NUTRIENT STATUS OF TUMON BAY IN RELATION TO INTERTIDAL BLOOMS OF THE FILAMENTOUS GREEN ALGA, *ENTEROMORPHA CLATHRATA*

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Tumon Bay, Guam’s premier tourist location, receives over one million overseas visitors each year (photo: courtesy John Jocson, WERI)

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF PLATES (cont.)

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

In Guam, intertidal blooms of the filamentous green alga, *Enteromorpha clathrata*, typically occur on beaches under the influence of groundwater intrusion. This particular species is especially abundant in Tumon Bay, Guam's premier tourist location, on the northwest side of the island. Local hoteliers in this area consider the algal blooms unsightly and a very real threat to tourism. The blooms are commonly believed to be associated with high levels of nitrate (NO_3^-) that occur naturally in Guam's groundwater (2-3 mg/l). However, the distribution and abundance of *E. clathrata* in Tumon Bay seems to have paralleled commercial development in the area, which suggests other factors are also important. Previously, reactive P (RP) levels approaching 500 µg/l were detected in surface runoff from the gardens of one of Guam's leading hotels overlooking Agana Bay. Since P is normally limiting in Guam's nearshore waters, it was hypothesized that similar releases from hotel gardens along the waterfront, in Tumon Bay, account for the green algal problem as it is today.

In the current study N, P and silica (SiO_2) levels were determined in emergent groundwater seeps and springs from 9 intertidal sites (mostly 50-100 m apart) in Agana Bay and 70 intertidal sites (~50 m apart) in Tumon Bay. RP levels in Agana Bay ranged from 12.7-30.6 µg/l with the highest level occurring closest to the hotel mentioned above, at the northern end of the bay. The highest levels of NO_3-N (1.3-4.0 mg/l) and SiO_2 (2.7-5.5 mg/l) were also found here. In Tumon Bay, RP levels ranged from 1.3-31.9 µg/l while NO_3-N and SiO_2 were <0.01-7.9 mg/l and 0.42-3.8 mg/l respectively. RP accounted for >90% of total P in all samples while NO_3-N was the predominant form of dissolved inorganic nitrogen (DIN = NO_3-N + NO_2-N + NH_4-N). Levels of all three nutrients were far more variable in seeps than springs. NO_3-N concentrations generally decreased with increased salinity while the reverse was true for SiO_2. No significant correlation was found between RP and salinity.

Levels of all three nutrients in Tumon Bay seeps and springs were compared with those found in groundwater from 96 drinking water production wells located further inland. A comparison of frequency distribution histograms between beach and well data sets showed the measure of central tendency for RP in seep and spring samples was displaced to the right of that for the wells implying that the aquifer was not the only source of P into the bay. The reverse was found to be the case for NO_3-N (as a result of conservative mixing in the transition zone) while measures of central tendency for Si were the same for both data sets.

Tumon Bay nearshore waters were collected daily from 9 sites over a three-month period. NO_3-N and RP behaved conservatively in the surf zone and were rapidly diluted and dispersed. Close to 70% of all samples taken ~50 m offshore contained RP levels below the threshold concentration (~3 µg/l) required to promote macroalgae blooms, whereas only 20% were below the threshold concentration for DIN (~70 µg/l). Thus, while N was generally present in oversupply in this region of the bay, P levels were frequently limiting. Such findings highlight the dramatic effect relatively small anthropogenic inputs of RP could have on the abundance and distribution of *E. clathrata* in the bay. Hotel managers are, therefore, advised to pay close attention to the landscaping activities that go on in their grounds in order to eliminate, or at least minimize excess fertilizer and water applications to their lawns and gardens.

