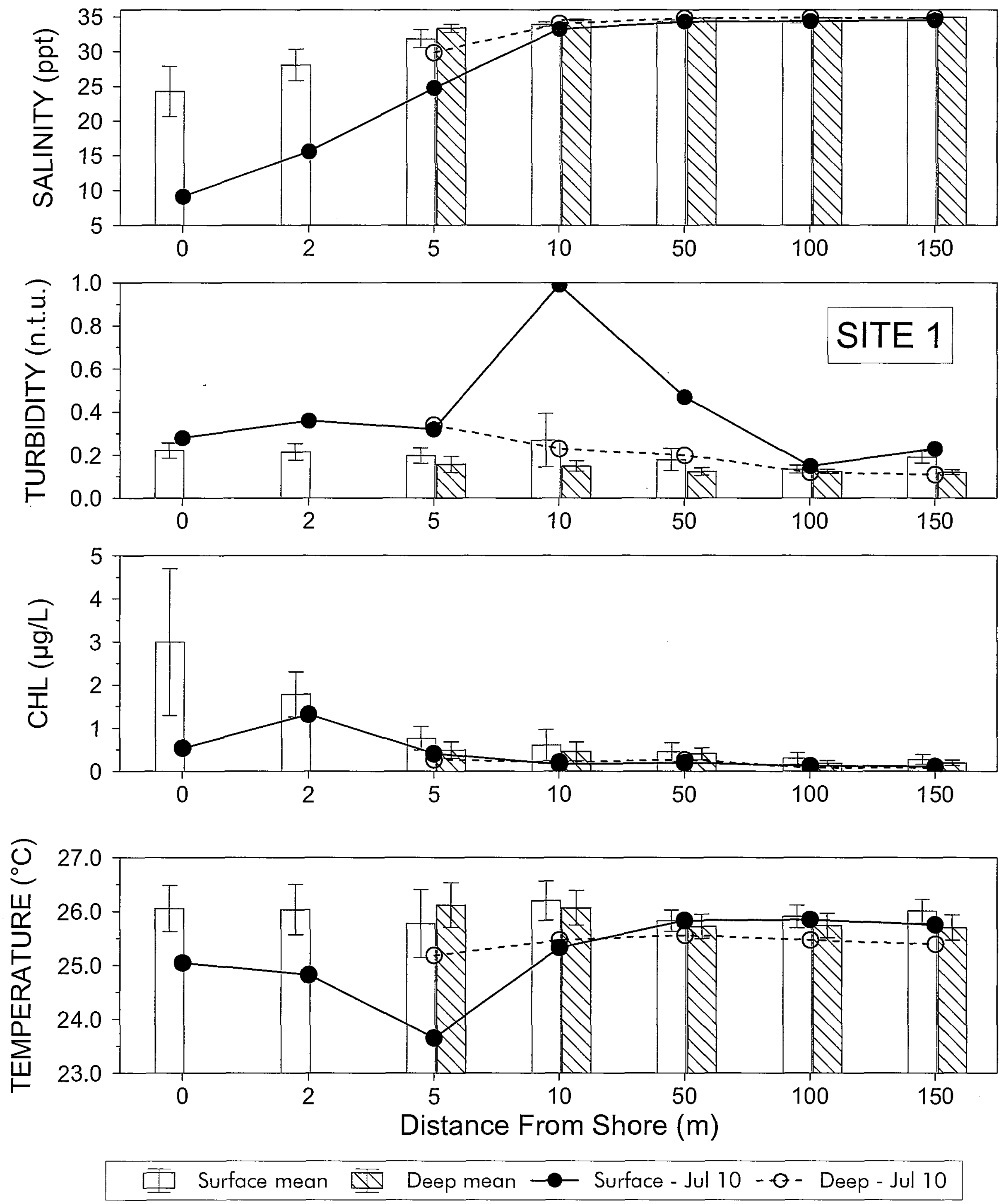

FIGURE 6. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent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

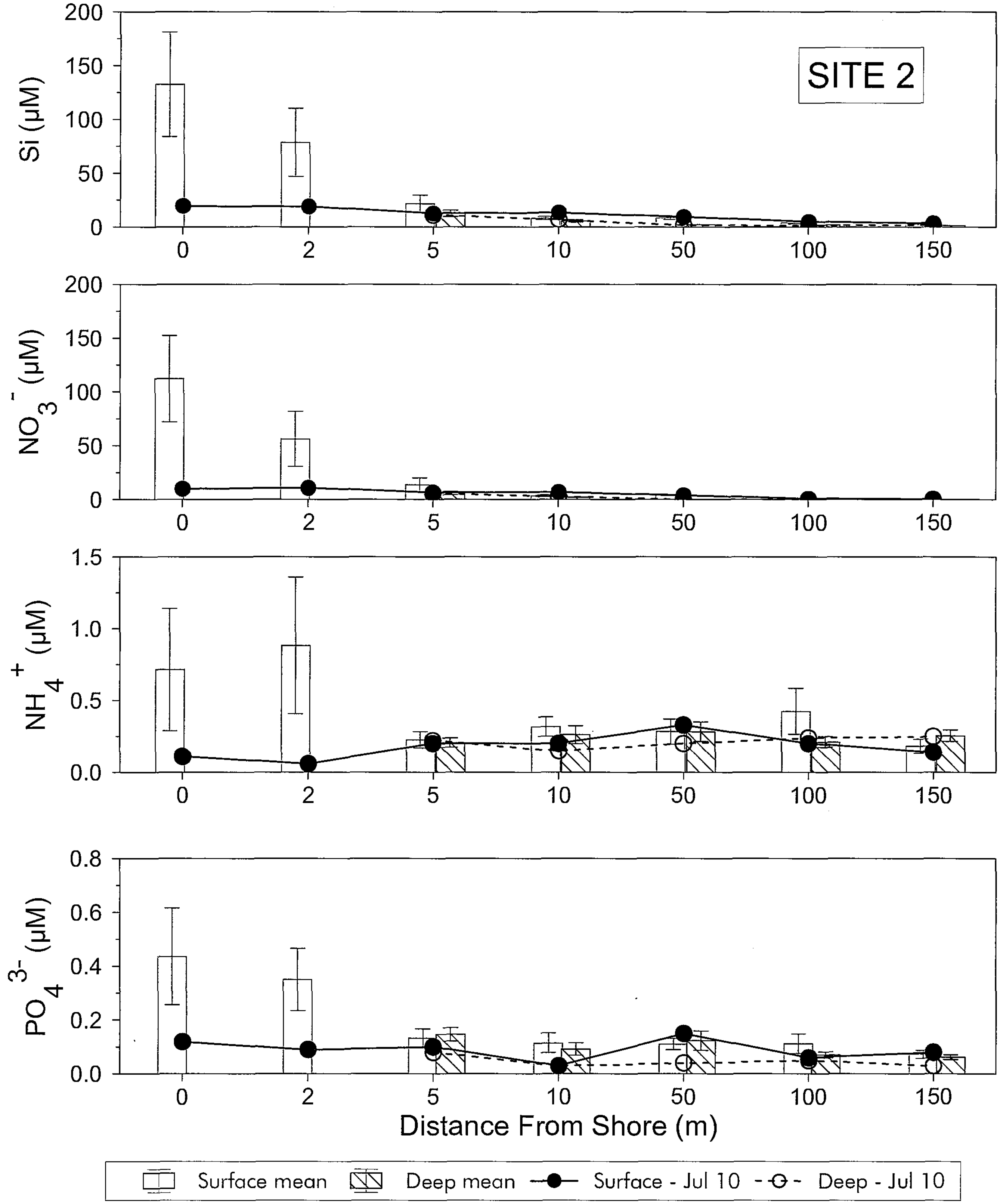

FIGURE 7. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean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

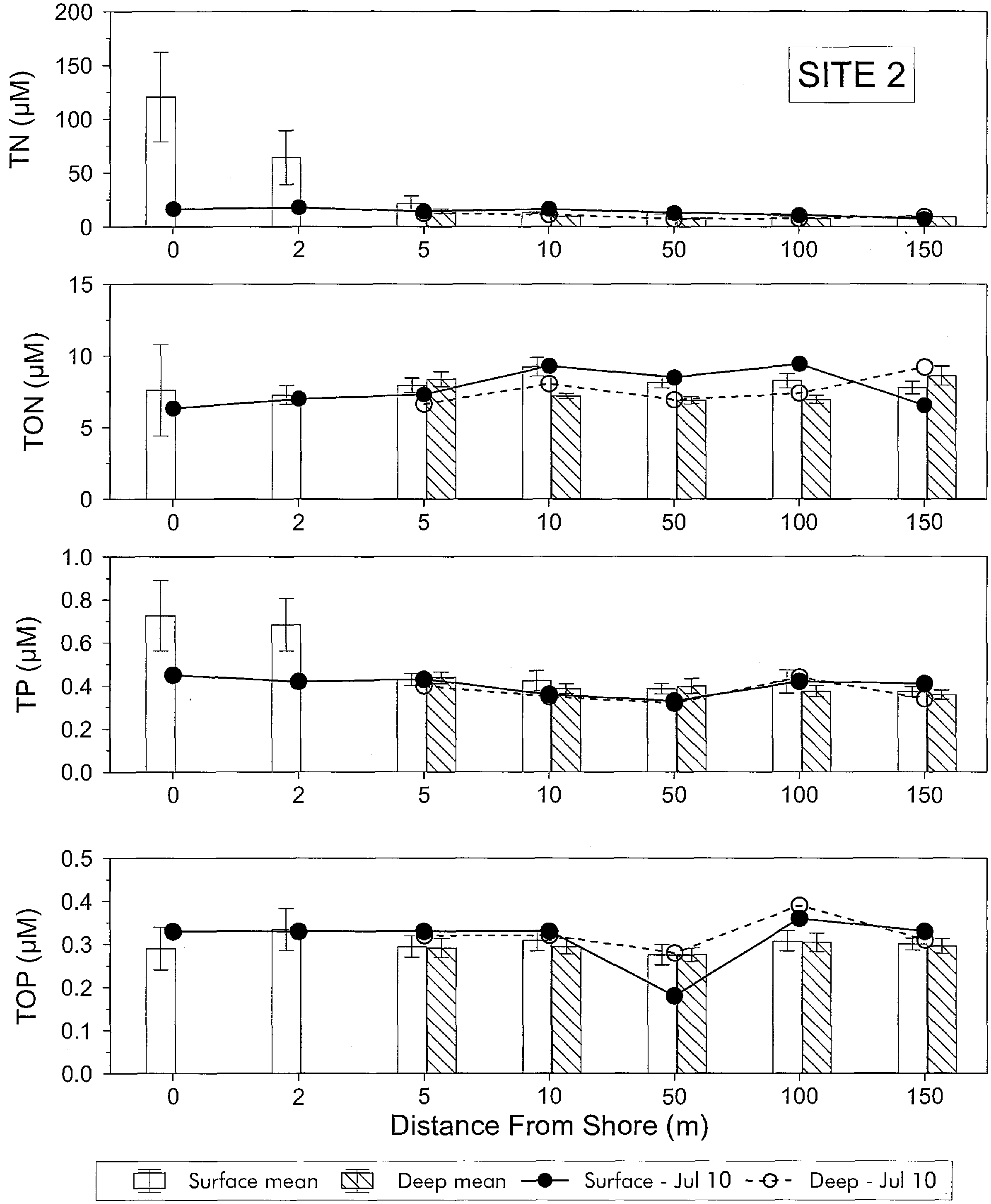

FIGURE 8. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

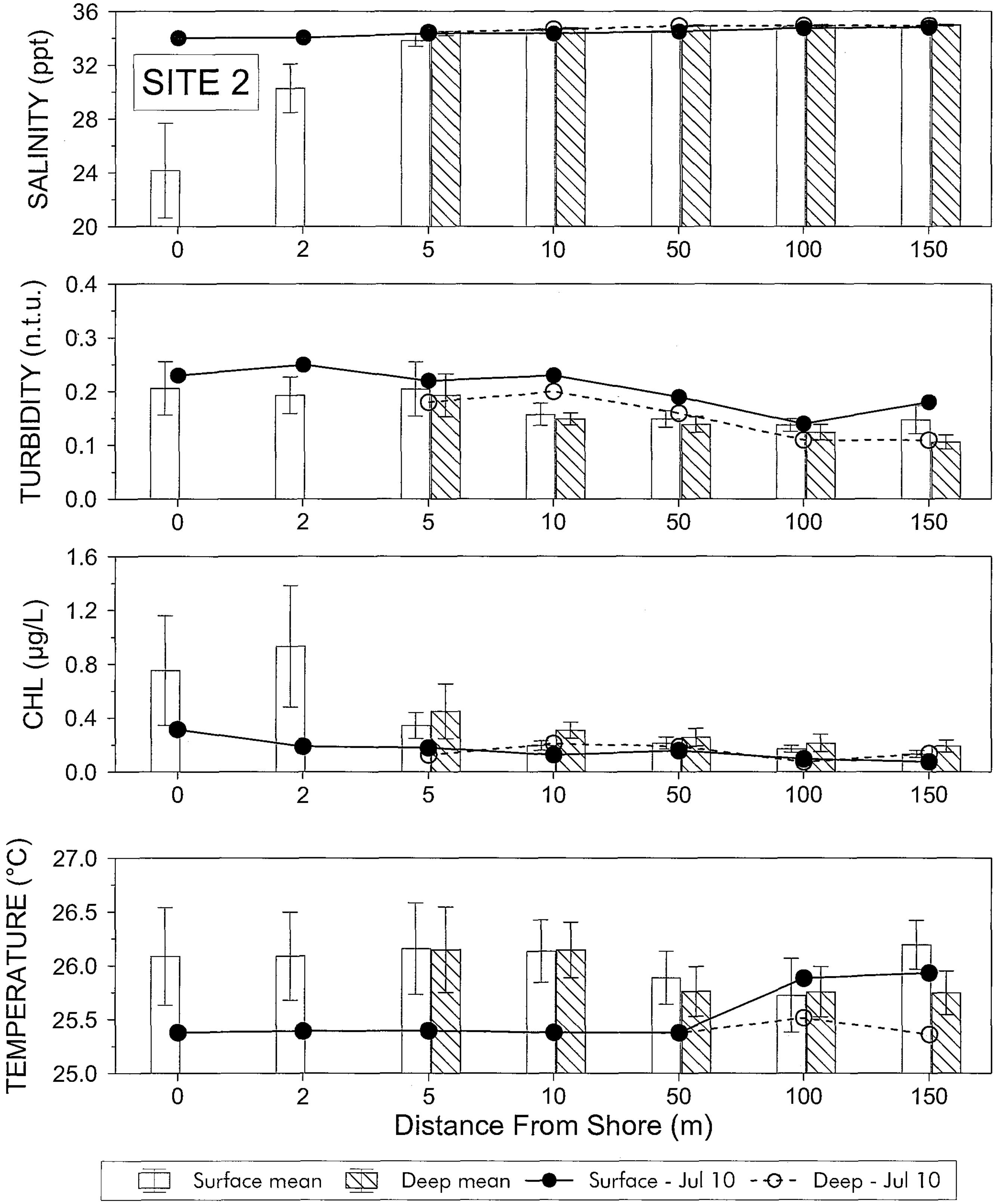

FIGURE 9. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

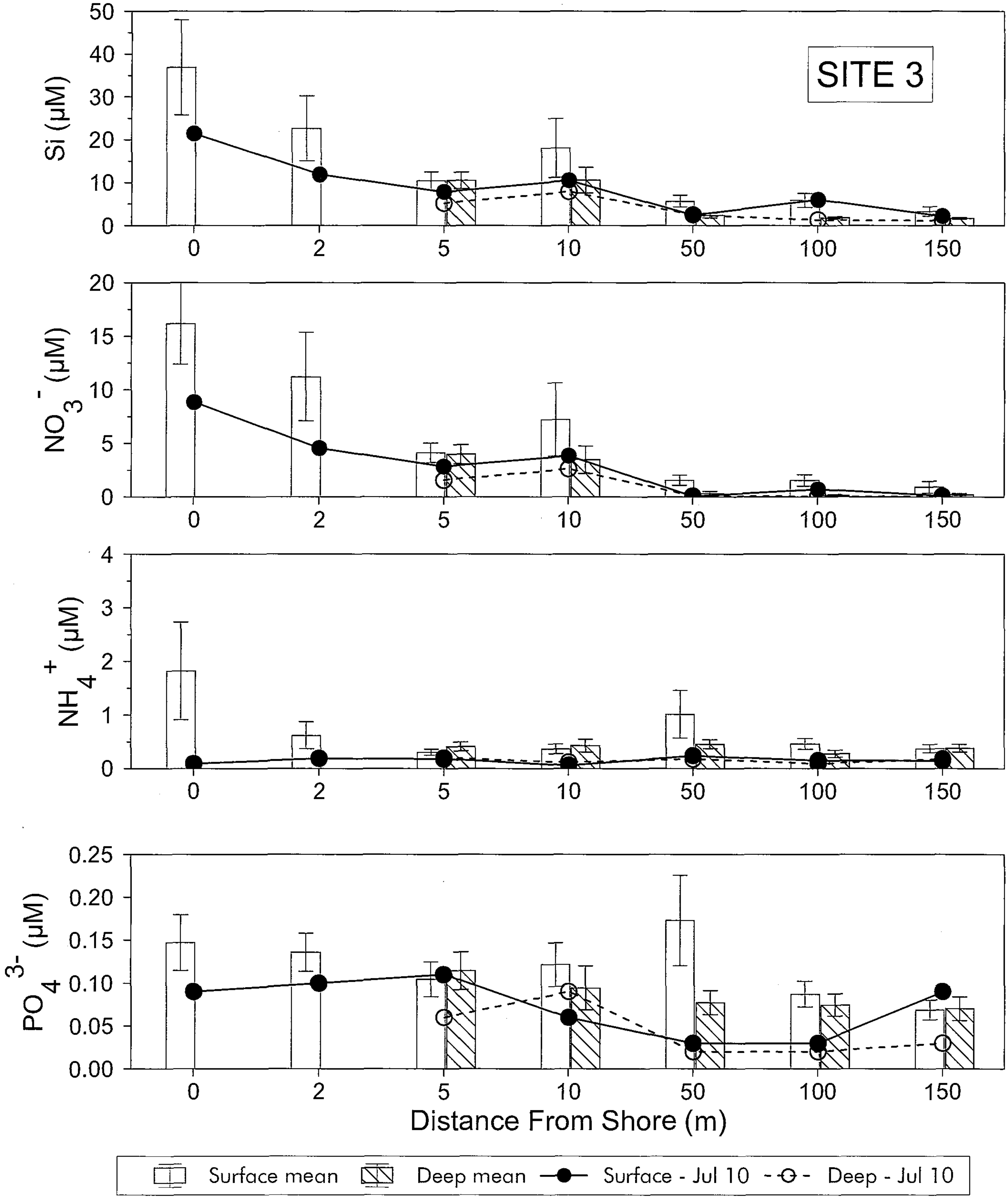

FIGURE 10. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

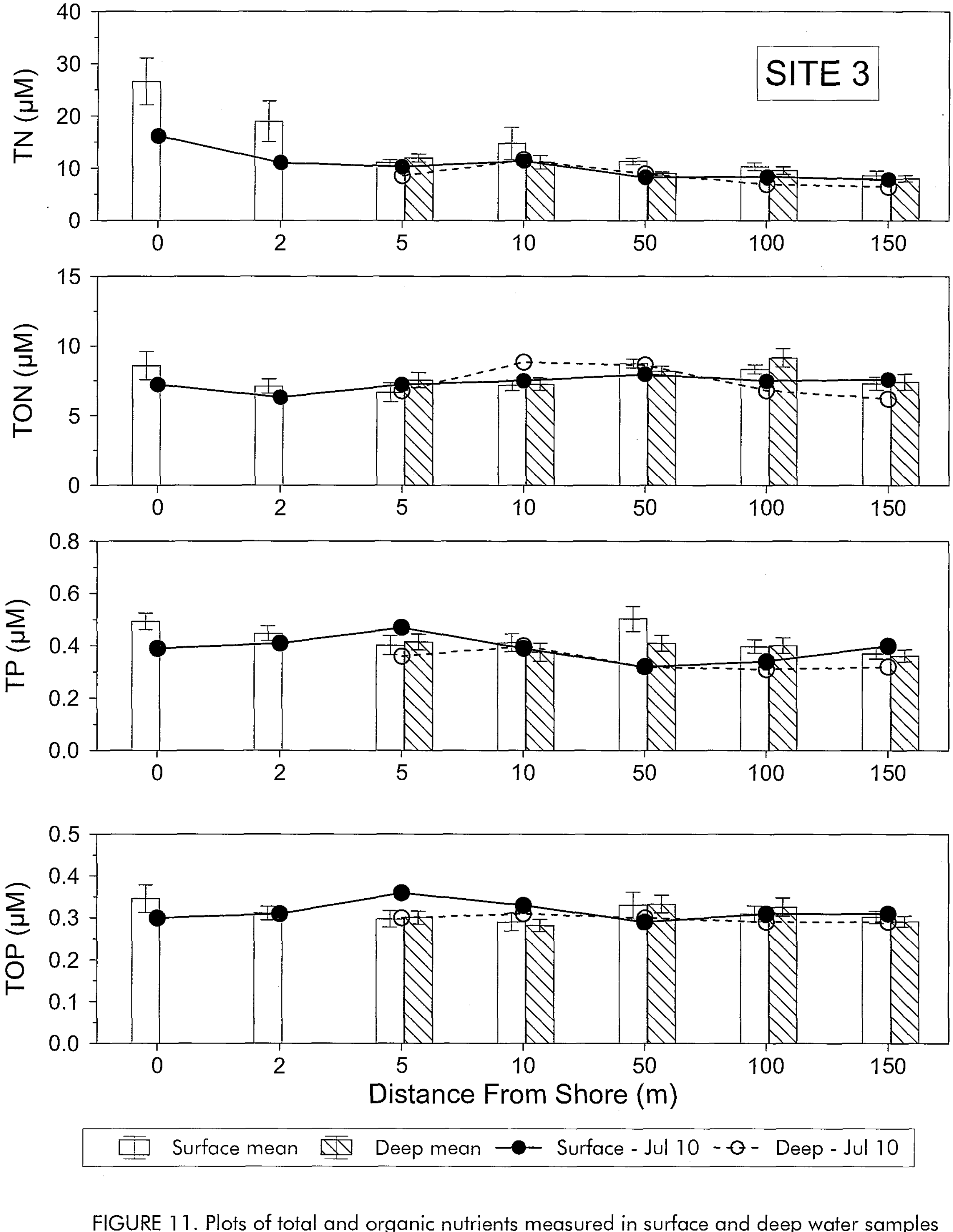

FIGURE 11. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

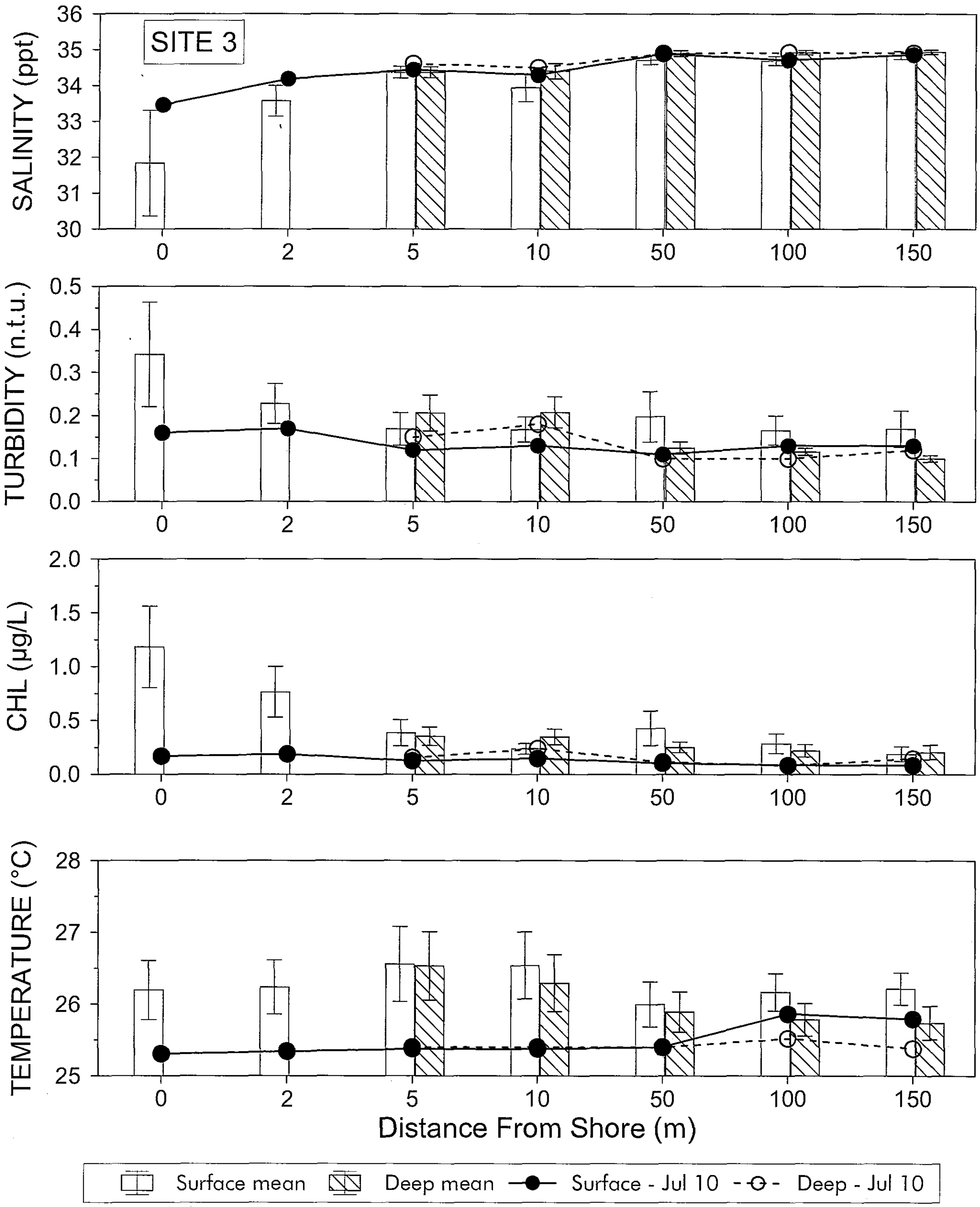

FIGURE 12. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

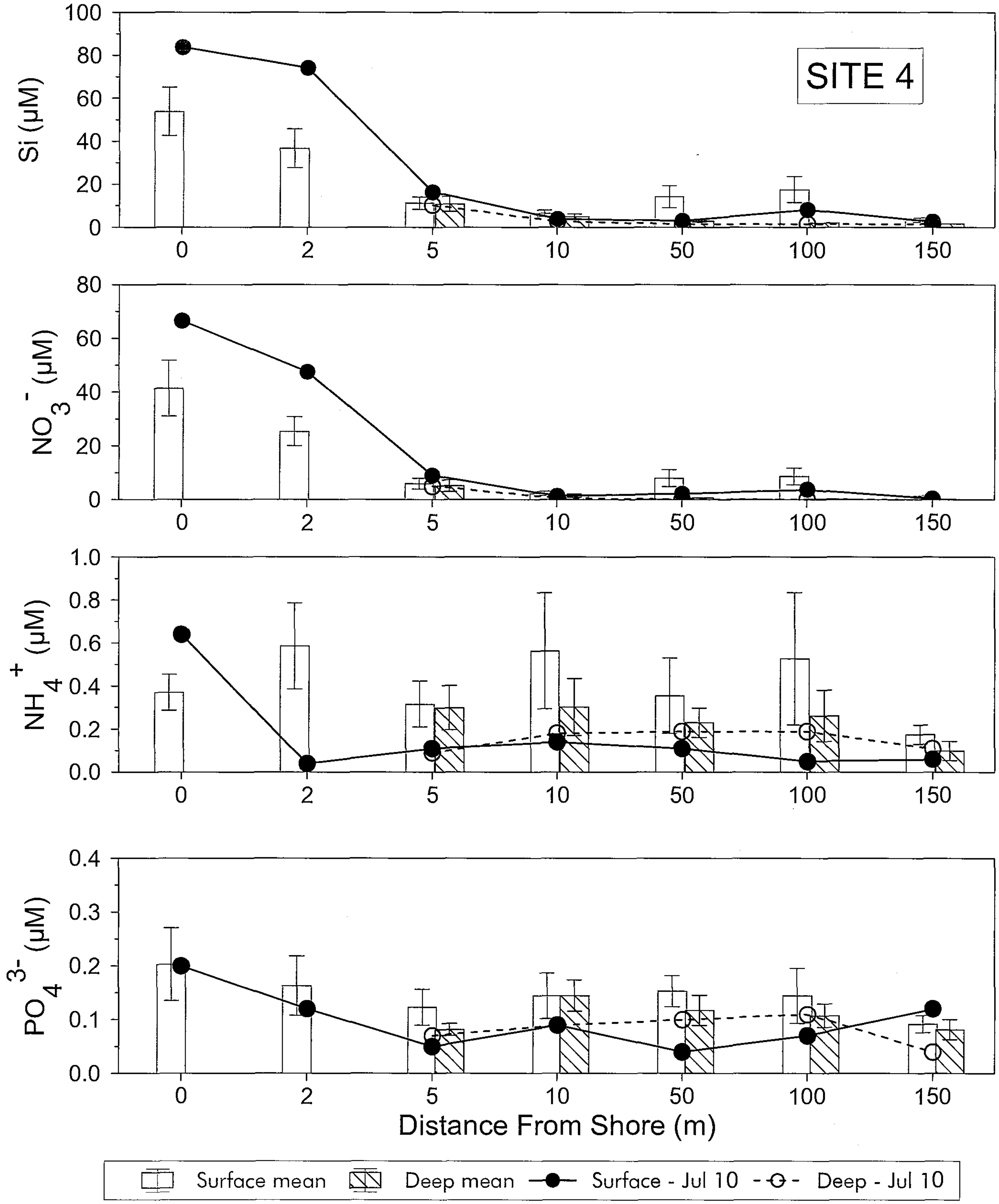

FIGURE 13. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

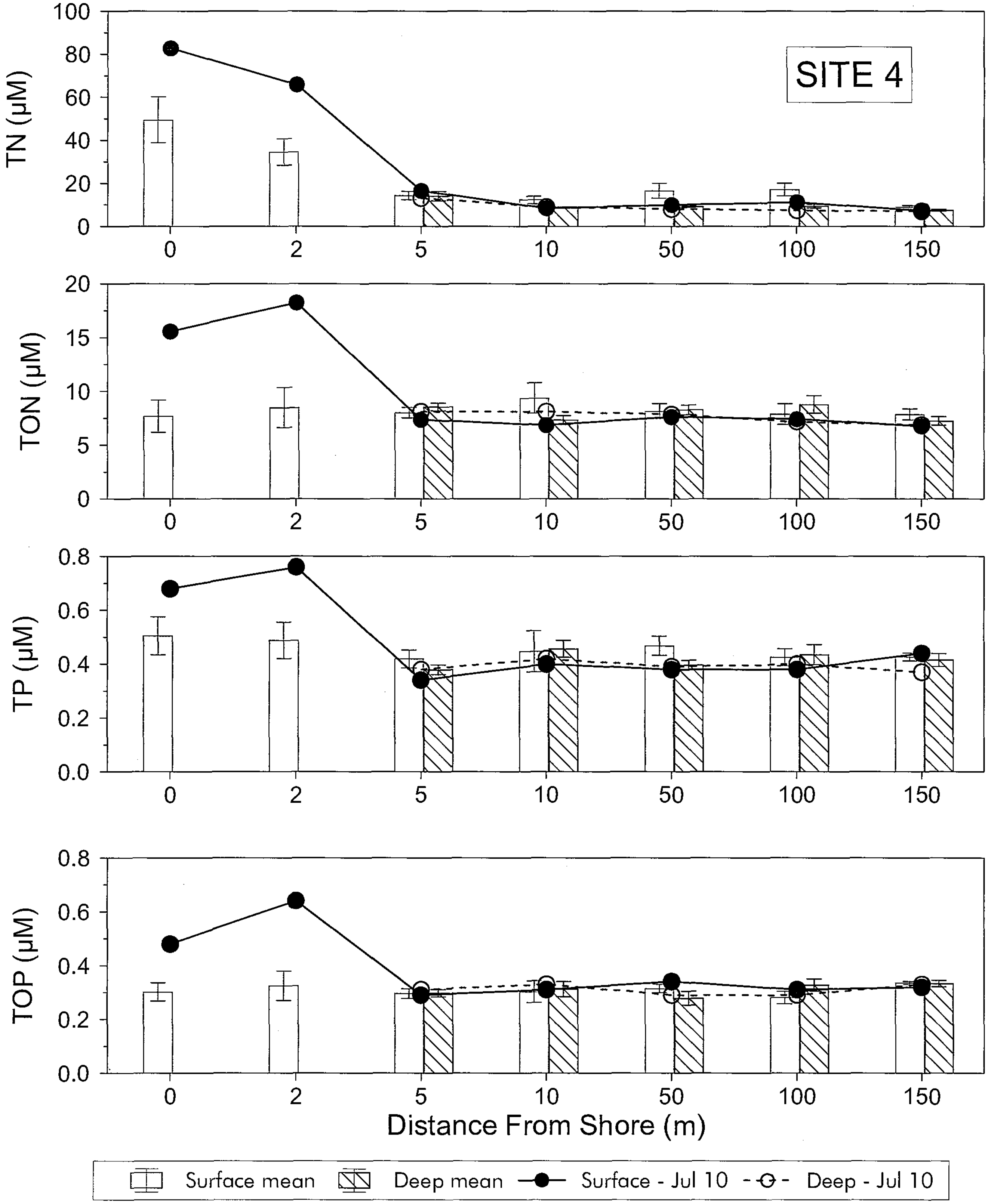

FIGURE 14. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

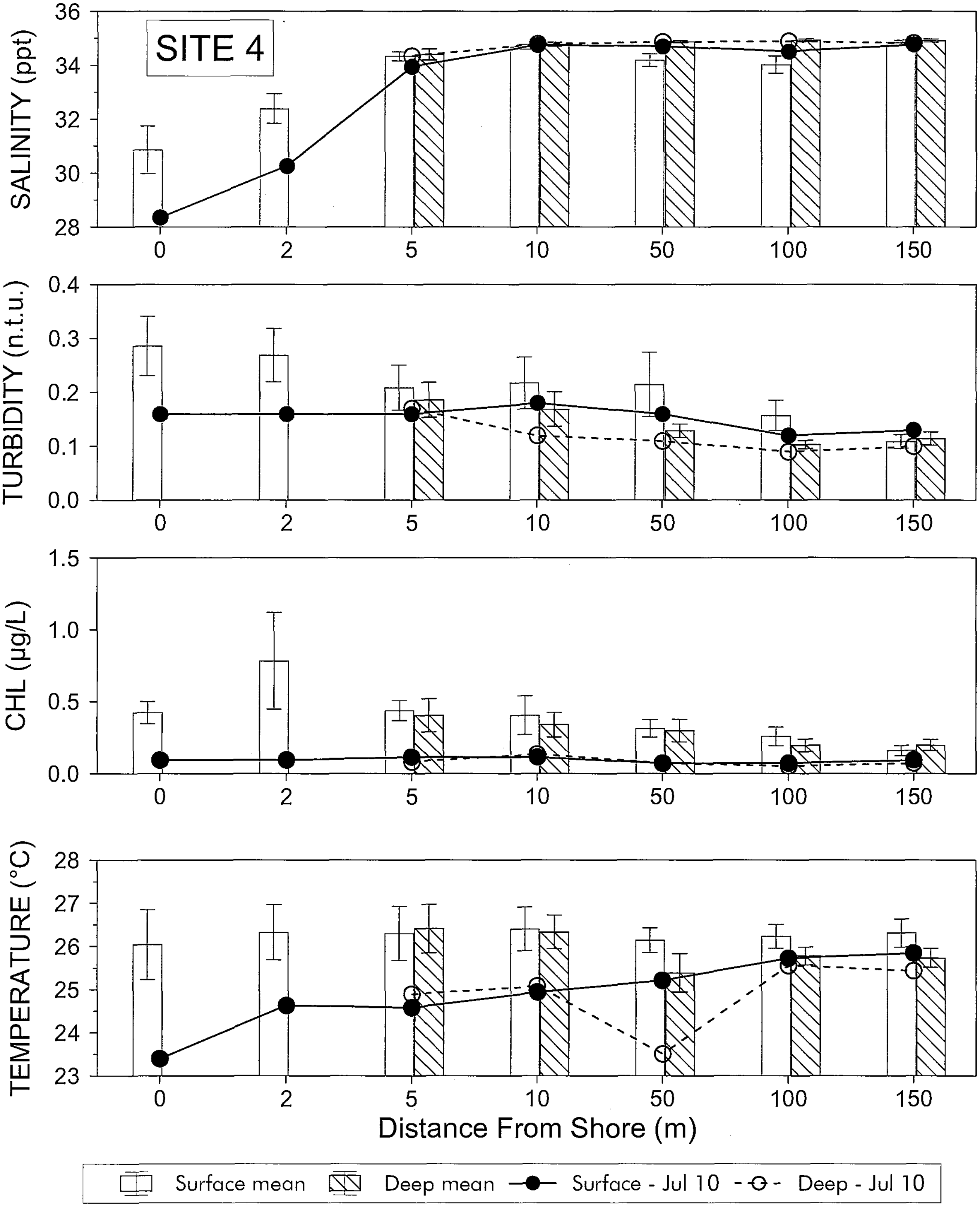

FIGURE 15. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

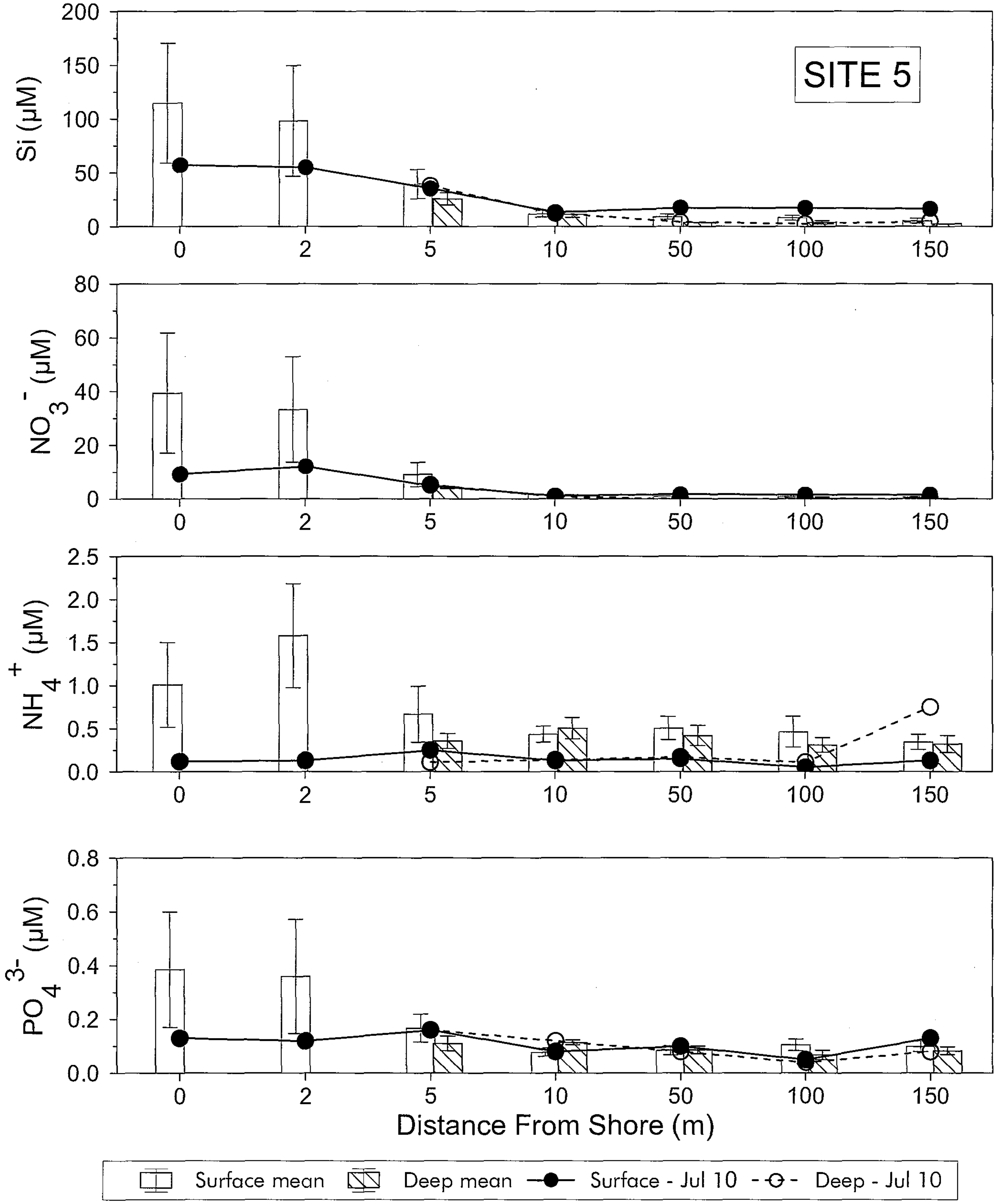

FIGURE 16. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

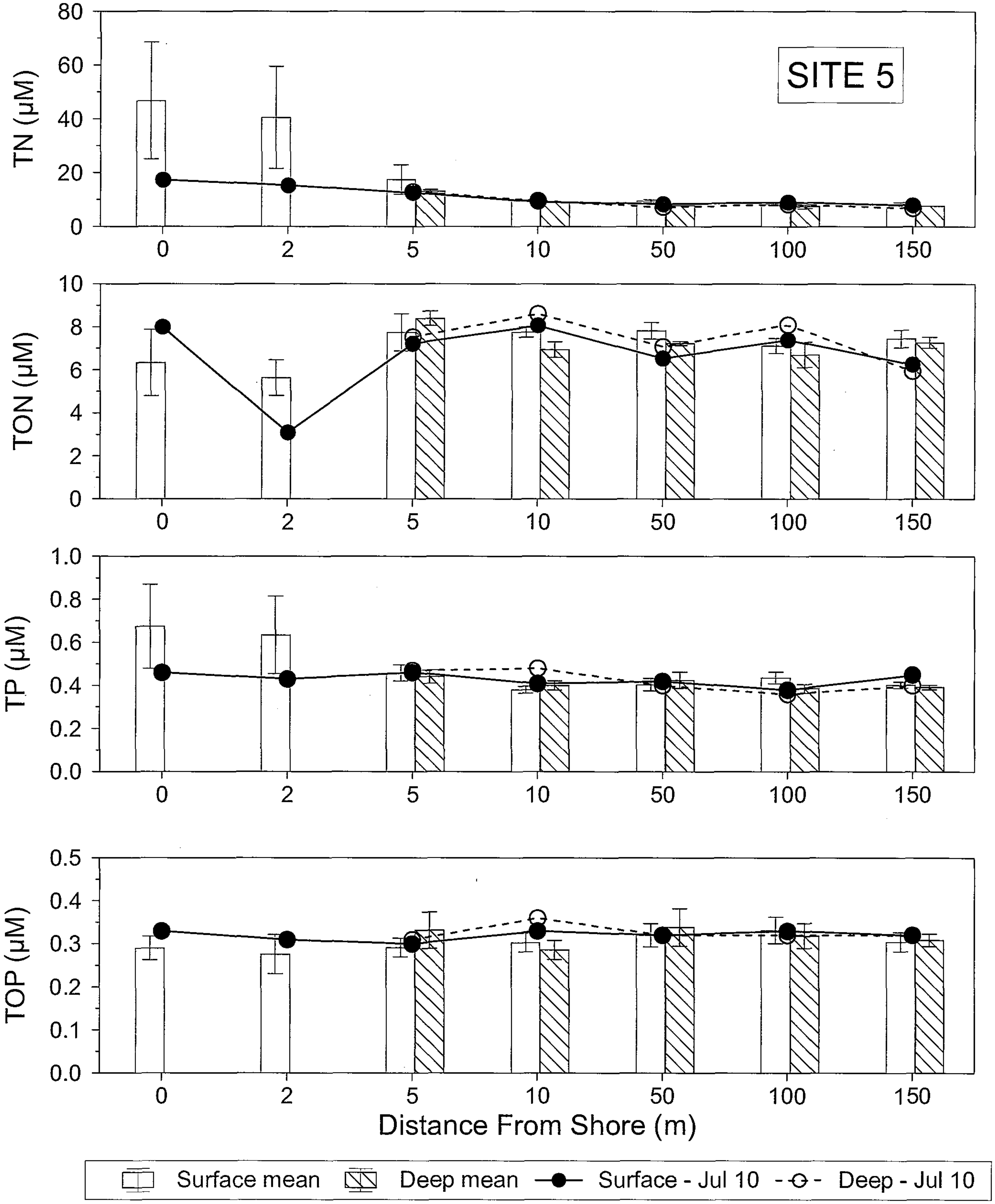

FIGURE 17. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

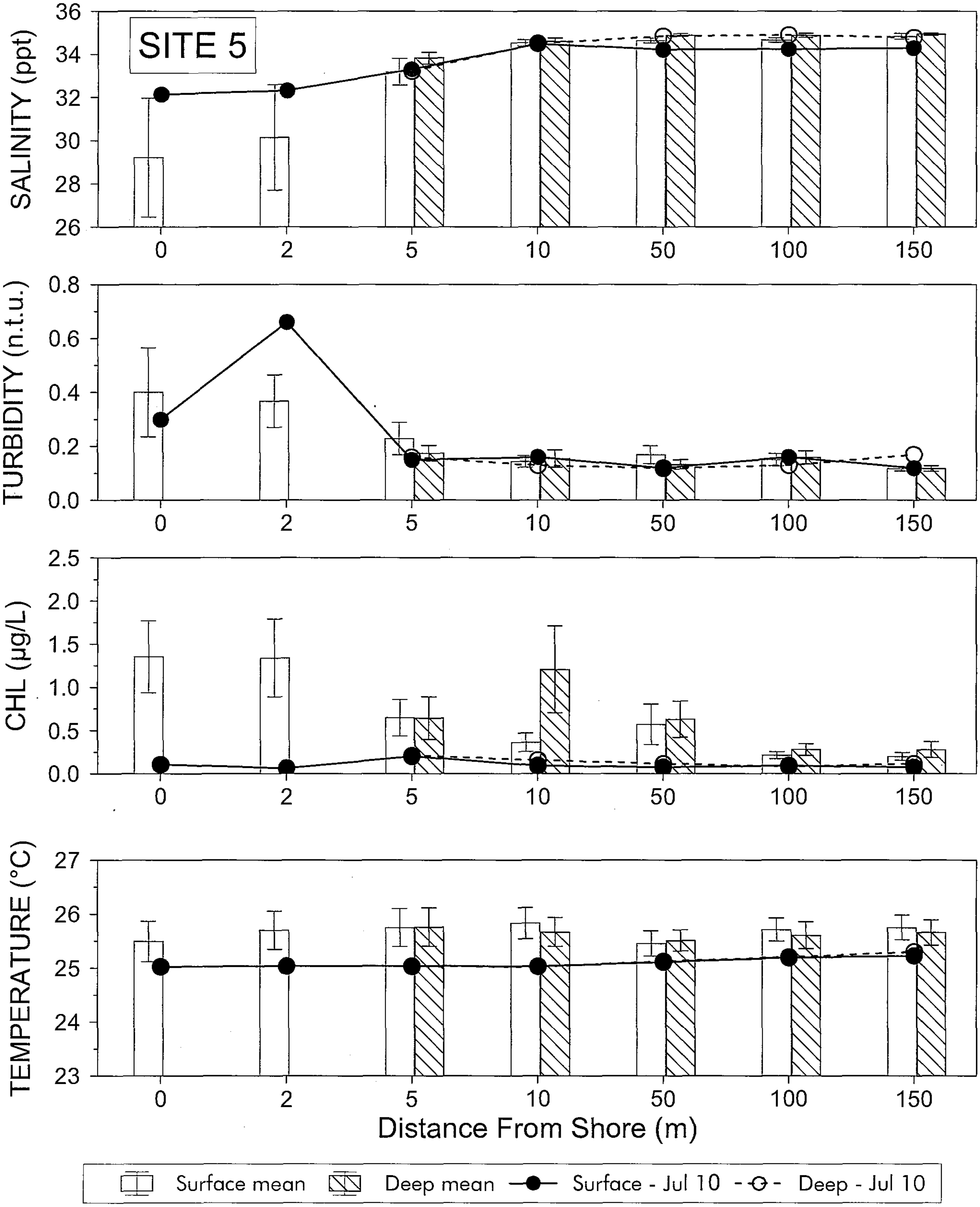

FIGURE 18. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=7). Error bars represent standard error of the mean. For site location, see Figure 1.