INTRODUCTION

Tumon Bay is the center of Guam's tourist industry, receiving close to a million overseas visitors each year. Located on the northwestern shores of the island, this premier location is bordered by a number of first-class hotels and a vast array of shopping outlets, restaurants, and recreational facilities. Maintaining the natural beauty of Tumon Bay is clearly tantamount to maintaining a healthy economy. Not surprisingly, then, some considerable effort is made by beachfront hotel managers to preserve the bay's aesthetic appeal, particularly in the intertidal region where vacationers spend much of their time sunbathing and relaxing. This process is both costly and labor intensive. It involves not only the collection of litter and the usual array of marine debris washed in by the tide, but also the daily removal of unsightly green alga that grows prolifically in the intertidal zone. The alga, *Enteromorpha clathrata*, is not a recent invader. On the contrary, it occurs naturally on Guam, although its growth and increased abundance along the shore of Tumon Bay appears to have paralleled the commercial development in the area over the last 30 years. Today, luxuriant blooms of *E. clathrata* occur year-round along much of intertidal zone and are considered by many to be a very real threat to the tourism industry. Identifying and controlling the factors driving the growth of this species in Tumon Bay are, therefore of importance to the future economy of the island.

It is popularly believed that growth of *E. clathrata* in Tumon Bay is primarily associated with nutrient enrichment (Matson 1996), although there are those who believe it is linked to a decline in herbivorous fish populations as a result of over fishing in the area (FitzGerald 1976). It seems probable that both factors are important, although, as yet, there is no hard evidence to support either. Certainly, members of this genus are well known indicators of nutrient enrichment elsewhere in the world (Lapoint *et al.,* 1993; 1997; Lapointe and Thacker, 2002) and Tumon Bay has no shortage of potential nutrient sources along its foreshores, including stormwater runoff from impervious surfaces, leaky sewer pipes, and groundwater intrusion. Of these, the latter is frequently cited as the most likely promoter of algal growth due to the naturally enriched levels of dissolved inorganic nitrogen (N) in Guam's groundwater (predominantly in the form of nitrate) and the high incidence of permanent seeps and springs in Tumon Bay (Matson 1991). The fact that *E. clathrata* typically occurs on other Guam beaches influenced by groundwater intrusion, even in relatively remote parts of the island, lends weight to the importance of groundwater as a controlling factor. However, the nitrate enrichment theory does not explain why *E. clathrata* has become more abundant in Tumon Bay in recent years.

An alternative explanation put forward by Denton *et al.* (1998) suggests that growth of *E. clathrata* on Guam is normally controlled by phosphorus (P) limitations and that hotel development in Tumon Bay, and concomitant increases in landscaping activities, have increased P availability in the area as a result of poor management practices, i.e., excessive irrigation and over use of chemical fertilizers. This suggestion was made following the discovery of high soluble reactive phosphorus (RP) levels (up to 482 mg/l) in runoff from the gardens of one of Guam's leading hotels, at the northern end of Agana Bay. It is noteworthy that Agana Bay has far fewer hotels than Tumon Bay and doesn't have the same algal problem despite numerous seeps and springs in the area.

In the current investigation, we determined concentrations of total dissolved N, nitrate-N (NO_3-N), nitrite-N (NO_2-N), ammonium-N (NH_4-N), total dissolved P, RP, silica (SiO_2) and chloride (Cl) in seeps and springs from the intertidal zone of Agana Bay and Tumon Bay. Dissolved inorganic nitrogen (DIN = NH_4 + NO_3 + NO_2) and RP levels were compared directly with those found in groundwater taken directly from the island's karst limestone aquifer, further inland, in an attempt to identify nutrient contributions from the lower Tumon Basin. Seawater samples were also taken for analysis from discrete locations within Tumon Bay itself to highlight nearshore nutrient dilution and dispersion rates in relation to threshold concentrations of DIN and RP required to promote algal blooms. The SiO_2 analysis provided clues on the subbasin origins of source water intruding into each bay.

MATERIALS AND METHODS

In July 2000, groundwater seep and spring samples were collected during a late afternoon low tide (early evening) from 9 intertidal sites (mostly 50-100m apart) in the northern half of Agana Bay. Similar samples were collected monthly (June-August 2000) from 70 intertidal sites (~50 m apart) along the entire length of Tumon Bay (Fig. 1). The latter sampling excursions were carried out over a period of three days (early to late afternoon) on each occasion. Each water sample was withdrawn directly into a pre-cleaned 50-ml polyethylene syringe and passed through a 0.45 µm in-line filter into a 50-ml polypropylene screw-cap tube. All samples were collected in duplicate and chilled immediately.

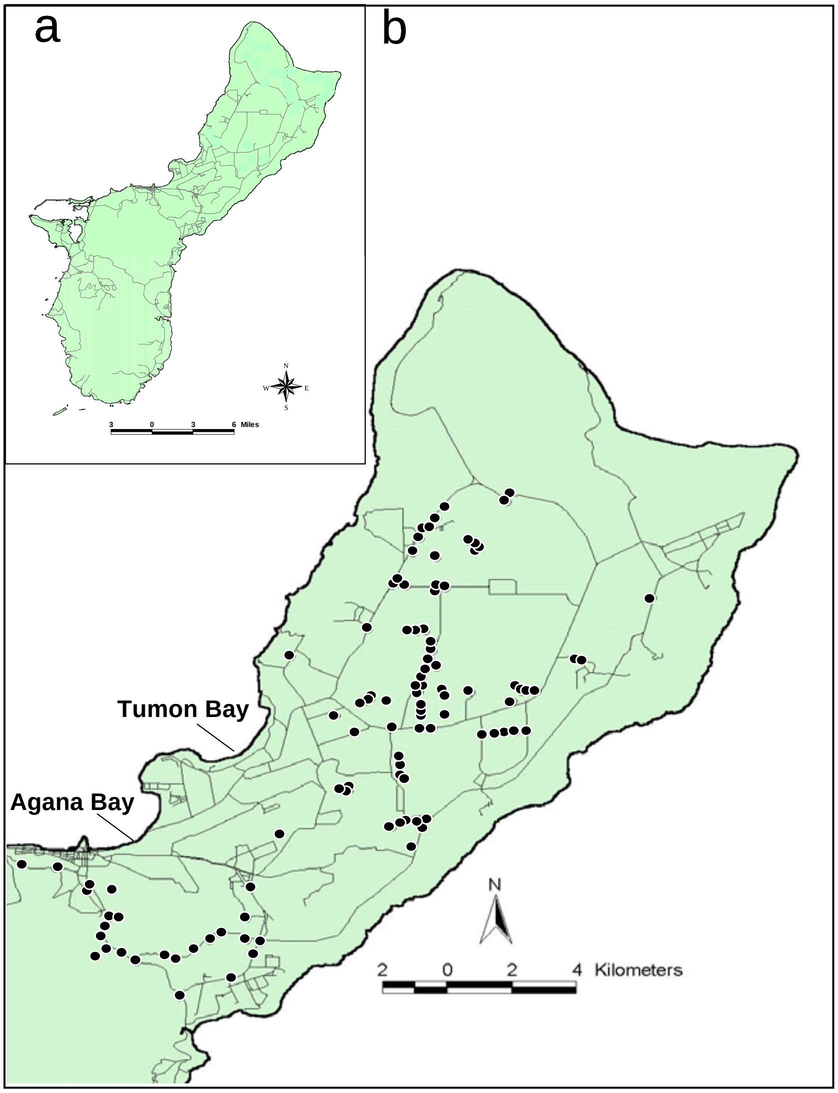

Figure 1: Map of Guam (13°28'N, 144°45'E: inset a) and northern half of the island (b) showing Tumon Bay and Agana Bay, and the drinking water production wells (closed circles) sampled during this study

Groundwater samples from further inland were obtained from 96 of the Government of Guam's drinking water production wells (Fig. 1) in four different subbasins in the northern half of the island. The samples were collected by authorized personnel of the Guam Waterworks Authority (GWA) Monitoring Laboratory, at the wellhead of about a third of the wells, every three months, over a nine-month period (June 2000-March 2001). The unfiltered samples (insignificant suspended solids) were captured directly in duplicate 50-ml polypropylene screw-cap tubes and chilled immediately without further treatment.