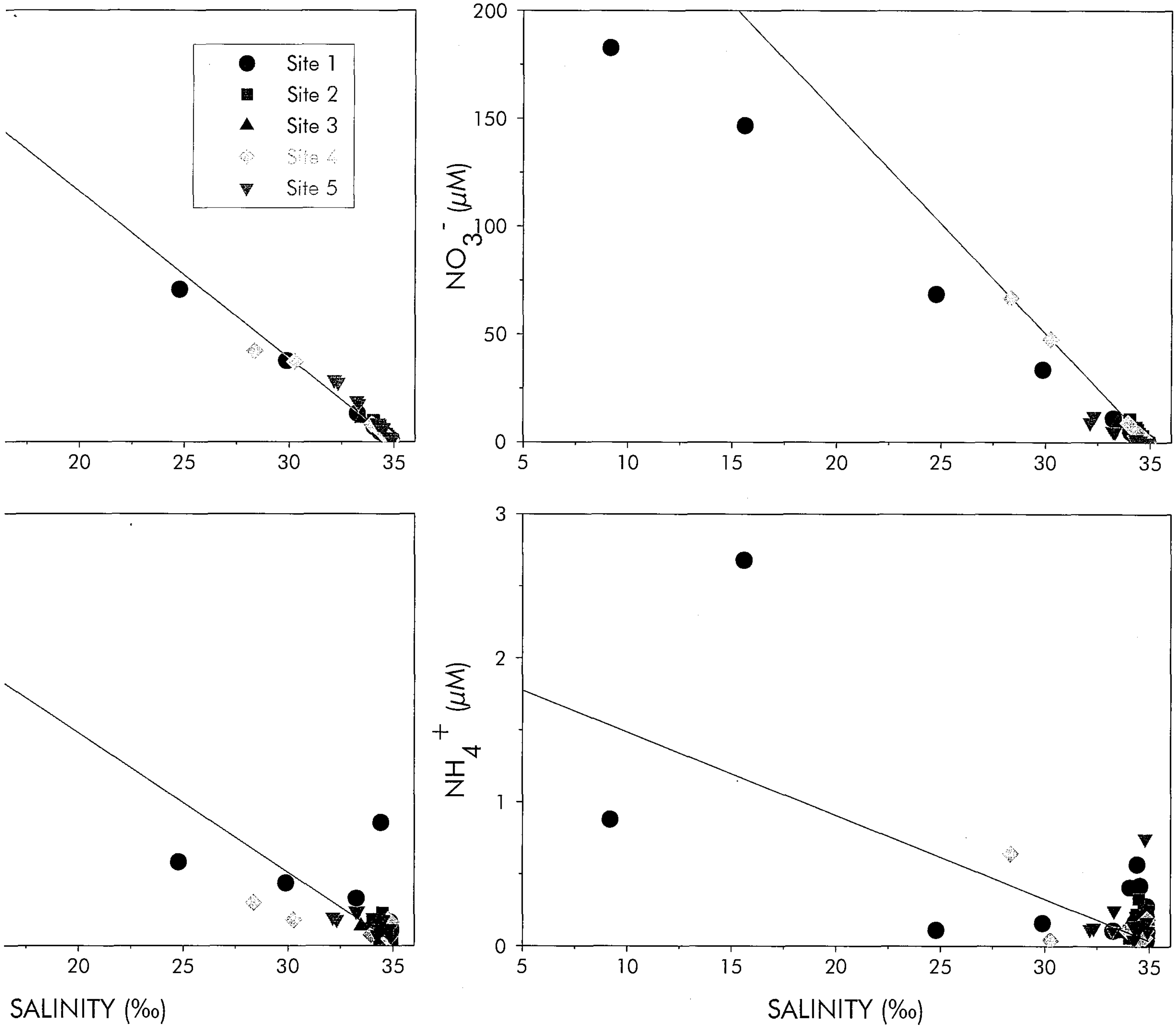

diagram showing concentration of dissolved nutrients from samples collected at five transect sites offshore
ɔject site in Wailea, Maui on July 11, 2010 as functions of salinity. Straight line in each plot is conservative
ɘd by connecting the concentrations in open coastal water with water from a golf course irrigation well.
tions, see Figure 1.

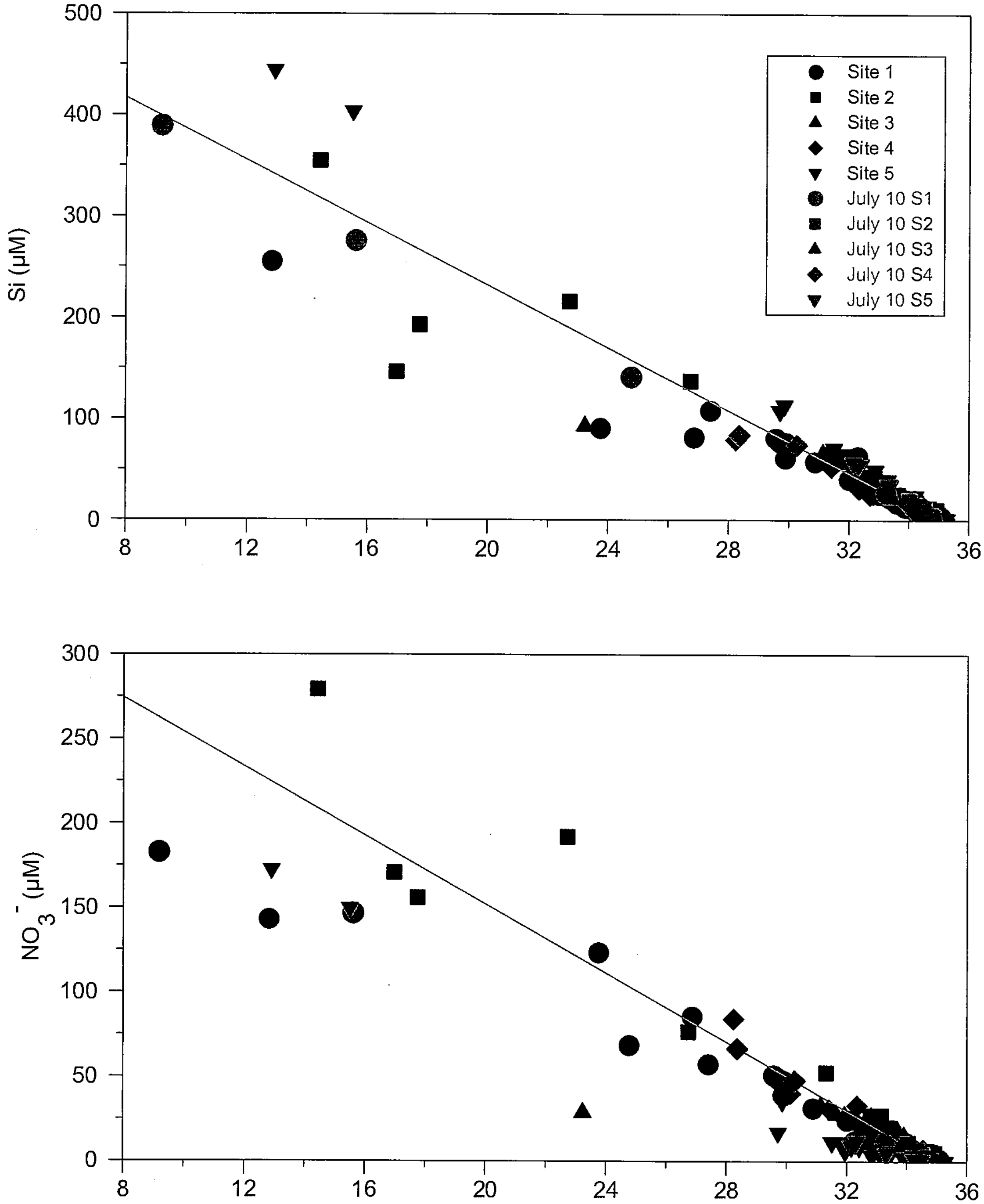

FIGURE 20. Silicate and nitrate, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and September 2009 (N=6). Red symbols are data from the most recent 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.

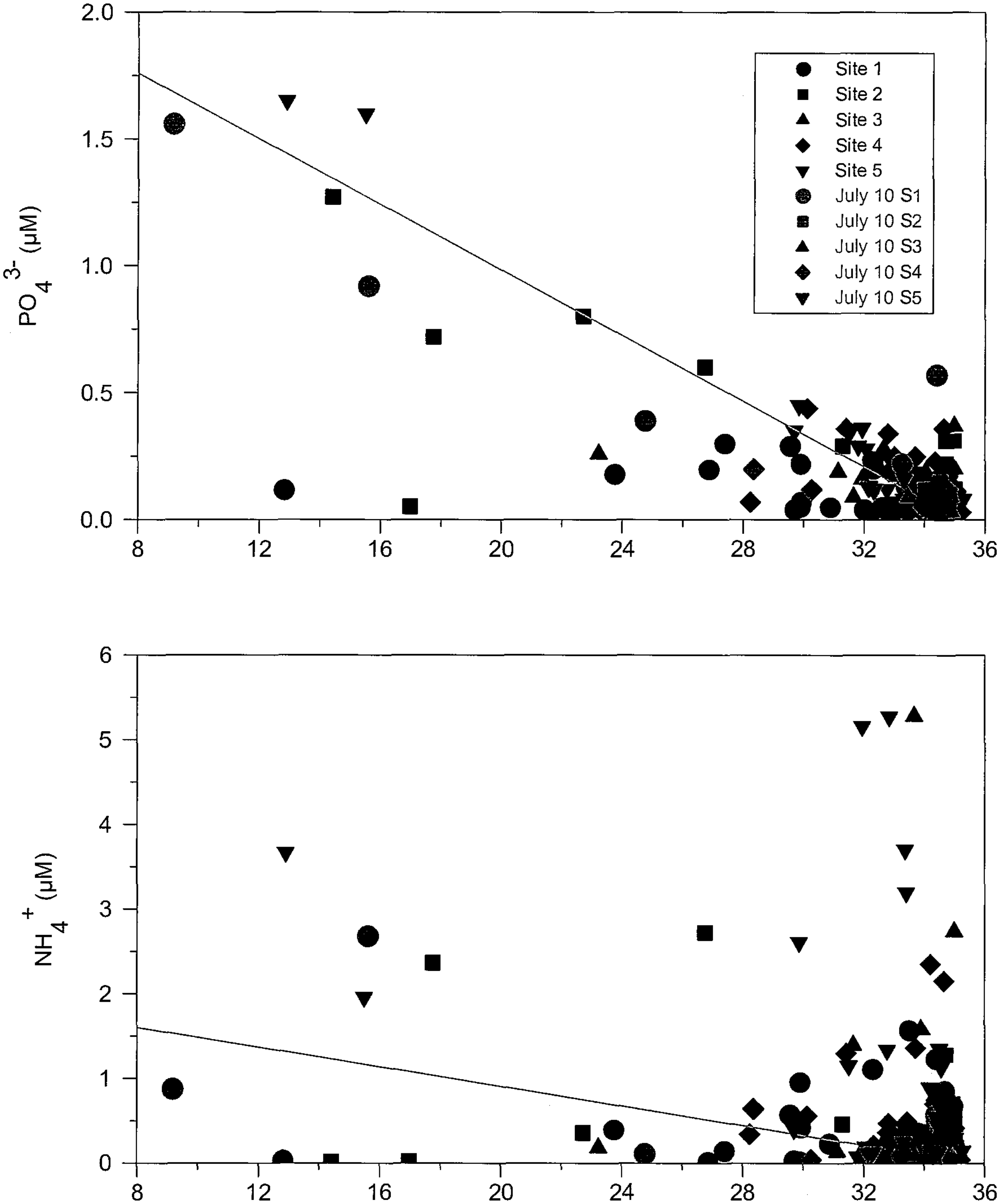

FIGURE 21. Phosphate and ammonium, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and September 2009 (N=6). Red symbols are data from the most recent 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.

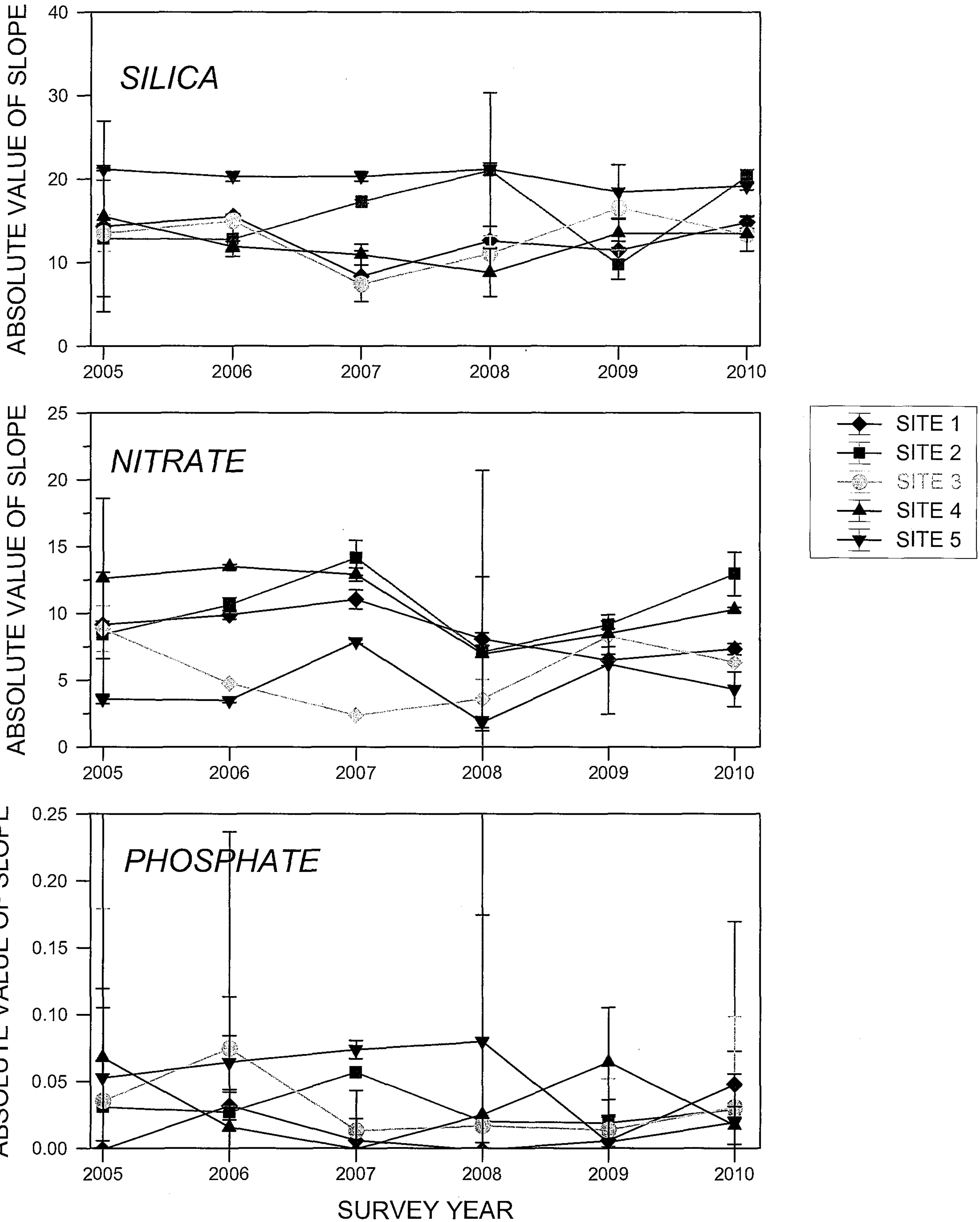

FIGURE 22. Time-course plots of absolute values of slopes of linear regressions of concentrations of silca, nitrate and phosphate as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations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

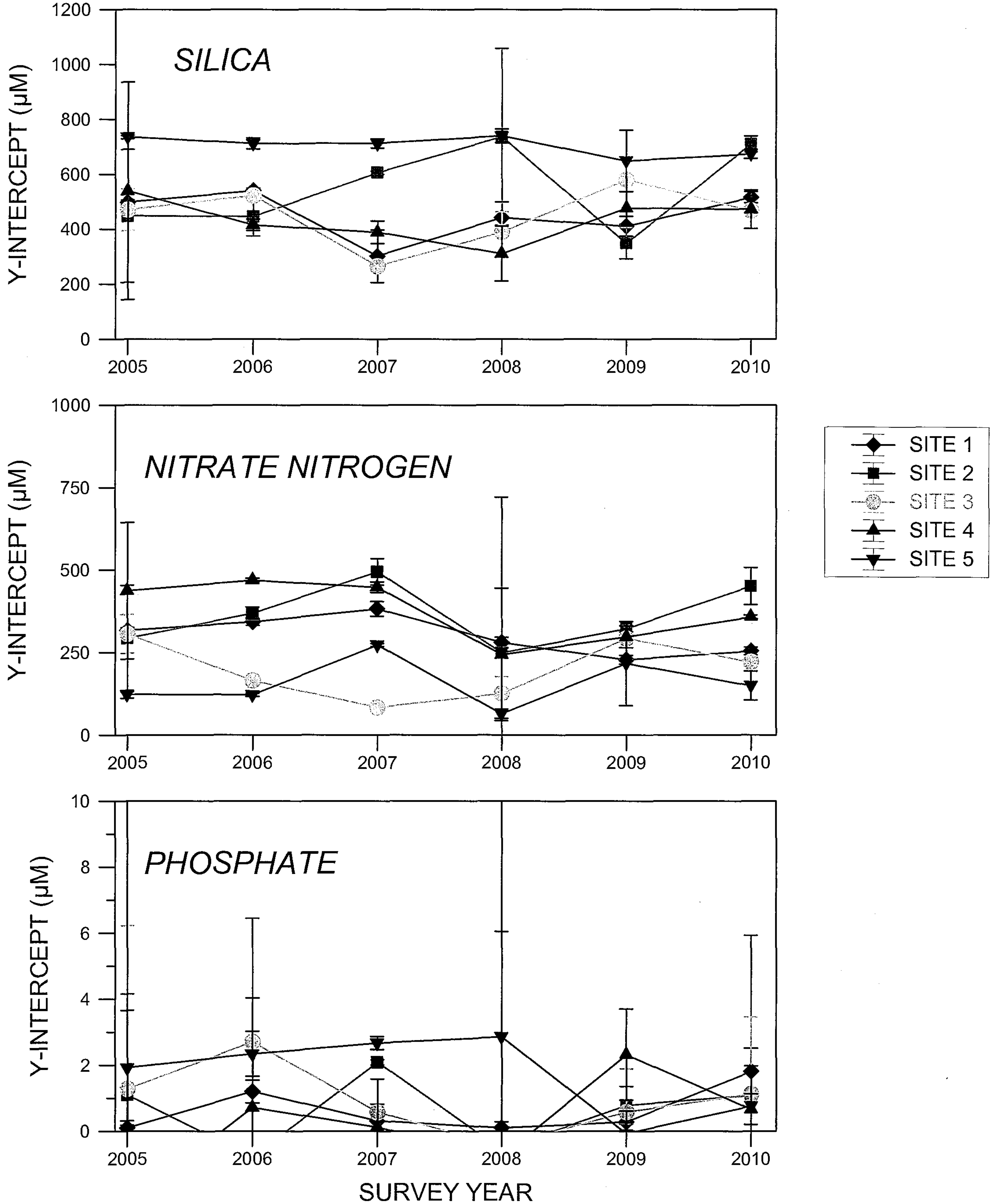

FIGURE 23. Time-course plots of Y-intercepts of linear regressions of concentrations of silca, nitrate and phosphorus as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations of sampling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

MARINE ENVIRONMENTAL

MONITORING PROGRAM:

HONUA'ULA

WAILEA, MAUI

WATER CHEMISTRY

REPORT 1-2011

Prepared for

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By

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Honolulu, HI 96722

Submitted
September 2011

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. 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, 250 of which will be provided off-site, thus reducing the total number of homes on-site to 1,150), 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 one 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.

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 retention of surface drainage on the golf course, and a private waste 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.

With the intention of evaluating these effects, one of the Conditions of Zoning for Honua'ula (No. 20) stipulated:

> *"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.*
>
> *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."

To date, HIDOH, which is the agency responsible for developing TMDL's (rather than property owners) has not performed this action for any marine areas off Maui.

This report represents the fifth monitoring effort to take place since the establishment of conditions of Zoning (Condition 20). 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. The following report conducted in March 2011 presents the results of the overall eighth phase of the monitoring program for the Honua'ula project.

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 Palau'ea 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 Honua'ula. 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 was conducted on March 6, 2011 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.

Typically, part of the monitoring program includes collection of water samples from irrigation wells on the Wailea golf course. Sampling of wells was not conducted during this phase of monitoring owing to logistic constraints. Data from the previous well sampling conducted on February 11, 2009 is used for evaluation of groundwater mixing with ocean water in the Results section below. 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 μM (0.14 μg/L) for NO_3^- and NH_4^+, 0.01 μM (0.31 μg/L) for PO_4^{3-}, 0.1 μM (1.4 μg/L) for TN and 0.1 μM (3.1 μg/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 μg/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 March 6, 2011 reported in micromolar units (μM). Table 2 shows similar results presented in units of micrograms per liter (μg/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 μM and μg/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 ($\pm$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^-, TN , salinity and temperature. In addition, nutrient concentrations in surface waters are generally elevated compared to the concentration of the corresponding sample of bottom water (Figure 2 and 3, Tables 1 and 2).

For all nutrients with distinct horizontal gradients, slopes of concentrations were steepest within 10 m of the shoreline at all five transect sites. Beyond 10 m from the shoreline, concentrations of nutrients decreased progressively with distance from shore but at a substantially reduced gradient compared with the zone within 10 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 Site 1(Five Graves) , where surface concentrations of NO_3^- near the shoreline were three orders of magnitude higher than samples collected at the seaward end of the transect. Salinity was correspondingly lower near the shoreline compared to offshore samples, with values differing by 27.9‰ between the shoreline and offshore terminus of the transect at Site 1 (Tables 1 and 2). Similar patterns were evident at Sites 2, 3, 4 and 5, but the horizontal gradients were far less pronounced compared to the patterns at Transect 1.

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. During the March 2011 survey, horizontal gradients extended to 50 m from the shoreline at Sites 1, 3 and 5 while at Sites 2 and 4, the horizontal gradients dissipated at distances less than 50 m of the shoreline (Tables 1 and 3).

Surface concentrations of PO_4^{3-} and TP also showed a pattern of elevated concentration within 10 m of the shoreline at Transect sites 1, 5 and 3 (Figure 2, Tables 1 and 2). There were no consistent gradients of PO_4^{3-} and TP at the other sites.

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 and among the five sites (Figure 2). Surface concentrations of NH_4^+ were highest near the shoreline at all sites except Site 4; beyond the shoreline there was no distinct pattern (Figure 2, Tables 1 and 2). With the exception of a few shoreline samples at, surface concentrations of TOP and TON were relatively constant at all sampling locations on transect sites during the March 2011 survey (Figure 2).

Turbidity was elevated at the shoreline and decreased with distance from shore at all five transect sites during the March 2011 survey (Figure 3 and Tables 1 and 2). Site 3 (downslope of the middle of the project area) had distinctly higher turbidity levels compared to the other four sites, reaching a maximum of 1.4 NTU in the sample collected at the shoreline (Table 1). Similar to turbidity, values of Chl *a* were distinctly higher at Sites 1 and 3 compared to the other three sites. Surface temperature ranged between a low of 24.4°C near the shoreline to 27.9°C in the offshore waters with an approximate 2.5°C - 3.3°C difference within any one transect during March 2011 (Tables 1 and 2, Figure 3).

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 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 March 2011 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 March 2011 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 at Sites 1 and 4, 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 ($\underline{+}$ 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 March 2011.

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 (Palau'ea), and Control Site 5 (Figures 4-18). In the most recent survey (March 2011) the concentrations of Si, NO_3^-, TN, PO_4^{3-} and TP were higher than the mean values at Sites 1 and 3 (Figures 4,5, 10 and 11). Salinity during the March 2011 survey was distinctly lower than the mean values at Sites 1 and 3, while at Sites 2, 4 and 5 salinity in the nearshore was higher than the mean values (Figures 6, 9, 12, 15 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).

With the exception of Site 4, turbidity measurements during March 2011 were higher than the mean values. Measurements of Chl *a* at Site 3 had higher than mean values during March 2011 in samples collected within 50 m of the shoreline (Figure 12). Temperature during March 2011 was higher than the mean values near the shoreline at all stations (Figures 6, 9, 12, 15 and 18).

These comparisons suggest that while there are some differences between surveys; water chemistry of the nearshore zone at Sites 1 and 4 was influenced by greater groundwater efflux during the March 2011 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 March 2011. 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 Irrigation Well No. 5 located to the northwest of the project area (sampled on February 11, 2009), and from the average concentrations of ocean water collected from near the bottom at the sampling locations 150 m offshore.

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 data points from Sites 1-5 fall in a linear array on, or very close to the conservative mixing line for Si. Such linearity indicates that groundwater (as defined by the concentration of SI) entering the ocean at these sites is a nearly pure mix of groundwater similar to that from Well No. 5, and open coastal water. It can be seen in Figure 20 that while data points from the present survey in March 2011 lie close to the conservative mixing line, deviations in concentrations of silica as functions of salinity have occurred in previous surveys. Such deviations of data points above the mixing line suggest input of other sources of groundwater enriched in Si relative to groundwater from Well No. 5.

The plots of NO_3^- versus salinity reveal a pattern that is not similar to Si, as data points from transect fall on three separate mixing lines. Data points from transects 2 and 4 lie on a straight line that is slightly above the conservative mixing line, while points from transects 1 and 3 fall on a line slightly below the conservative mixing line. The data points from transect 5, which is considered the control site fall substantially farther below the mixing line than any of the other four transects (Figure 19). A similar pattern is evident over the course of sampling in Figure 20, where many of the NO_3^- data points from transects 1, 3 and 5 during previous surveys fell below the mixing line. The reduced slope of the line prescribed by the data points from these areas suggest the possibility of removal of NO_3^- by turfgrass on the golf course following irrigation, and subsequent leaching to the groundwater.

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, particularly with respect to increased abundance of phytoplankton or benthic algae. 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 to benthic 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 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 high concentrations of NH_4^+, particularly at Transect Sites 2, 3 and 5. In contrast to the position of NO_3^- data points at nearshore sampling stations at Site 1 close to the mixing line, concentrations of NH_4^+ at these sampling sites fell far below the mixing line. 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 (Figure 19). Rather, NH_4^+ appears to be generated by natural biological activity in the ocean waters off of Wailea.

Phosphate phosphorus (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 correlation between PO_4^{3-} and salinity, with linearity similar to that of Si and NO_3^-. 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 is 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 2011 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 all 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 in the confidence limits for Sites 2 and 4 occurred during 2005 and 2008 (Tables 6 and 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 (2005-2011).

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. About half of the sixty samples collected were above the 10% criteria for NO_3^- under "dry" or "wet" conditions in the March 2011 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^-, thirteen measurements of NH_4^+, two measurements of TP, twenty measurements of TN, six measurements of turbidity and nine measurements of Chl *a* exceeded the 10% DOH criteria under "wet" conditions in March 2011.

Tables 3 and 4 show geometric means of samples collected at the each sampling location during the eight increments of the monitoring program conducted to date. 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 but one surface water measurements of NO_3^-, 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. SUMMARY

- The eighth phase of the water quality monitoring program for the planned Honua'ula project was carried out in March 2011. Sixty ocean water samples were collected on four transects spaced along the projects ocean frontage and one transect located outside of the project area. 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 (Palau'ea Beach), Site 3 was located off Palau'ea Beach downslope from the juncture of the Emerald and Blue Courses, and Site 4 was located off Ulua Beach 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 Wailea golf courses. 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 sample data collected in February 2009 from seven irrigation wells and a golf-course reservoir in the Wailea area upslope of the sampling area are given for comparison.

- Water chemistry constituents that occur in high concentration in groundwater (Si, NO_3^-, TN and PO_4^{3-}) displayed 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, and generally extended 50 – 100 m offshore. The steepest nearshore gradients, indicating the highest input of groundwater at the shoreline occurred at Site 1 (Five Graves), while the weakest gradients occurred at Sites 2 (Palau'ea Beach) and Site 5 ('Ahihi-kina'u). The steep horizontal gradients at all sampling sites 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 not sufficient to completely break down the density differences between the buoyant low salinity surface layer and denser underlying water.

- Water chemistry constituents that generally 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 March 2011 survey there was no apparent subsidy of NO_3^- from human activities on land 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 golf courses, or possibly leakage from old septic systems or cesspools that served residences in the vicinity of Site 1. Such subsidies were not evident in the most recent monitoring survey.

- 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 seven 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 2011. 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.

- The next phase of the Honua'ula monitoring program is scheduled for the the last quarter of quarter of 2011.

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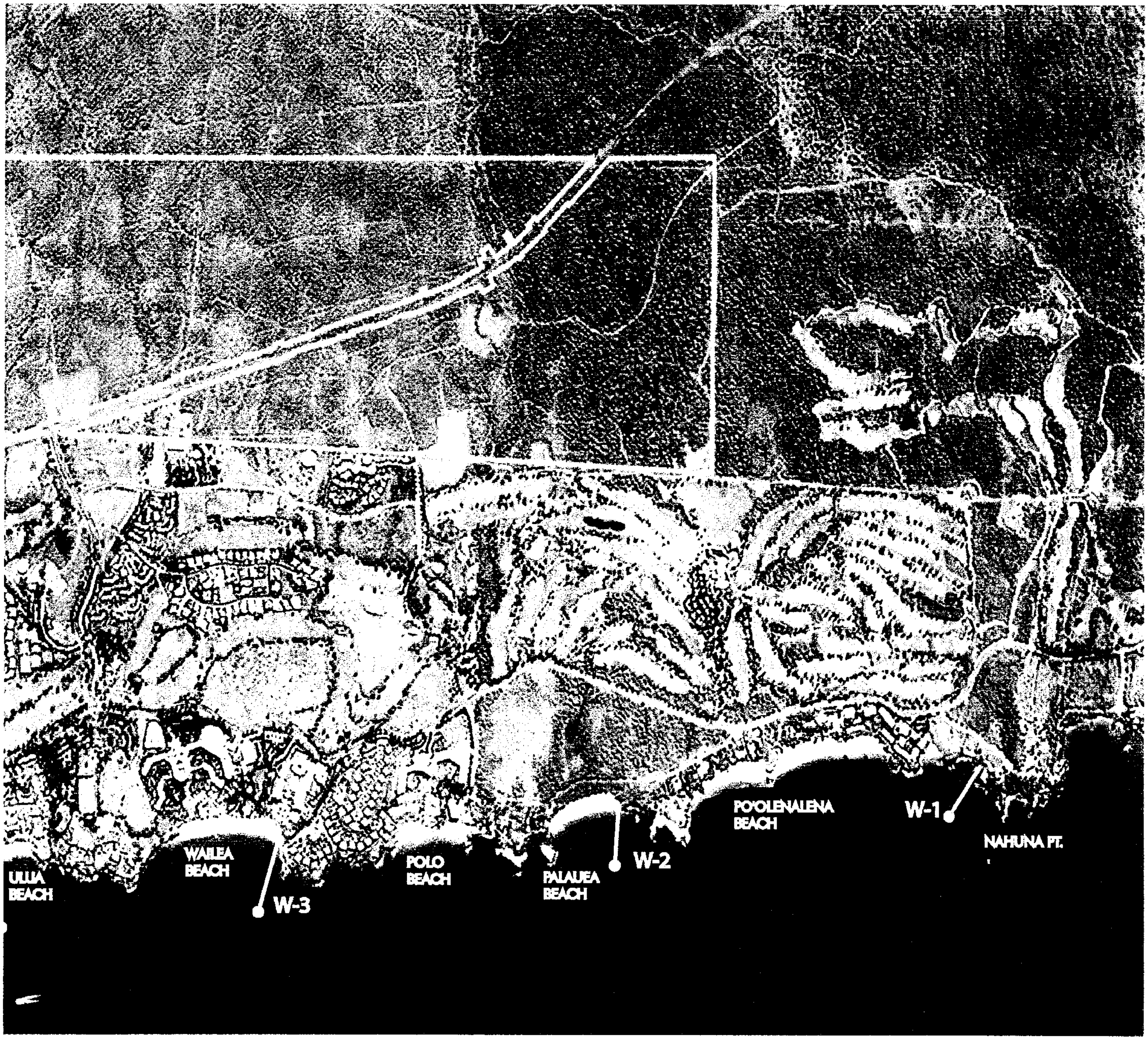


ıh of Wailea area showing boundaries of Honua'ula Project (in yellow) and locations of marine water
Transect W-5 is considered a control and is located in the 'Ahihi-kina'u Natural Area Reserve approximately
'ula Project site.

TABLE 1.Water chemistry measurements from ocean water samples collected in the vicinity of the Honua'ula project site on March 6, 2011. 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	1.13	177.5	0.54	363.1	0.21	10.08	1.34	188.1	0.71	7.144	2.43	26.8	8.06	100.0
	2 S	0.1	0.85	122.6	0.01	222.9	0.18	6.68	1.03	129.3	0.48	19.117	0.77	27.0	8.13	99.0
	5 S	0.1	0.37	52.12	0.16	92.01	0.21	6.30	0.58	58.58	0.35	29.164	0.23	26.8	8.20	98.6
	5 D	1.0	0.20	20.46	0.10	41.95	0.25	5.94	0.45	26.50	0.24	32.535	0.19	25.3	8.22	97.6
	10 S	0.1	0.17	17.12	0.11	34.48	0.25	5.87	0.42	23.10	0.14	32.986	0.13	25.5	8.20	97.5
	10 D	1.7	0.10	7.17	0.21	15.61	0.27	6.21	0.37	13.59	0.22	34.189	0.10	25.4	8.18	97.6
	50 S	0.1	0.10	4.50	0.15	9.09	0.27	5.98	0.37	10.63	0.15	34.586	0.47	24.5	8.09	97.0
	50 D	4.4	0.06	0.24	0.18	1.67	0.26	5.14	0.32	5.56	0.12	35.105	0.16	24.8	8.14	97.2
	100 S	0.1	0.06	0.23	0.04	1.50	0.28	6.62	0.34	6.89	0.12	35.123	0.10	24.9	8.15	95.8
	100 D	6.2	0.04	0.17	0.14	1.28	0.27	6.03	0.31	6.34	0.16	35.137	0.09	24.9	8.16	95.7
	150 S	0.1	0.05	0.19	0.12	1.23	0.31	5.75	0.36	6.06	0.08	35.086	0.08	24.9	8.15	95.4
	150 D	11.7	0.07	0.10	0.11	1.36	0.30	6.41	0.37	6.62	0.09	35.099	0.07	24.9	8.15	94.5
WAILEA 2	0 S	0.1	0.08	14.05	1.59	21.33	0.45	9.82	0.53	25.46	0.48	33.979	0.37	27.9	8.36	100.4
	2 S	0.1	0.13	11.68	0.60	18.88	0.29	5.47	0.42	17.75	0.24	34.171	0.16	26.3	8.23	99.4
	5 S	0.1	0.10	9.51	0.08	13.52	0.28	5.68	0.38	15.27	0.28	34.385	0.17	26.4	8.18	99.4
	5 D	1.0	0.11	3.27	0.29	5.33	0.28	6.12	0.39	9.68	0.24	34.862	0.33	26.2	8.15	101.9
	10 S	0.1	0.07	1.21	0.03	3.10	0.29	7.43	0.36	8.67	0.11	35.038	0.08	24.6	8.12	100.7
	10 D	2.0	0.13	0.28	0.05	1.81	0.30	6.19	0.43	6.52	0.12	35.092	0.13	24.7	8.14	99.4
	50 S	0.1	0.04	0.15	0.08	2.08	0.27	5.11	0.31	5.34	0.12	35.109	0.14	24.8	8.14	99.7
	50 D	4.9	0.08	0.16	0.32	1.48	0.30	4.72	0.38	5.20	0.12	35.125	0.10	24.8	8.15	97.4
	100 S	0.2	0.09	0.06	0.53	1.17	0.29	5.18	0.38	5.77	0.09	35.129	0.09	24.8	8.16	96.4
	100 D	8.7	0.08	0.04	0.13	1.19	0.30	5.41	0.38	5.58	0.13	35.117	0.21	24.9	8.16	97.3
	150 S	0.1	0.04	0.03	0.27	1.32	0.30	5.94	0.34	6.24	0.11	35.122	0.12	24.9	8.16	96.2
	150 D	14.4	0.06	0.01	1.03	1.20	0.29	5.18	0.35	6.22	0.12	35.148	0.08	24.9	8.17	96.4
WAILEA 3	0 S	0.1	0.28	23.61	0.86	47.14	0.34	5.78	0.62	30.25	1.40	31.599	1.28	27.3	8.17	100.4
	2 S	0.1	0.27	15.01	0.28	31.16	0.33	6.33	0.60	21.62	1.19	32.917	1.12	26.1	8.17	101.6
	5 S	0.1	0.17	13.78	0.19	29.79	0.36	7.36	0.53	21.33	0.86	33.065	1.83	26.1	8.17	101.5
	5 D	1.0	0.32	14.11	1.05	31.18	0.32	8.40	0.64	23.56	0.80	33.029	1.32	26.1	8.17	101.7
	10 S	0.1	0.15	5.58	0.37	12.91	0.28	6.72	0.43	12.67	0.46	34.288	0.80	26.1	8.17	98.7
	10 D	1.0	0.19	4.73	0.12	11.35	0.38	7.10	0.57	11.95	0.49	34.394	0.70	26.1	8.17	98.2
	50 S	0.1	0.09	3.31	0.14	8.89	0.27	5.95	0.36	9.40	0.17	34.675	0.14	24.6	8.12	98.4
	50 D	4.0	0.11	0.31	0.29	2.39	0.31	6.81	0.42	7.41	0.18	35.060	0.10	24.7	8.15	98.2
	100 S	0.1	0.10	0.71	BDL	2.93	0.31	6.12	0.41	6.83	0.17	35.034	0.09	24.6	8.14	99.3
	100 D	6.1	0.15	0.15	0.01	1.79	0.35	5.92	0.50	6.08	0.13	35.087	0.09	24.8	8.16	99.1
	150 S	0.1	0.13	0.20	0.13	1.70	0.37	7.17	0.50	7.50	0.11	35.093	0.37	24.8	8.16	97.5
	150 D	11.2	0.15	0.12	0.40	1.45	0.37	5.28	0.52	5.80	0.14	35.097	0.46	24.8	8.16	96.5
WAILEA 4	0 S	0.1	0.13	27.54	0.07	35.11	0.37	8.34	0.50	35.95	0.29	32.927	0.59	27.1	8.21	103.0
	2 S	0.1	0.06	23.93	0.06	31.83	0.31	6.99	0.37	30.98	0.20	33.236	0.30	26.9	8.22	100.2
	5 S	0.1	0.14	7.02	0.04	11.69	0.36	6.74	0.50	13.80	0.17	34.524	0.22	26.8	8.23	101.3
	5 D	1.0	0.09	2.18	0.01	4.94	0.30	6.14	0.39	8.33	0.20	34.915	0.19	26.5	8.20	100.4
	10 S	0.1	0.04	0.17	0.25	1.08	0.31	5.46	0.35	5.88	0.14	35.119	0.21	24.8	8.17	100.1
	10 D	1.0	0.11	0.22	0.04	1.37	0.39	6.32	0.50	6.58	0.10	35.145	0.07	24.8	8.16	99.3
	50 S	0.1	0.05	0.05	0.07	1.41	0.29	7.40	0.34	7.52	0.11	35.118	0.13	24.8	8.17	99.3
	50 D	5.2	0.06	0.06	0.12	1.38	0.31	6.86	0.37	7.04	0.08	35.144	0.13	24.9	8.17	99.1
	100 S	0.1	0.09	0.02	BDL	1.34	0.31	6.48	0.40	6.50	0.09	35.135	0.13	24.9	8.17	99.3
	100 D	9.8	0.11	0.06	0.08	1.28	0.39	5.64	0.50	5.78	0.10	35.123	0.09	24.9	8.17	98.3
	150 S	0.1	0.11	0.02	0.53	1.32	0.37	6.58	0.48	7.13	0.07	35.120	0.18	24.9	8.17	97.2
	150 D	12.3	0.04	BDL	BDL	1.35	0.31	5.40	0.35	5.40	0.09	35.145	0.09	24.8	8.17	96.9
WAILEA 5	0 S	0.1	0.35	15.74	1.11	85.87	0.32	4.89	0.67	21.74	0.54	30.748	0.26	26.8	8.20	100.4
	2 S	0.1	0.34	15.26	0.06	83.08	0.32	6.07	0.66	21.39	0.39	30.946	0.18	26.3	8.20	100.3
	5 S	0.1	0.29	11.05	0.10	62.68	0.32	6.22	0.61	17.37	0.26	32.041	0.20	25.7	8.19	101.2
	5 D	1.0	0.25	8.35	0.05	49.46	0.34	6.14	0.59	14.54	0.22	32.737	0.27	25.8	8.18	100.4
	10 S	0.1	0.12	0.79	0.38	7.56	0.28	4.55	0.40	5.72	0.16	34.906	0.09	25.3	8.10	99.2
	10 D	2.0	0.13	0.81	0.07	7.11	0.27	5.26	0.40	6.14	0.18	34.884	0.13	25.3	8.11	99.4
	50 S	0.1	0.13	3.60	0.18	16.60	0.29	5.56	0.42	9.34	0.15	34.407	0.12	24.7	8.12	97.2
	50 D	4.4	0.09	0.25	0.03	2.71	0.29	5.40	0.38	5.68	0.12	35.059	0.07	24.7	8.11	96.3
	100 S	0.1	0.08	0.12	0.07	1.86	0.29	5.77	0.37	5.96	0.15	35.063	0.07	24.7	8.13	95.5
	100 D	6.4	0.10	0.11	0.04	2.68	0.28	6.57	0.38	6.72	0.16	35.035	0.10	24.7	8.12	96.2
	150 S	0.1	0.09	0.12	0.06	2.31	0.28	5.73	0.37	5.91	0.10	35.049	0.08	24.7	8.14	95.9
	150 D	7.7	0.07	0.04	1.49	2.11	0.29	4.67	0.36	6.20	0.12	35.043	0.08	24.7	8.15	95.3
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 $\mu g/L$) collected off the Honua'ula project site on March 6, 2011. 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	35.00	2486	7.56	10204	6.50	141.2	41.50	2635	0.71	7.144	2.43	26.8	8.06	100.0
	2 S	0.1	26.33	1718	0.14	6264	5.58	93.6	31.90	1811	0.48	19.117	0.77	27.0	8.13	99.0
	5 S	0.1	11.46	730.0	2.24	2585	6.50	88.2	17.96	820.5	0.35	29.164	0.23	26.8	8.20	98.6
	5 D	1.0	6.19	286.6	1.40	1179	7.74	83.2	13.94	371.2	0.24	32.535	0.19	25.3	8.22	97.6
	10 S	0.1	5.27	239.8	1.54	968.9	7.74	82.2	13.01	323.5	0.14	32.986	0.13	25.5	8.20	97.5
	10 D	1.7	3.10	100.4	2.94	438.6	8.36	87.0	11.46	190.3	0.22	34.189	0.10	25.4	8.18	97.6
	50 S	0.1	3.10	63.03	2.10	255.4	8.36	83.8	11.46	148.9	0.15	34.586	0.47	24.5	8.09	97.0
	50 D	4.4	1.86	3.36	2.52	46.93	8.05	72.0	9.91	77.87	0.12	35.105	0.16	24.8	8.14	97.2
	100 S	0.1	1.86	3.22	0.56	42.15	8.67	92.7	10.53	96.50	0.12	35.123	0.10	24.9	8.15	95.8
	100 D	6.2	1.24	2.38	1.96	35.97	8.36	84.5	9.60	88.80	0.16	35.137	0.09	24.9	8.16	95.7
	150 S	0.1	1.55	2.66	1.68	34.56	9.60	80.5	11.15	84.88	0.08	35.086	0.08	24.9	8.15	95.4
	150 D	11.7	2.17	1.40	1.54	38.22	9.29	89.8	11.46	92.72	0.09	35.099	0.07	24.9	8.15	94.5
WAILEA 2	0 S	0.1	2.48	196.8	22.27	599.4	13.94	137.5	16.42	356.6	0.48	33.979	0.37	27.9	8.36	100.4
	2 S	0.1	4.03	163.6	8.40	530.5	8.98	76.6	13.01	248.6	0.24	34.171	0.16	26.3	8.23	99.4
	5 S	0.1	3.10	133.2	1.12	379.9	8.67	79.6	11.77	213.9	0.28	34.385	0.17	26.4	8.18	99.4
	5 D	1.0	3.41	45.80	4.06	149.8	8.67	85.7	12.08	135.6	0.24	34.862	0.33	26.2	8.15	101.9
	10 S	0.1	2.17	16.95	0.42	87.11	8.98	104.1	11.15	121.4	0.11	35.038	0.08	24.6	8.12	100.7
	10 D	2.0	4.03	3.92	0.70	50.86	9.29	86.7	13.32	91.32	0.12	35.092	0.13	24.7	8.14	99.4
	50 S	0.1	1.24	2.10	1.12	58.45	8.36	71.6	9.60	74.79	0.12	35.109	0.14	24.8	8.14	99.7
	50 D	4.9	2.48	2.24	4.48	41.59	9.29	66.1	11.77	72.83	0.12	35.125	0.10	24.8	8.15	97.4
	100 S	0.2	2.79	0.84	7.42	32.88	8.98	72.6	11.77	80.81	0.09	35.129	0.09	24.8	8.16	96.4
	100 D	8.7	2.48	0.56	1.82	33.44	9.29	75.8	11.77	78.15	0.13	35.117	0.21	24.9	8.16	97.3
	150 S	0.1	1.24	0.42	3.78	37.09	9.29	83.2	10.53	87.40	0.11	35.122	0.12	24.9	8.16	96.2
	150 D	14.4	1.86	0.14	14.43	33.72	8.98	72.6	10.84	87.12	0.12	35.148	0.08	24.9	8.17	96.4
WAILEA 3	0 S	0.1	8.67	330.7	12.05	1325	10.53	81.0	19.20	423.7	1.40	31.599	1.28	27.3	8.17	100.4
	2 S	0.1	8.36	210.2	3.92	875.6	10.22	88.7	18.58	302.8	1.19	32.917	1.12	26.1	8.17	101.6
	5 S	0.1	5.27	193.0	2.66	837.1	11.15	103.1	16.42	298.7	0.86	33.065	1.83	26.1	8.17	101.5
	5 D	1.0	9.91	197.6	14.71	876.2	9.91	117.7	19.82	330.0	0.80	33.029	1.32	26.1	8.17	101.7
	10 S	0.1	4.65	78.15	5.18	362.8	8.67	94.1	13.32	177.5	0.46	34.288	0.80	26.1	8.17	98.7
	10 D	1.0	5.88	66.25	1.68	318.9	11.77	99.4	17.65	167.4	0.49	34.394	0.70	26.1	8.17	98.2
	50 S	0.1	2.79	46.36	1.96	249.8	8.36	83.3	11.15	131.7	0.17	34.675	0.14	24.6	8.12	98.4
	50 D	4.0	3.41	4.34	4.06	67.16	9.60	95.4	13.01	103.8	0.18	35.060	0.10	24.7	8.15	98.2
	100 S	0.1	3.10	9.94	BDL	82.33	9.60	85.7	12.70	95.66	0.17	35.034	0.09	24.6	8.14	99.3
	100 D	6.1	4.65	2.10	0.14	50.30	10.84	82.9	15.49	85.16	0.13	35.087	0.09	24.8	8.16	99.1
	150 S	0.1	4.03	2.80	1.82	47.77	11.46	100.4	15.49	105.0	0.11	35.093	0.37	24.8	8.16	97.5
	150 D	11.2	4.65	1.68	5.60	40.75	11.46	74.0	16.11	81.23	0.14	35.097	0.46	24.8	8.16	96.5
WAILEA 4	0 S	0.1	4.03	385.7	0.98	986.6	11.46	116.8	15.49	503.5	0.29	32.927	0.59	27.1	8.21	103.0
	2 S	0.1	1.86	335.2	0.84	894.4	9.60	97.9	11.46	433.9	0.20	33.236	0.30	26.9	8.22	100.2
	5 S	0.1	4.34	98.32	0.56	328.5	11.15	94.4	15.49	193.3	0.17	34.524	0.22	26.8	8.23	101.3
	5 D	1.0	2.79	30.53	0.14	138.8	9.29	86.0	12.08	116.7	0.20	34.915	0.19	26.5	8.20	100.4
	10 S	0.1	1.24	2.38	3.50	30.35	9.60	76.5	10.84	82.36	0.14	35.119	0.21	24.8	8.17	100.1
	10 D	1.0	3.41	3.08	0.56	38.50	12.08	88.5	15.49	92.16	0.10	35.145	0.07	24.8	8.16	99.3
	50 S	0.1	1.55	0.70	0.98	39.62	8.98	103.6	10.53	105.3	0.11	35.118	0.13	24.8	8.17	99.3
	50 D	5.2	1.86	0.84	1.68	38.78	9.60	96.1	11.46	98.60	0.08	35.144	0.13	24.9	8.17	99.1
	100 S	0.1	2.79	0.28	BDL	37.65	9.60	90.8	12.39	91.04	0.09	35.135	0.13	24.9	8.17	99.3
	100 D	9.8	3.41	0.84	1.12	35.97	12.08	79.0	15.49	80.95	0.10	35.123	0.09	24.9	8.17	98.3
	150 S	0.1	3.41	0.28	7.42	37.09	11.46	92.2	14.87	99.86	0.07	35.120	0.18	24.9	8.17	97.2
	150 D	12.3	1.24	BDL	BDL	37.94	9.60	75.6	10.84	75.63	0.09	35.145	0.09	24.8	8.17	96.9
WAILEA 5	0 S	0.1	10.84	220.5	15.55	2412.9	9.91	68.5	20.75	304.5	0.54	30.748	0.26	26.8	8.20	100.4
	2 S	0.1	10.53	213.7	0.84	2334.5	9.91	85.0	20.44	299.6	0.39	30.946	0.18	26.3	8.20	100.3
	5 S	0.1	8.98	154.8	1.40	1761.3	9.91	87.1	18.89	243.3	0.26	32.041	0.20	25.7	8.19	101.2
	5 D	1.0	7.74	117.0	0.70	1389.8	10.53	86.0	18.27	203.6	0.22	32.737	0.27	25.8	8.18	100.4
	10 S	0.1	3.72	11.06	5.32	212.4	8.67	63.7	12.39	80.11	0.16	34.906	0.09	25.3	8.10	99.2
	10 D	2.0	4.03	11.34	0.98	199.8	8.36	73.7	12.39	86.00	0.18	34.884	0.13	25.3	8.11	99.4
	50 S	0.1	4.03	50.42	2.52	466.5	8.98	77.9	13.01	130.8	0.15	34.407	0.12	24.7	8.12	97.2
	50 D	4.4	2.79	3.50	0.42	76.15	8.98	75.6	11.77	79.55	0.12	35.059	0.07	24.7	8.11	96.3
	100 S	0.1	2.48	1.68	0.98	52.27	8.98	80.8	11.46	83.48	0.15	35.063	0.07	24.7	8.13	95.5
	100 D	6.4	3.10	1.54	0.56	75.31	8.67	92.0	11.77	94.12	0.16	35.035	0.10	24.7	8.12	96.2
	150 S	0.1	2.79	1.68	0.84	64.91	8.67	80.3	11.46	82.78	0.10	35.049	0.08	24.7	8.14	95.9
	150 D	7.7	2.17	0.56	20.87	59.29	8.98	65.4	11.15	86.84	0.12	35.043	0.08	24.7	8.15	95.3
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=8). 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	0.23	70.49	0.33	127.7	0.28	7.16	0.60	84.53	0.24	19.005	1.04	26.11	8.11	104.93
	2 S	1	0.21	49.37	0.08	93.90	0.30	7.93	0.58	61.37	0.22	26.011	1.28	26.14	8.14	104.49
	5 S	1	0.08	18.17	0.05	38.95	0.28	8.22	0.41	29.54	0.19	31.248	0.46	25.89	8.13	103.64
	5 D	2.5	0.12	9.60	0.26	23.51	0.29	8.55	0.44	20.01	0.13	33.175	0.29	25.92	8.13	103.53
	10 S	1	0.08	7.31	0.17	18.35	0.28	7.95	0.38	17.33	0.17	33.620	0.29	26.00	8.12	105.56
	10 D	3	0.07	2.58	0.22	7.95	0.29	7.81	0.37	11.53	0.14	34.441	0.26	25.90	8.12	104.95
	50 S	1	0.06	3.42	0.27	9.42	0.30	8.11	0.36	13.25	0.14	34.295	0.30	25.77	8.12	101.46
	50 D	4.5	0.07	0.29	0.13	2.23	0.30	7.81	0.38	8.48	0.11	34.836	0.29	25.63	8.12	96.97
	100 S	1	0.07	2.26	0.19	7.03	0	7.68	0.38	12.07	0.12	34.374	0.20	25.90	8.13	98.59
	100 D	10	0.04	0.12	0.15	1.76	0.29	7.87	0.35	8.31	0.11	34.919	0.14	25.63	8.13	96.05
	150 S	1	0.05	0.70	0.25	3.22	0.31	8.79	0.38	10.60	0.16	34.721	0.16	25.95	8.12	96.89
	150 D	15	0.06	0.07	0.17	1.49	0.31	8.24	0.38	8.59	0.10	34.925	0.14	25.59	8.13	95.07
WAILEA 2	0 S	1	0.14	23.20	0.14	36.46	0.24	6.40	0.54	42.71	0.20	25.890	0.42	26.39	8.14	98.80
	2 S	1	0.17	15.13	0.18	24.78	0.28	7.04	0.52	28.54	0.18	31.432	0.40	26.15	8.14	100.11
	5 S	1	0.10	6.74	0.15	12.65	0.29	7.86	0.41	16.41	0.18	34.010	0.26	26.20	8.13	100.42
	5 D	2.5	0.12	3.71	0.20	7.86	0.29	7.86	0.43	12.28	0.17	34.527	0.31	26.14	8.14	100.88
	10 S	1	0.08	1.70	0.17	6.21	0.30	8.89	0.40	11.96	0.14	34.682	0.17	25.92	8.13	100.20
	10 D	3	0.06	1.04	0.16	3.66	0.30	7.35	0.38	9.00	0.13	34.795	0.26	25.94	8.13	100.18
	50 S	1	0.07	2.29	0.13	6.20	0.27	7.67	0.36	10.86	0.13	34.647	0.18	25.88	8.14	97.71
	50 D	4.5	0.09	0.14	0.28	1.81	0.28	7.03	0.39	7.69	0.12	34.945	0.20	25.67	8.14	94.16
	100 S	1	0.09	0.79	0.27	3.33	0.30	7.92	0.41	9.69	0.12	34.822	0.15	25.72	8.14	96.19
	100 D	10	0.07	0.05	0.18	1.43	0.30	7.05	0.38	7.39	0.12	34.968	0.18	25.65	8.15	95.03
	150 S	1	0.06	0.26	0.17	2.67	0.29	7.73	0.36	8.89	0.13	34.842	0.12	26.10	8.14	96.33
	150 D	15	0.06	0.04	0.25	1.40	0.29	7.82	0.36	8.31	0.10	34.992	0.14	25.64	8.15	94.90
WAILEA 3	0 S	1	0.14	9.39	0.44	25.49	0.32	8.27	0.49	21.98	0.30	31.704	0.62	26.41	8.15	99.21
	2 S	1	0.13	5.42	0.29	15.52	0.31	7.22	0.45	15.94	0.26	33.584	0.49	26.24	8.14	99.27
	5 S	1	0.09	3.24	0.24	10.22	0.31	7.19	0.41	11.94	0.20	34.218	0.42	26.44	8.14	99.25
	5 D	2.5	0.12	3.27	0.37	10.40	0.30	8.12	0.44	12.97	0.23	34.216	0.38	26.43	8.14	99.18
	10 S	1	0.11	3.67	0.28	11.96	0.28	7.12	0.41	13.02	0.17	33.985	0.26	26.43	8.13	98.11
	10 D	5	0.09	2.22	0.26	8.96	0.29	7.44	0.40	11.05	0.21	34.386	0.35	26.27	8.14	98.33
	50 S	1	0.11	0.97	0.39	5.30	0.32	8.44	0.45	10.86	0.15	34.700	0.26	25.85	8.14	97.41
	50 D	10	0.07	0.13	0.41	2.25	0.33	8.11	0.42	8.94	0.13	34.912	0.21	25.78	8.15	95.89
	100 S	1	0.07	0.79	0.21	4.37	0.31	8.02	0.39	9.67	0.16	34.740	0.20	25.96	8.14	97.25
	100 D	15	0.07	0.05	0.13	1.74	0.32	8.25	0.40	8.58	0.12	34.946	0.17	25.69	8.15	95.27
	150 S	1	0.07	0.33	0.28	2.74	0.31	7.51	0.39	8.64	0.14	34.865	0.16	25.96	8.14	94.81
	150 D	20	0.07	0.08	0.33	1.53	0.30	7.04	0.39	7.59	0.11	34.965	0.19	25.63	8.15	93.96
WAILEA 4	0 S	1	0.10	17.14	0.21	28.76	0.30	7.78	0.44	34.29	0.26	31.610	0.41	26.25	8.13	101.62
	2 S	1	0.07	11.63	0.17	20.52	0.32	8.33	0.42	26.95	0.22	32.885	0.49	26.43	8.15	101.05
	5 S	1	0.08	2.83	0.15	7.79	0.30	7.89	0.41	12.87	0.17	34.421	0.39	26.41	8.15	103.23
	5 D	2.5	0.08	2.12	0.12	6.48	0.30	8.25	0.39	12.03	0.17	34.522	0.29	26.41	8.15	100.80
	10 S	1	0.09	0.70	0.29	3.75	0.30	8.98	0.41	10.75	0.18	34.810	0.27	26.10	8.15	101.13
	10 D	3	0.11	0.45	0.16	3.10	0.31	7.54	0.45	8.74	0.14	34.874	0.22	26.07	8.14	100.51
	50 S	1	0.10	2.38	0.21	6.31	0.31	8.37	0.43	13.52	0.17	34.376	0.25	26.13	8.12	96.86
	50 D	10	0.08	0.15	0.17	2.14	0.27	8.35	0.39	8.98	0.11	34.942	0.21	25.41	8.14	93.52
	100 S	1	0.08	1.93	0.16	6.53	0.29	7.88	0.40	12.59	0.14	34.408	0.19	26.08	8.13	96.49
	100 D	15	0.09	0.09	0.16	1.72	0.33	8.10	0.44	8.61	0.10	34.967	0.15	25.68	8.14	94.81
	150 S	1	0.07	0.31	0.15	2.84	0.33	7.50	0.42	8.67	0.10	34.856	0.14	26.18	8.14	95.21
	150 D	25	0.06	0.03	0.07	1.56	0.33	7.15	0.40	7.43	0.10	34.953	0.16	25.61	8.15	95.13
WAILEA 5	0 S	1	0.23	17.09	0.57	81.67	0.30	5.37	0.63	30.06	0.30	28.274	0.59	25.63	8.10	96.85
	2 S	1	0.18	14.19	0.58	66.96	0.26	6.13	0.59	26.53	0.29	29.441	0.41	25.76	8.10	97.99
	5 S	1	0.15	6.22	0.48	36.57	0.30	8.32	0.49	16.44	0.21	32.854	0.39	25.70	8.11	99.65
	5 D	1.5	0.07	4.26	0.28	26.01	0.30	8.04	0.43	13.07	0.16	33.579	0.37	25.72	8.12	99.98
	10 S	1	0.06	1.50	0.37	10.88	0.29	7.60	0.37	9.61	0.14	34.486	0.19	25.70	8.10	98.95
	10 D	2.5	0.11	1.47	0.32	10.74	0.28	6.84	0.40	8.87	0.14	34.531	0.30	25.59	8.10	97.38
	50 S	1	0.09	1.12	0.31	8.72	0.30	7.36	0.40	9.26	0.15	34.569	0.19	25.44	8.12	94.61
	50 D	9	0.07	0.12	0.19	3.16	0.30	6.93	0.39	7.42	0.13	34.891	0.26	25.43	8.11	93.92
	100 S	1	0.10	0.40	0.22	5.91	0.30	6.97	0.42	8.06	0.15	34.671	0.15	25.63	8.11	95.20
	100 D	14	0.06	0.09	0.16	2.74	0.29	6.95	0.37	7.52	0.15	34.877	0.18	25.51	8.13	94.18
	150 S	1	0.07	0.22	0.23	3.13	0.29	7.24	0.39	8.09	0.11	34.834	0.13	25.65	8.13	95.44
	150 D	18	0.06	0.04	0.24	2.00	0.30	6.98	0.38	7.59	0.12	34.930	0.15	25.54	8.14	94.65
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 $\mu g/L$) collected at five sites off of Honua'ula, Wailea, Maui since the inception of monitoring in June 2005 (N=8). 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 ($\mu g/L$)	NO3 ($\mu g/L$)	NH4 ($\mu g/L$)	Si ($\mu g/L$)	TOP ($\mu g/L$)	TON ($\mu g/L$)	TP ($\mu g/L$)	TN ($\mu g/L$)	TURB (NTU)	SALINITY (ppt)	CHL a ($\mu g/L$)	TEMP (deg.C)	pH (std.units)	O2 % Sat
WAILEA 1	0 S	1	7.12	987.3	4.62	3586	8.67	100.3	18.58	1184	0.24	19.01	1.04	26.11	8.11	104.93
	2 S	1	6.50	691.5	1.12	2638	9.29	111.1	17.96	859.5	0.22	26.01	1.28	26.14	8.14	104.49
	5 S	1	2.47	254.5	0.70	1094	8.67	115.1	12.69	413.7	0.19	31.25	0.46	25.89	8.13	103.64
	5 D	2.5	3.71	134.5	3.64	660.4	8.98	119.8	13.62	280.3	0.13	33.18	0.29	25.92	8.13	103.53
	10 S	1	2.47	102.4	2.38	515.5	8.67	111.3	11.76	242.7	0.17	33.62	0.29	26.00	8.12	105.56
	10 D	3	2.16	36.13	3.08	223.3	8.98	109.4	11.46	161.5	0.14	34.44	0.26	25.90	8.12	104.95
	50 S	1	1.85	47.90	3.78	264.6	9.29	113.6	11.15	185.6	0.14	34.30	0.30	25.77	8.12	101.46
	50 D	4.5	2.16	4.06	1.82	62.64	9.29	109.4	11.76	118.8	0.11	34.84	0.29	25.63	8.12	96.97
	100 S	1	2.16	31.65	2.66	197.5	5.88	107.6	11.76	169.1	0.12	34.37	0.20	25.90	8.13	98.59
	100 D	10	1.23	1.68	2.10	49.44	8.98	110.2	10.84	116.4	0.11	34.92	0.14	25.63	8.13	96.05
	150 S	1	1.54	9.80	3.50	90.45	9.60	123.1	11.76	148.5	0.16	34.72	0.16	25.95	8.12	96.89
	150 D	15	1.85	0.98	2.38	41.85	9.60	115.4	11.76	120.3	0.10	34.93	0.14	25.59	8.13	95.07
WAILEA 2	0 S	1	4.33	324.9	1.96	1024	7.43	89.63	16.72	598.2	0.20	25.89	0.42	26.39	8.14	98.80
	2 S	1	5.26	211.9	2.52	696.1	8.67	98.60	16.10	399.7	0.18	31.43	0.40	26.15	8.14	100.11
	5 S	1	3.09	94.40	2.10	355.3	8.98	110.1	12.69	229.8	0.18	34.01	0.26	26.20	8.13	100.42
	5 D	2.5	3.71	51.96	2.80	220.8	8.98	110.1	13.31	172.0	0.17	34.53	0.31	26.14	8.14	100.88
	10 S	1	2.47	23.81	2.38	174.4	9.29	124.5	12.38	167.5	0.14	34.68	0.17	25.92	8.13	100.20
	10 D	3	1.85	14.56	2.24	102.8	9.29	102.9	11.76	126.1	0.13	34.80	0.26	25.94	8.13	100.18
	50 S	1	2.16	32.07	1.82	174.2	8.36	107.4	11.15	152.1	0.13	34.65	0.18	25.88	8.14	97.71
	50 D	4.5	2.78	1.96	3.92	50.84	8.67	98.46	12.07	107.7	0.12	34.95	0.20	25.67	8.14	94.16
	100 S	1	2.78	11.06	3.78	93.54	9.29	110.9	12.69	135.7	0.12	34.82	0.15	25.72	8.14	96.19
	100 D	10	2.16	0.70	2.52	40.17	9.29	98.74	11.76	103.5	0.12	34.97	0.18	25.65	8.15	95.03
	150 S	1	1.85	3.64	2.38	75.00	8.98	108.3	11.15	124.5	0.13	34.84	0.12	26.10	8.14	96.33
	150 D	15	1.85	0.56	3.50	39.33	8.98	109.5	11.15	116.4	0.10	34.99	0.14	25.64	8.15	94.90
WAILEA 3	0 S	1	4.33	131.5	6.16	716.0	9.91	115.8	15.17	307.9	0.30	31.70	0.62	26.41	8.15	99.21
	2 S	1	4.02	75.91	4.06	436.0	9.60	101.1	13.93	223.3	0.26	33.58	0.49	26.24	8.14	99.27
	5 S	1	2.78	45.37	3.36	287.1	9.60	100.7	12.69	167.2	0.20	34.22	0.42	26.44	8.14	99.25
	5 D	2.5	3.71	45.79	5.18	292.1	9.29	113.7	13.62	181.7	0.23	34.22	0.38	26.43	8.14	99.18
	10 S	1	3.40	51.40	3.92	336.0	8.67	99.72	12.69	182.4	0.17	33.99	0.26	26.43	8.13	98.11
	10 D	5	2.78	31.09	3.64	251.7	8.98	104.2	12.38	154.8	0.21	34.39	0.35	26.27	8.14	98.33
	50 S	1	3.40	13.58	5.46	148.9	9.91	118.2	13.93	152.1	0.15	34.70	0.26	25.85	8.14	97.41
	50 D	10	2.16	1.82	5.74	63.20	10.22	113.6	13.00	125.2	0.13	34.91	0.21	25.78	8.15	95.89
	100 S	1	2.16	11.06	2.94	122.8	9.60	112.3	12.07	135.4	0.16	34.74	0.20	25.96	8.14	97.25
	100 D	15	2.16	0.70	1.82	48.88	9.91	115.5	12.38	120.2	0.12	34.95	0.17	25.69	8.15	95.27
	150 S	1	2.16	4.62	3.92	76.97	9.60	105.2	12.07	121.0	0.14	34.87	0.16	25.96	8.14	94.81
	150 D	20	2.16	1.12	4.62	42.98	9.29	98.60	12.07	106.3	0.11	34.97	0.19	25.63	8.15	93.96
WAILEA 4	0 S	1	3.09	240.1	2.94	807.9	9.29	109.0	13.62	480.3	0.26	31.61	0.41	26.25	8.13	101.62
	2 S	1	2.16	162.9	2.38	576.4	9.91	116.7	13.00	377.5	0.22	32.89	0.49	26.43	8.15	101.05
	5 S	1	2.47	39.63	2.10	218.8	9.29	110.5	12.69	180.3	0.17	34.42	0.39	26.41	8.15	103.23
	5 D	2.5	2.47	29.69	1.68	182.0	9.29	115.5	12.07	168.5	0.17	34.52	0.29	26.41	8.15	100.80
	10 S	1	2.78	9.80	4.06	105.3	9.29	125.8	12.69	150.6	0.18	34.81	0.27	26.10	8.15	101.13
	10 D	3	3.40	6.30	2.24	87.08	9.60	105.6	13.93	122.4	0.14	34.87	0.22	26.07	8.14	100.51
	50 S	1	3.09	33.33	2.94	177.2	9.60	117.2	13.31	189.4	0.17	34.38	0.25	26.13	8.12	96.86
	50 D	10	2.47	2.10	2.38	60.11	8.36	117.0	12.07	125.8	0.11	34.94	0.21	25.41	8.14	93.52
	100 S	1	2.47	27.03	2.24	183.4	8.98	110.4	12.38	176.3	0.14	34.41	0.19	26.08	8.13	96.49
	100 D	15	2.78	1.26	2.24	48.31	10.22	113.4	13.62	120.6	0.10	34.97	0.15	25.68	8.14	94.81
	150 S	1	2.16	4.34	2.10	79.78	10.22	105.0	13.00	121.4	0.10	34.86	0.14	26.18	8.14	95.21
	150 D	25	1.85	0.42	0.98	43.82	10.22	100.1	12.38	104.1	0.10	34.95	0.16	25.61	8.15	95.13
WAILEA 5	0 S	1	7.12	239.4	7.98	2294	9.29	75.21	19.51	421.0	0.30	28.27	0.59	25.63	8.10	96.85
	2 S	1	5.57	198.7	8.12	1881	8.05	85.85	18.27	371.6	0.29	29.44	0.41	25.76	8.10	97.99
	5 S	1	4.64	87.11	6.72	1027	9.29	116.5	15.17	230.3	0.21	32.85	0.39	25.70	8.11	99.65
	5 D	1.5	2.16	59.66	3.92	730.6	9.29	112.6	13.31	183.1	0.16	33.58	0.37	25.72	8.12	99.98
	10 S	1	1.85	21.00	5.18	305.6	8.98	106.4	11.46	134.6	0.14	34.49	0.19	25.70	8.10	98.95
	10 D	2.5	3.40	20.58	4.48	301.7	8.67	95.80	12.38	124.2	0.14	34.53	0.30	25.59	8.10	97.38
	50 S	1	2.78	15.68	4.34	244.9	9.29	103.1	12.38	129.7	0.15	34.57	0.19	25.44	8.12	94.61
	50 D	9	2.16	1.68	2.66	88.76	9.29	97.06	12.07	103.9	0.13	34.89	0.26	25.43	8.11	93.92
	100 S	1	3.09	5.60	3.08	166.0	9.29	97.62	13.00	112.9	0.15	34.67	0.15	25.63	8.11	95.20
	100 D	14	1.85	1.26	2.24	76.97	8.98	97.34	11.46	105.3	0.15	34.88	0.18	25.51	8.13	94.18
	150 S	1	2.16	3.08	3.22	87.92	8.98	101.4	12.07	113.3	0.11	34.83	0.13	25.65	8.13	95.44
	150 D	18	1.85	0.56	3.36	56.18	9.29	97.76	11.76	106.3	0.12	34.93	0.15	25.54	8.14	94.65
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.

ı 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
ıpling site locations, see Figure 1.

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)
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
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
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
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
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
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
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
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

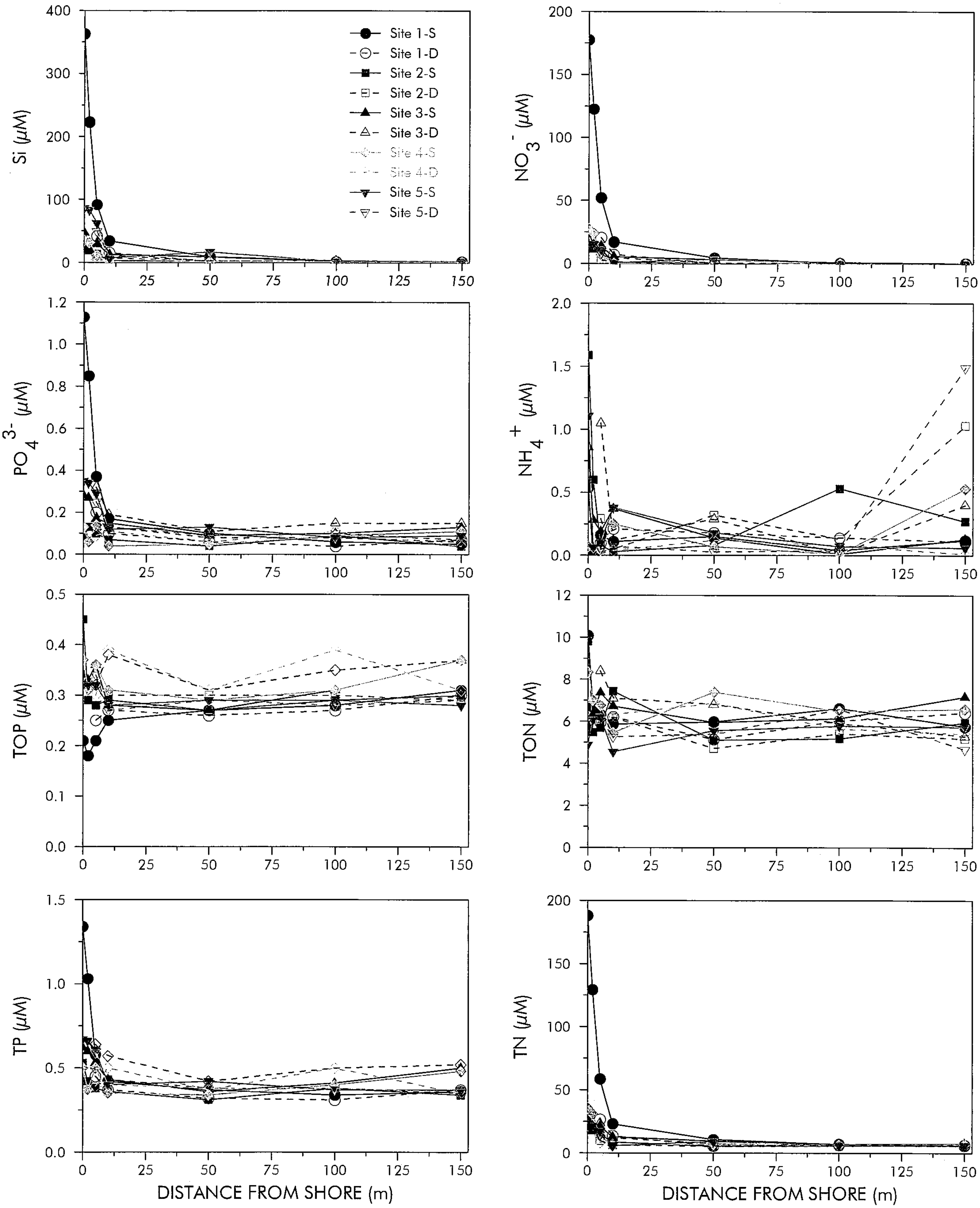


FIGURE 2. Plots of dissolved nutrients in surface (S) and deep (D) samples collected on March 6, 2011 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. For site locations, see Figure 1.

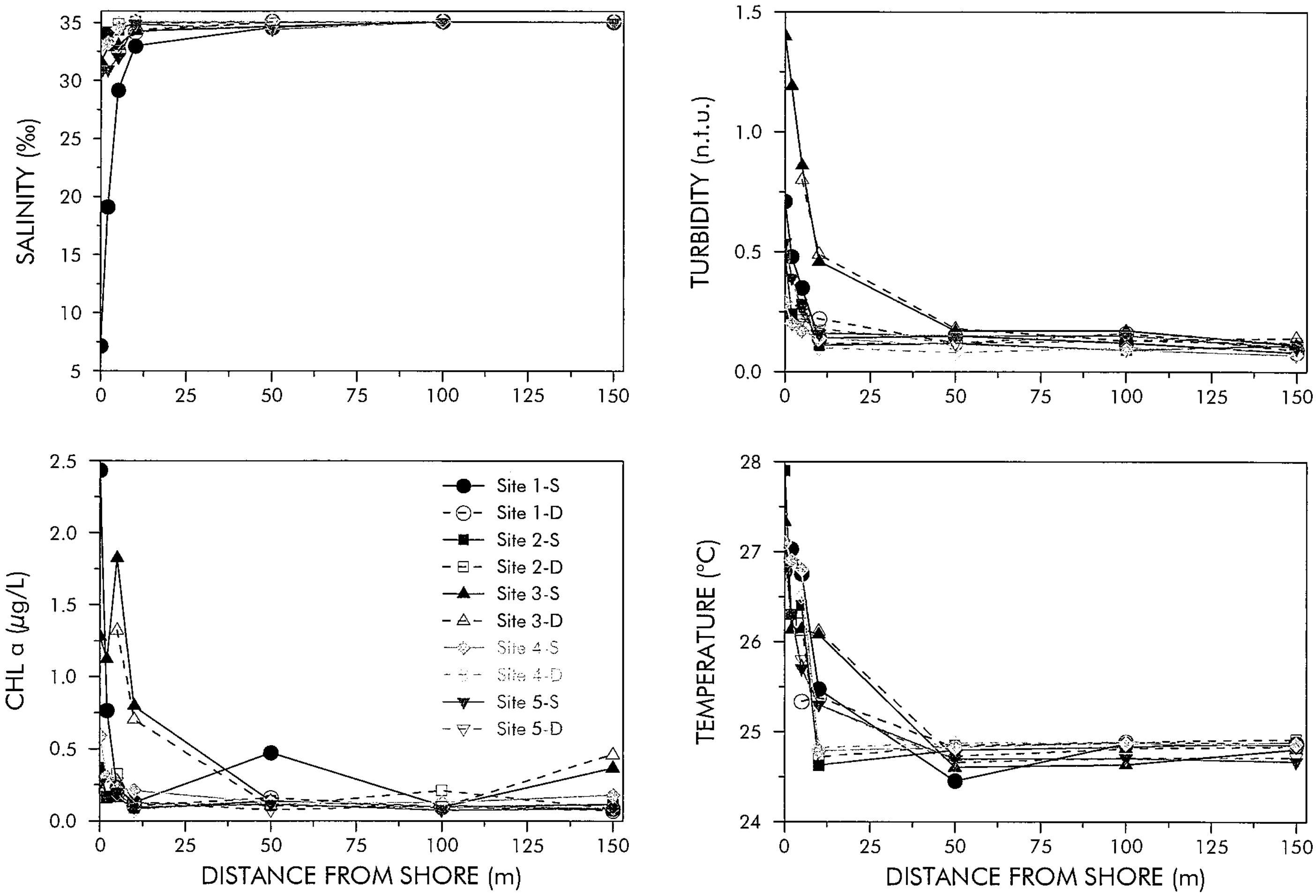


FIGURE 3. Plots of water chemistry constituents in surface (S) and deep (D) samples collected on March 6, 2011 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. For site locations, see Figure 1.