Seawater samples were also collected almost daily from within Tumon Bay over a period of four months (February-May 2001). The samples were taken early in the morning (7:30-8:30 AM) directly in front of 9 bayside hotels and one beach bar, at the surf zone and further offshore (~50 m) in waist deep water (~1 m). Seven of the sites were adjacent to emergent springs, five of them major. All samples were filtered and treated in the same manner as described earlier.

In the laboratory, samples were stored overnight at 4^{o}C and analyzed the next day using a four-channel, automated, flow injection ion analyzer (Lachet, Australia). Relatively unstable RP, NO_2-N and NH_4-N were analyzed first followed by NO_3-N, SiO_2 and Cl using the manufactures recommended QuickChem® methods. Total N and P were determined later following persulfate oxidation.

Plate 1: Luxuriant blooms of *Enteromorpha clathrata* exposed at low tide in Tumon Bay

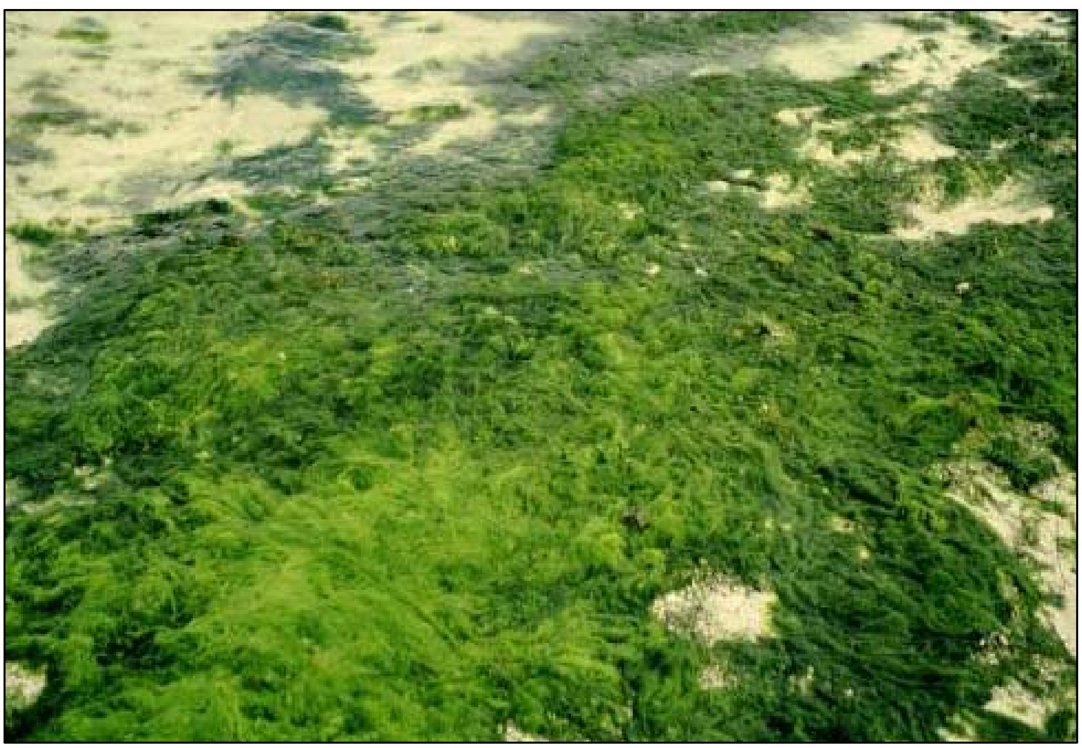

Plate 2: Close-up of *Enteromorpha clathrata* at low tide in Tumon Bay

Plate 3: Manually removing *Enteromorpha clathrata* at low tide in Tumon Bay

Plate 4: Tractor drawn mechanical sand-rake used daily for beach cleaning in Tumon Bay

Plate 5: Some consider *Enteromorpha clathrata* a real threat to tourism in Tumon Bay