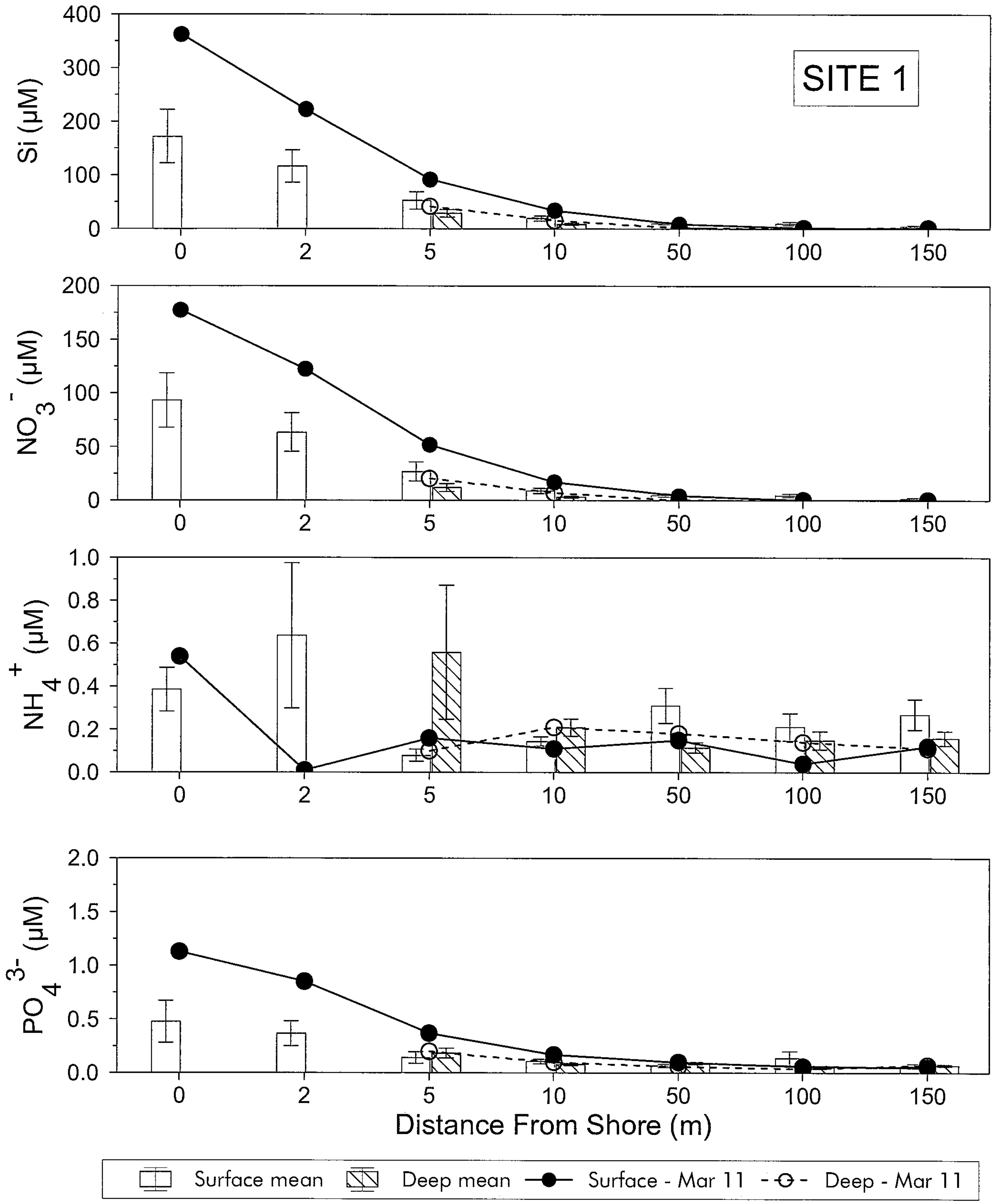


FIGURE 4. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

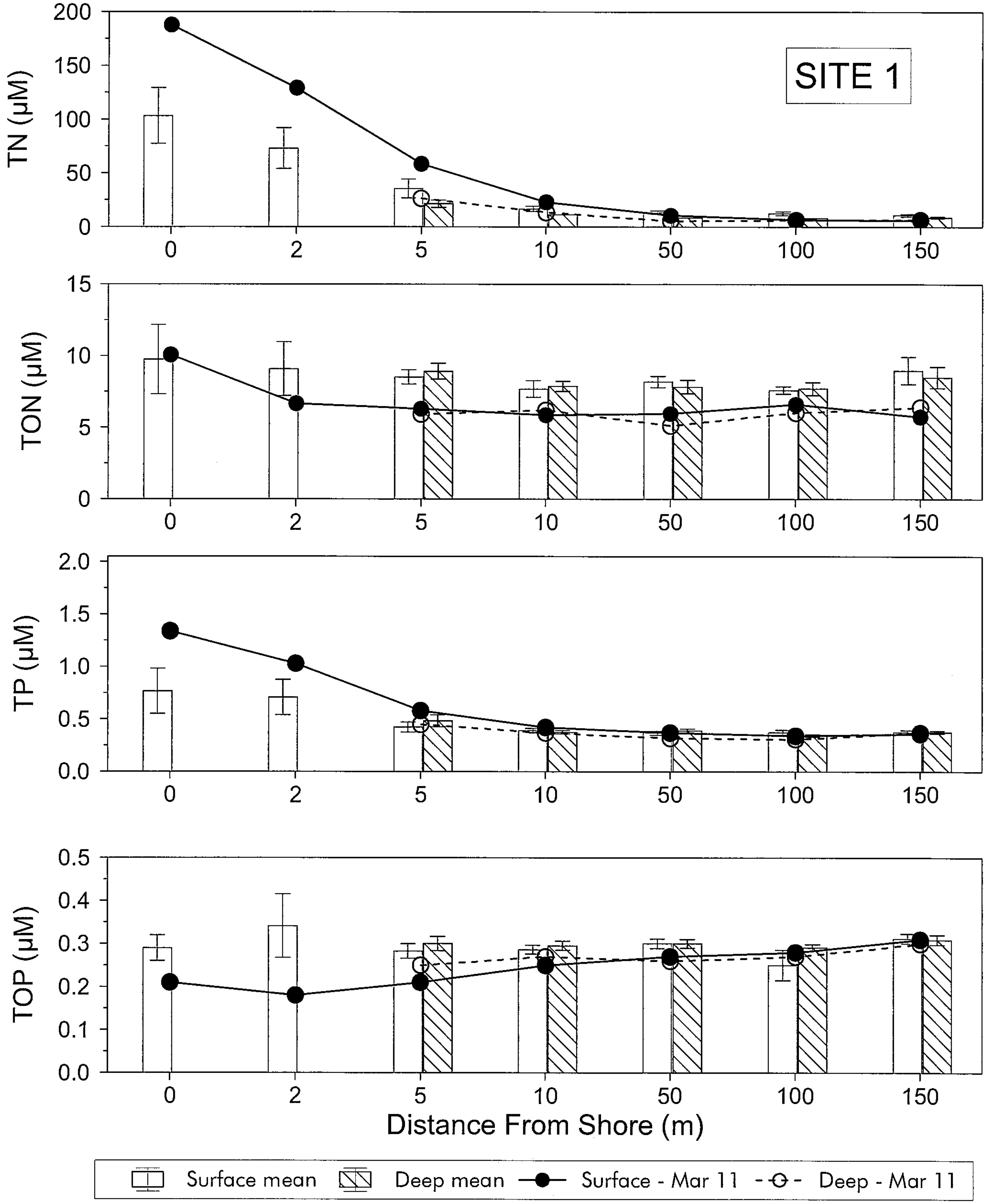


FIGURE 5. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

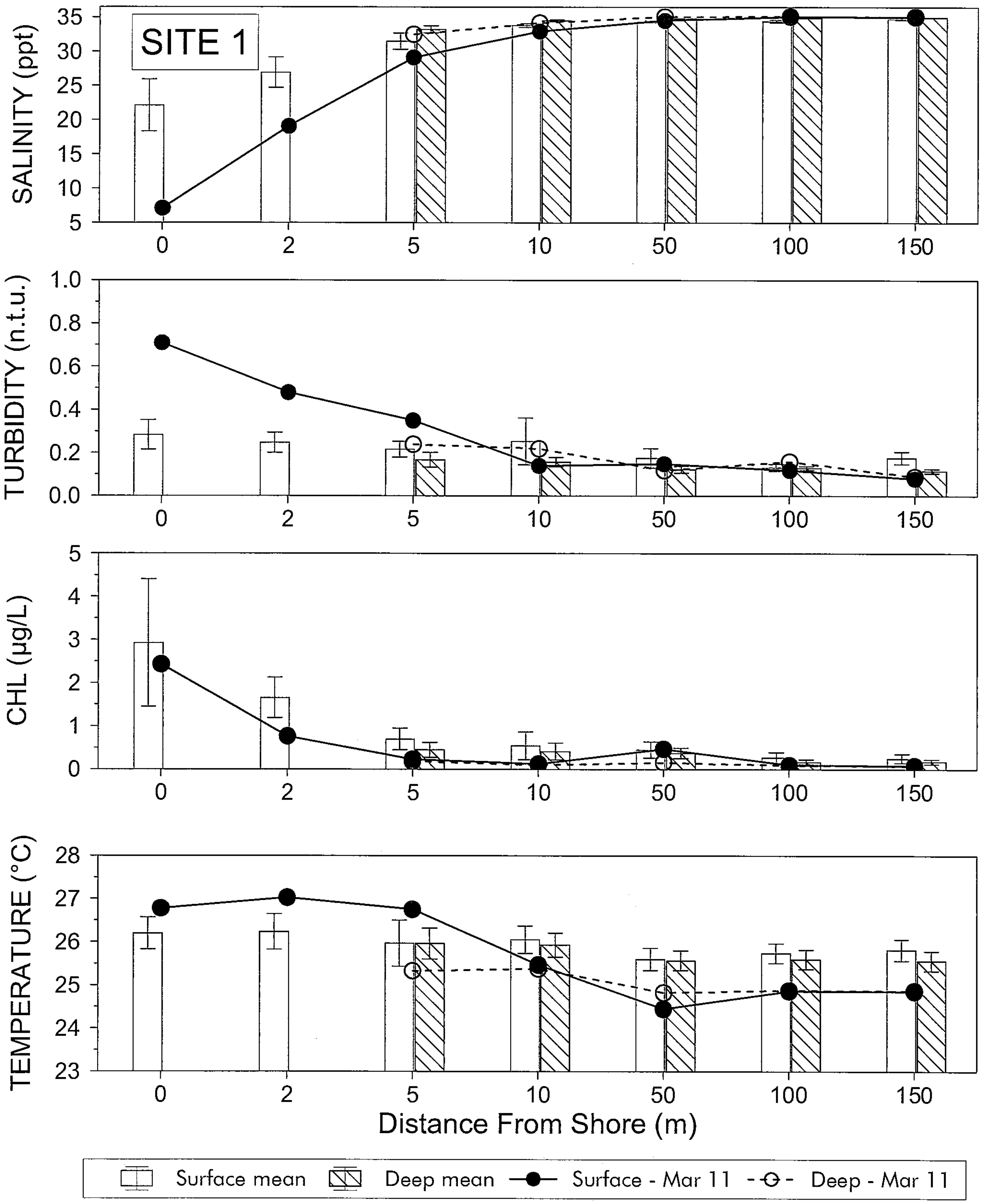


FIGURE 6. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent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

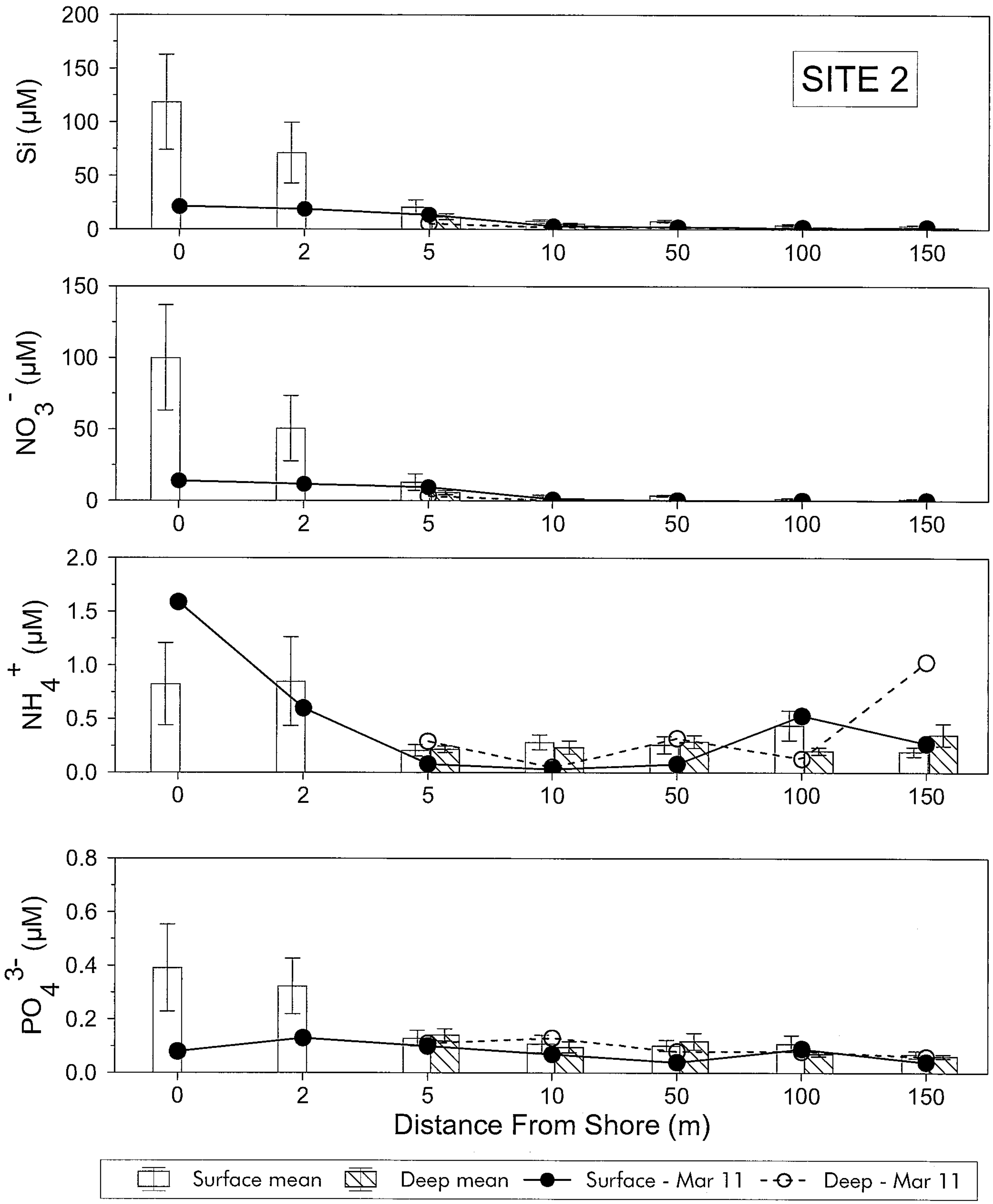


FIGURE 7. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

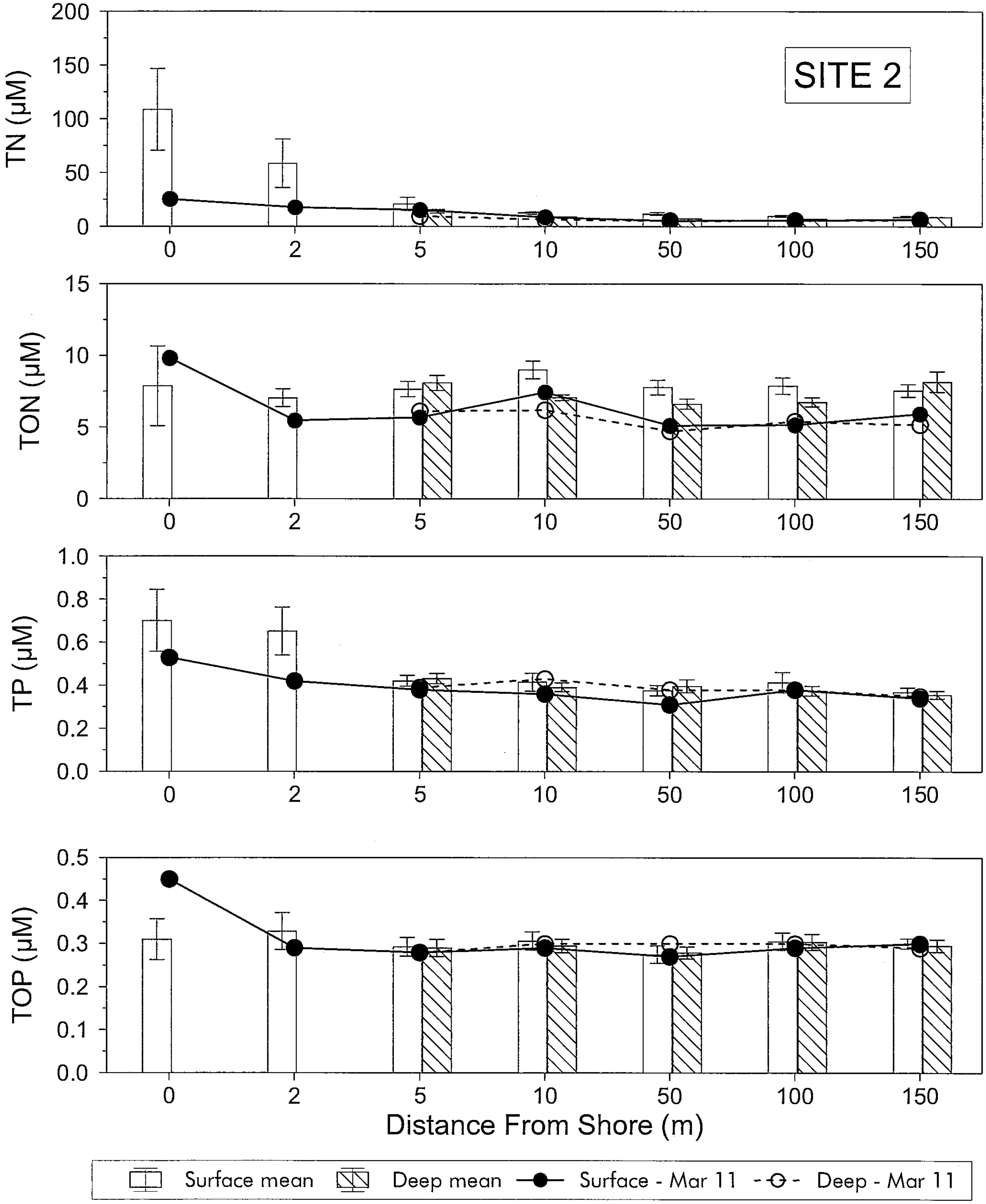


FIGURE 8. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent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

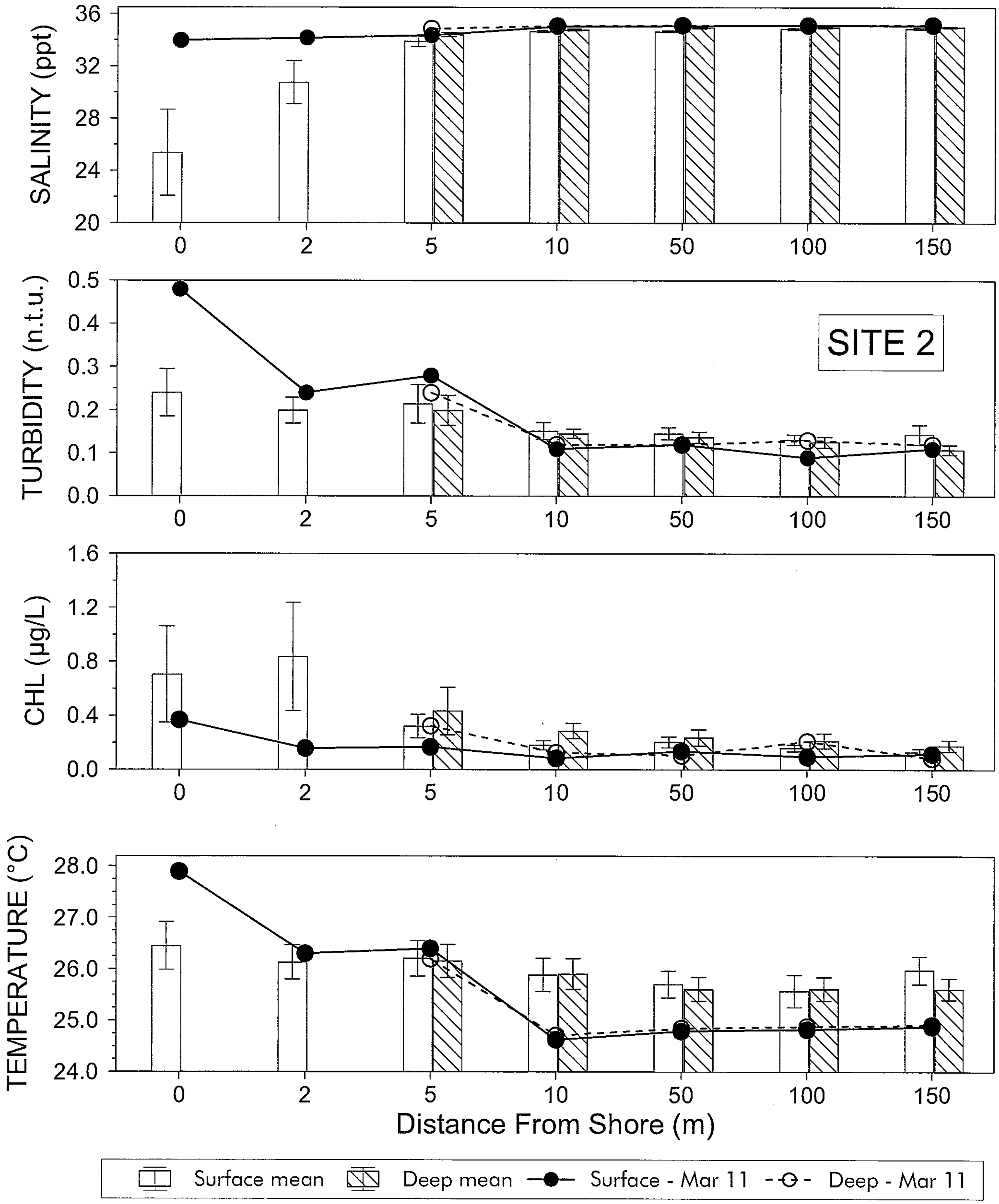


FIGURE 9. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

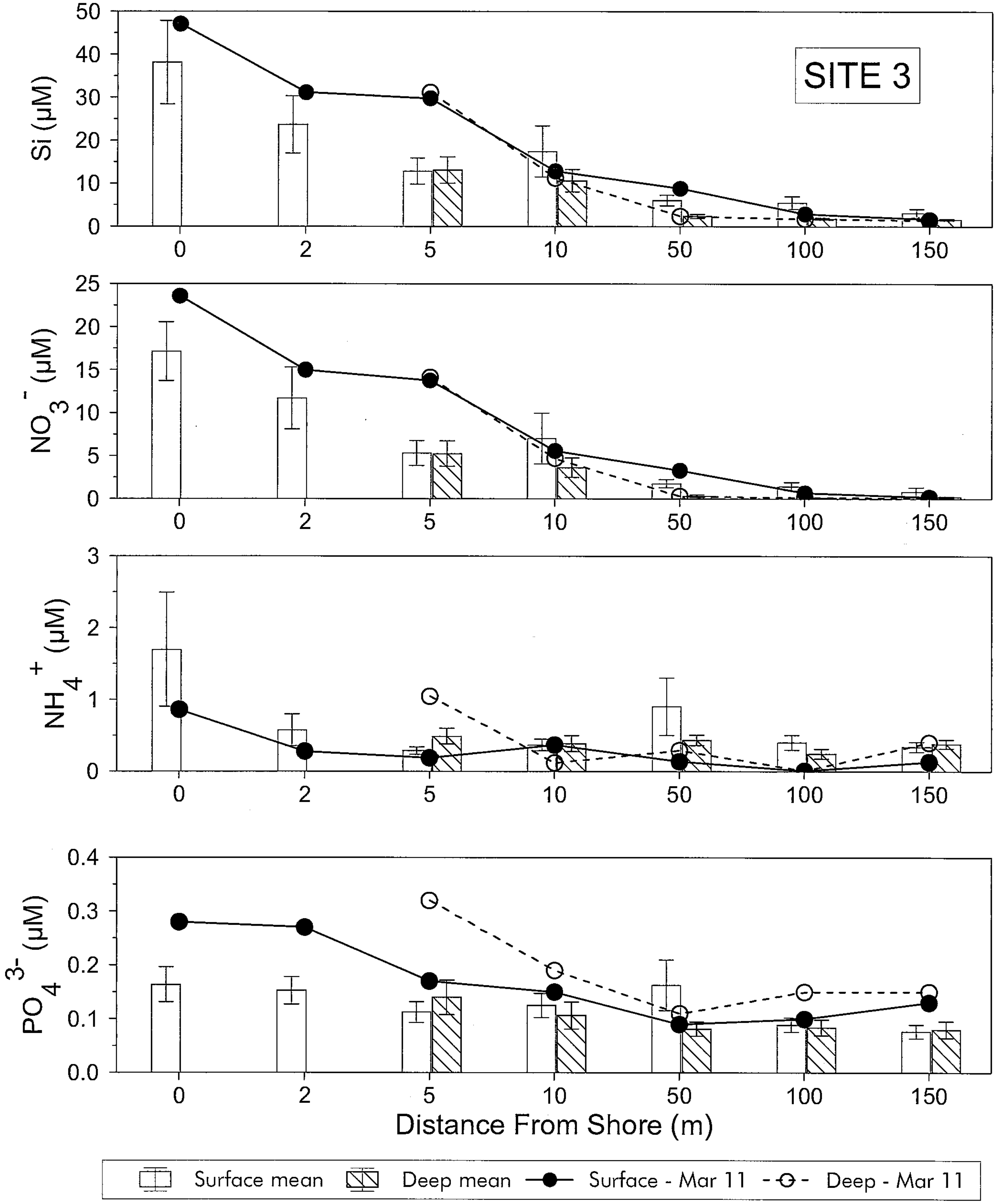


FIGURE 10. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

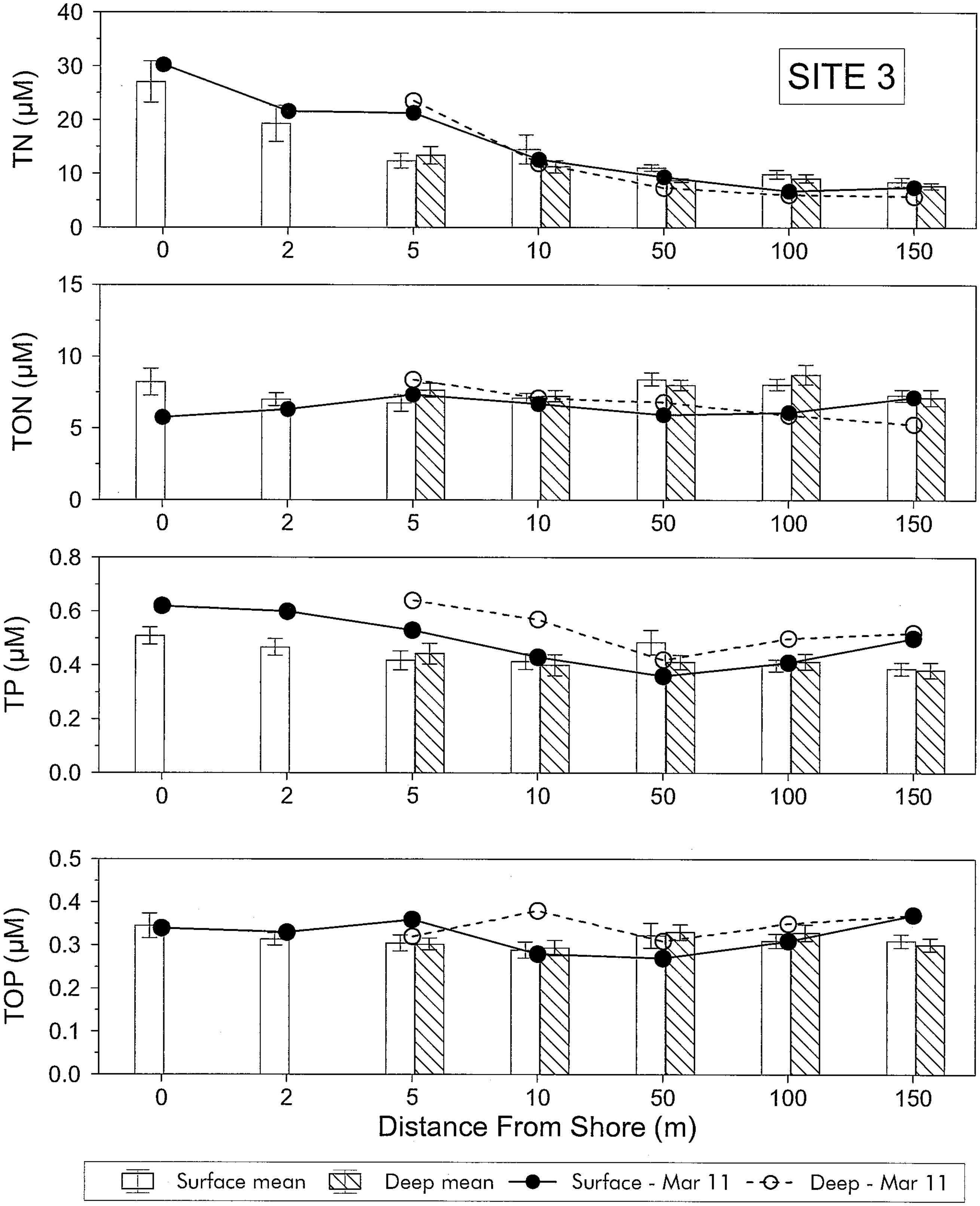


FIGURE 11. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

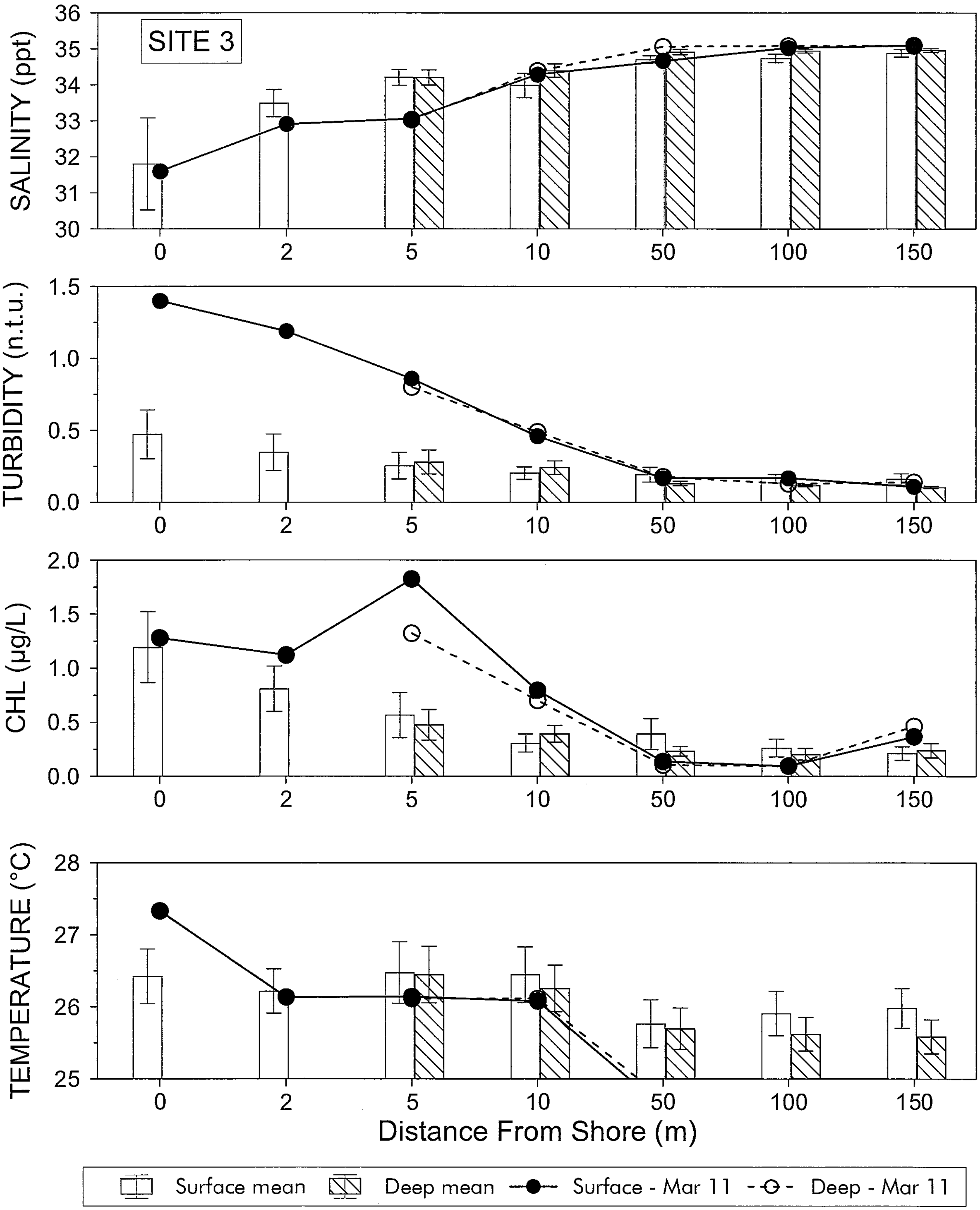


FIGURE 12. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

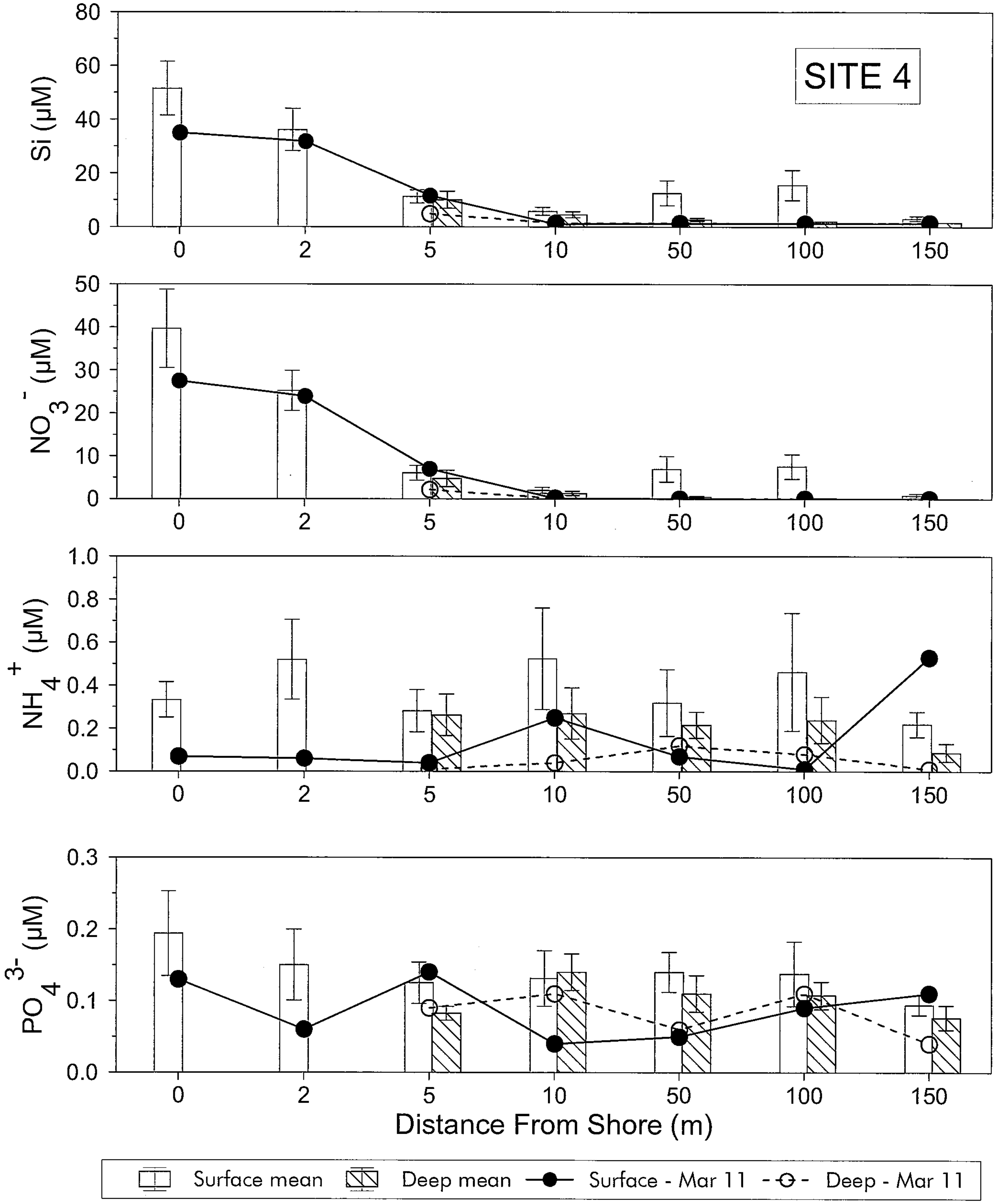


FIGURE 13. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

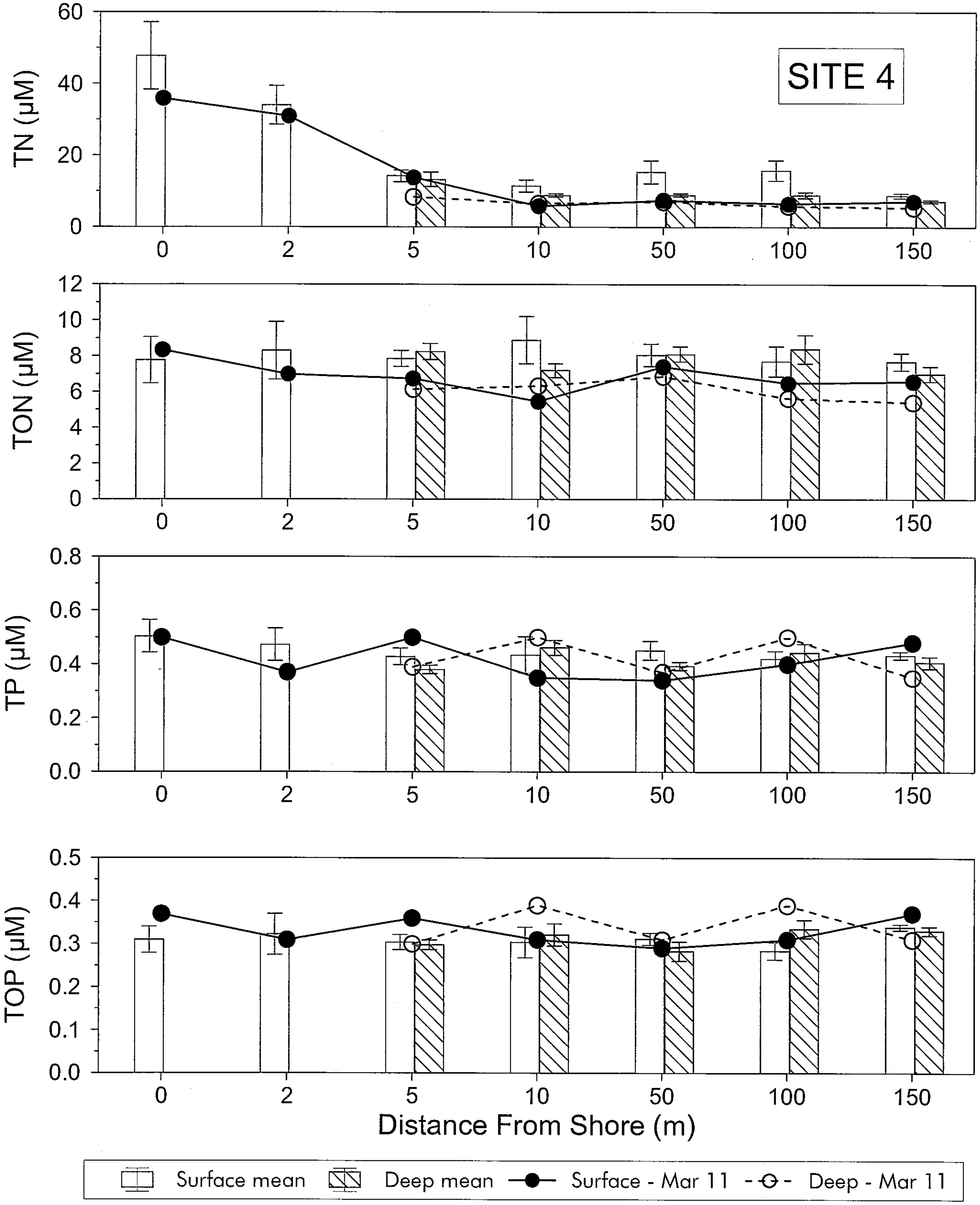


FIGURE 14. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

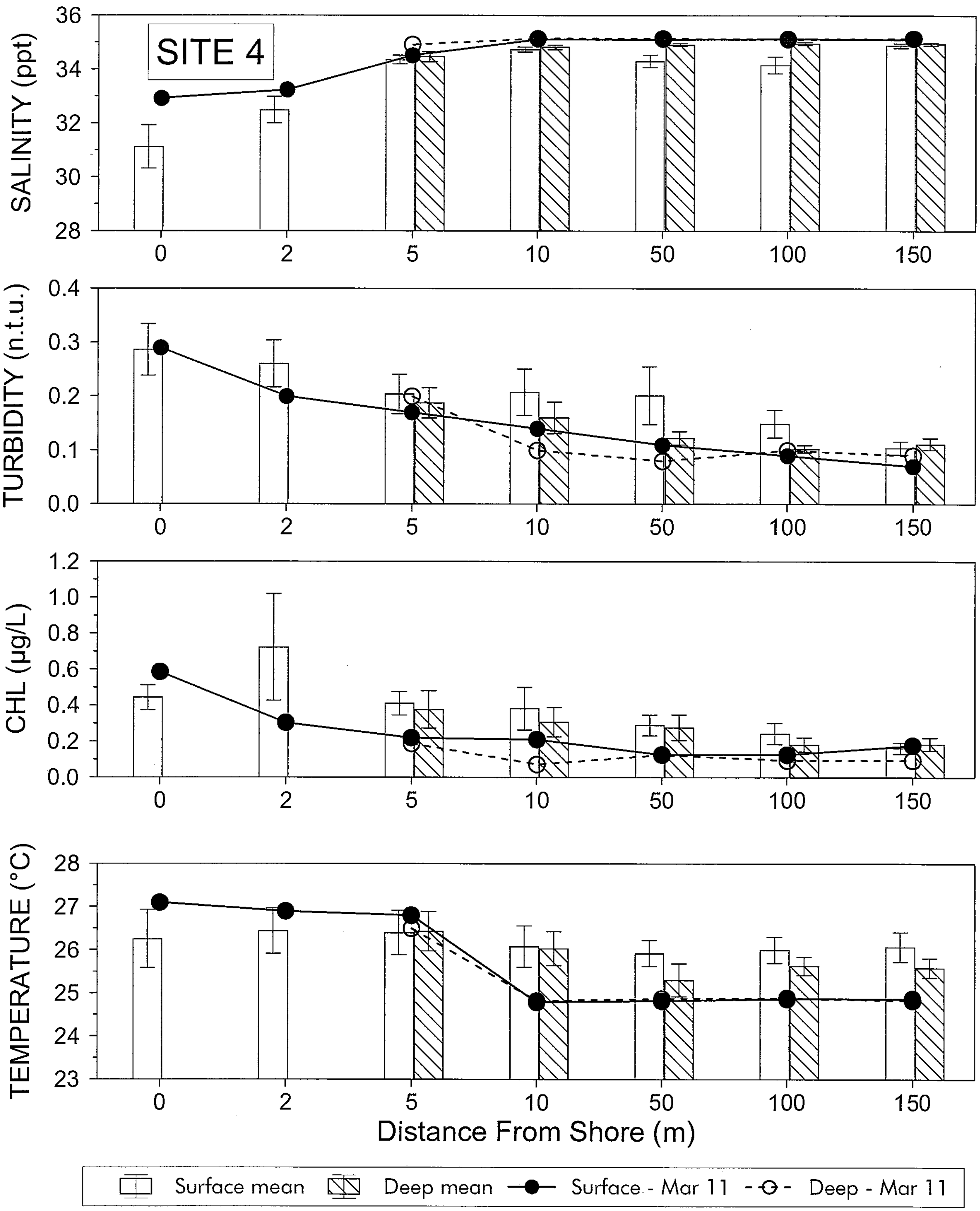


FIGURE 15. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

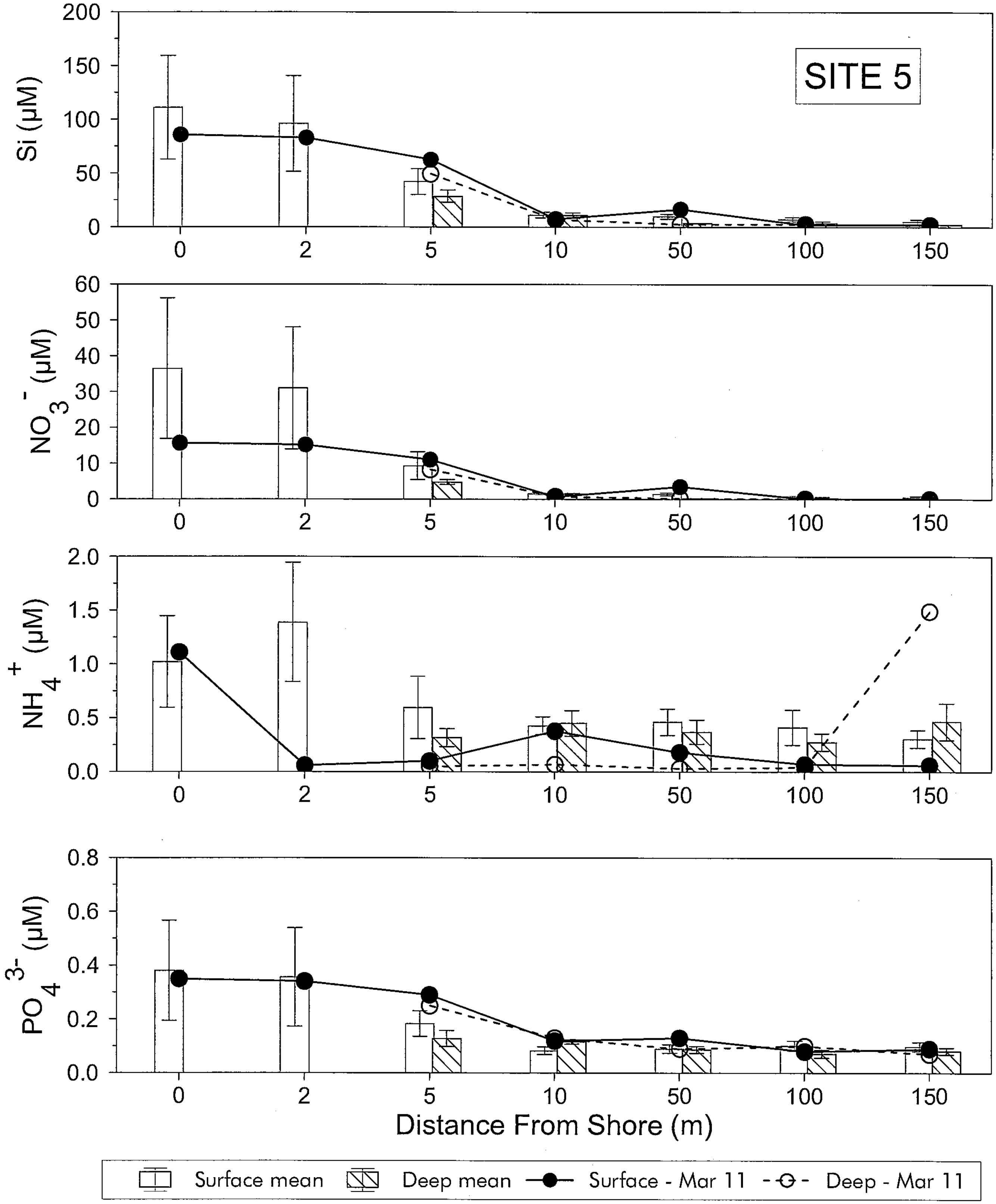


FIGURE 16. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

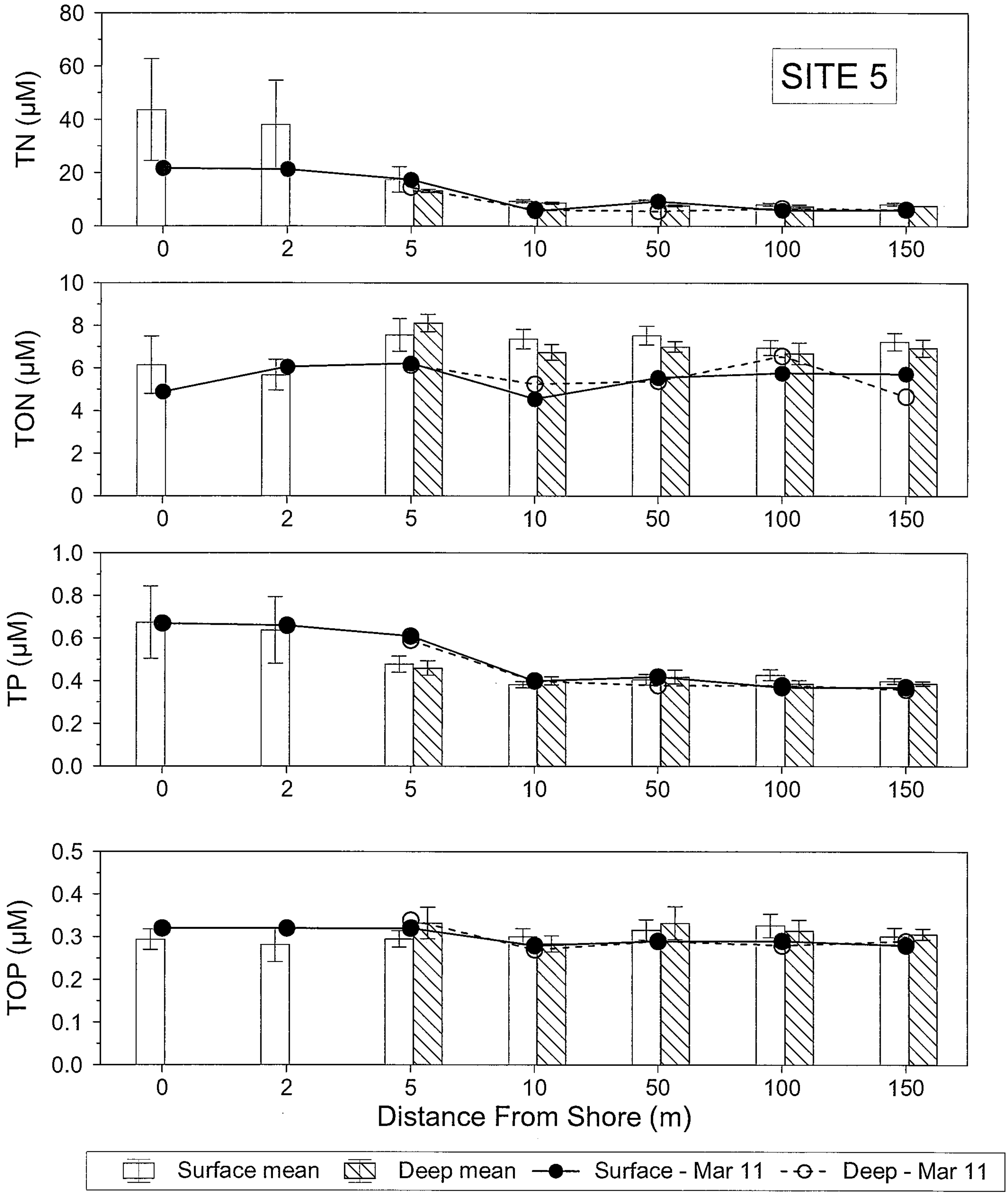


FIGURE 17. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

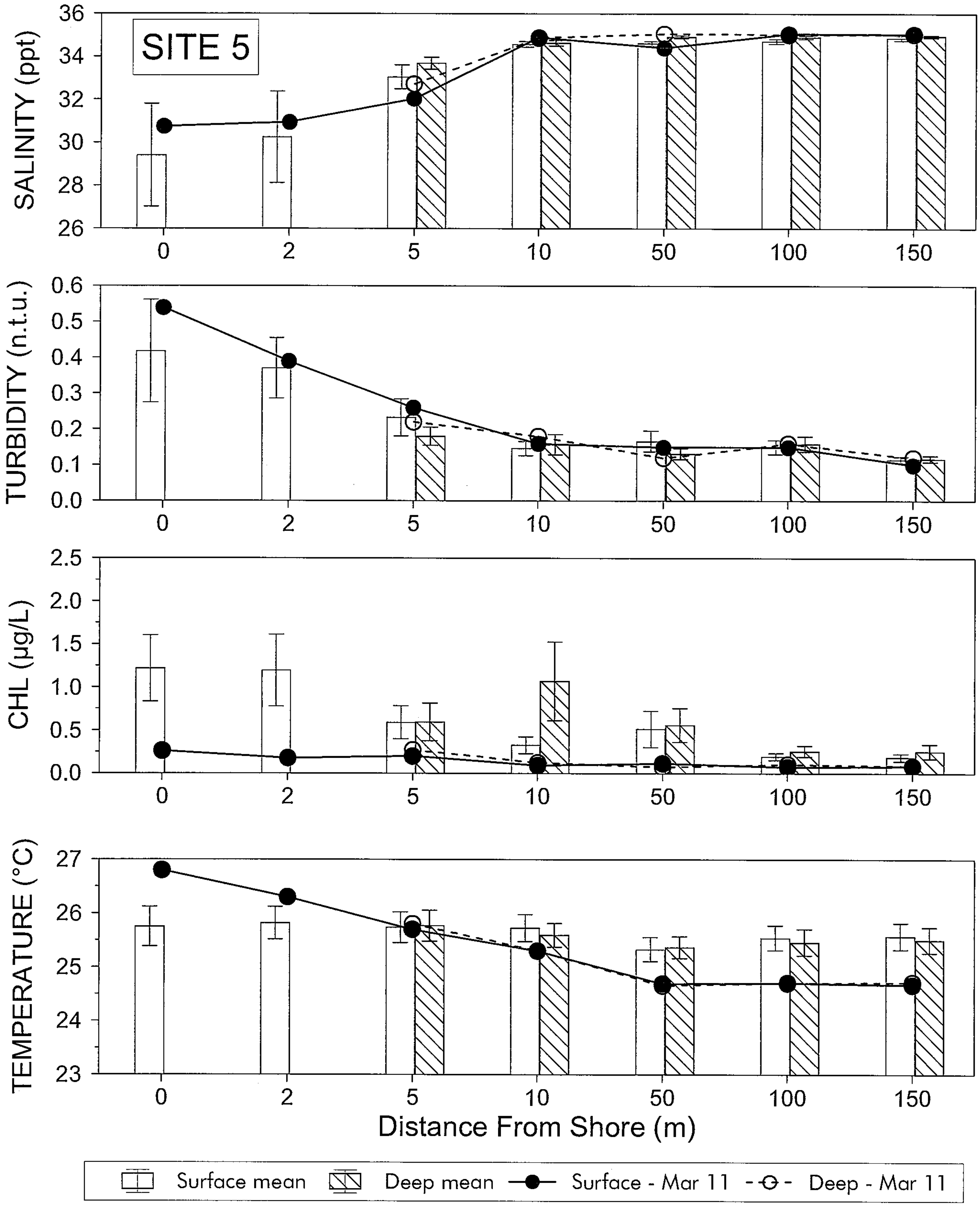


FIGURE 18. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=8). Error bars represent standard error of the mean. For site location, see Figure 1.