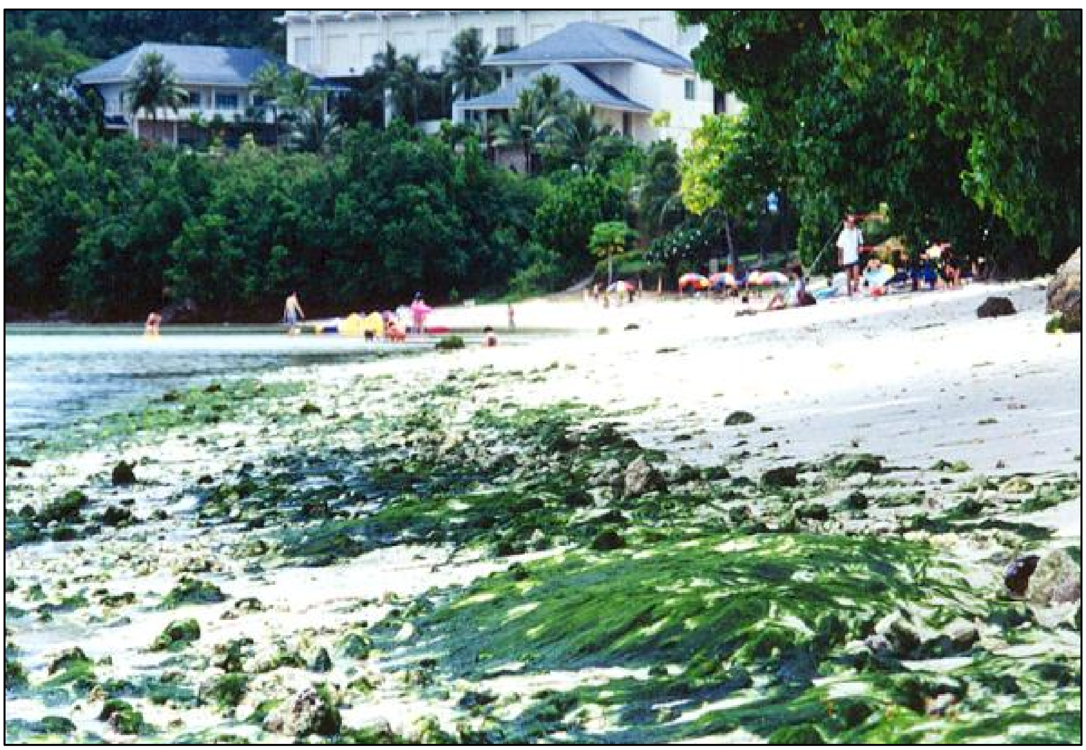

Plate 6: Tourists gather at the far end of the Tumon Bay beach away from unsightly alga

Plate 7: Groundwater seep fields occur along much of the beach in Tumon Bay

Plate 8: Nine major and numerous minor groundwater springs discharge into Tumon Bay

RESULTS AND DISCUSSION

Reactive phosphorus (RP), ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N) and dissolved inorganic nitrogen (DIN) levels determined in the different water types are summarized in Table 1 together with DIN:RP molar ratios and silica (SiO_2) concentrations. Complete data sets for all parameters measured are included in the appendices at the end of this report. Salinities were derived from the chloride data assuming 550 mg Cl/l = 1.0 $^0/_{00}$ (Stumm and Morgan 1981).

<u>Agana Bay Seeps and Springs</u>:
RP levels in spring and seep samples from Agana Bay ranged from 12.7-30.6 µg/l (overall geometric mean: 19.0 µg/l). The highest concentration occurred at the northern end of the bay closest to the hotel where high RP levels in surface runoff had previously been identified (Denton *et al.,* 1998). Runoff from the hotel grounds drains into a retention pond located on the peninsula that separates Agana Bay from Tumon Bay. The P enriched spring sample was collected from the base of this rocky peninsula. NO_3-N concentrations for the Agana Bay sites ranged from 1.3-4.0 mg/l (overall geometric mean: 2.5 mg/l) and accounted for 97-100% of DIN. Once again the highest concentration was found at the northern end of the bay closest to the hotel. On average, DIN represented ~97% of total N indicating negligible to nonexistent contributions from organic-N. SiO_2 levels ranged from 2.7-5.5 mg/l (geometric mean: 3.3 mg/l) and peaked at the northern end of the bay. The degree of Si enrichment in groundwater is presumably a reflection of travel time within the aquifer, in addition to the qualitative and quantitative characteristics of secondary silicates within surface soils, the limestone plateau and the underlying basalt.

<u>Tumon Bay Seeps and Springs</u>:
RP accounted for >95% of total P in almost all spring and seep samples taken from Tumon Bay. Values exceeded the Guam Environmental Protection Agency water quality standard of 25 µg/l for category M-1 (excellent) marine waters (GEPA, 2001) in only 6% of the total number analyzed. Levels in the nine major springs entering Tumon Bay ranged from 14.0-25.4 µg/l (geometric mean: 17.0 µg/l). Two adjacent springs had significantly higher RP levels than the other springs monitored (Fig. 2) and clearly represent aquifer source waters that are chemically different from those feeding other major springs along the beach. It is noteworthy that *E. clathrata* was especially abundant in this region of the bay (see Plate 1).

Compared with spring water, RP levels in seeps were considerably more variable in both space and time, with levels ranging from 1.3-31.9 µg/l (geometric mean: 14.1 µg/l). Such variability did not correlate with salinity fluctuations (Fig. 3) and may reflect losses as a result of biotic uptake in the slower moving pore waters, on the one hand, coupled with redox mediated releases of iron bound P from oxygen depleted beach sediments, on the other. Episodic nutrient inputs associated with landscaping activities along the waterfront may also be a contributing factor, since excess irrigation water moving through the shallow soil profile is more likely to show up on the beach as seepage rather than as a fast flowing spring. It is worth noting here that runoff from the hotels fronting Tumon Bay is not discharged into storm drains or storm sewers, but permeates slowly into the intertidal zone, via an underground network of infiltration chambers.

NO_3-N levels in the springs and seeps from Tumon Bay are presented in Fig. 4. Levels in spring samples ranged from 1.54-3.24 mg/l (geometric mean: 2.16. mg/l) while those in seeps were far more variable and ranged from <0.001-7.9 mg/l (geometric mean: 1.23 mg/l). A scatter plot of the data against salinity revealed a highly significant negative correlation between the two variables and is indicative of conservative mixing in the transition zone (Fig. 5). Once again NO_3-N accounted for almost all of DIN in the great majority of the samples analyzed. Detectable levels of NO_2-N were encountered in 33% of the spring samples (1.3-9.0 µg/l) and 74% of the seeps (0.9-414 µg/l), while NH_4-N was detected in 15% and 41% of spring (3.5-10.0 µg/l) and seep samples (1.1-387 µg/l) respectively. The higher incidence of reduced nitrogen species in beach seeps is redox related and reflects generally lower levels of dissolved oxygen in beach sediment pore waters compared with emergent spring water.

Dissolved SiO_2 levels in Tumon Bay seeps and springs ranged from 0.42-3.78 mg/l (geometric mean: 1.36 mg/l) and were generally lower than those encountered in Agana Bay. This would suggest that groundwater flowing into each comes from subbasins within the aquifer that are geochemically quite distinct from one another. Certainly, groundwater sitting directly on top of basement rock (parabasal groundwater), as opposed to saltwater (basal groundwater), will be relatively enriched in Si derived from the dissolution of secondary volcaniclastic silicates. Since clays are an important source of Si to the aquifer, the nature and depth of the overlying soil is an important consideration here. Hence, the relatively low SiO_2 levels in beach seeps (0.28-0.56 mg/l) from thin soiled terrain to the north of Tumon Bay (Matson 1991) are to be expected.