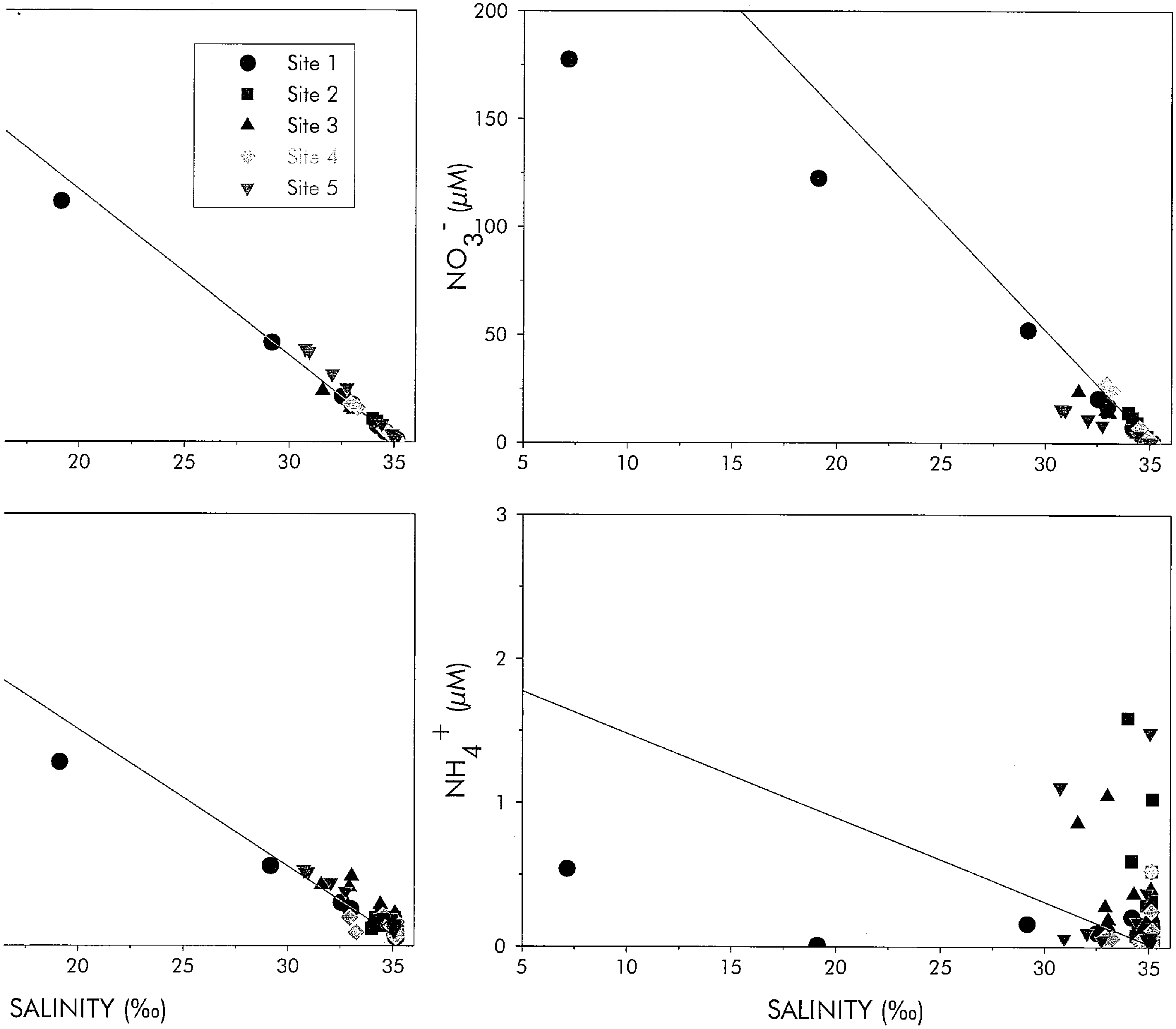


diagram showing concentration of dissolved nutrients from samples collected at five transect sites offshore
ɔject site in Wailea, Maui on March 6, 2011 as functions of salinity. Straight line in each plot is conservative
ɘd by connecting the concentrations in open coastal water with water from a golf course irrigation well.
tions, see Figure 1.

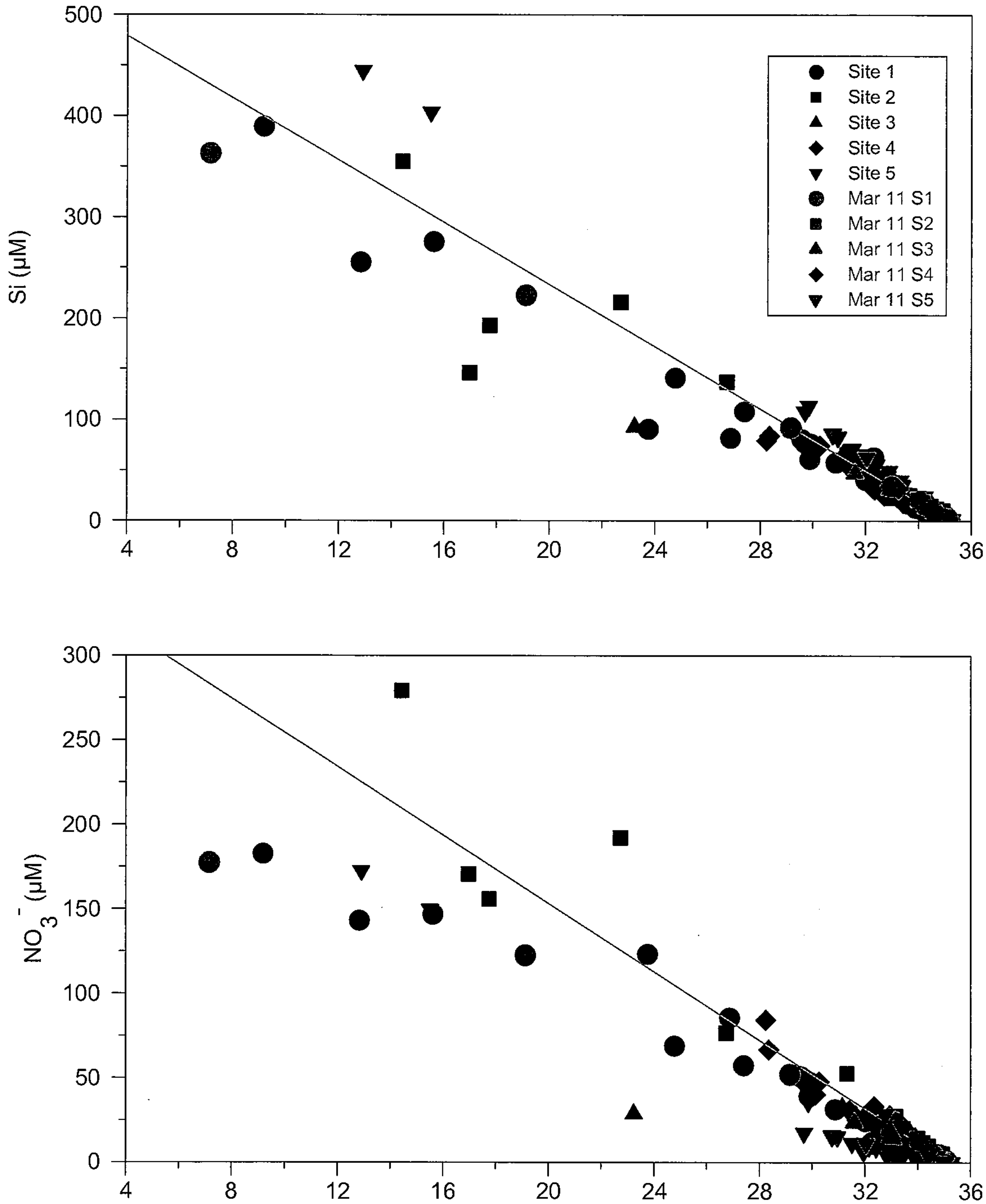
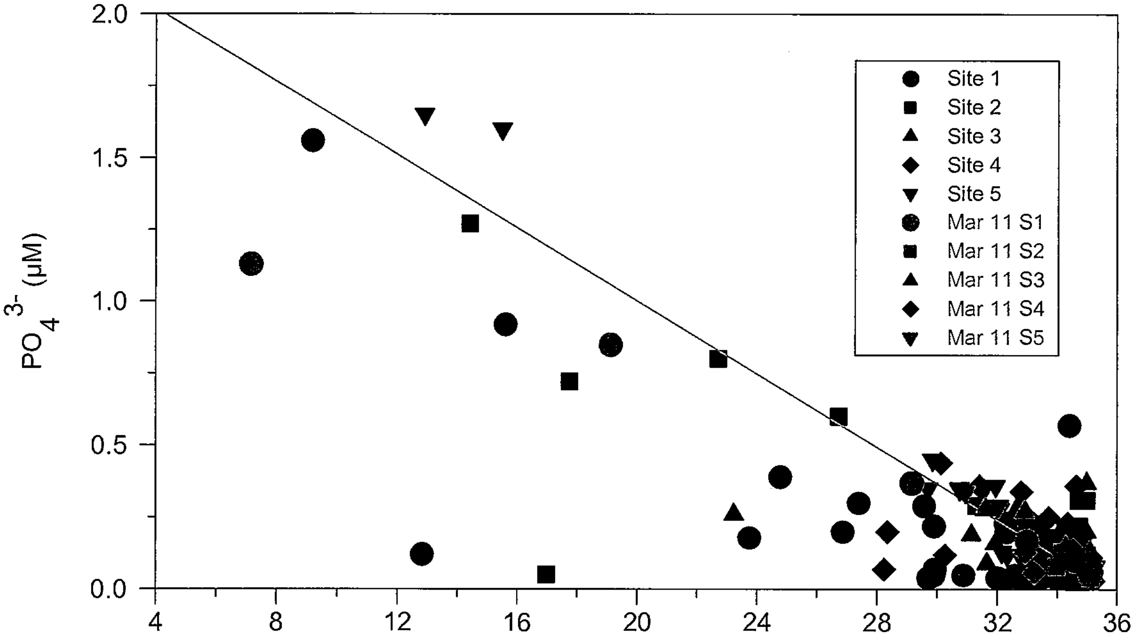


FIGURE 20. Silicate and nitrate, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and July 2010 (N=7). Red symbols are data from the most recent survey. 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.



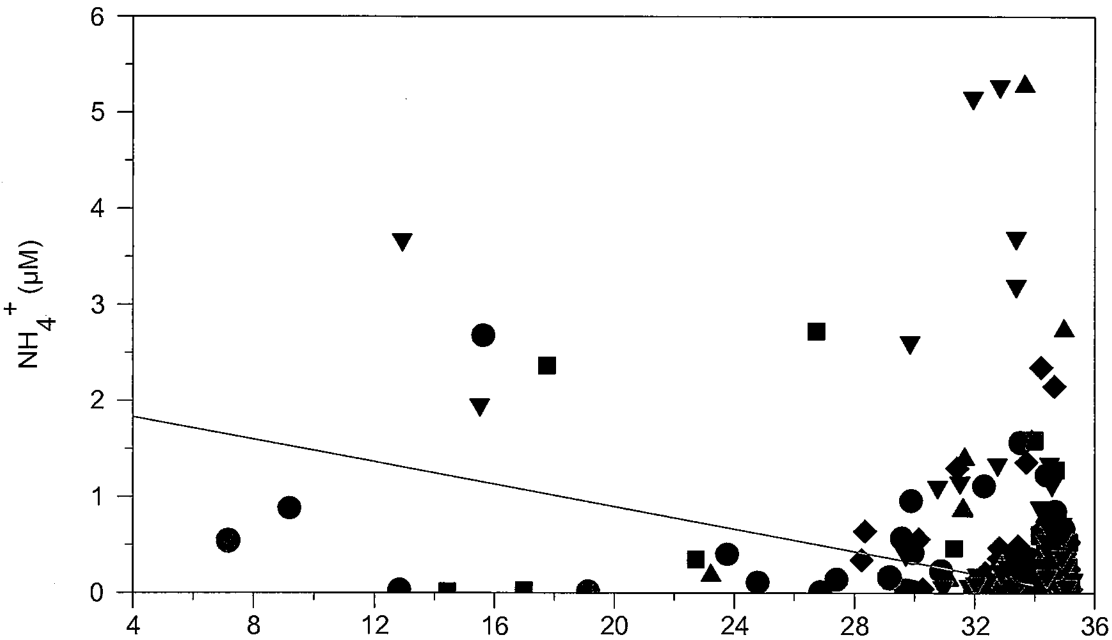


FIGURE 21. Phosphate and ammonium, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and July 2010 (N=7). Red symbols are data from the most recent survey. 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.

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 March 2011. 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 and 2010 (N=7), twice per year in 2009 (N=14) and once, to date for 2011 (N=7). 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
2010	515.27	7.85	495.09	535.45
2011	463.22	8.04	442.56	483.88
REGSLOPE	-1.57	16.55	-44.13	40.98
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
2010	708.83	11.33	679.71	737.94
2011	615.32	15.57	575.29	655.35
REGSLOPE	27.47	27.71	-43.76	98.69
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
2010	467.31	18.09	420.82	513.81
2011	458.52	8.49	436.69	480.36
REGSLOPE	6.07	20.72	-47.21	59.34
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
2010	471.84	27.13	402.11	541.57
2011	553.16	9.59	528.52	577.81
REGSLOPE	8.64	17.38	-36.05	53.33
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
2010	673.09	6.27	656.98	689.21
2011	683.29	8.16	662.30	704.27
REGSLOPE	-10.66	5.07	-23.69	2.38

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
2010	-14.78	0.28	-15.49	-14.06
2011	-13.03	0.27	-13.74	-12.33
REGSLOPE	0.08	0.50	-1.21	1.37
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
2010	-20.26	0.33	-21.10	-19.41
2011	-17.48	0.45	-18.63	-16.32
REGSLOPE	-0.76	0.81	-2.83	1.31
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
2010	-13.32	0.53	-14.67	-11.97
2011	-12.99	0.25	-13.64	-12.35
REGSLOPE	-0.16	0.60	-1.71	1.39
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
2010	-13.45	0.82	-15.55	-11.34
2011	-15.71	0.28	-16.42	-14.99
REGSLOPE	-0.23	0.50	-1.53	1.07
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
2010	-19.14	0.19	-19.62	-18.66
2011	-19.40	0.24	-20.03	-18.77
REGSLOPE	0.33	0.15	-0.06	0.73

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 March 2011. 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 and 2010 (N=7), twice per year in 2009 (N=14) and once, to date for 2011 (N=7). 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
2010	1.80	0.27	1.11	2.50
2011	1.49	0.08	1.29	1.70
REGSLOPE	0.19	0.12	-0.13	0.51
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
2010	1.08	1.88	-3.75	5.92
2011	1.54	0.74	-0.37	3.45
REGSLOPE	27.47	27.71	-43.76	98.69
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
2010	1.12	0.91	-1.22	3.45
2011	1.96	0.38	0.99	2.92
REGSLOPE	6.07	20.72	-47.21	59.34
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
2010	0.65	0.18	0.19	1.12
2011	0.50	0.61	-1.05	2.06
REGSLOPE	8.64	17.38	-36.05	53.33
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
2010	0.76	0.47	-0.46	1.97
2011	2.23	0.08	2.01	2.44
REGSLOPE	-10.66	5.07	-23.69	2.38

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
2010	-0.05	0.01	-0.07	-0.02
2011	-0.04	0.00	-0.05	-0.03
REGSLOPE	0.08	0.50	-1.21	1.37
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
2010	-0.03	0.05	-0.17	0.11
2011	-0.04	0.02	-0.10	0.01
REGSLOPE	-0.76	0.81	-2.83	1.31
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
2010	-0.03	0.03	-0.10	0.04
2011	-0.05	0.01	-0.08	-0.02
REGSLOPE	-0.16	0.60	-1.71	1.39
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
2010	-0.02	0.01	-0.03	0.00
2011	-0.01	0.02	-0.06	0.03
REGSLOPE	-0.23	0.50	-1.53	1.07
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
2010	-0.02	0.01	-0.06	0.02
2011	-0.06	0.00	-0.07	-0.05
REGSLOPE	0.33	0.15	-0.06	0.73

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 March 2011. 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 and 2010 (N=7), twice per year in 2009 (N=14) and once, to date for 2011 (N=7). 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
2010	253.63	4.57	241.88	265.38
2011	233.77	10.13	207.74	259.81
REGSLOPE	-20.76	7.71	-40.58	-0.95
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
2010	450.47	21.87	394.24	506.69
2011	432.04	5.14	418.84	445.25
REGSLOPE	27.47	27.71	-43.76	98.69
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
2010	220.36	6.33	204.08	236.64
2011	234.76	1.49	230.92	238.60
REGSLOPE	6.07	20.72	-47.21	59.34
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
2010	357.71	2.10	352.32	363.10
2011	441.60	3.85	431.70	451.50
REGSLOPE	8.64	17.38	-36.05	53.33
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
2010	148.96	16.96	105.35	192.57
2011	126.20	3.06	118.33	134.07
REGSLOPE	X Variable 1	-10.66	0.09	-23.69

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
2010	-7.31	0.16	-7.72	-6.89
2011	-6.53	0.35	-7.42	-5.64
REGSLOPE	0.08	0.50	-1.21	1.37
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
2010	-12.93	0.64	-14.56	-11.29
2011	-12.30	0.15	-12.68	-11.92
REGSLOPE	-0.76	0.81	-2.83	1.31
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
2010	-6.32	0.18	-6.79	-5.84
2011	-6.68	0.04	-6.79	-6.57
REGSLOPE	-0.16	0.60	-1.71	1.39
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
2010	-10.26	0.06	-10.42	-10.10
2011	-12.57	0.11	-12.86	-12.29
REGSLOPE	-0.23	0.50	-1.53	1.07
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
2010	-4.30	0.50	-5.60	-3.00
2011	-3.59	0.09	-3.82	-3.35
REGSLOPE	0.33	0.15	-0.06	0.73

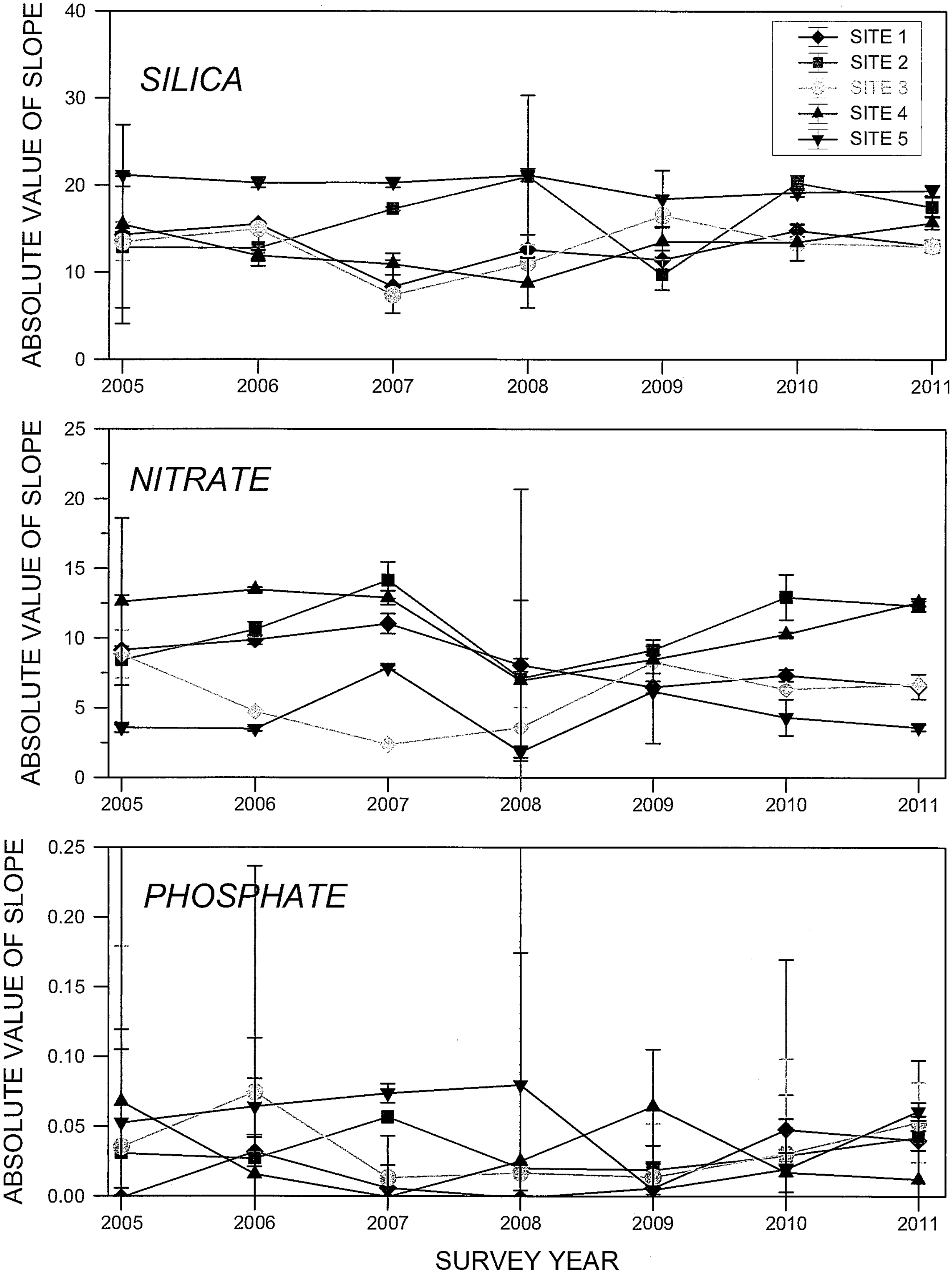


FIGURE 22. Time-course plots of absolute values of slopes of linear regressions of concentrations of silca, nitrate and phosphate as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations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

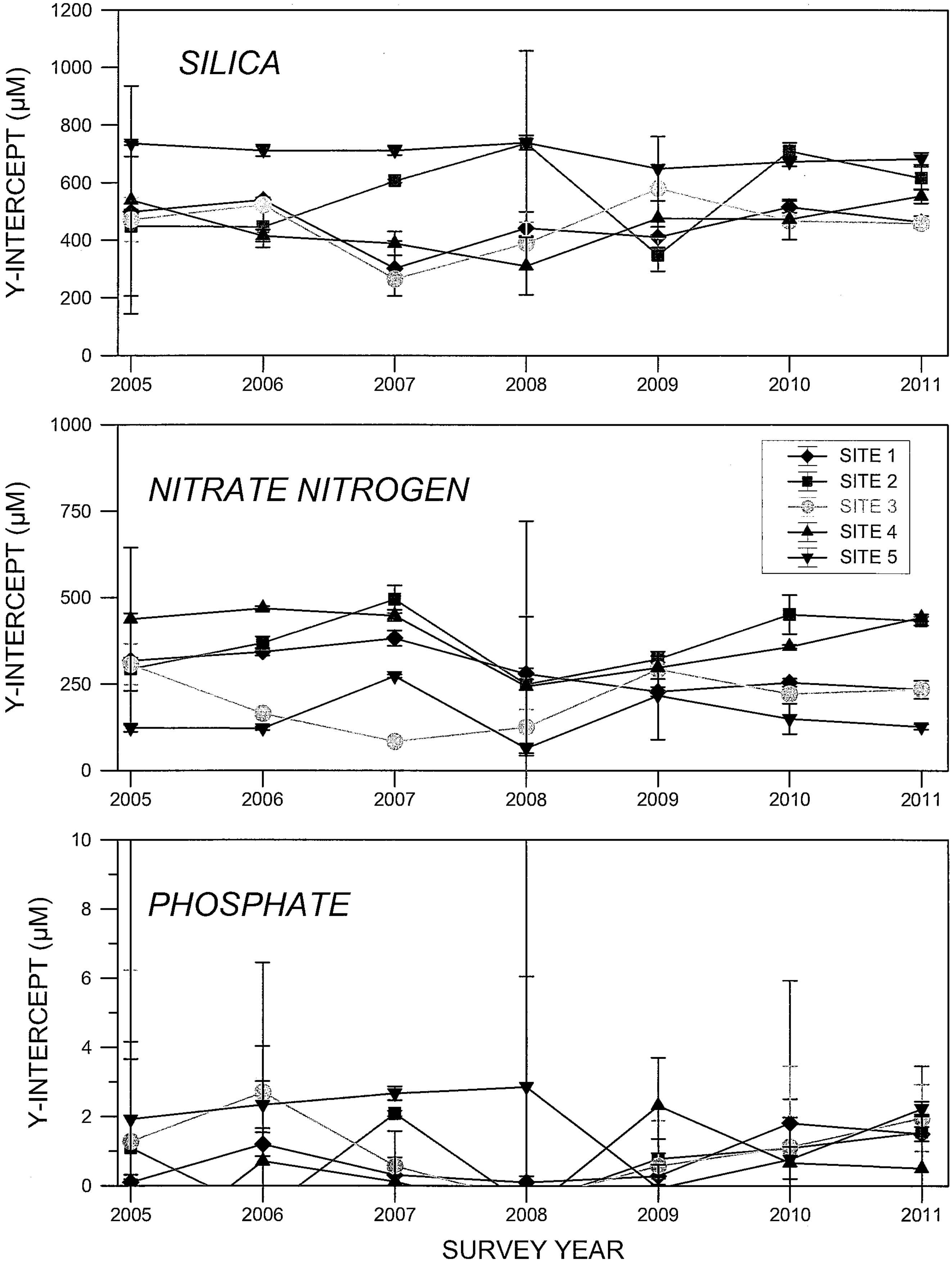


FIGURE 23. Time-course plots of Y-intercepts of linear regressions of concentrations of silca, nitrate and phosphorus as functions of salinity collected annually at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations of sampling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

MARINE ENVIRONMENTAL
MONITORING PROGRAM:
HONUA'ULA
WAILEA, MAUI

WATER CHEMISTRY

REPORT 1-2012

Prepared for

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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. 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, 250 of which will be provided off-site, thus reducing the total number of homes on-site to 1,150), 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 one 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.

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 retention of surface drainage on the golf course, and a private waste 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.

With the intention of evaluating these effects, one of the Conditions of Zoning for Honua'ula (No. 20) stipulated:

> "*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.*
>
> *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."

To date, HIDOH, which is the agency responsible for developing TMDL's (rather than property owners) has not performed this action for any marine areas off Maui.

This report represents the tenth monitoring effort to take place since the establishment of conditions of Zoning (Condition 20). 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.

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 Palau'ea 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 Honua'ula. 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 was conducted on July 16, 2012 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.

Typically, part of the monitoring program includes collection of water samples from irrigation wells on the Wailea golf course. Sampling of wells was not conducted during this phase of monitoring owing to logistic constraints. Data from the previous well sampling conducted on February 11, 2009 is used for evaluation of groundwater mixing with ocean water in the Results section below. 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 μM (0.14 μg/L) for NO_3^- and NH_4^+, 0.01 μM (0.31 μg/L) for PO_4^{3-}, 0.1 μM (1.4 μg/L) for TN and 0.1 μM (3.1 μg/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 μg/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 July 16, 2012 reported in micromolar units (μM). Table 2 shows similar results presented in units of micrograms per liter (μg/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 μM and μg/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^-, TN and salinity (Figure 2 and 3, Tables 1 and 2). The slopes of concentrations of these constituents were steepest within 10 m of the shoreline. Beyond 10 m from the shoreline, concentrations of nutrients, salinity and temperature decreased progressively with distance from shore but at a substantially reduced gradient compared with the zone within 10 m of the shoreline. While nutrient concentrations were highest near 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 1and 5 (Five Graves and the 'Ahihi-kina'u Control) , where surface concentrations of NO_3^- near the shoreline were an order of magnitude higher than samples collected at the seaward end of the transects. Salinity was correspondingly lower near the shoreline compared to offshore samples, with values differing by 5-9‰ between the shoreline and the offshore ends of the transects (Tables 1 and 2). Similar patterns were evident at Sites 2, 3 and 4, but the horizontal gradients were far less pronounced compared to the patterns at Transects 1and 5.

As there were no flowing streams in the area, 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 3), 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 a combination of the magnitude of the flux of groundwater entering the ocean from land, and the degree of physical mixing processes (primarily wind and wave stirring) at the sampling location. During the July 2012 survey, horizontal gradients extended from about 10 m (Sites 2, 3 and 4) to 100 m from the shoreline (Site 1) (Tables 1 and 3).

Surface concentrations of PO_4^{3-} and TP showed a similar pattern of elevated concentration within 10 m of the shoreline only at Sites 1 and 5 (Figures 2 and 3). At Sites 2, 3 and 4, concentrations of PO_4^{3-} and TP showed no change with distance offshore (Tables 1 and 2).

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 and among the five sites (Figure 2). Surface concentrations of NH_4^+ were lowest near the shoreline at sites 1, 3 and 5, but beyond the shoreline sample there was no distinct gradient of increasing or decreasing values (Figure 2, Tables 1 and 2). At Site 2 concentrations of NH_4^+ were highest near the shoreline (Figure 2). At Sites 1 and 5 surface concentrations of TOP increased with increasing distance offshore (Figure 2) while at the other sites, no distinct patterns in TOP were evident. In contrast, surface concentrations of TON were relatively constant at all sampling locations and of the same magnitude among all five transect sites during the July 2012 survey (Figure 2).

Turbidity was elevated at the shoreline and decreased with distance from shore at all five transect sites during the July 2012 survey (Figure 3 and Tables 1 and 2). At Site 1 and Site 5 (the 'Ahihi-kina'u Control transect) turbidity levels in the nearshore area were higher than at the other sites (Table 1). Similar to turbidity, values of Chl *a* were distinctly higher near the shoreline relative to sampling sites farther from shore at all five sites (Figure 3). Surface temperature ranged between 23.8°C and 25.7°C during the July 2012 survey with the coolest measurements from the shoreline at Sites 1 and 5 (23.8°C and 24.3°C, respectively).

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) that are not sufficient to completely mix the entire water column. During the July 2012 survey, vertical stratification was evident by higher nutrient concentrations (Si, NO_3^-, PO_4^{3-}, TN) in surface samples relative to bottom water at all sites. Salinity showed a reverse trend with higher values in bottom samples compared to surface samples. Such gradients suggest that groundwater entering the ocean near the shoreline 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 July 2012 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.

C. Temporal Comparison of Monitoring Results

Figures 4-18 show mean concentrations ($\pm$ 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 July 2012.

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 (Palau'ea), and Control Site 5 (Figures 4-18). In the most recent survey (July 2012) the concentrations of Si, NO_3^-, TN, PO_4^{3-} and TP at all sites were lower, or near the mean values (Figures 4, 5, 10 and 11).

Temperature during the July 2012 survey was approximately 0.5°C lower than the mean values in samples collected near the shoreline at all sites (Figures 6, 9, 12, 15 and 18). Values of turbidity were higher during the July 2012 survey than all of the mean values. Elevated turbidity was evident in the nearshore zone at Control site 5 suggesting that the high values were the result of physical processes (wave mixing) that occurred throughout the sampling regime (Figures 9 and 12). Excursions from the mean values have been observed in past surveys, most notable in December 2007 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 has not been in influenced by greater groundwater efflux during the July 2012 survey compared to the average values of surveys conducted in past years. Rather, data from the most recent survey indicate lower groundwater nutrient input to the nearshore ocean compared to the averages from all past surveys. 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 and Makena, 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 July 2012. 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 Irrigation Well No. 5 located to the northwest of the project area (sampled on February 11, 2009), and from the average concentrations of ocean water collected from near the bottom at the sampling locations 150 m offshore.

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 with several exceptions, all data points from Sites 1-5 fall in a linear array on, or very close to the conservative mixing line for Si. While two data points from each of Sites 1 and 5 deviate somewhat from the mixing line at salinities below 31‰, the overall linearity indicates that groundwater (as defined by the concentration of Si) entering the ocean at these sites is a mix of groundwater similar to that from Well No. 5, and open coastal water. When all data points from the entire data set extending from 2005 to 2012 are plotted versus salinity, there are numerous deviations from the mixing line at salinities below about 30‰ (Figure 20). The deviation of data points above and below the mixing line suggests periodic input of other sources of groundwater with different concentrations of Si relative to groundwater from Well No. 5.

The plots of NO_3^- versus salinity reveal a pattern that is not similar to Si, as nearly all the data points from all five transect sites fall well below the conservative mixing line. Data points from transects 1, 2, 3 and 4 form a single linear array with a slope well below the conservative mixing line. The data points from transect 5, which is considered the control site fall substantially farther below the mixing line than any of the other four transects (Figure 19). A similar pattern has been evident over the course of sampling with many of the NO_3^- data points from transects 1, 3 and 5 falling below the mixing line (Figure 20). The reduced slope of the line prescribed by the data points from these areas suggest the possibility of removal of NO_3^- by turfgrass on the golf course following irrigation, and subsequent leaching to the groundwater.

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, particularly with respect to increased abundance of phytoplankton or benthic algae. 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 to benthic 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 nitrogen, NH_4^+, does not show a linear pattern of distribution with respect to salinity (Figure 19). Samples with the highest concentrations of NH_4^+ occurred at the highest salinities (34-35‰), while the lowest values of NH_4^+ from Site 1 occurred at the lowest salinities (Figure 19). The lack of an inverse relationship between salinity and concentration of NH_4^+ during both the most recent sampling event (Figure 19) and over the entire course of the monitoring program (Figure 21) 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.

Phosphate phosphorus (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 data points fall in a straight line with linearity similar to that of Si and NO_3^-. 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 4-6 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 is the major nutrient constituents found in fertilizers.

The term "REGSLOPE" in Tables 4-6 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. Examination of Figures 22 and 23, as well as Tables 4-6 reveal that none of the slopes or Y-intercepts of Si from 2005 to 2012 at any of the transect sites exhibit any indication of progressively increasing or decreasing values over the course of monitoring. In all 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 over the course of the monitoring program (Tables 4-6). The situation for or NO_3^- was similar, with one exception at Site 1, where there is a statistically significant increase in the absolute value of the slope of the linear regression values (Table 5). Examination of the direction of the slope in Figure 22 indicates that the significant slope is decreasing with time, indicating that there is a decreasing input of NO_3^- relative to salinity over the course of the monitoring program.

Patterns in the time course mixing analysis for PO_4^{3-} are not as definitive as for Si and NO_3^-. While there is a statistically significant positive Y-intercept at Site 1 (Table 6) there are no statistically significant slopes of regression lines at any of the survey sites. 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 (2005-2012).

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. Thirty-one of the 60 samples collected were above the 10% criteria for NO_3^- under "dry" or "wet" conditions in the July 2012 survey (Table 1). In addition, all but two measurements of TN and NH_4^+ exceeded the DOH 10% standards under "wet" conditions. Similar percentages of samples exceeded the 10% limit for NO_3^- during many of the previous surveys. Thirteen measurements of turbidity also exceeded the 10% DOH criteria under "wet" conditions in July 2012. No measurements of TP or Chl a exceeded the standard criteria.

Tables 7 and 8 show geometric means of samples collected at the each sampling location during the ten increments of the monitoring program conducted to date. 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 but two surface water measurements of NO_3^-, 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. SUMMARY

- The tenth phase of the water quality monitoring program for the planned Honua'ula project was carried out in July 2012. Sixty ocean water samples were collected on four transects spaced along the projects ocean frontage and one transect located outside of the project area. 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 (Palau'ea Beach), Site 3 was located off Palau'ea Beach downslope from the juncture of the Emerald and Blue Courses, and Site 4 was located off Ulua Beach 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 Wailea golf courses. 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 sample data collected in February 2009 from seven irrigation wells and a golf-course reservoir in the Wailea area upslope of the sampling area are given for comparison.

- Water chemistry constituents that occur in high concentration in groundwater (Si, NO_3^-, TN and PO_4^{3-}) displayed 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, and generally extended to no more than 50 m offshore. The steepest nearshore gradients, indicating the highest input of groundwater at the shoreline occurred at Sites 1 and 5 (Five Graves and 'Ahihi-kina'u), while the weakest gradients occurred at Sites 2 (Palau'ea Beach) and Site 4 (Ulua Beach). The horizontal gradients at all sampling sites 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 not sufficient to completely break down the density differences between the buoyant low salinity surface layer and denser underlying water.

- Water chemistry constituents that generally do not occur in high concentrations in groundwater (NH_4^+, TOP, and TON) did not display distinct horizontal or vertical trends. Values of Chl *a* and turbidity displayed weak gradients, with the highest values near the shoreline. It is likely that these elevated values are the result of wave-suspended sediment and plant fragments in the nearshore zone.

- The concentrations of water chemistry constituents measured during the July 2012 survey were compared with the mean values of samples collected at the same locations during nine preceding surveys. These comparisons revealed that there were no large changes in water quality characteristics in the most recent survey relative to the averaged data set. Hence, it can be concluded that that there is no progressive increases in additions of materials from land to the ocean off the Honua'ula project site.

- Scaling nutrient concentrations to salinity indicates that during the July 2012 survey there was no apparent subsidy of NO_3^- from human activities on land to the nearshore ocean at any of the sites. In fact, based on a conservative mixing line constructed by connecting the endpoint concentrations of well water and ocean water, it appears that there is either removal of NO_3^- in the nearshore zone, or that the groundwater entering the ocean is not of the same composition as the well water used to construct the mixing line. During previous surveys substantial subsidies of NO_3^- at some sampling locations have been evident. The likely cause of the subsidies of NO_3^- in past surveys was either leaching of landscaping fertilizers to groundwater. Such subsidies were not evident in the most recent monitoring survey.

- 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 is only a single statistically significant decrease over the seven years of monitoring at any of the survey sites (there were no statistically significant increases). 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 2012. Further monitoring will be of interest to note the future direction of the oscillating trends noted in the last seven 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 anthropogenic land uses. Rather, natural groundwater discharge can cause water chemistry characteristics to exceed DOH standards.

- The next phase of the Honua'ula monitoring program is scheduled for the first half of 2013.

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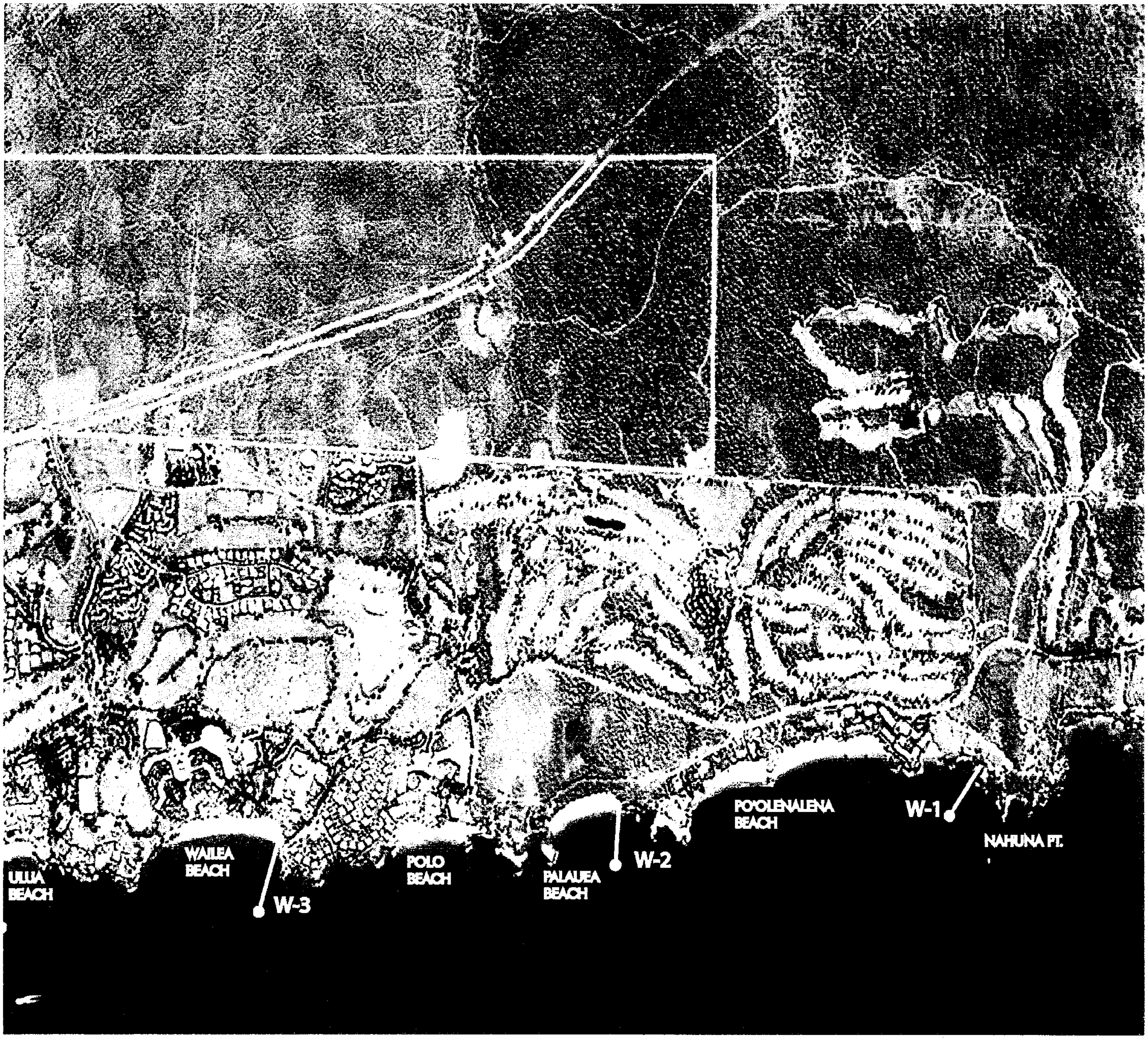


ıh of Wailea area showing boundaries of Honua'ula Project (in yellow) and locations of marine water
Transect W-5 is considered a control and is located in the 'Ahihi-kina'u Natural Area Reserve approximately
'ula Project site.

TABLE 1.Water chemistry measurements from ocean water samples collected in the vicinity of the Honua'ula project site on July 16, 2012. 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)	PO_4^{3-} (µM)	NO_3^- (µM)	NH_4^- (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	0.75	38.17	0.64	181.1	0.09	11.45	0.83	50.26	0.56	25.422	0.10	23.8	8.17	101.3
	2 S	0.1	0.58	28.27	0.61	79.93	0.13	10.85	0.71	39.74	0.61	27.588	0.13	24.1	8.15	103.4
	5 S	0.1	0.34	14.18	0.60	67.13	0.18	10.72	0.52	25.50	1.46	30.912	0.07	25.1	8.19	102.1
	5 D	1.0	0.22	8.65	0.61	45.52	0.25	12.13	0.46	21.38	0.59	32.256	0.10	25.2	8.20	101.8
	10 S	0.1	0.19	7.21	0.54	33.44	0.26	11.74	0.45	19.48	0.47	33.073	0.07	24.9	8.19	99.4
	10 D	1.7	0.19	5.09	0.74	25.69	0.32	11.73	0.52	17.57	0.98	33.604	0.07	25.1	8.17	100.6
	50 S	0.1	0.14	3.39	0.63	16.94	0.46	12.34	0.60	16.36	0.75	34.093	0.06	25.1	8.17	99.0
	50 D	4.4	0.17	0.10	1.20	2.03	0.43	12.93	0.60	14.22	0.30	35.027	0.06	25.3	8.22	97.7
	100 S	0.1	0.10	2.42	0.57	14.39	0.35	11.77	0.45	14.75	0.27	34.249	0.02	25.1	8.17	98.4
	100 D	6.2	0.12	BDL	1.46	1.31	0.40	10.88	0.51	12.35	0.13	35.052	0.04	25.3	8.22	101.0
	150 S	0.1	0.15	1.71	0.95	9.49	0.39	9.88	0.54	12.54	0.30	34.611	0.06	25.2	8.20	100.4
	150 D	11.7	0.16	1.40	1.56	1.76	0.39	9.95	0.55	12.90	0.19	35.043	0.04	25.3	8.21	101.8
WAILEA 2	0 S	0.1	0.13	3.81	1.31	17.97	0.32	13.26	0.45	18.38	0.53	34.121	0.05	25.5	8.21	98.3
	2 S	0.1	0.16	4.20	1.72	16.94	0.32	12.73	0.48	18.64	0.93	34.200	0.06	25.5	8.25	99.2
	5 S	0.1	0.17	3.14	1.21	10.42	0.37	12.47	0.54	16.82	0.32	34.626	0.09	25.2	8.21	99.3
	5 D	1.0	0.17	1.64	0.51	6.29	0.39	13.64	0.55	15.78	0.61	34.832	0.05	25.5	8.22	97.3
	10 S	0.1	0.16	1.49	0.62	5.94	0.35	13.13	0.51	15.23	0.30	34.846	0.06	25.4	8.21	99.0
	10 D	2.0	0.14	0.05	0.54	1.75	0.42	12.99	0.56	13.58	0.16	35.048	0.04	25.4	8.22	99.8
	50 S	0.1	0.16	2.77	0.68	9.42	0.39	13.77	0.55	17.22	0.25	34.679	0.09	25.2	8.20	100.7
	50 D	4.9	0.15	0.02	0.95	2.18	0.40	12.78	0.55	13.75	0.25	35.053	0.09	25.4	8.21	100.8
	100 S	0.2	0.14	1.85	0.48	7.17	0.38	12.71	0.52	15.04	0.20	34.733	0.03	25.3	8.21	101.3
	100 D	8.7	0.13	0.09	0.86	1.84	0.38	12.26	0.51	13.20	0.15	35.040	0.02	25.3	8.22	98.3
	150 S	0.1	0.16	2.22	0.76	8.11	0.37	12.48	0.53	15.47	0.16	34.686	0.02	25.3	8.21	99.5
	150 D	14.4	0.14	0.01	0.84	1.75	0.40	13.23	0.54	14.09	0.14	35.047	0.03	25.3	8.23	103.5
WAILEA 3	0 S	0.1	0.20	4.19	0.59	16.28	0.38	12.46	0.58	17.24	0.36	33.892	0.05	25.5	8.24	96.3
	2 S	0.1	0.16	2.52	0.60	10.16	0.45	13.09	0.61	16.22	0.83	34.379	0.05	25.5	8.21	96.4
	5 S	0.1	0.11	0.31	0.79	2.66	0.50	13.58	0.61	14.67	0.20	35.025	0.05	25.5	8.23	na
	5 D	1.0	0.11	0.09	0.49	1.87	0.49	12.92	0.60	13.49	0.18	35.049	0.03	25.5	8.22	na
	10 S	0.1	BDL	0.14	1.28	2.98	0.37	12.91	0.37	14.34	0.21	35.012	0.08	25.3	8.21	99.1
	10 D	1.0	0.12	0.02	0.91	2.06	0.40	13.37	0.52	14.29	0.22	35.044	0.03	25.4	8.22	99.5
	50 S	0.1	0.11	0.23	0.95	2.62	0.38	13.29	0.49	14.47	0.16	34.999	0.06	25.2	8.22	99.6
	50 D	4.0	BDL	0.13	1.55	2.75	0.38	13.72	0.38	15.40	0.29	34.997	0.07	25.4	8.22	100.5
	100 S	0.1	0.14	0.18	0.80	2.88	0.40	13.64	0.54	14.63	0.34	35.011	0.05	25.1	8.22	99.2
	100 D	6.1	0.13	BDL	0.88	1.48	0.37	13.65	0.50	14.53	0.38	35.058	0.04	25.4	8.22	100.8
	150 S	0.1	0.01	0.24	1.35	3.03	0.29	13.67	0.29	15.26	0.28	35.010	0.03	25.2	8.22	99.7
	150 D	11.2	BDL	0.01	1.81	1.91	0.36	15.80	0.37	17.63	0.23	35.060	0.03	25.3	8.22	99.7
WAILEA 4	0 S	0.1	0.11	4.59	1.49	16.68	0.33	13.35	0.44	19.43	0.45	33.828	0.07	25.7	8.23	98.1
	2 S	0.1	0.10	2.27	1.04	12.05	0.41	14.66	0.51	17.96	0.33	34.376	0.07	25.7	8.25	98.1
	5 S	0.1	0.12	1.08	1.17	4.45	0.35	14.77	0.48	17.01	0.34	34.899	0.06	25.4	8.22	98.6
	5 D	1.0	0.13	0.14	1.19	2.33	0.33	15.09	0.46	16.43	0.20	35.046	0.06	25.4	8.22	100.2
	10 S	0.1	BDL	0.96	1.51	2.80	0.27	15.21	0.27	17.68	0.22	34.937	0.08	25.3	8.21	100.2
	10 D	1.0	BDL	BDL	2.02	2.06	0.35	16.81	0.35	18.83	0.18	35.050	0.05	25.4	8.22	100.2
	50 S	0.1	BDL	1.21	1.17	3.43	0.33	16.17	0.33	18.55	0.25	34.907	0.06	25.3	8.21	99.6
	50 D	5.2	0.01	0.08	1.21	1.85	0.35	16.33	0.36	17.62	0.23	35.044	0.06	25.4	8.22	102.1
	100 S	0.1	0.02	0.55	2.05	2.76	0.36	16.03	0.37	18.63	0.31	34.983	0.06	25.0	8.21	99.6
	100 D	9.8	0.11	0.11	0.84	2.45	0.36	15.68	0.47	16.63	0.20	35.043	0.05	25.3	8.22	102.9
	150 S	0.1	0.10	0.81	0.75	3.07	0.38	16.11	0.48	17.67	0.25	34.947	0.04	25.3	8.21	100.3
	150 D	12.3	0.09	BDL	0.98	1.45	0.38	16.09	0.47	17.07	0.16	35.059	0.02	25.3	8.21	102.9
WAILEA 5	0 S	0.1	0.52	6.53	0.71	102.1	0.20	14.48	0.73	21.72	0.87	30.513	0.14	24.3	8.17	97.8
	2 S	0.1	0.42	5.83	0.86	84.75	0.23	13.78	0.65	20.47	1.24	31.128	0.15	23.8	8.13	96.8
	5 S	0.1	0.23	2.50	0.65	32.36	0.22	13.43	0.44	16.57	0.42	33.617	0.08	24.7	8.15	99.3
	5 D	1.0	0.22	1.77	0.85	22.51	0.29	13.49	0.50	16.11	0.38	34.119	0.10	24.9	8.15	99.6
	10 S	0.1	0.16	0.72	0.84	9.41	0.30	13.50	0.46	15.06	0.29	34.710	0.05	24.9	8.17	98.7
	10 D	2.0	0.27	0.31	0.86	5.77	0.32	13.55	0.59	14.71	0.27	34.911	0.02	25.0	8.18	97.3
	50 S	0.1	0.05	0.35	0.92	5.56	0.37	13.96	0.42	15.22	0.30	34.897	0.04	25.1	8.18	93.6
	50 D	4.4	0.13	0.09	1.16	2.49	0.30	13.50	0.43	14.74	0.22	35.014	0.00	25.1	8.20	112.2
	100 S	0.1	0.09	0.11	1.30	3.43	0.29	13.71	0.38	15.12	0.51	35.007	0.00	24.9	8.21	98.0
	100 D	6.4	0.13	0.10	1.13	3.38	0.32	13.47	0.45	14.70	0.33	35.000	0.05	25.0	8.19	96.4
	150 S	0.1	0.15	BDL	1.30	2.27	0.38	13.29	0.52	14.59	0.14	35.049	0.05	25.1	8.22	99.3
	150 D	7.7	0.14	BDL	1.80	1.25	0.28	12.64	0.42	14.43	0.25	35.045	0.06	25.1	8.23	97.9
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 $\mu g/L$) collected off the Honua'ula project site on July 16, 2012. 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)	PO_4^{3-} ($\mu g/L$)	NO_3^- ($\mu g/L$)	NH_4^+ ($\mu g/L$)	Si ($\mu g/L$)	TOP ($\mu g/L$)	TON ($\mu g/L$)	TP ($\mu g/L$)	TN ($\mu g/L$)	TURB (NTU)	SALINITY (ppt)	CHL a ($\mu g/L$)	TEMP (deg.C)	pH (std.units)	O2 % Sat
WAILEA 1	0 S	0.1	23.11	534.6	8.99	5088	2.63	160.3	25.74	703.9	0.56	25.422	0.10	23.8	8.17	101.3
	2 S	0.1	17.96	396.0	8.60	2246	3.96	152.0	21.93	556.6	0.61	27.588	0.13	24.1	8.15	103.4
	5 S	0.1	10.47	198.6	8.42	1886	5.70	150.2	16.17	357.2	1.46	30.912	0.07	25.1	8.19	102.1
	5 D	1.0	6.69	121.1	8.50	1279	7.62	169.8	14.31	299.4	0.59	32.256	0.10	25.2	8.20	101.8
	10 S	0.1	5.95	100.9	7.54	939.7	8.11	164.4	14.06	272.9	0.47	33.073	0.07	24.9	8.19	99.4
	10 D	1.7	5.98	71.32	10.41	721.8	10.00	164.3	15.98	246.1	0.98	33.604	0.07	25.1	8.17	100.6
	50 S	0.1	4.31	47.49	8.75	475.9	14.19	172.8	18.49	229.1	0.75	34.093	0.06	25.1	8.17	99.0
	50 D	4.4	5.30	1.37	16.79	56.93	13.19	181.1	18.49	199.2	0.30	35.027	0.06	25.3	8.22	97.7
	100 S	0.1	3.07	33.85	7.97	404.4	10.90	164.8	13.97	206.6	0.27	34.249	0.02	25.1	8.17	98.4
	100 D	6.2	3.69	BDL	20.50	36.67	12.23	152.4	15.92	172.9	0.13	35.052	0.04	25.3	8.22	101.0
	150 S	0.1	4.68	23.96	13.29	266.8	12.05	138.3	16.73	175.6	0.30	34.611	0.06	25.2	8.20	100.4
	150 D	11.7	4.99	19.58	21.79	49.51	11.92	139.4	16.91	180.7	0.19	35.043	0.04	25.3	8.21	101.8
WAILEA 2	0 S	0.1	4.12	53.36	18.36	505.0	9.94	185.7	14.06	257.5	0.53	34.121	0.05	25.5	8.21	98.3
	2 S	0.1	4.83	58.78	24.05	476.0	9.97	178.3	14.81	261.1	0.93	34.200	0.06	25.5	8.25	99.2
	5 S	0.1	5.33	43.99	16.88	292.7	11.40	174.7	16.73	235.6	0.32	34.626	0.09	25.2	8.21	99.3
	5 D	1.0	5.14	22.93	7.07	176.7	11.92	191.1	17.07	221.1	0.61	34.832	0.05	25.5	8.22	97.3
	10 S	0.1	5.08	20.80	8.61	166.9	10.84	184.0	15.92	213.4	0.30	34.846	0.06	25.4	8.21	99.0
	10 D	2.0	4.21	0.73	7.62	49.29	13.04	181.9	17.25	190.2	0.16	35.048	0.04	25.4	8.22	99.8
	50 S	0.1	5.02	38.85	9.48	264.6	12.05	192.8	17.07	241.2	0.25	34.679	0.09	25.2	8.20	100.7
	50 D	4.9	4.52	0.28	13.29	61.15	12.45	179.0	16.97	192.6	0.25	35.053	0.09	25.4	8.21	100.8
	100 S	0.2	4.21	25.93	6.71	201.4	11.74	178.0	15.95	210.6	0.20	34.733	0.03	25.3	8.21	101.3
	100 D	8.7	4.03	1.27	11.98	51.65	11.71	171.7	15.73	184.9	0.15	35.040	0.02	25.3	8.22	98.3
	150 S	0.1	4.96	31.15	10.67	228.0	11.37	174.8	16.32	216.6	0.16	34.686	0.02	25.3	8.21	99.5
	150 D	14.4	4.27	0.11	11.82	49.09	12.48	185.4	16.76	197.3	0.14	35.047	0.03	25.3	8.23	103.5
WAILEA 3	0 S	0.1	6.29	58.70	8.26	457.5	11.77	174.5	18.06	241.4	0.36	33.892	0.05	25.5	8.24	96.3
	2 S	0.1	4.99	35.30	8.45	285.6	13.81	183.4	18.80	227.1	0.83	34.379	0.05	25.5	8.21	96.4
	5 S	0.1	3.44	4.34	11.05	74.75	15.36	190.1	18.80	205.5	0.20	35.025	0.05	25.5	8.23	na
	5 D	1.0	3.41	1.20	6.85	52.63	15.21	180.9	18.61	189.0	0.18	35.049	0.03	25.5	8.22	na
	10 S	0.1	BDL	2.00	17.96	83.82	11.37	180.8	11.37	200.8	0.21	35.012	0.08	25.3	8.21	99.1
	10 D	1.0	3.69	0.28	12.70	57.94	12.39	187.2	16.07	200.2	0.22	35.044	0.03	25.4	8.22	99.5
	50 S	0.1	3.44	3.19	13.29	73.71	11.83	186.1	15.27	202.6	0.16	34.999	0.06	25.2	8.22	99.6
	50 D	4.0	BDL	1.78	21.67	77.25	11.71	192.2	11.71	215.6	0.29	34.997	0.07	25.4	8.22	100.5
	100 S	0.1	4.27	2.56	11.23	80.82	12.39	191.1	16.66	204.9	0.34	35.011	0.05	25.1	8.22	99.2
	100 D	6.1	4.03	BDL	12.33	41.59	11.55	191.2	15.58	203.5	0.38	35.058	0.04	25.4	8.22	100.8
	150 S	0.1	0.15	3.35	18.95	85.09	8.83	191.4	8.98	213.7	0.28	35.010	0.03	25.2	8.22	99.7
	150 D	11.2	BDL	0.20	25.41	53.61	11.21	221.3	11.34	246.9	0.23	35.060	0.03	25.3	8.22	99.7
WAILEA 4	0 S	0.1	3.50	64.23	20.90	468.7	10.10	186.9	13.60	272.1	0.45	33.828	0.07	25.7	8.23	98.1
	2 S	0.1	3.10	31.77	14.58	338.6	12.54	205.3	15.64	251.6	0.33	34.376	0.07	25.7	8.25	98.1
	5 S	0.1	3.84	15.13	16.33	125.0	10.93	206.8	14.77	238.3	0.34	34.899	0.06	25.4	8.22	98.6
	5 D	1.0	4.12	2.00	16.72	65.56	10.22	211.3	14.34	230.1	0.20	35.046	0.06	25.4	8.22	100.2
	10 S	0.1	BDL	13.43	21.16	78.62	8.36	213.0	8.36	247.6	0.22	34.937	0.08	25.3	8.21	100.2
	10 D	1.0	BDL	BDL	28.26	57.77	10.78	235.4	10.78	263.7	0.18	35.050	0.05	25.4	8.22	100.2
	50 S	0.1	BDL	16.95	16.43	96.50	10.22	226.5	10.22	259.9	0.25	34.907	0.06	25.3	8.21	99.6
	50 D	5.2	0.28	1.05	16.96	51.90	10.81	228.8	11.09	246.8	0.23	35.044	0.06	25.4	8.22	102.1
	100 S	0.1	0.56	7.66	28.66	77.50	11.03	224.6	11.58	260.9	0.31	34.983	0.06	25.0	8.21	99.6
	100 D	9.8	3.50	1.51	11.77	68.79	11.09	219.6	14.59	232.8	0.20	35.043	0.05	25.3	8.22	102.9
	150 S	0.1	3.10	11.40	10.56	86.27	11.77	225.6	14.87	247.5	0.25	34.947	0.04	25.3	8.21	100.3
	150 D	12.3	2.79	BDL	13.66	40.75	11.71	225.4	14.50	239.1	0.16	35.059	0.02	25.3	8.21	102.9
WAILEA 5	0 S	0.1	16.17	91.46	9.99	2870	6.29	202.8	22.46	304.2	0.87	30.513	0.14	24.3	8.17	97.8
	2 S	0.1	13.01	81.70	12.03	2381	6.97	193.0	19.98	286.7	1.24	31.128	0.15	23.8	8.13	96.8
	5 S	0.1	7.00	34.94	9.12	909.2	6.72	188.0	13.72	232.1	0.42	33.617	0.08	24.7	8.15	99.3
	5 D	1.0	6.75	24.78	11.85	632.6	8.86	189.0	15.61	225.6	0.38	34.119	0.10	24.9	8.15	99.6
	10 S	0.1	4.86	10.07	11.74	264.4	9.23	189.1	14.09	210.9	0.29	34.710	0.05	24.9	8.17	98.7
	10 D	2.0	8.42	4.36	12.00	162.1	9.88	189.7	18.31	206.1	0.27	34.911	0.02	25.0	8.18	97.3
	50 S	0.1	1.58	4.93	12.82	156.2	11.52	195.5	13.10	213.2	0.30	34.897	0.04	25.1	8.18	93.6
	50 D	4.4	4.06	1.20	16.18	70.08	9.29	189.1	13.35	206.4	0.22	35.014	0.00	25.1	8.20	112.2
	100 S	0.1	2.63	1.51	18.19	96.47	9.11	192.1	11.74	211.8	0.51	35.007	0.00	24.9	8.21	98.0
	100 D	6.4	4.03	1.40	15.85	94.92	10.04	188.6	14.06	205.9	0.33	35.000	0.05	25.0	8.19	96.4
	150 S	0.1	4.61	BDL	18.26	63.87	11.61	186.1	16.23	204.4	0.14	35.049	0.05	25.1	8.22	99.3
	150 D	7.7	4.43	BDL	25.17	35.07	8.61	177.0	13.04	202.1	0.25	35.045	0.06	25.1	8.23	97.9
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. Water chemistry measurements in μM (top) and $\mu g/L$ (bottom) 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.

WELL	PO_4^{3-} (μM)	NO_3^- (μM)	NH_4^+ (μM)	Si (μM)	TOP (μM)	TON (μM)	TP (μM)	TN (μM)	SALINITY (ppt)
2	2.00	225.6	bdl	524.2	0.16	9.36	2.16	235.0	1.48
5	2.16	337.6	1.96	513.1	0.08	2.40	2.24	342.0	1.78
6	2.00	158.7	1.96	516.6	0.16	33.48	2.16	194.2	1.27
7	2.32	257.6	1.60	511.6	0.16	4.40	2.48	263.6	1.89
8	1.96	170.2	2.48	495.2	0.36	24.08	2.32	196.8	2.13
9	1.84	142.0	0.60	482.5	0.60	72.94	2.44	215.5	1.84
10	2.00	218.9	0.64	479.3	0.44	17.28	2.44	236.8	1.58
Res	0.44	145.3	4.48	301.8	1.36	53.56	1.80	203.3	1.98

WELL	PO_4^{3-} ($\mu g/L$)	NO_3^- ($\mu g/L$)	NH_4^+ ($\mu g/L$)	Si ($\mu g/L$)	TOP ($\mu g/L$)	TON ($\mu g/L$)	TP ($\mu g/L$)	TN ($\mu g/L$)	SALINITY (ppt)
2	62.00	3159	bdl	14729	4.96	131.0	66.96	3290	1.48
5	66.96	4727	27.44	14418	2.48	33.6	69.44	4788	1.78
6	62.00	2222	27.44	14515	4.96	468.7	66.96	2718	1.27
7	71.92	3606	22.40	14375	4.96	61.6	76.88	3690	1.89
8	60.76	2383	34.72	13915	11.16	337.1	71.92	2755	2.13
9	57.04	1987	8.40	13559	18.60	1021.2	75.64	3017	1.84
10	62.00	3065	8.96	13469	13.64	241.9	75.64	3316	1.58
Res	13.64	2034	62.72	8482	42.16	749.8	55.80	2846	1.98

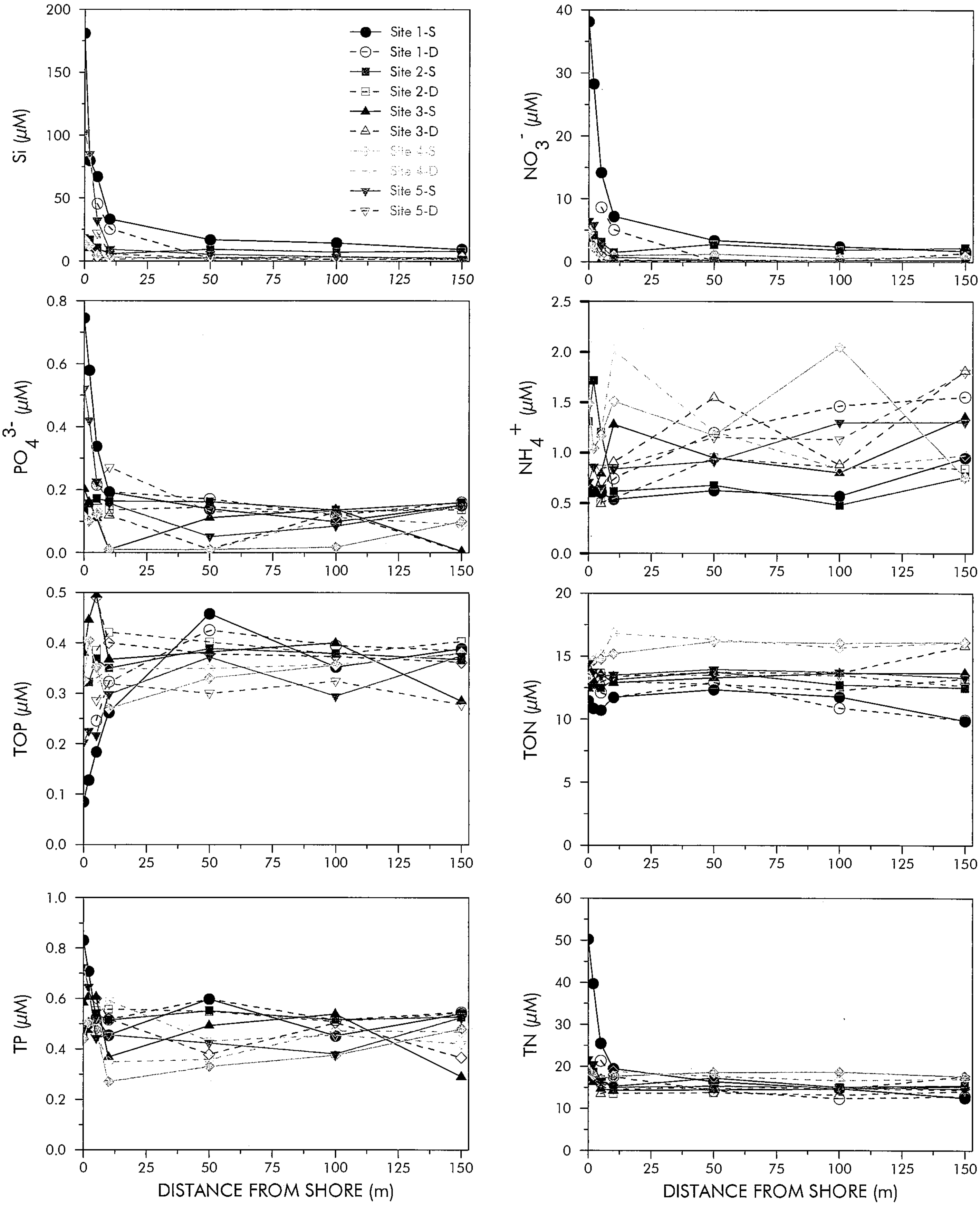


FIGURE 2. Plots of dissolved nutrients in surface (S) and deep (D) samples collected on July 16, 2012 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. For site locations, see Figure 1.

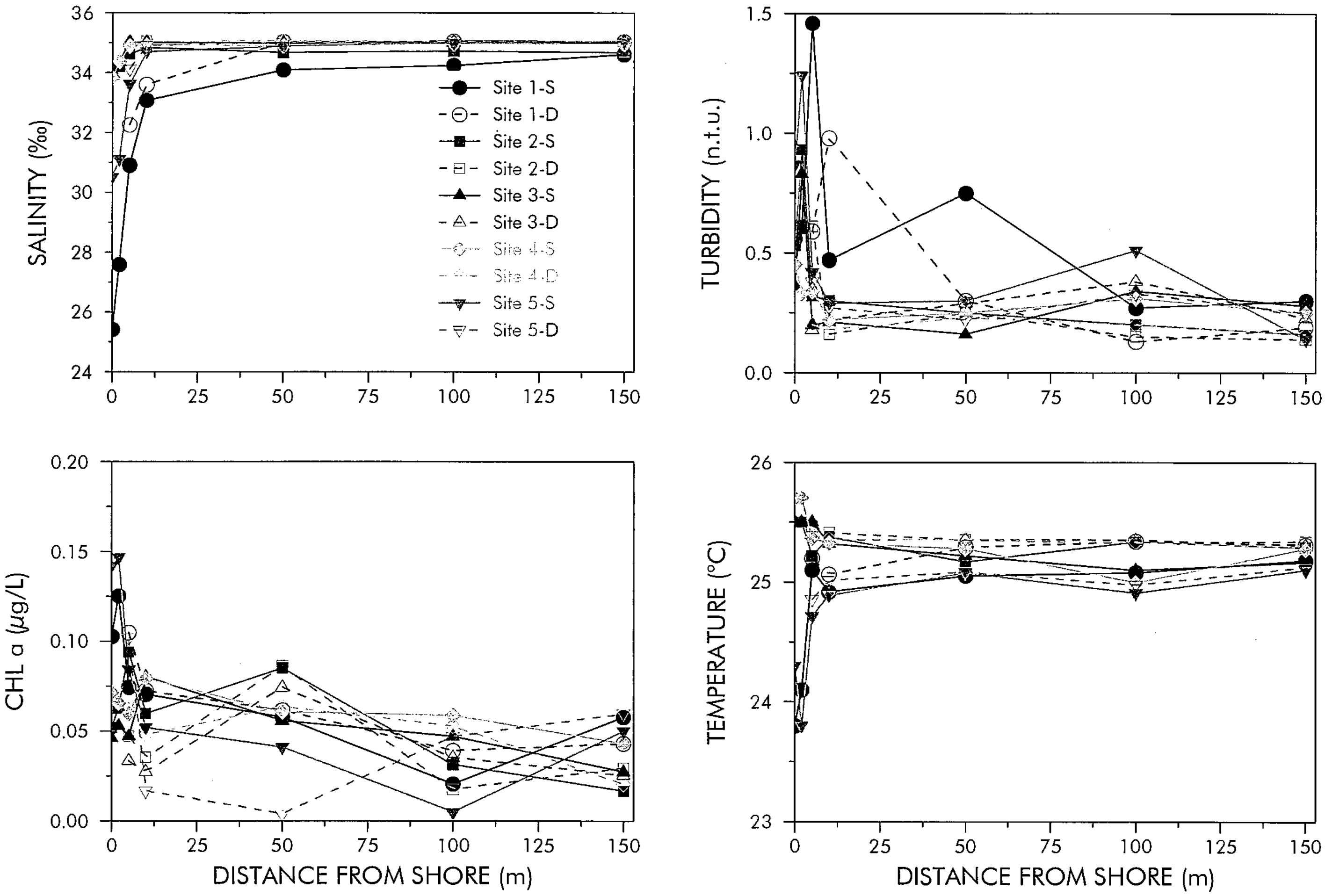


FIGURE 3. Plots of water chemistry constituents in surface (S) and deep (D) samples collected on July 16, 2012 as a function of distance from the shoreline offshore of Honua`ula, Wailea, Maui. For site locations, see Figure 1.

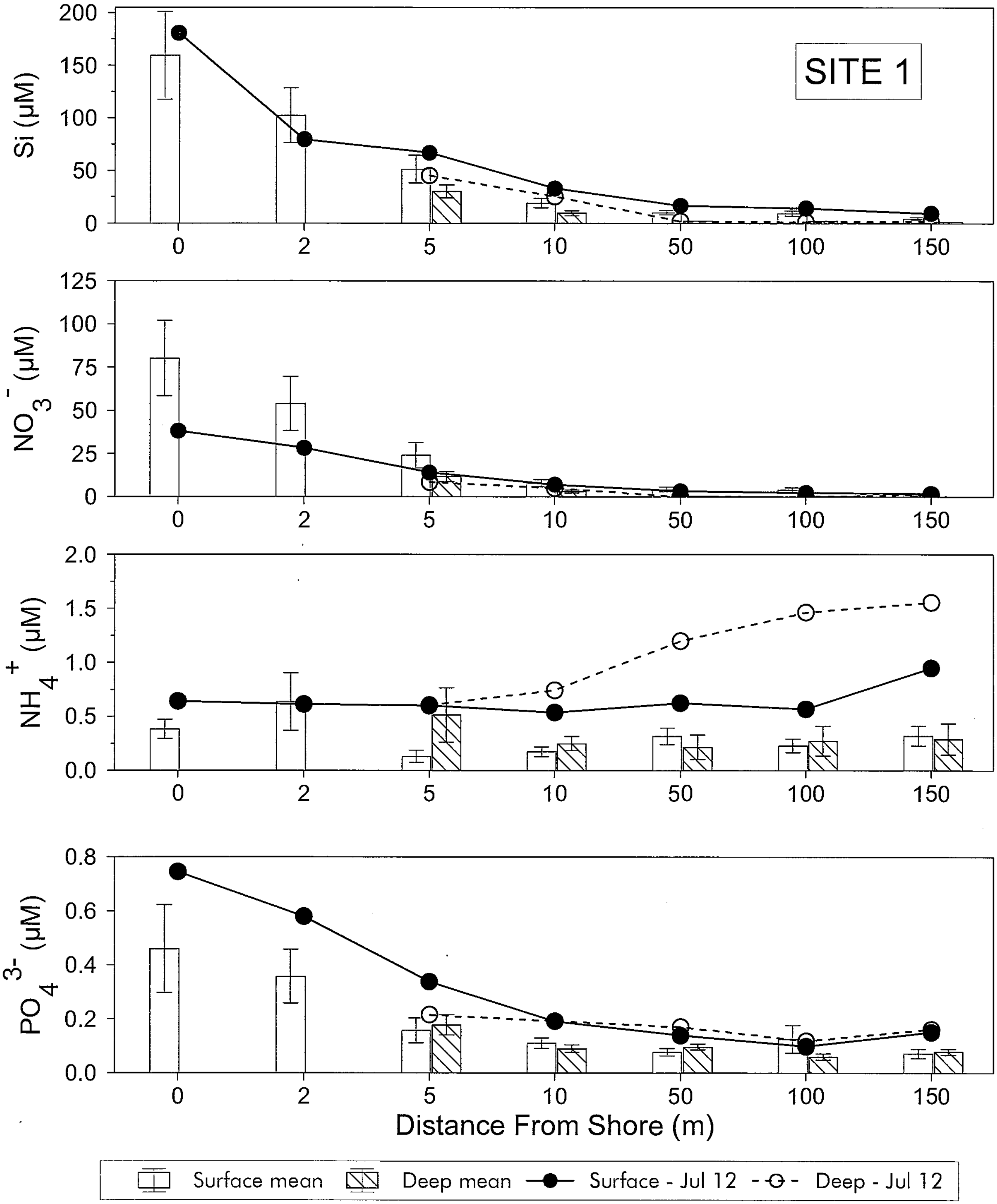


FIGURE 4. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

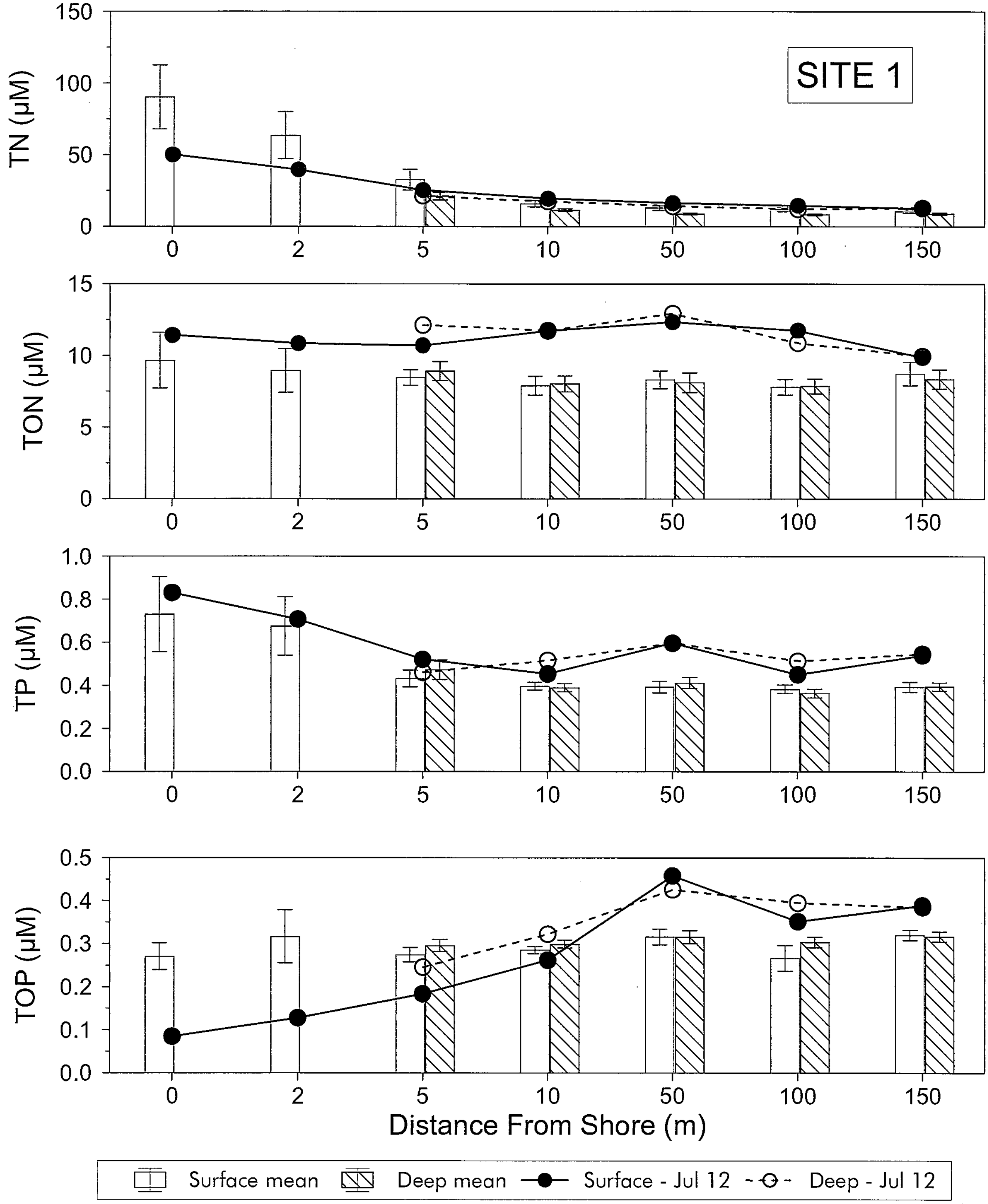


FIGURE 5. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

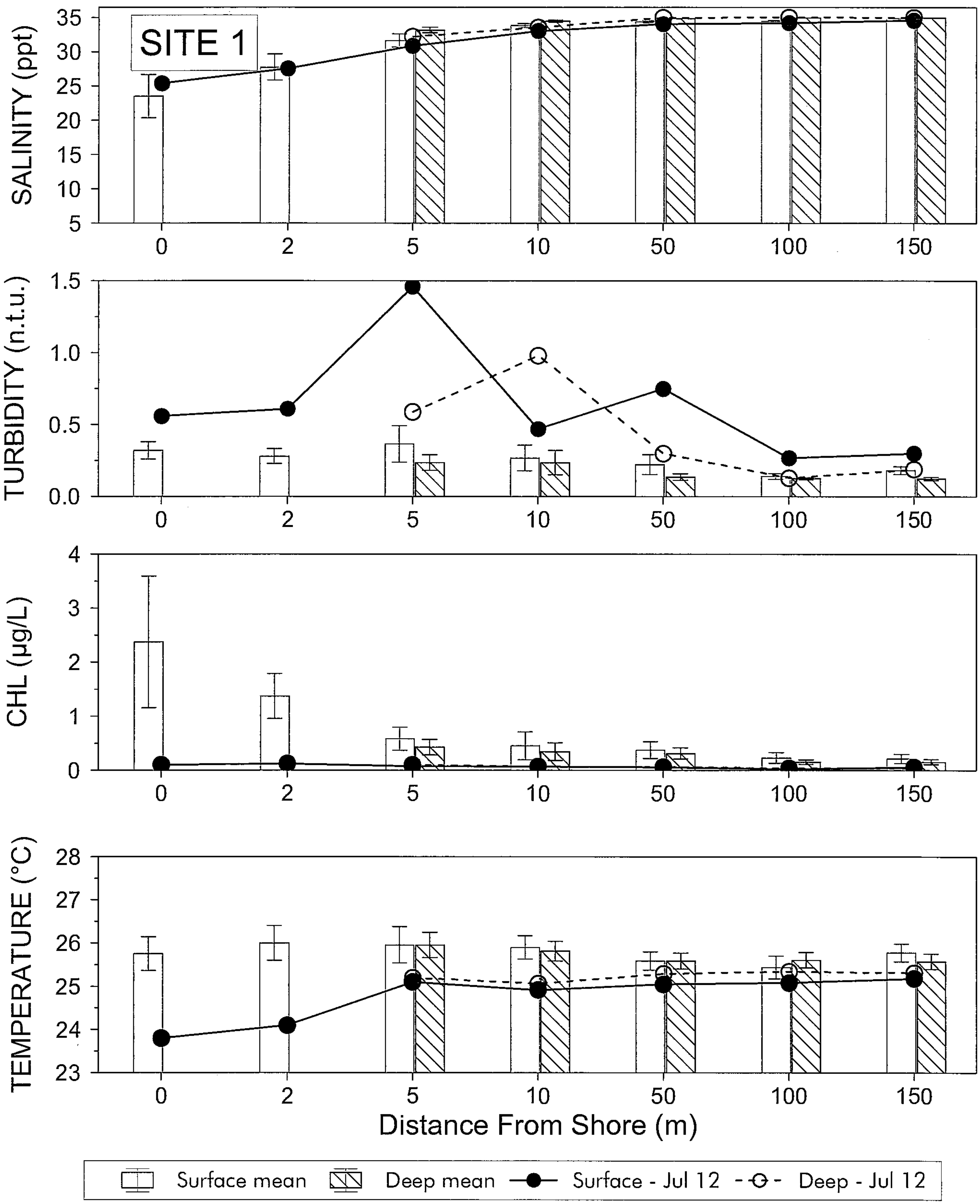


FIGURE 6. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 1, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent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