The obvious sinusoidal shape of the SiO_2 data set when plotted against site (space) along the beach was thought to be an artifact of sampling associated with tidal changes over time (Fig. 6). Although simple linear correlation analysis failed to identify any significant relationship between SiO_2 and Cl (Fig. 7), polynomial regression analysis of the spatial plots yielded lines of similar shape for each data set (Figs. 8 a and b). This strongly suggests the two variables are somehow related to one another in a positive fashion. Given that Si levels in seawater from Tumon Bay are appreciably lower than those found in emergent groundwater (Matson 1991), this relationship cannot be rationalized in simple conservative terms in the same way as it can for NO_3-N (Figs. 8 b and c). A more likely explanation is that low salinity sediment pore waters are enriched with Si from the dissolution of clays and various siliceous biogenic components (e.g., diatoms, radiolaria, sea urchin and sponge spicules, etc.) during low tide and flushed out of the sediments as brackish seeps on a rising tide.

<u>GWA Production Wells</u>:
RP levels in the 96 GWA drinking water production wells sampled are presented graphically in Fig. 9 and ranged from 6.7-38.5 µg/l (geometric mean: 13.4 µg/l). Guam soils are generally P depleted and so the naturally low levels of RP in the aquifer largely reflect contributions from the dissolution of relatively insoluble apatites in the limestone plateau (Matson 1991). Only five wells yielded RP values in excess of 25 µg/l and only one scored above 35.0 µg/l. Four of these wells are located in the *Yigo-Tumon Trough*, a natural valley formed by the basement volcanics to the northeast of Tumon Bay (Jenson *et al.*, 1997). It is noteworthy that much of the groundwater entering the bay comes from this particular subbasin. The geometric mean RP level for the 50 wells sampled within this region was 13.1 µg/l compared with 13.9 µg/l for all remaining wells analyzed island wide. Frequency distribution histograms of all well and beach

data sets are plotted together in Fig. 10. It can be seen that the measure of central tendency of the latter is somewhat displaced to the right suggesting the aquifer may not be the only source of RP into the bay.

NO_3-N accounted for >99% of DIN in all well waters analyzed with concentrations ranging from 0.79-5.78 mg/l (geometric mean: 2.36 mg/l) (Fig. 11). NH_4-N was detected in 35% of the samples at a concentration range of 1.7-30.7 µg/l and was probably desorbed from surface soils around the wellheads. NO_2-N was consistently below an analytical detection limit of 0.7 µg/l. Matson (1991) reported average NO_3-N levels in aquifer water of 1.6 µg/l rising to a maximum of 6.3 µg/l, which is not too far removed from the findings of this study. In earlier works he demonstrates that the nitrate enrichment is the result of the oxidation of organic N and NH_4^+ in soil overlying the carbonate plateau (Matson 1987) and that levels in the aquifer change rapidly in response to rainfall events (Matson 1989).

The combined frequency distribution histograms for NO_3-N in well and beach data sets are presented in Fig. 12. In this particular instance, the measure of central tendency in the seep and spring data is marginally displaced to the left of that for the wells as a result of the seawater dilution effect. The salinity of well waters rarely exceeded $1^0/_{00}$ and averaged 0.07 $^0/_{00}$ in contrast to averages of 3.0 $^0/_{00}$ and 4.8 $^0/_{00}$ in spring and seeps respectively. In fact, 18% of all seep samples had salinities greater than 10 $^0/_{00}$.

SiO_2 concentrations in GWA well water from the Agana subbasin were appreciably higher and more variable than those found in samples from the other three subbasins (Fig. 13). This presumably reflects topographical differences in the underlying bedrock, which rises close to the surface along the southwestern edge of this subbasin and generates a relatively high proportion of parabasal groundwater. The overlying limestone is also very different in this area; referred to as detrital or 'argillaceous' limestone, it is clay-rich. Groundwater flowing seaward from the Agana subbasin into Agana Bay would thus account for the relatively high SiO_2 concentration in spring and seeps at this location compared with Tumon Bay. Wells within the Yigo-Tumon subbasin yielded SiO_2 values of 0.56-3.44 mg/l (geometric mean: 1.32 mg/l), very similar to the range (and mean) found in Tumon Bay seeps and springs. Clearly, little if any groundwater from the Agana subbasin makes its way into Tumon Bay. It is noteworthy that Matson (1991) also noted distinct subbasin differences in the Si content of Guam's groundwater.