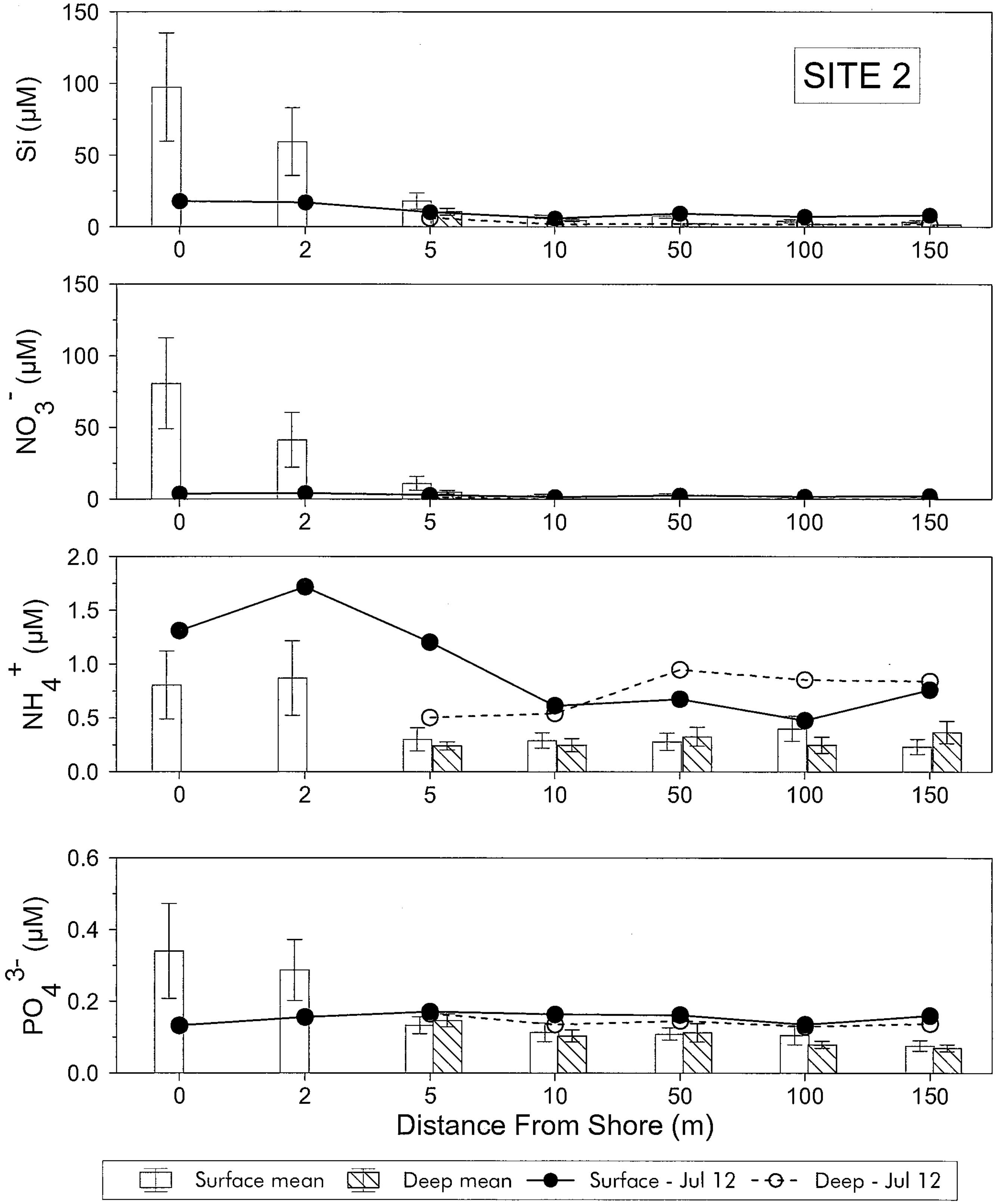


FIGURE 7. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

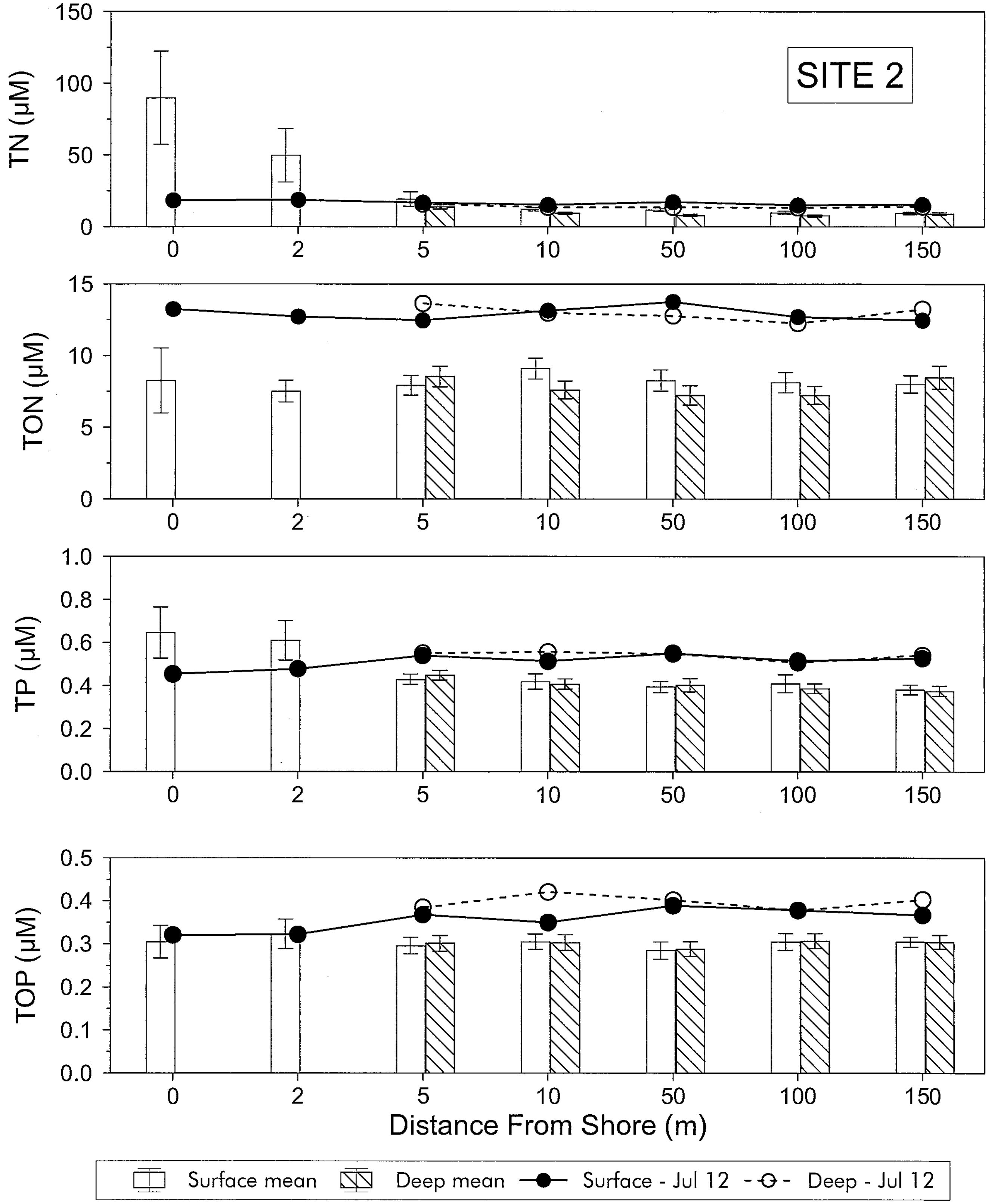


FIGURE 8. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

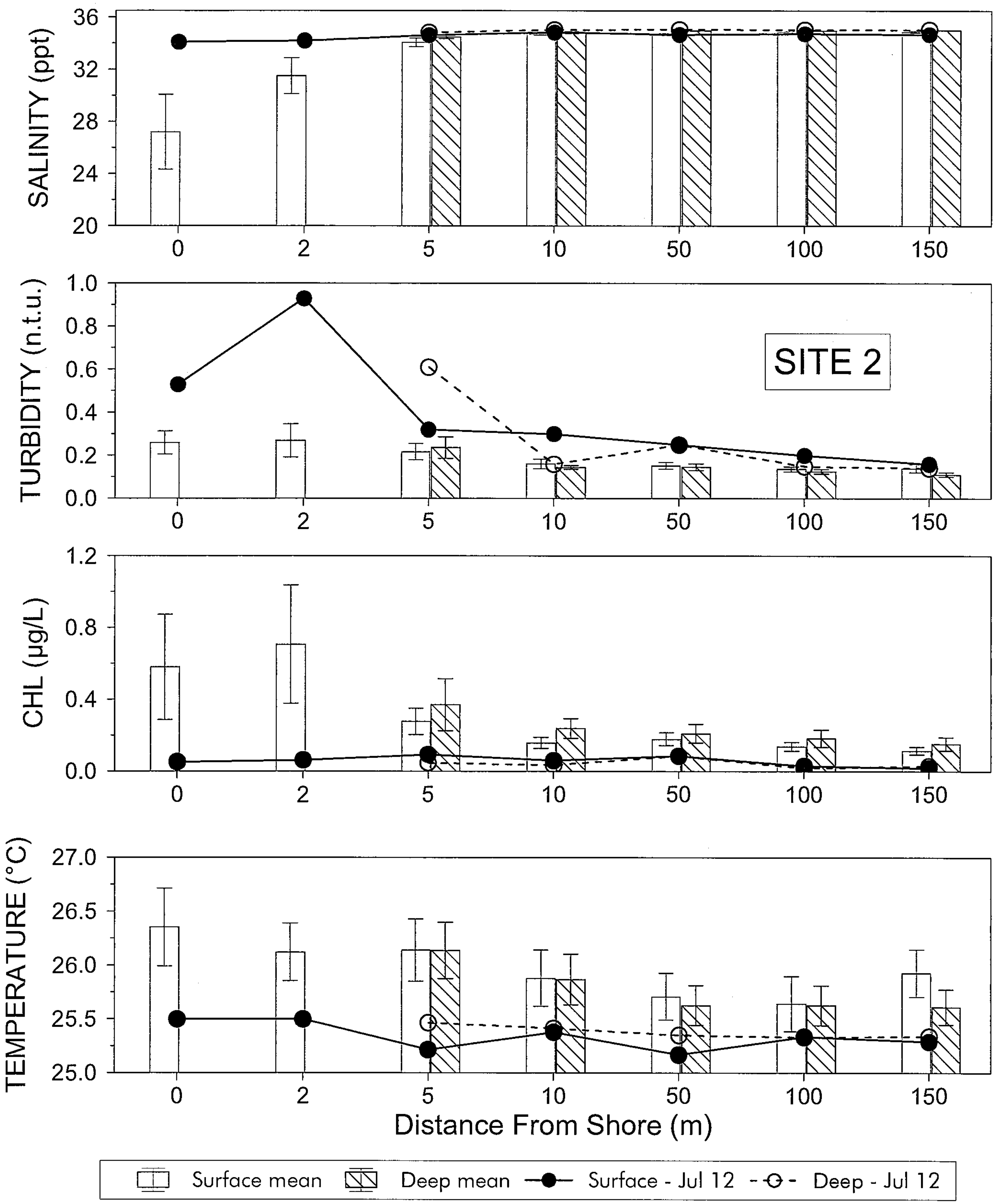


FIGURE 9. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 2, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

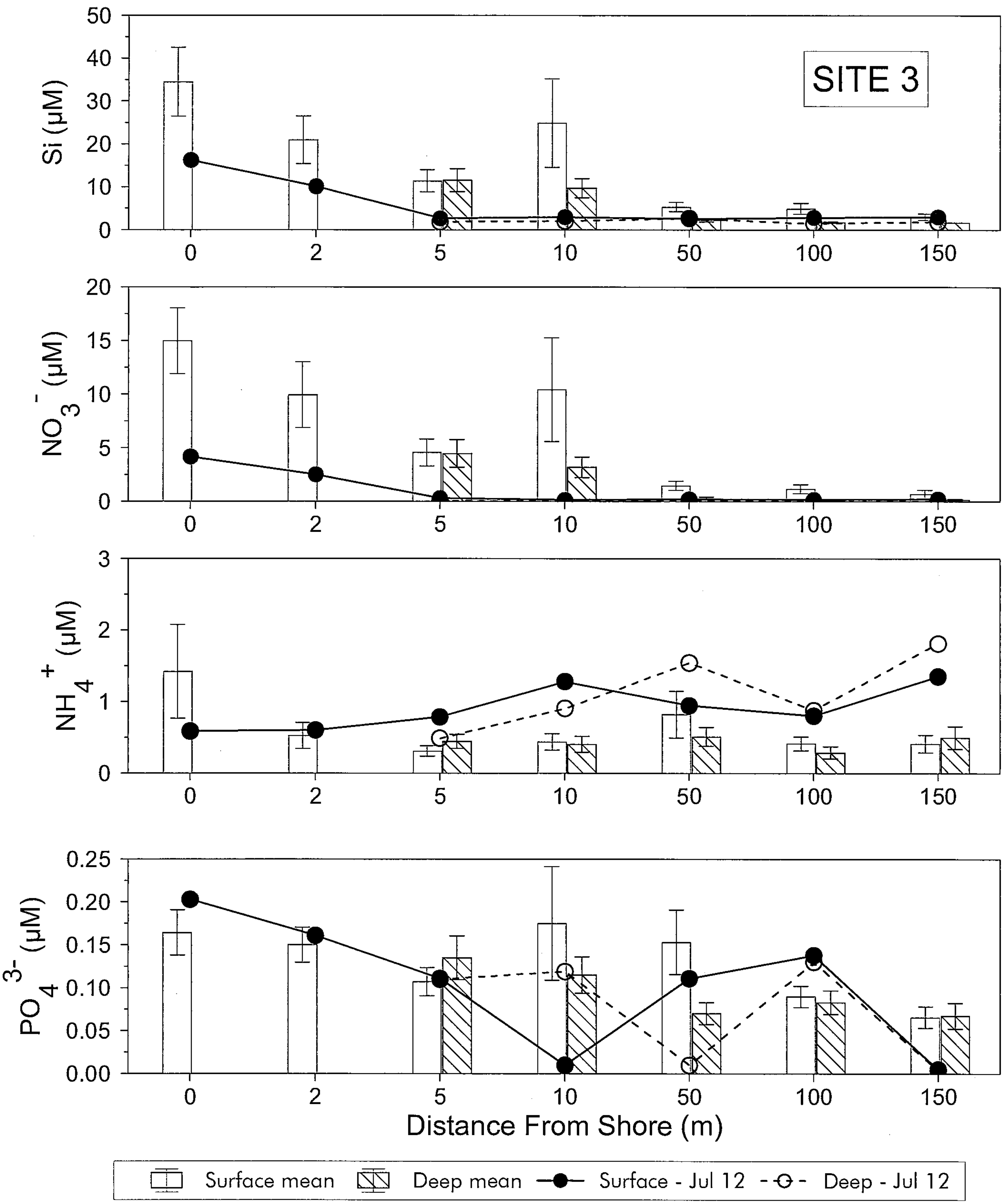


FIGURE 10. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean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

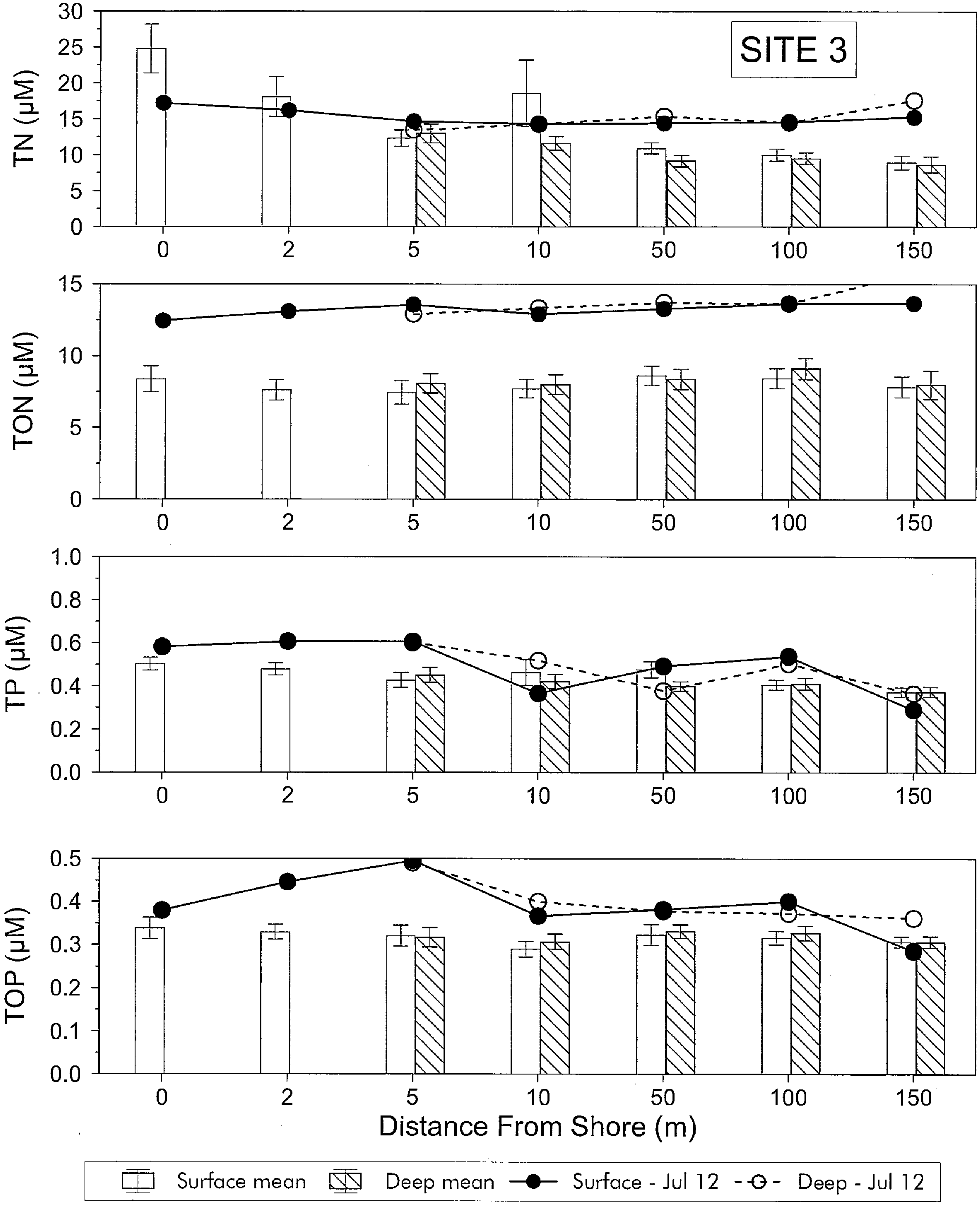


FIGURE 11. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

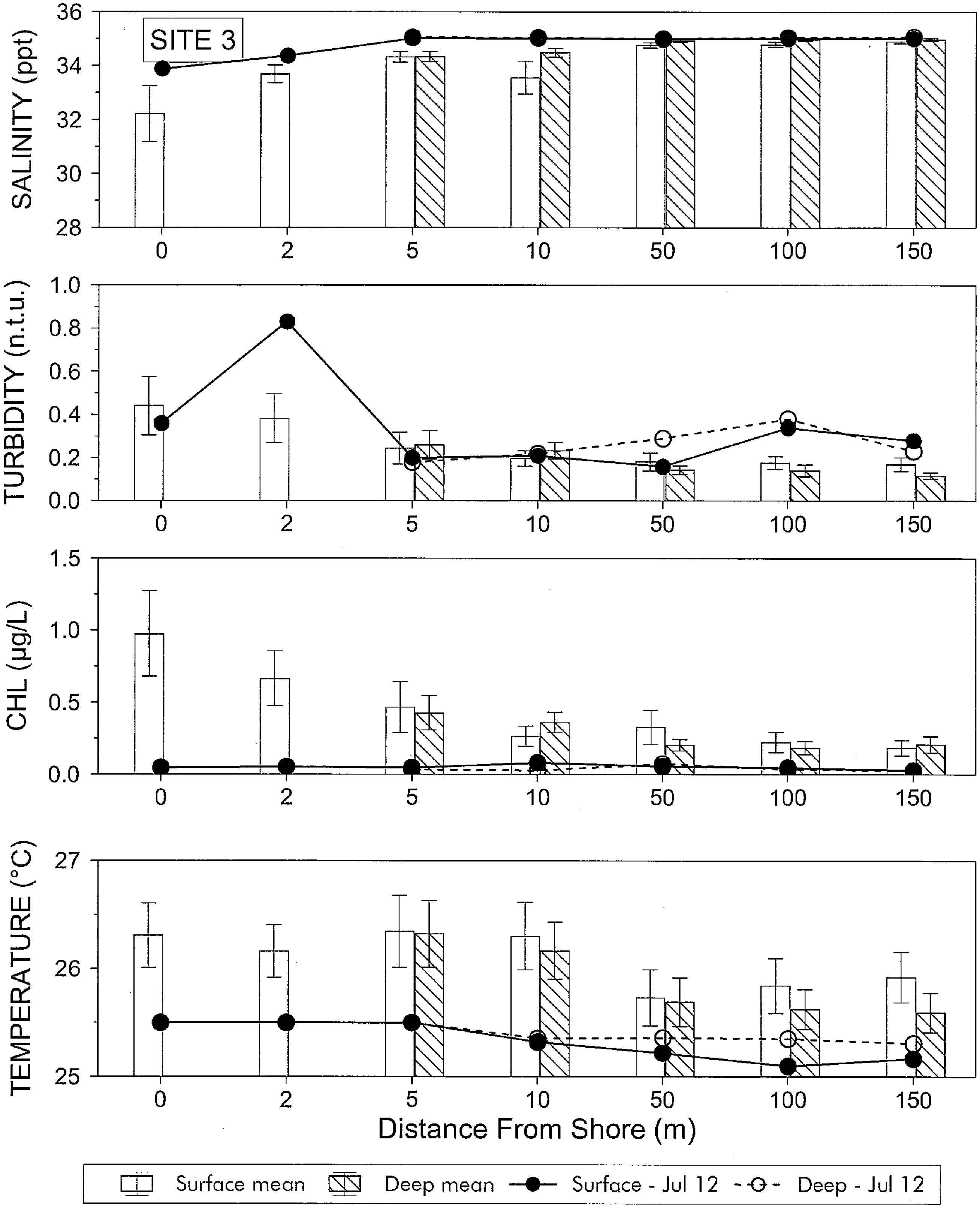


FIGURE 12. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 3, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

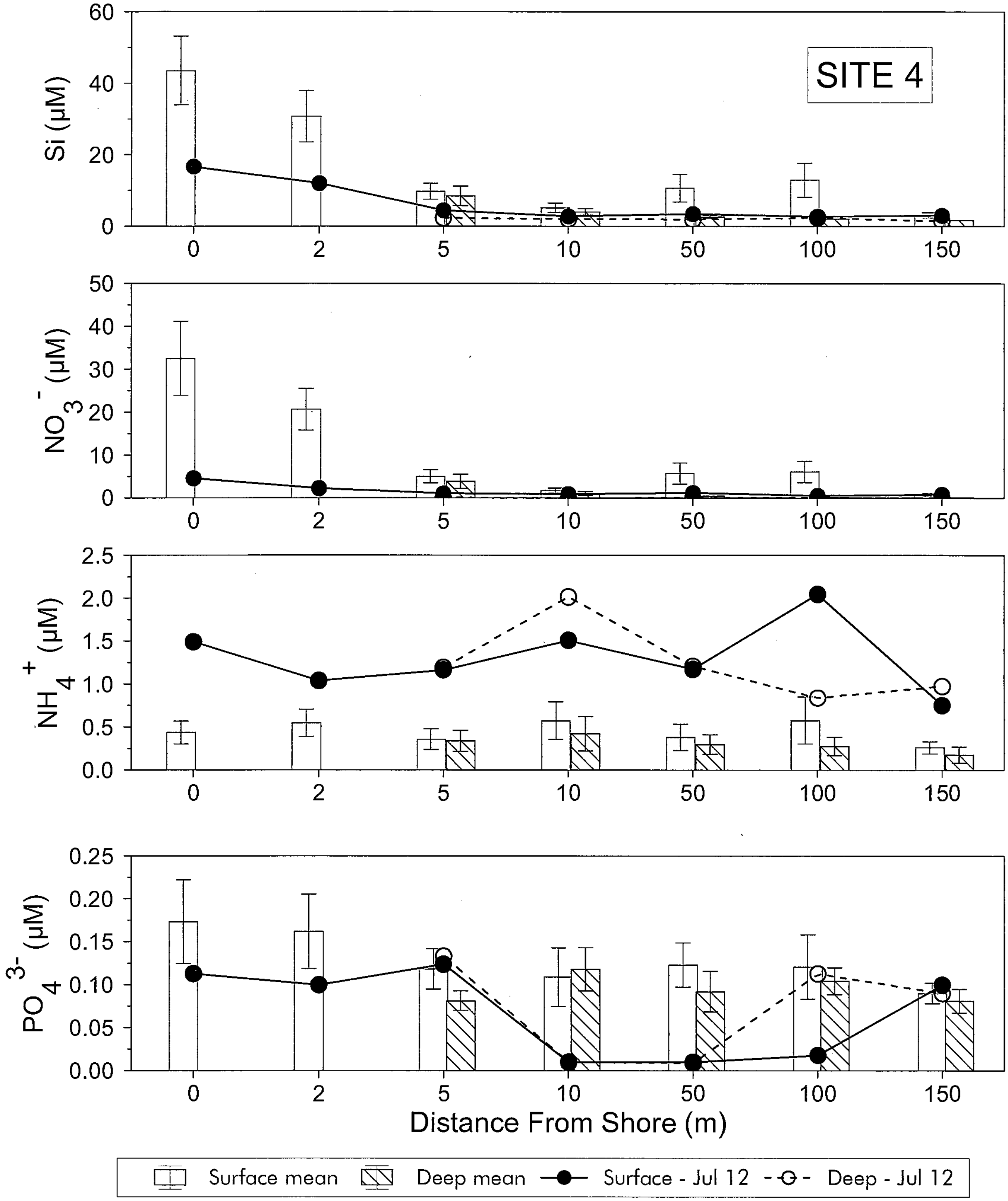


FIGURE 13. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

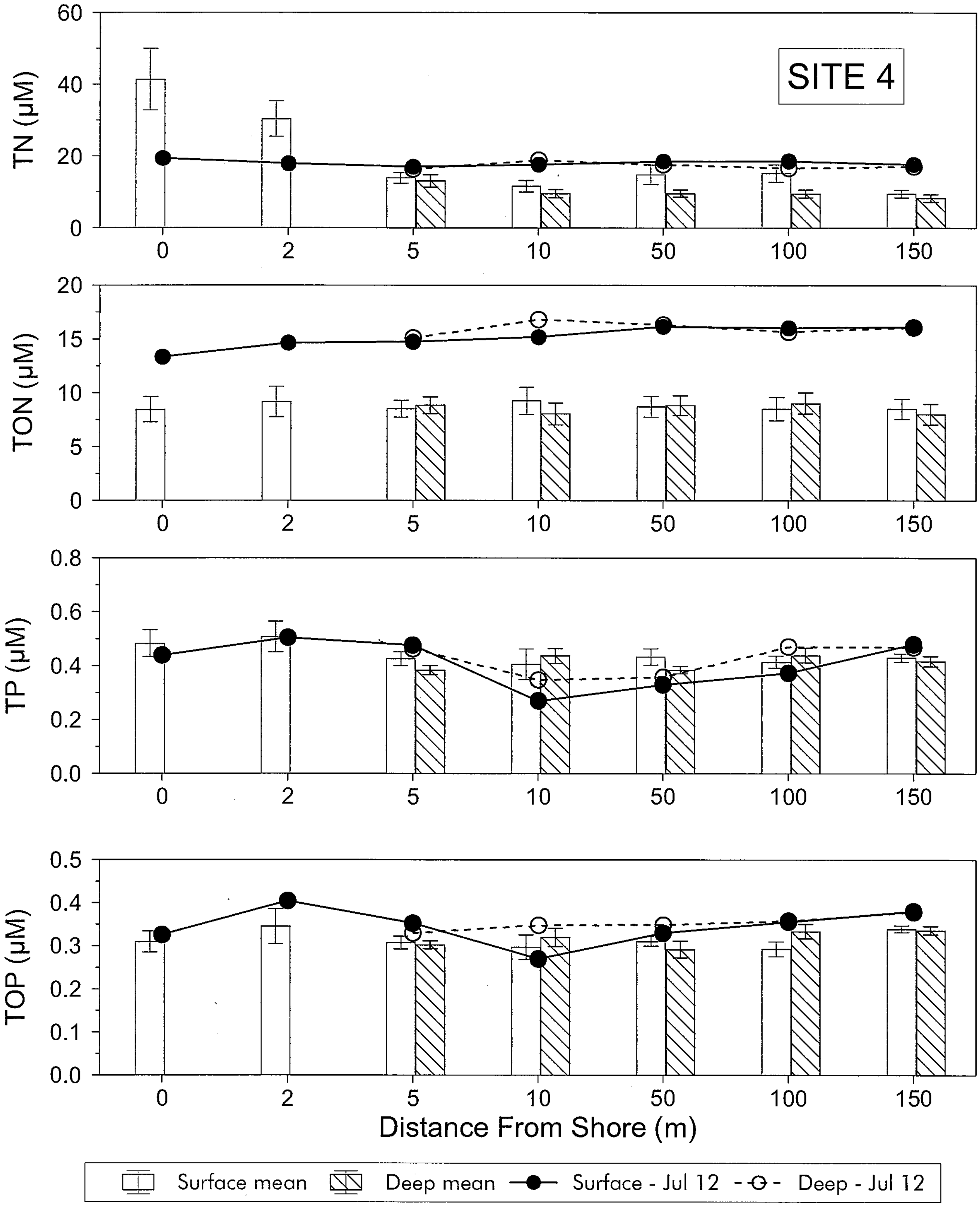


FIGURE 14. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

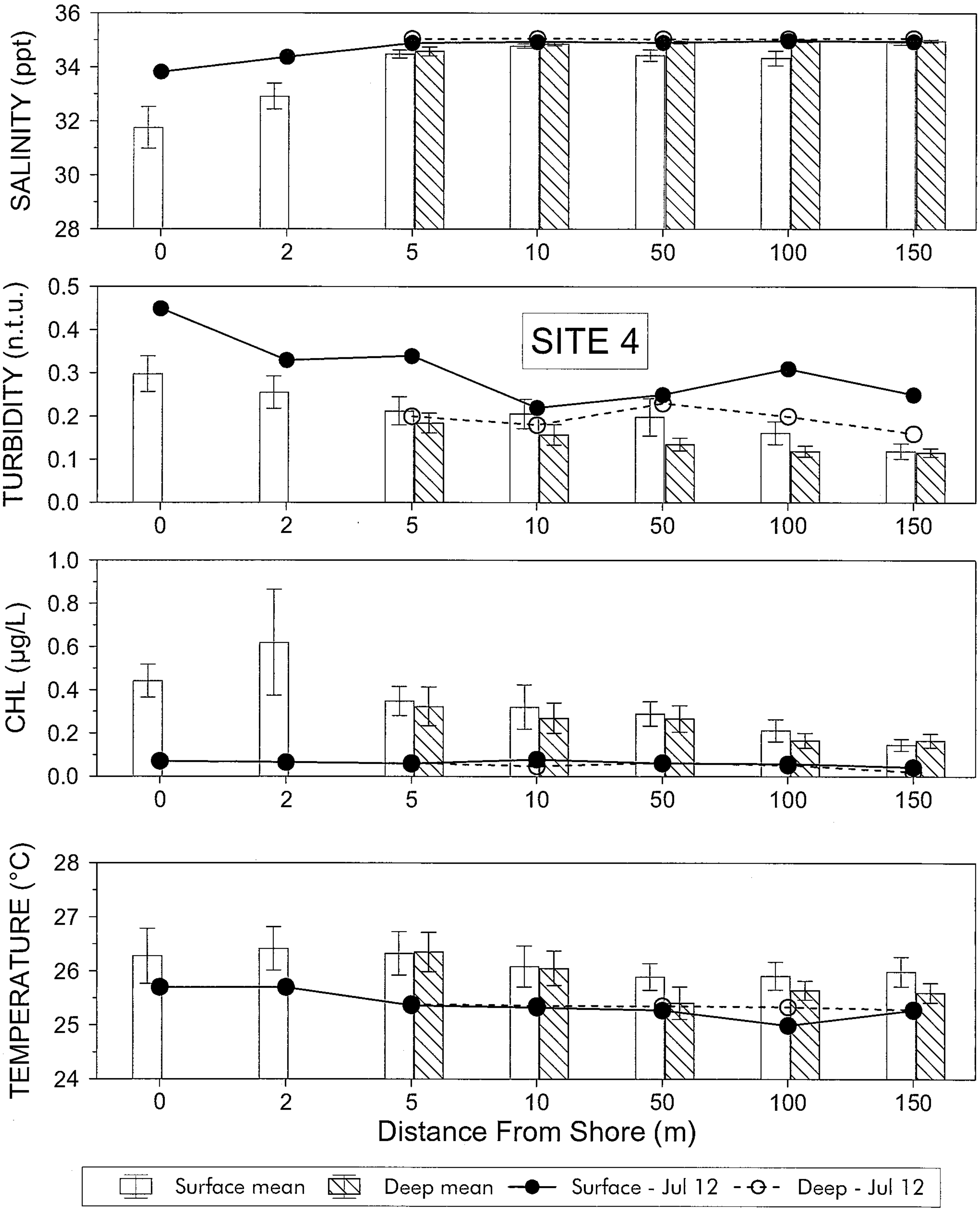


FIGURE 15. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 4, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

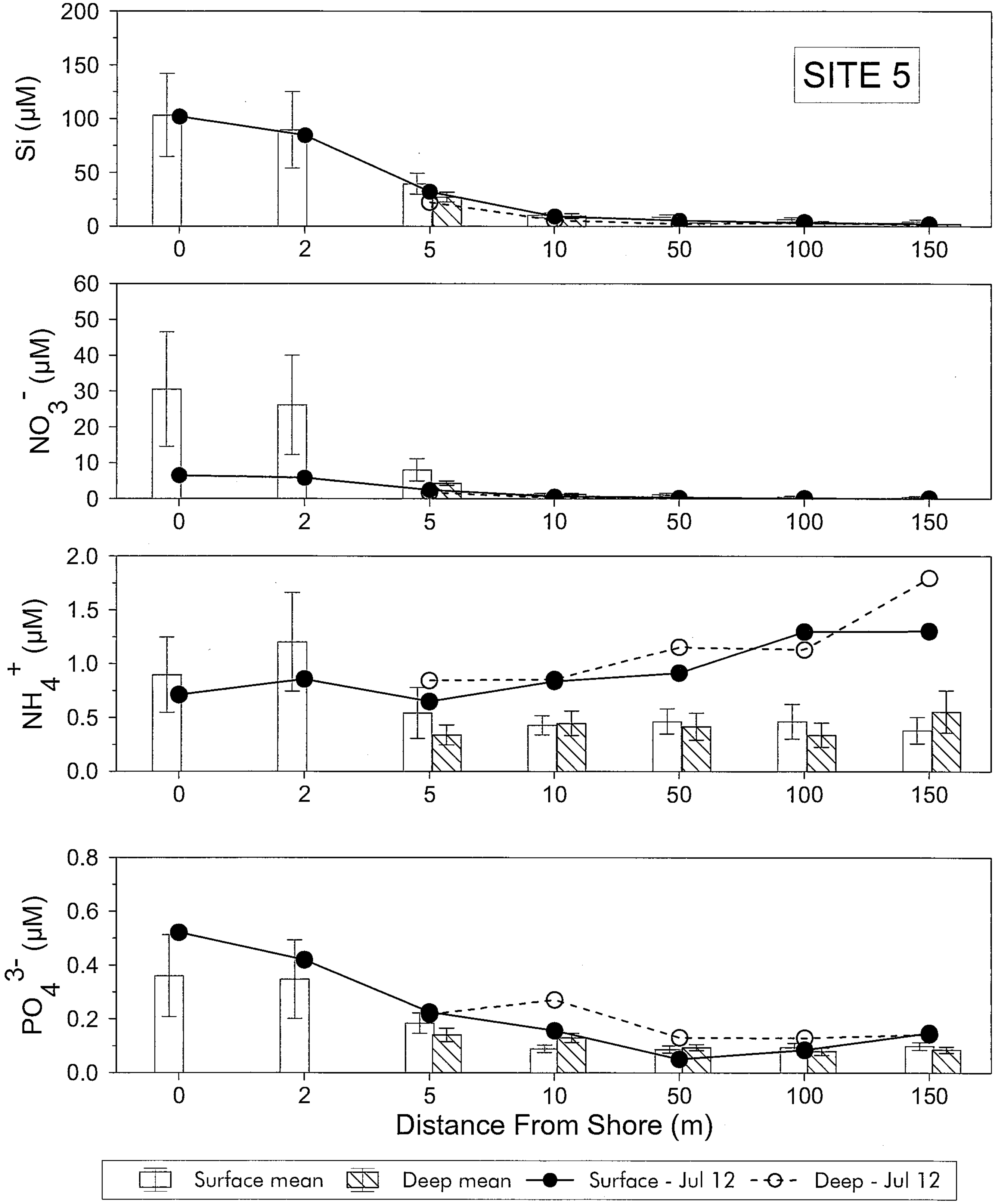


FIGURE 16. Plots of dissolved nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

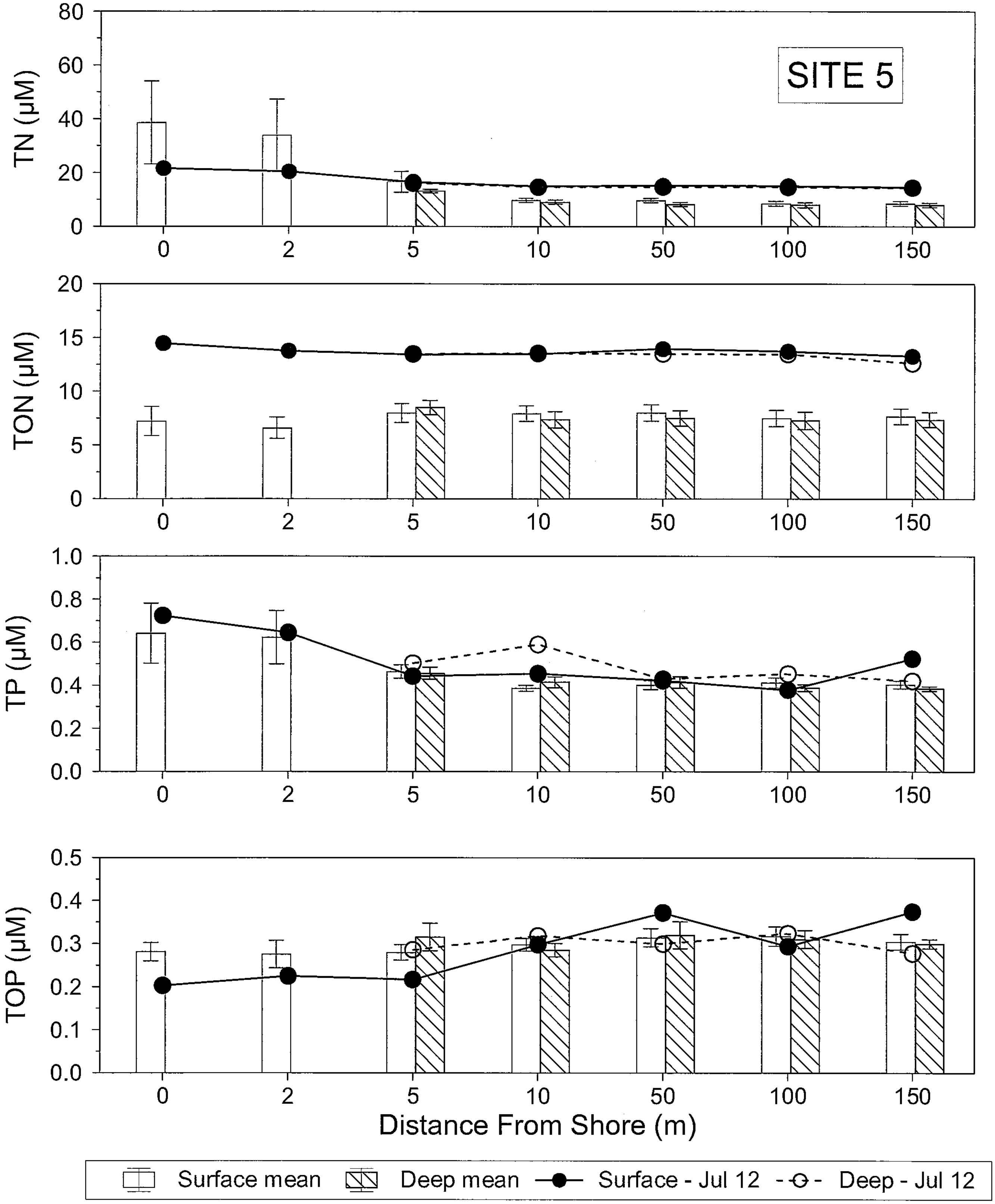


FIGURE 17. Plots of total and organic nutrients measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.

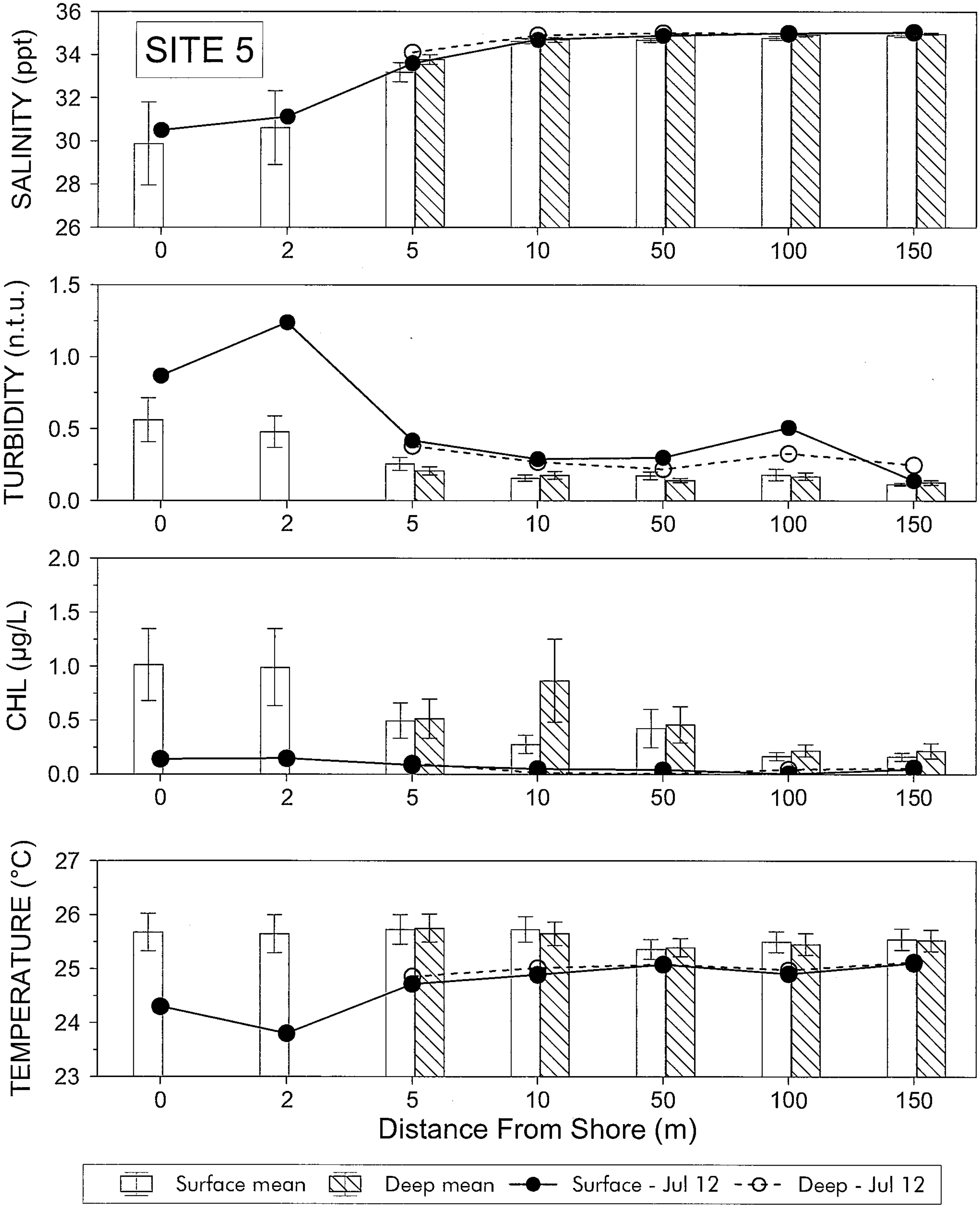
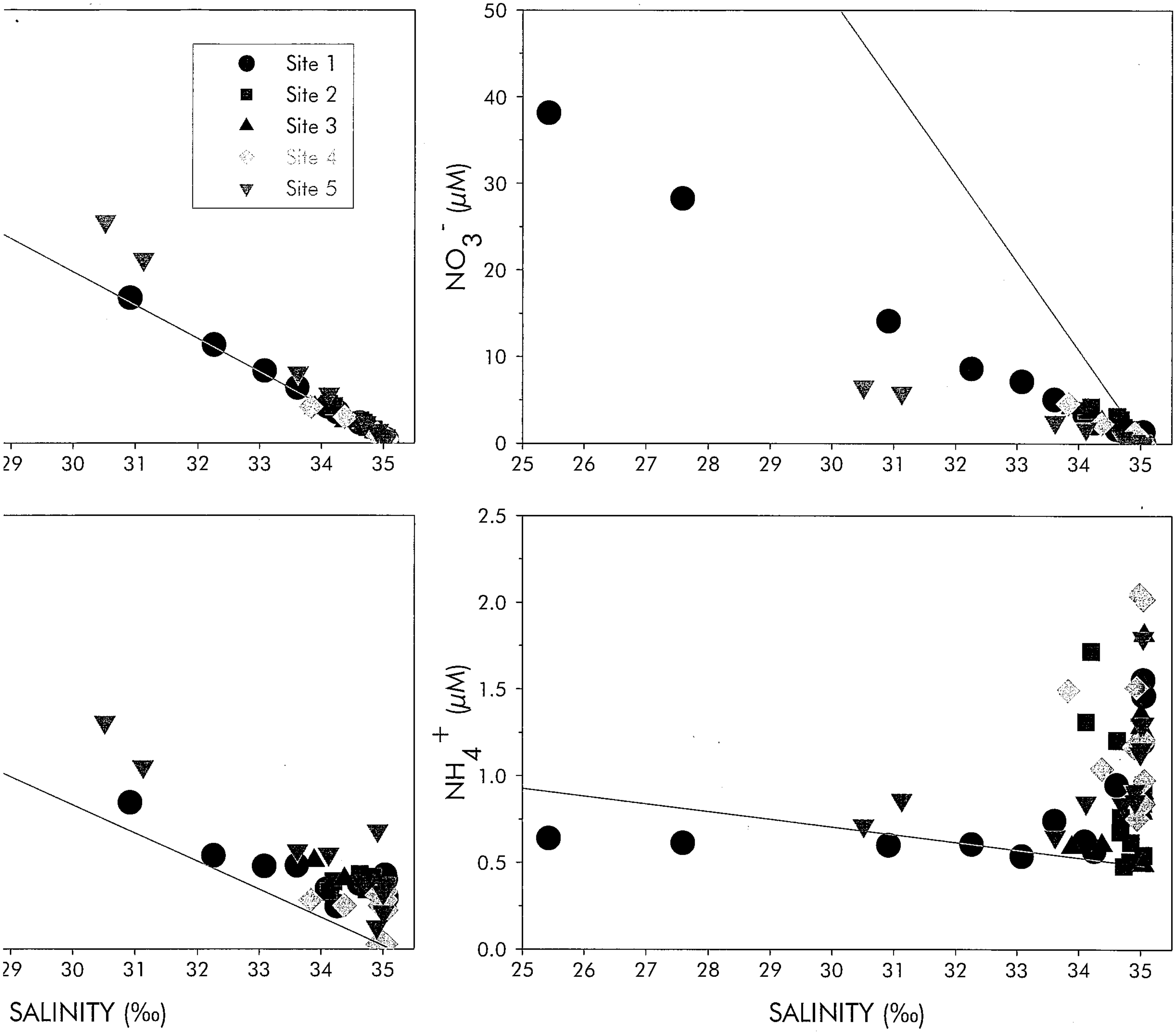


FIGURE 18. Plots of water quality constituents measured in surface and deep water samples as a function of distance from the shoreline at Transect Site 5, offshore of Honua`ula, Wailea, Maui. Data points with connecting lines are from samples collected during the most recent survey. Bar graphs represent mean values at each sampling station for all surveys conducted since June 2005 (N=10). Error bars represent standard error of the mean. For site location, see Figure 1.



xing diagram showing concentration of dissolved nutrients from samples collected at five transect sites offshore a project site in Wailea, Maui on July 16, 2012 as functions of salinity. Straight line in each plot is conservative tructed by connecting the concentrations in open coastal water with water from a golf course irrigation well. locations, see Figure 1.

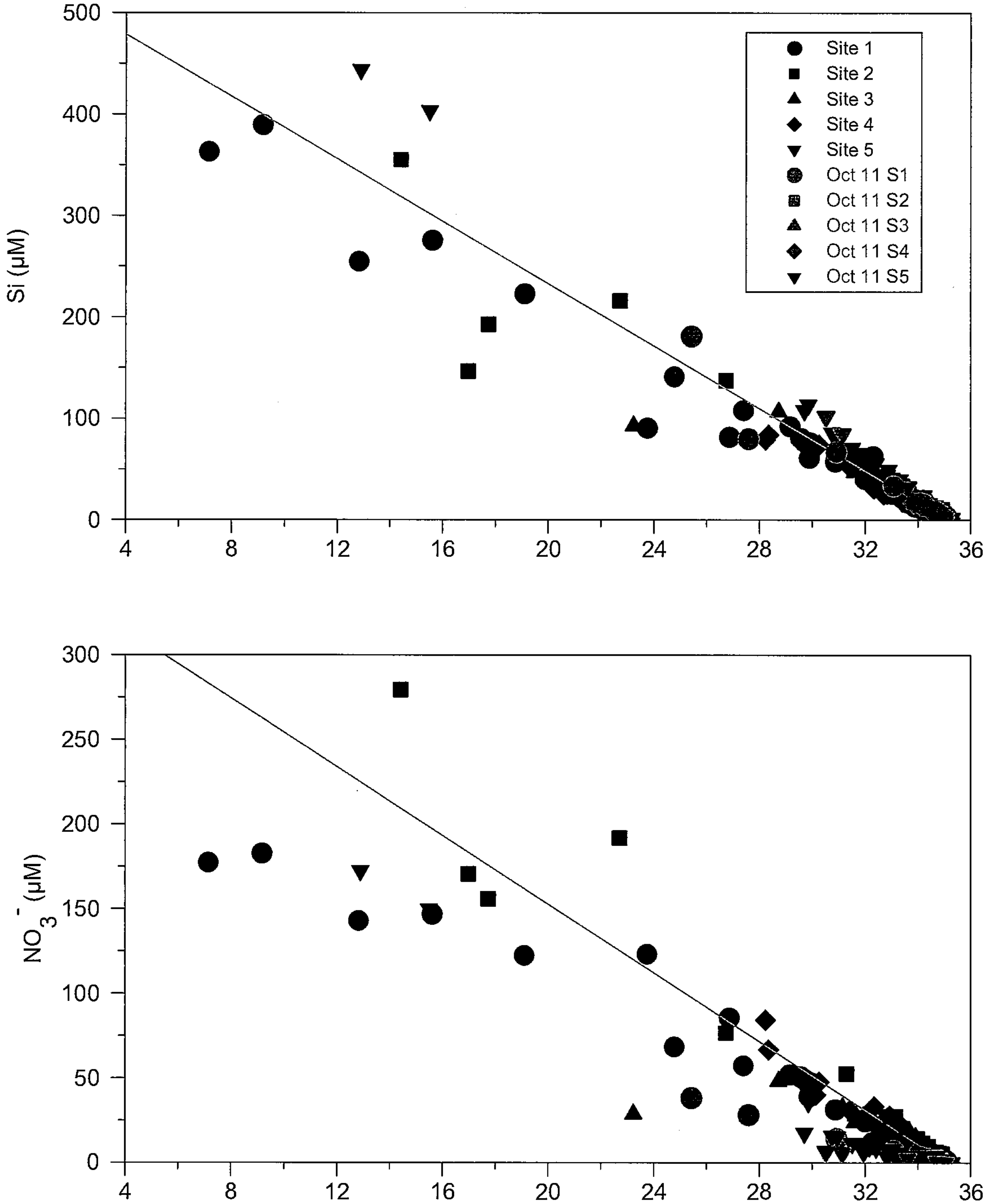


FIGURE 20. Silicate and nitrate, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and October 2011 (N=9). Red symbols are data from the most recent survey. 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.

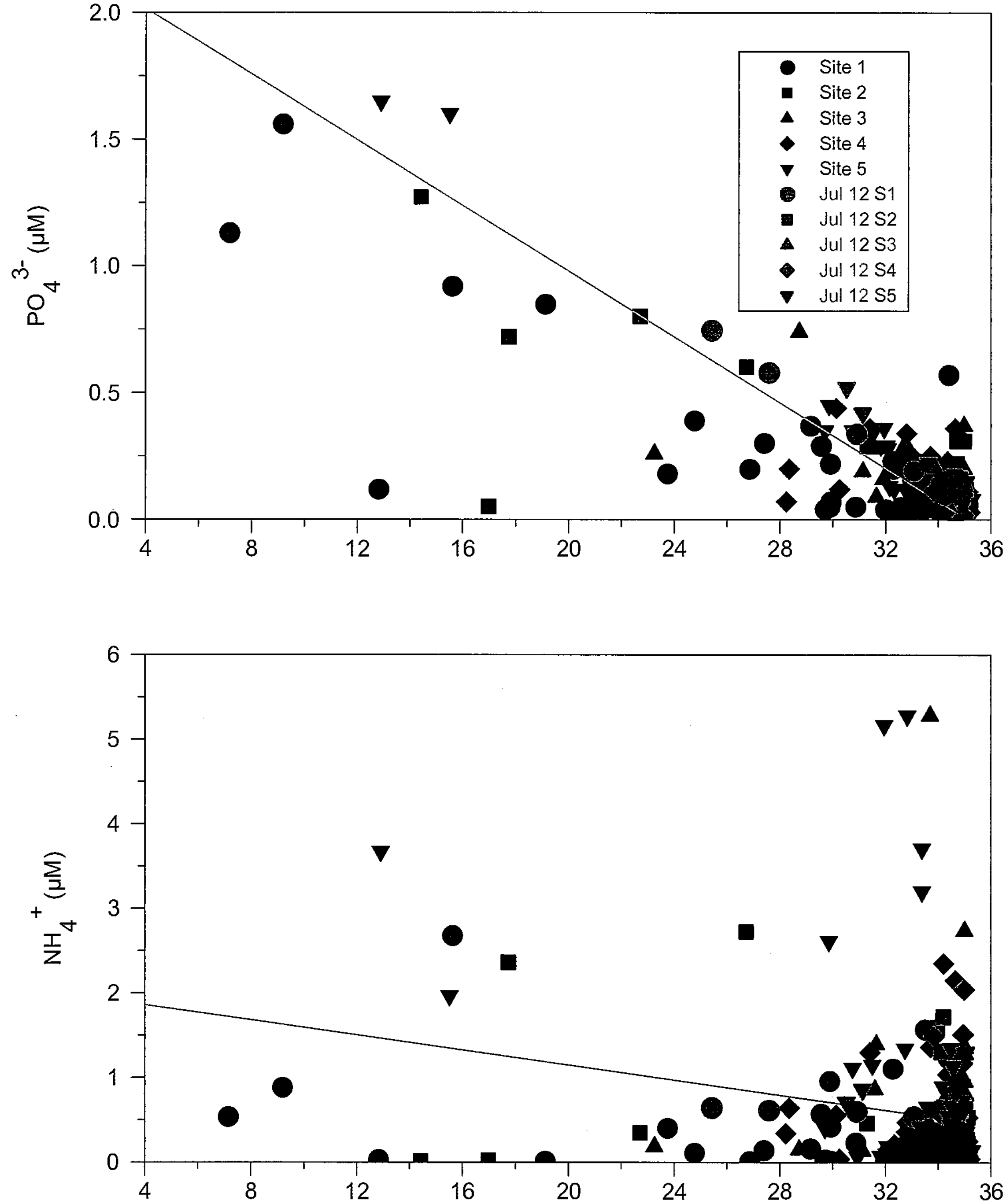


FIGURE 21. Phosphate and ammonium, plotted as a function of salinity for surface samples collected since June 2005 at five sites offshore of Honua`ula, Wailea, Maui. Black symbols represent data from surveys conducted between June 2005 and October 2011 (N=9). Red symbols are data from the most recent 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.

TABLE 4. 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 July 2012. 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 and 2010 (N=7), twice per year in 2009 and 2011 (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
2010	515.27	7.85	495.09	535.45
2011	464.80	5.70	452.37	477.22
2012	556.90	76.26	360.86	752.95
REGSLOPE	7.72	13.42	-25.13	40.56
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
2010	708.83	11.33	679.71	737.94
2011	620.78	15.58	586.84	654.72
2012	594.47	30.53	516.00	672.94
REGSLOPE	21.64	20.96	-29.63	72.92
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
2010	467.31	18.09	420.82	513.81
2011	551.45	18.16	511.88	591.02
2012	420.31	6.90	402.57	438.06
REGSLOPE	7.06	16.62	-33.61	47.73
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
2010	471.84	27.13	402.11	541.57
2011	555.76	8.62	536.97	574.54
2012	445.92	28.32	373.13	518.71
REGSLOPE	5.51	13.17	-26.70	37.73
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
2010	673.09	6.27	656.98	689.21
2011	688.21	7.10	672.74	703.68
2012	759.53	9.55	734.99	784.08
REGSLOPE	-1.89	6.13	-16.88	13.09

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
2010	-14.78	0.28	-15.49	-14.06
2011	-13.13	0.18	-13.52	-12.74
2012	-15.89	2.41	-22.10	-9.69
REGSLOPE	-0.21	0.41	-1.20	0.79
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
2010	-20.26	0.33	-21.10	-19.41
2011	-17.64	0.45	-18.62	-16.67
2012	-16.89	0.88	-19.16	-14.62
REGSLOPE	-0.60	0.61	-2.09	0.89
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
2010	-13.32	0.53	-14.67	-11.97
2011	-15.69	0.54	-16.86	-14.52
2012	-11.92	0.20	-12.44	-11.41
REGSLOPE	-0.19	0.48	-1.37	0.99
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
2010	-13.45	0.82	-15.55	-11.34
2011	-15.79	0.25	-16.33	-15.25
2012	-12.67	0.82	-14.76	-10.57
REGSLOPE	-0.14	0.38	-1.08	0.79
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
2010	-19.14	0.19	-19.62	-18.66
2011	-19.57	0.21	-20.03	-19.11
2012	-21.61	0.28	-22.34	-20.88
REGSLOPE	0.08	0.18	-0.37	0.52

TABLE 5. 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 July 2012. 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, 2010 and 2012 (N=7), twice per year in 2009 and 2011 (N=14). 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
2010	253.63	4.57	241.88	265.38
2011	235.52	6.82	220.66	250.37
2012	137.47	3.04	129.65	145.30
REGSLOPE	-26.52	6.70	-42.91	-10.13
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
2010	450.47	21.87	394.24	506.69
2011	442.07	15.82	407.60	476.53
2012	116.51	22.41	58.91	174.12
REGSLOPE	-10.96	20.22	-60.44	38.52
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
2010	220.36	6.33	204.08	236.64
2011	258.92	4.32	249.51	268.33
2012	124.95	2.44	118.67	131.23
REGSLOPE	-2.60	13.99	-36.83	31.64
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
2010	357.71	2.10	352.32	363.10
2011	449.61	7.88	432.45	466.77
2012	112.16	7.84	92.01	132.31
REGSLOPE	-30.74	16.91	-72.11	10.62
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
2010	148.96	16.96	105.35	192.57
2011	126.90	2.74	120.94	132.87
2012	50.47	1.19	47.42	53.51
REGSLOPE	-8.30	11.81	-37.21	20.60

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
2010	-7.31	0.16	-7.72	-6.89
2011	-6.66	0.21	-7.12	-6.19
2012	-3.94	0.10	-4.19	-3.69
REGSLOPE	0.77	0.19	0.30	1.25
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
2010	-12.93	0.64	-14.56	-11.29
2011	-12.60	0.45	-13.59	-11.61
2012	-3.29	0.65	-4.96	-1.62
REGSLOPE	0.32	0.58	-1.09	1.74
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
2010	-6.32	0.18	-6.79	-5.84
2011	-7.39	0.13	-7.67	-7.11
2012	-3.56	0.07	-3.74	-3.38
REGSLOPE	0.08	0.40	-0.90	1.06
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
2010	-10.26	0.06	-10.42	-10.10
2011	-12.82	0.23	-13.31	-12.32
2012	-3.19	0.23	-3.77	-2.60
REGSLOPE	0.90	0.49	-0.29	2.08
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
2010	-4.30	0.50	-5.60	-3.00
2011	-3.62	0.08	-3.79	-3.44
2012	-1.44	0.04	-1.53	-1.34
REGSLOPE	0.24	0.34	-0.59	1.07

TABLE 6. 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 July 2012. 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 and 2010 (N=7), twice per year in 2009 and 2011 (N=14). 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
2010	1.80	0.27	1.11	2.50
2011	1.50	0.07	1.36	1.65
2012	2.48	0.10	2.22	2.73
REGSLOPE	0.27	0.10	0.02	0.53
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
2010	1.08	1.88	-3.75	5.92
2011	1.48	0.90	-0.48	3.44
2012	-0.67	0.72	-2.53	1.19
REGSLOPE	-0.03	0.18	-0.48	0.41
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
2010	1.12	0.91	-1.22	3.45
2011	3.36	0.30	2.70	4.01
2012	4.23	1.78	-0.34	8.79
REGSLOPE	0.32	0.23	-0.25	0.88
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
2010	0.65	0.18	0.19	1.12
2011	0.45	1.02	-1.76	2.66
2012	2.20	1.60	-1.90	6.30
REGSLOPE	0.41	0.18	-0.04	0.86
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
2010	0.76	0.47	-0.46	1.97
2011	2.15	0.30	1.51	2.80
2012	3.21	0.29	2.46	3.95
REGSLOPE	-0.01	0.19	-0.46	0.45

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
2010	-0.05	0.01	-0.07	-0.02
2011	-0.04	0.00	-0.05	-0.04
2012	-0.07	0.00	-0.08	-0.06
REGSLOPE	-0.01	0.00	-0.01	0.00
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
2010	-0.03	0.05	-0.17	0.11
2011	-0.04	0.03	-0.10	0.02
2012	0.02	0.02	-0.03	0.08
REGSLOPE	0.00	0.01	-0.01	0.01
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
2010	-0.03	0.03	-0.10	0.04
2011	-0.09	0.01	-0.11	-0.07
2012	-0.12	0.05	-0.25	0.01
REGSLOPE	-0.01	0.01	-0.03	0.01
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
2010	-0.02	0.01	-0.03	0.00
2011	-0.01	0.03	-0.07	0.05
2012	-0.06	0.05	-0.18	0.06
REGSLOPE	-0.01	0.01	-0.02	0.00
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
2010	-0.02	0.01	-0.06	0.02
2011	-0.06	0.01	-0.08	-0.04
2012	-0.09	0.01	-0.11	-0.07
REGSLOPE	0.00	0.01	-0.01	0.01

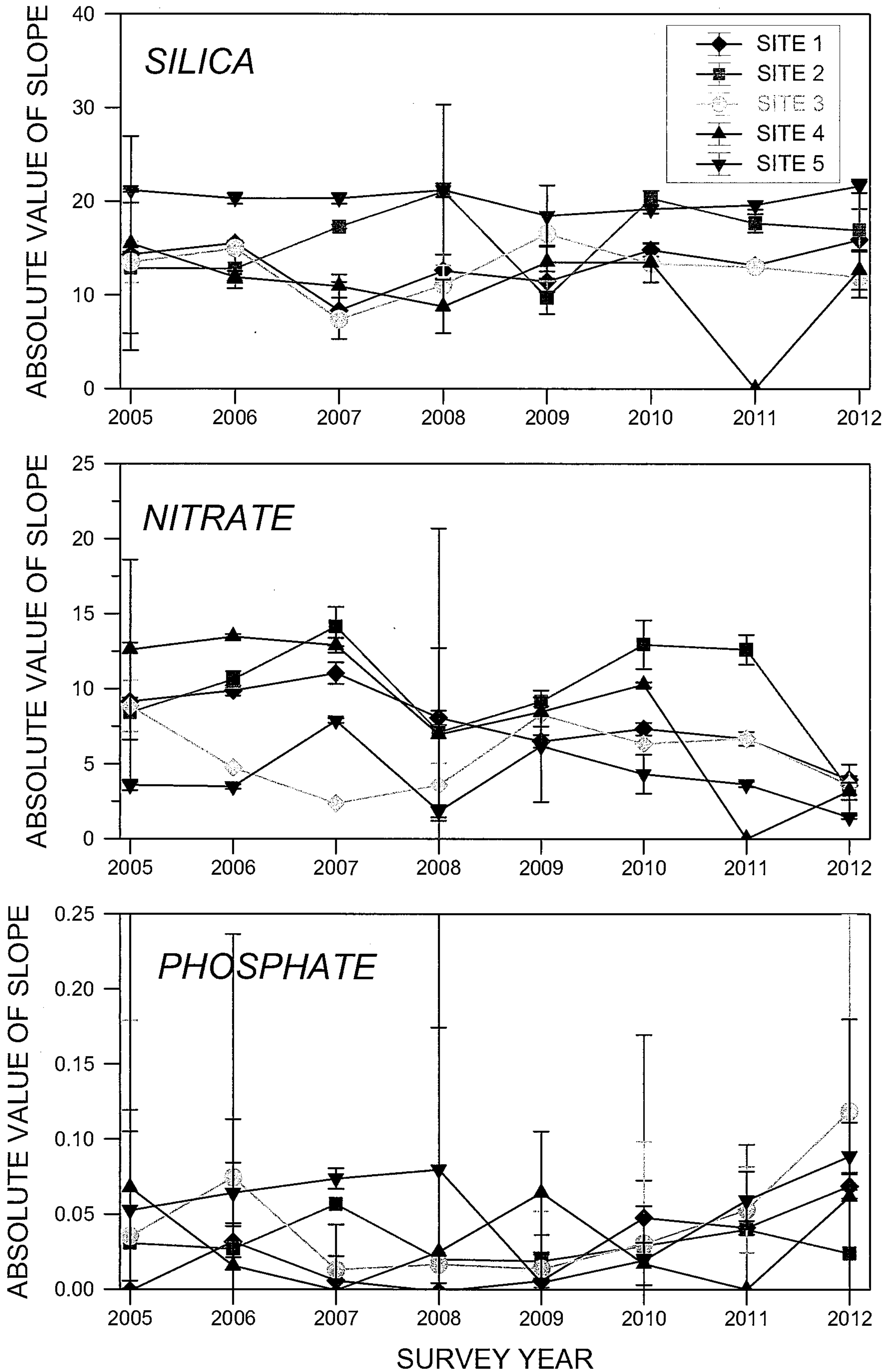


FIGURE 22. Time-course plots of absolute values of slopes of linear regressions of concentrations of silca, nitrate and phosphate as functions of salinity collected twice yearly at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations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

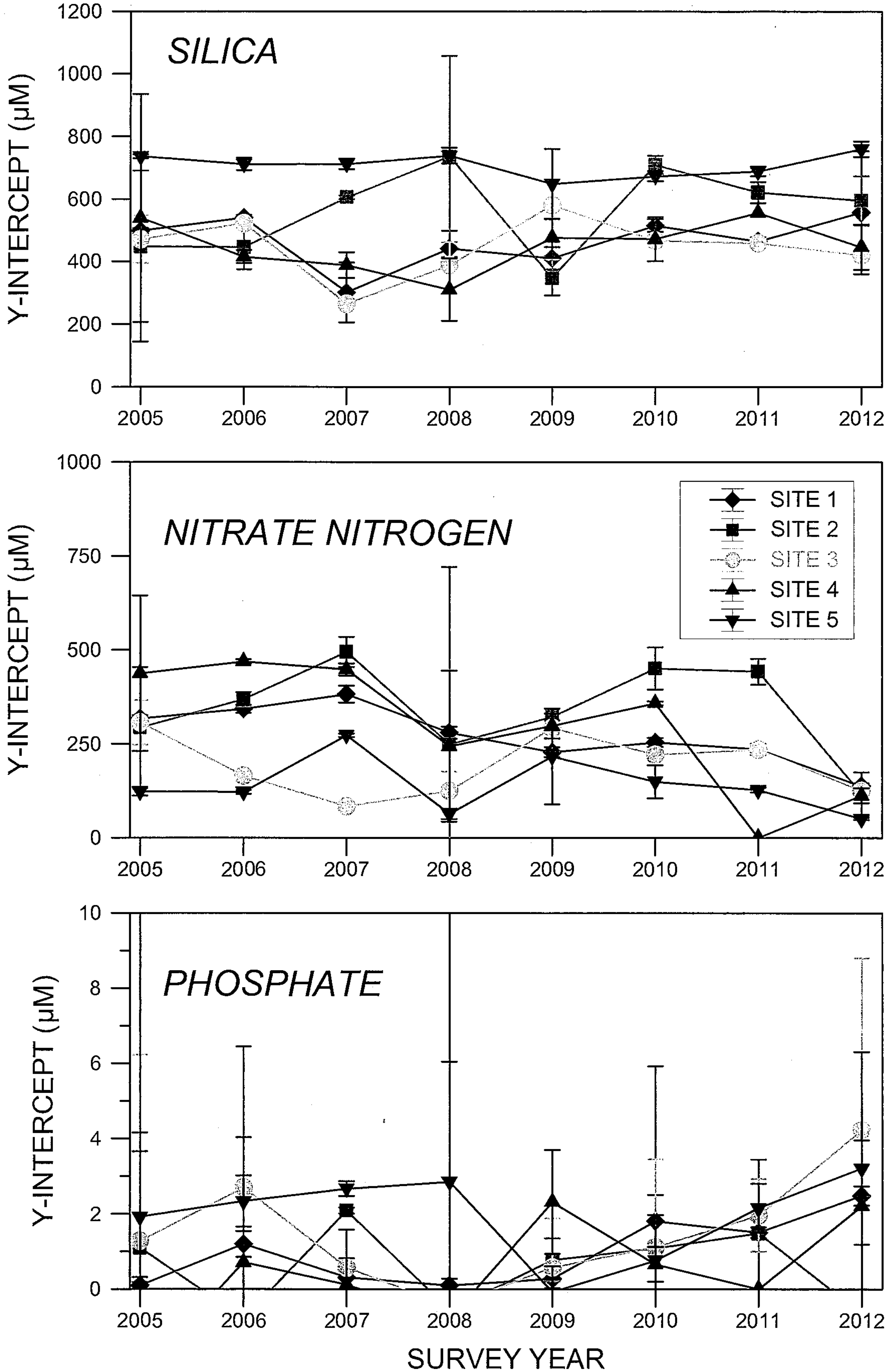


FIGURE 23. Time-course plots of Y-intercepts of linear regressions of concentrations of silca, nitrate and phosphorus as functions of salinity collected twice yearly at each of the transect monitoring stations off of Honua`ula, Wailea, Maui. Error bars are 95% confidence limits. For locations of sampling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

TABLE 7. Geometric mean data from water chemistry measurements (in μM) collected at five sites off of Hanua'ula, Wailea, Maui since the inception of monitaring in June 2005 (N=10). 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)	PO_4^{3-} (μM)	NO_3^- (μM)	NH_4^+ (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	0.21	57.79	0.31	117.7	0.25	7.51	0.58	71.09	0.27	20.655	0.71	25.73	8.13	103.82
	2 S	1	0.21	36.34	0.12	75.76	0.28	7.94	0.57	49.30	0.24	26.902	0.88	25.95	8.16	106.12
	5 S	1	0.10	16.84	0.07	39.28	0.27	8.15	0.42	27.50	0.26	31.445	0.35	25.90	8.15	105.43
	5 D	2.5	0.12	9.73	0.24	25.47	0.28	8.49	0.44	19.92	0.17	33.113	0.28	25.92	8.15	105.03
	10 S	1	0.09	5.52	0.17	15.82	0.28	8.01	0.39	15.85	0.19	33.700	0.22	25.87	8.13	104.30
	10 D	3	0.08	2.09	0.22	7.76	0.30	7.86	0.38	11.23	0.17	34.412	0.19	25.80	8.13	103.70
	50 S	1	0.06	2.67	0.25	8.64	0.31	8.10	0.38	12.42	0.16	34.350	0.22	25.72	8.13	100.86
	50 D	4.5	0.08	0.22	0.14	2.16	0.31	7.93	0.40	8.56	0.12	34.884	0.21	25.63	8.14	97.56
	100 S	1	0.07	1.47	0.18	6.51	0.21	7.74	0.38	11.37	0.12	34.427	0.14	25.59	8.14	98.95
	100 D	10	0.05	0.08	0.17	1.71	0.30	7.91	0.36	8.38	0.11	34.944	0.12	25.63	8.15	97.35
	150 S	1	0.06	0.56	0.26	3.33	0.32	8.51	0.39	10.14	0.16	34.743	0.13	25.89	8.14	97.56
	150 D	15	0.07	0.09	0.19	1.51	0.31	8.08	0.39	8.59	0.11	34.948	0.12	25.60	8.15	96.71
WAILEA 2	0 S	1	0.14	16.12	0.17	28.92	0.24	6.89	0.51	34.04	0.21	27.406	0.30	26.32	8.16	99.62
	2 S	1	0.16	11.56	0.23	21.24	0.28	7.36	0.51	24.61	0.21	32.014	0.32	26.13	8.16	100.86
	5 S	1	0.10	5.66	0.18	11.47	0.29	7.97	0.42	15.38	0.18	34.154	0.22	26.14	8.15	101.43
	5 D	2.5	0.13	3.28	0.22	7.39	0.30	8.22	0.44	12.29	0.19	34.589	0.24	26.12	8.15	101.41
	10 S	1	0.09	1.27	0.16	5.54	0.30	8.88	0.41	11.45	0.14	34.734	0.14	25.91	8.14	100.16
	10 D	3	0.07	0.62	0.16	3.21	0.30	7.71	0.39	9.12	0.13	34.846	0.18	25.90	8.15	100.21
	50 S	1	0.08	1.64	0.14	5.85	0.27	8.02	0.38	10.85	0.14	34.693	0.15	25.84	8.15	98.62
	50 D	4.5	0.08	0.10	0.24	1.92	0.29	7.42	0.39	8.04	0.13	34.966	0.17	25.67	8.15	95.67
	100 S	1	0.08	0.62	0.22	3.47	0.30	8.02	0.40	9.60	0.12	34.834	0.12	25.74	8.16	97.36
	100 D	10	0.07	0.05	0.17	1.60	0.31	7.34	0.39	7.70	0.12	34.974	0.13	25.65	8.16	95.99
	150 S	1	0.06	0.30	0.15	2.88	0.30	8.05	0.37	9.21	0.13	34.846	0.09	26.03	8.15	97.06
	150 D	15	0.06	0.03	0.22	1.45	0.30	8.04	0.37	8.50	0.10	35.004	0.11	25.63	8.16	96.45
WAILEA 3	0 S	1	0.15	8.58	0.36	24.13	0.31	8.29	0.48	20.53	0.30	32.121	0.42	26.31	8.16	98.44
	2 S	1	0.13	4.79	0.27	14.21	0.32	7.64	0.47	15.31	0.29	33.763	0.34	26.19	8.16	99.14
	5 S	1	0.09	2.51	0.19	8.75	0.32	7.63	0.42	11.92	0.20	34.344	0.29	26.33	8.15	99.56
	5 D	2.5	0.12	2.21	0.30	8.61	0.31	8.34	0.45	12.57	0.21	34.348	0.30	26.32	8.15	99.60
	10 S	1	0.10	3.43	0.30	12.96	0.28	7.57	0.44	15.19	0.17	33.519	0.21	26.30	8.14	98.87
	10 D	5	0.10	1.42	0.23	7.80	0.31	8.01	0.42	11.39	0.20	34.479	0.27	26.19	8.15	99.09
	50 S	1	0.11	0.75	0.32	4.53	0.32	8.53	0.45	10.58	0.15	34.761	0.20	25.80	8.15	98.33
	50 D	10	0.06	0.12	0.39	2.22	0.33	8.28	0.40	9.07	0.13	34.934	0.18	25.76	8.16	97.12
	100 S	1	0.07	0.51	0.22	3.97	0.31	8.24	0.40	9.66	0.16	34.795	0.16	25.89	8.15	97.91
	100 D	15	0.06	0.04	0.14	1.73	0.32	8.59	0.40	8.92	0.13	34.969	0.14	25.68	8.16	96.61
	150 S	1	0.05	0.22	0.28	2.72	0.31	7.84	0.38	8.87	0.14	34.895	0.13	25.91	8.15	96.27
	150 D	20	0.05	0.06	0.34	1.60	0.30	7.62	0.38	8.20	0.11	34.986	0.15	25.63	8.16	95.47
WAILEA 4	0 S	1	0.10	12.64	0.25	23.37	0.30	8.34	0.43	29.23	0.27	32.129	0.37	26.27	8.15	101.71
	2 S	1	0.09	8.45	0.21	17.31	0.34	9.04	0.45	24.14	0.21	33.225	0.39	26.41	8.17	101.33
	5 S	1	0.08	2.17	0.18	6.53	0.31	8.37	0.41	12.68	0.18	34.530	0.29	26.34	8.17	102.98
	5 D	2.5	0.07	1.39	0.15	5.23	0.30	8.68	0.39	11.92	0.17	34.627	0.23	26.34	8.16	101.48
	10 S	1	0.06	0.63	0.27	3.43	0.29	9.16	0.38	10.78	0.18	34.843	0.21	26.10	8.16	101.68
	10 D	3	0.08	0.29	0.18	2.87	0.31	8.00	0.42	9.15	0.14	34.908	0.19	26.07	8.16	101.28
	50 S	1	0.08	1.74	0.23	5.46	0.31	8.73	0.41	13.05	0.17	34.494	0.23	26.06	8.14	97.60
	50 D	10	0.06	0.15	0.16	2.18	0.28	8.78	0.38	9.40	0.12	34.957	0.20	25.48	8.15	95.33
	100 S	1	0.07	1.32	0.17	5.34	0.30	8.40	0.40	12.43	0.15	34.529	0.16	25.98	8.14	97.28
	100 D	15	0.09	0.09	0.14	1.87	0.33	8.57	0.43	9.07	0.11	34.981	0.13	25.68	8.15	96.19
	150 S	1	0.07	0.27	0.17	2.91	0.33	8.08	0.42	9.17	0.11	34.880	0.12	26.08	8.15	96.29
	150 D	25	0.06	0.02	0.09	1.63	0.33	7.85	0.41	8.16	0.11	34.974	0.13	25.62	8.16	96.69
WAILEA 5	0 S	1	0.21	14.16	0.47	77.96	0.28	6.21	0.59	27.23	0.39	28.934	0.47	25.58	8.13	99.25
	2 S	1	0.19	12.16	0.47	65.38	0.26	6.69	0.58	24.26	0.36	29.944	0.34	25.61	8.12	99.88
	5 S	1	0.15	5.37	0.33	34.67	0.28	8.43	0.47	15.56	0.23	33.033	0.30	25.69	8.13	102.38
	5 D	1.5	0.09	3.76	0.22	25.08	0.29	8.29	0.43	12.93	0.18	33.684	0.32	25.71	8.14	101.06
	10 S	1	0.06	1.18	0.31	9.49	0.29	7.96	0.37	9.76	0.14	34.555	0.16	25.70	8.11	100.16
	10 D	2.5	0.12	1.01	0.25	8.96	0.28	7.26	0.41	9.03	0.16	34.611	0.19	25.64	8.11	100.64
	50 S	1	0.08	0.85	0.26	7.54	0.30	7.65	0.40	9.31	0.15	34.643	0.15	25.44	8.12	94.49
	50 D	9	0.08	0.12	0.20	3.08	0.29	7.24	0.39	7.75	0.13	34.914	0.16	25.44	8.12	95.44
	100 S	1	0.09	0.32	0.22	5.03	0.30	7.29	0.41	8.31	0.16	34.741	0.10	25.57	8.13	95.76
	100 D	14	0.06	0.09	0.17	2.75	0.29	7.30	0.38	7.86	0.15	34.904	0.14	25.49	8.14	94.01
	150 S	1	0.07	0.12	0.24	2.81	0.29	7.48	0.39	8.26	0.11	34.876	0.11	25.60	8.15	96.64
	150 D	18	0.06	0.03	0.23	1.90	0.30	7.22	0.38	7.83	0.12	34.952	0.13	25.55	8.15	95.58
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 8. 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=10). 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)	PO_4^{3-} (μg/L)	NO_3^- (μg/L)	NH_4^- (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	6.50	809.4	4.34	3306	7.74	105.2	17.96	995.7	0.27	20.655	0.71	25.73	8.13	103.82
	2 S	1	6.50	509.0	1.68	2128	8.67	111.2	17.65	690.5	0.24	26.902	0.88	25.95	8.16	106.12
	5 S	1	3.09	235.9	0.98	1103	8.36	114.1	13.00	385.2	0.26	31.445	0.35	25.90	8.15	105.43
	5 D	2.5	3.71	136.3	3.36	715.5	8.67	118.9	13.62	279.0	0.17	33.113	0.28	25.92	8.15	105.03
	10 S	1	2.78	77.31	2.38	444.4	8.67	112.2	12.07	222.0	0.19	33.700	0.22	25.87	8.13	104.30
	10 D	3	2.47	29.27	3.08	218.0	9.29	110.1	11.76	157.3	0.17	34.412	0.19	25.80	8.13	103.70
	50 S	1	1.85	37.39	3.50	242.7	9.60	113.4	11.76	174.0	0.16	34.350	0.22	25.72	8.13	100.86
	50 D	4.5	2.47	3.08	1.96	60.67	9.60	111.1	12.38	119.9	0.12	34.884	0.21	25.63	8.14	97.56
	100 S	1	2.16	20.58	2.52	182.9	6.50	108.4	11.76	159.2	0.12	34.427	0.14	25.59	8.14	98.95
	100 D	10	1.54	1.12	2.38	48.03	9.29	110.8	11.15	117.4	0.11	34.944	0.12	25.63	8.15	97.35
	150 S	1	1.85	7.84	3.64	93.54	9.91	119.2	12.07	142.0	0.16	34.743	0.13	25.89	8.14	97.56
	150 D	15	2.16	1.26	2.66	42.42	9.60	113.2	12.07	120.3	0.11	34.948	0.12	25.60	8.15	96.71
WAILEA 2	0 S	1	4.33	225.8	2.38	812.4	7.43	96.50	15.79	476.8	0.21	27.406	0.30	26.32	8.16	99.62
	2 S	1	4.95	161.9	3.22	596.6	8.67	103.1	15.79	344.7	0.21	32.014	0.32	26.13	8.16	100.86
	5 S	1	3.09	79.27	2.52	322.2	8.98	111.6	13.00	215.4	0.18	34.154	0.22	26.14	8.15	101.43
	5 D	2.5	4.02	45.93	3.08	207.6	9.29	115.1	13.62	172.1	0.19	34.589	0.24	26.12	8.15	101.41
	10 S	1	2.78	17.78	2.24	155.6	9.29	124.4	12.69	160.4	0.14	34.734	0.14	25.91	8.14	100.16
	10 D	3	2.16	8.68	2.24	90.17	9.29	108.0	12.07	127.7	0.13	34.846	0.18	25.90	8.15	100.21
	50 S	1	2.47	22.96	1.96	164.3	8.36	112.3	11.76	152.0	0.14	34.693	0.15	25.84	8.15	98.62
	50 D	4.5	2.47	1.40	3.36	53.93	8.98	103.9	12.07	112.6	0.13	34.966	0.17	25.67	8.15	95.67
	100 S	1	2.47	8.68	3.08	97.47	9.29	112.3	12.38	134.5	0.12	34.834	0.12	25.74	8.16	97.36
	100 D	10	2.16	0.70	2.38	44.94	9.60	102.8	12.07	107.8	0.12	34.974	0.13	25.65	8.16	95.99
	150 S	1	1.85	4.20	2.10	80.90	9.29	112.7	11.46	129.0	0.13	34.846	0.09	26.03	8.15	97.06
	150 D	15	1.85	0.42	3.08	40.73	9.29	112.6	11.46	119.1	0.10	35.004	0.11	25.63	8.16	96.45
WAILEA 3	0 S	1	4.64	120.2	5.04	677.8	9.60	116.1	14.86	287.5	0.30	32.121	0.42	26.31	8.16	98.44
	2 S	1	4.02	67.08	3.78	399.2	9.91	107.0	14.55	214.4	0.29	33.763	0.34	26.19	8.16	99.14
	5 S	1	2.78	35.15	2.66	245.8	9.91	106.9	13.00	167.0	0.20	34.344	0.29	26.33	8.15	99.56
	5 D	2.5	3.71	30.95	4.20	241.9	9.60	116.8	13.93	176.1	0.21	34.348	0.30	26.32	8.15	99.60
	10 S	1	3.09	48.04	4.20	364.0	8.67	106.0	13.62	212.8	0.17	33.519	0.21	26.30	8.14	98.87
	10 D	5	3.09	19.88	3.22	219.1	9.60	112.2	13.00	159.5	0.20	34.479	0.27	26.19	8.15	99.09
	50 S	1	3.40	10.50	4.48	127.2	9.91	119.5	13.93	148.2	0.15	34.761	0.20	25.80	8.15	98.33
	50 D	10	1.85	1.68	5.46	62.36	10.22	116.0	12.38	127.0	0.13	34.934	0.18	25.76	8.16	97.12
	100 S	1	2.16	7.14	3.08	111.5	9.60	115.4	12.38	135.3	0.16	34.795	0.16	25.89	8.15	97.91
	100 D	15	1.85	0.56	1.96	48.60	9.91	120.3	12.38	124.9	0.13	34.969	0.14	25.68	8.16	96.61
	150 S	1	1.54	3.08	3.92	76.40	9.60	109.8	11.76	124.2	0.14	34.895	0.13	25.91	8.15	96.27
	150 D	20	1.54	0.84	4.76	44.94	9.29	106.7	11.76	114.8	0.11	34.986	0.15	25.63	8.16	95.47
WAILEA 4	0 S	1	3.09	177.0	3.50	656.5	9.29	116.8	13.31	409.4	0.27	32.129	0.37	26.27	8.15	101.71
	2 S	1	2.78	118.4	2.94	486.2	10.53	126.6	13.93	338.1	0.21	33.225	0.39	26.41	8.17	101.33
	5 S	1	2.47	30.39	2.52	183.4	9.60	117.2	12.69	177.6	0.18	34.530	0.29	26.34	8.17	102.98
	5 D	2.5	2.16	19.46	2.10	146.9	9.29	121.6	12.07	167.0	0.17	34.627	0.23	26.34	8.16	101.48
	10 S	1	1.85	8.82	3.78	96.35	8.98	128.3	11.76	151.0	0.18	34.843	0.21	26.10	8.16	101.68
	10 D	3	2.47	4.06	2.52	80.62	9.60	112.0	13.00	128.2	0.14	34.908	0.19	26.07	8.16	101.28
	50 S	1	2.47	24.37	3.22	153.4	9.60	122.3	12.69	182.8	0.17	34.494	0.23	26.06	8.14	97.60
	50 D	10	1.85	2.10	2.24	61.24	8.67	123.0	11.76	131.7	0.12	34.957	0.20	25.48	8.15	95.33
	100 S	1	2.16	18.48	2.38	150.0	9.29	117.7	12.38	174.1	0.15	34.529	0.16	25.98	8.14	97.28
	100 D	15	2.78	1.26	1.96	52.53	10.22	120.0	13.31	127.0	0.11	34.981	0.13	25.68	8.15	96.19
	150 S	1	2.16	3.78	2.38	81.74	10.22	113.2	13.00	128.4	0.11	34.880	0.12	26.08	8.15	96.29
	150 D	25	1.85	0.28	1.26	45.79	10.22	109.9	12.69	114.3	0.11	34.974	0.13	25.62	8.16	96.69
WAILEA 5	0 S	1	6.50	198.3	6.58	2190	8.67	86.97	18.27	381.4	0.39	28.934	0.47	25.58	8.13	99.25
	2 S	1	5.88	170.3	6.58	1837	8.05	93.70	17.96	339.8	0.36	29.944	0.34	25.61	8.12	99.88
	5 S	1	4.64	75.21	4.62	973.9	8.67	118.1	14.55	217.9	0.23	33.033	0.30	25.69	8.13	102.38
	5 D	1.5	2.78	52.66	3.08	704.5	8.98	116.1	13.31	181.1	0.18	33.684	0.32	25.71	8.14	101.06
	10 S	1	1.85	16.52	4.34	266.6	8.98	111.5	11.46	136.7	0.14	34.555	0.16	25.70	8.11	100.16
	10 D	2.5	3.71	14.14	3.50	251.7	8.67	101.7	12.69	126.5	0.16	34.611	0.19	25.64	8.11	100.64
	50 S	1	2.47	11.90	3.64	211.8	9.29	107.1	12.38	130.4	0.15	34.643	0.15	25.44	8.12	94.49
	50 D	9	2.47	1.68	2.80	86.52	8.98	101.4	12.07	108.5	0.13	34.914	0.16	25.44	8.12	95.44
	100 S	1	2.78	4.48	3.08	141.3	9.29	102.1	12.69	116.4	0.16	34.741	0.10	25.57	8.13	95.76
	100 D	14	1.85	1.26	2.38	77.25	8.98	102.2	11.76	110.1	0.15	34.904	0.14	25.49	8.14	94.01
	150 S	1	2.16	1.68	3.36	78.93	8.98	104.8	12.07	115.7	0.11	34.876	0.11	25.60	8.15	96.64
	150 D	18	1.85	0.42	3.22	53.37	9.29	101.1	11.76	109.7	0.12	34.952	0.13	25.55	8.15	95.58
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.