Frequency distribution histograms of the SiO_2 data sets for Tumon Bay seeps and springs and all well samples, other than those from the Agana subbasin, are plotted together in Fig. 14. Both histograms, though marginally skewed to the right, had identical modes. The closely similar measures of central tendency indicate no appreciable net losses or gains of Si during the movement of groundwater from the aquifer into Tumon Bay.

Tumon Bay Surf Zone and Nearshore Waters:
The analysis of seawater from Tumon Bay showed that emergent groundwater is rapidly diluted and dispersed at the surf zone. Plots of salinity against nutrient concentrations (Fig. 15) indicate that both RP and NO_3-N behave conservatively in the mixing zone, affected only by the physical process of dilution with seawater. Although there are numerous subtidal springs in Tumon Bay, dilution is essentially complete within ~50 m of the shoreline where RP and DIN concentrations are predominantly <3 µg/l and from 100-400 µg/l respectively. Occasionally, very low levels of

RP (<0.2 µg/l) and DIN (<10 µg/l) were recorded in this region. Such samples (<5%) were considered to be representative of oligotrophic oceanic waters that wash over the reef crest into the bay at high tide.

NH_4-N was detected in 10% of the surf zone samples (1.5-216 µg/l) and 4% of those taken further offshore (1.5-29.7 µg/l). Occurrences were most frequently coincident with obvious algal decomposition in nearby sediments. NO_2-N levels were consistently below the limits of analytical detection. Although Si was not recorded in Tumon Bay nearshore waters during the present study, earlier work by Matson (1991) puts levels at 28-476 µg/l, considerably lower than the majority of those found here in intruding groundwater (range: 196-1,760 µg/l; geometric mean: 467 µg/l as Si).

Clearly, the nutrient status of Tumon Bay is predominantly determined by groundwater discharges from the aquifer. Levels encountered in nearshore waters will therefore be highest during calm weather conditions, especially during the wet season when discharge rates are maximal. This undoubtedly explains why blooms of *Enteromorpha clathrata* are especially prolific in Tumon Bay at this time of the year.

Table 1: Nutrient Concentrations (µg/l) in Groundwater and Shallow Nearshore Waters of Northern Guam

Location	Sample Type	n	Sampling Events	Statisitic	RP	NH_4^+	NO_3^-	DIN	DIN:RP (molar ratio)	SiO_2
Agana Bay	Intertidal Seep	2	1	Range Mean	15.4 - 18.2 16.7	<1.06 -	2071 - 2566 2305	2076 - 2566 2308	59 - 62 60	2709 - 3819 3216
Agana Bay	intertidal Spring	7	1	Range Mean	12.7 - 30.6 19.8	<1.06 - 23.4 nc	1335 - 4014 2520	1372 - 4014 2535	28 - 110 56	2732 - 5471 3422
Tumon Bay	Intertidal Seep	65	3	Range Mean	1.3 - 31.9 14.1	<1.06 - 387 nc	0.53 - 7942 1226	7.2 - 8357 1677	0.1 - 288 57	420-3775 1354
Tumon Bay	Intertidal Spring	9	3	Range Mean	14.0 - 25.4 17.0	<1.06 - 10.0 nc	1546 - 3241 2164	1560 - 3241 2202	36 - 94 57	753-2455 1406
Tumon Bay	Surf (mixing) Zone	10	50	Range Mean	0.17 - 13.3 2.17	<1.06 - 216 nc	7.6 - 2540 130	7.6 - 2540 235	0.8 - 248 39	- -
Tumon Bay	50 m Offshore	10	50	Range Mean	0.08 - 7.46 1.32	<1.06 - 29.7 nc	0.92 - 1325 120	0.92 - 1325 174	0.3 - 469 64	- -
Northern Guam	Production Wells	97	3	Range Mean	6.7 - 38.5 13.4	<1.06 - 30.7 nc	793 - 5779 2362	793 - 5786 2537	20 - 201 86	561-15028 1912

nc = not calculable; dashes indicate no data

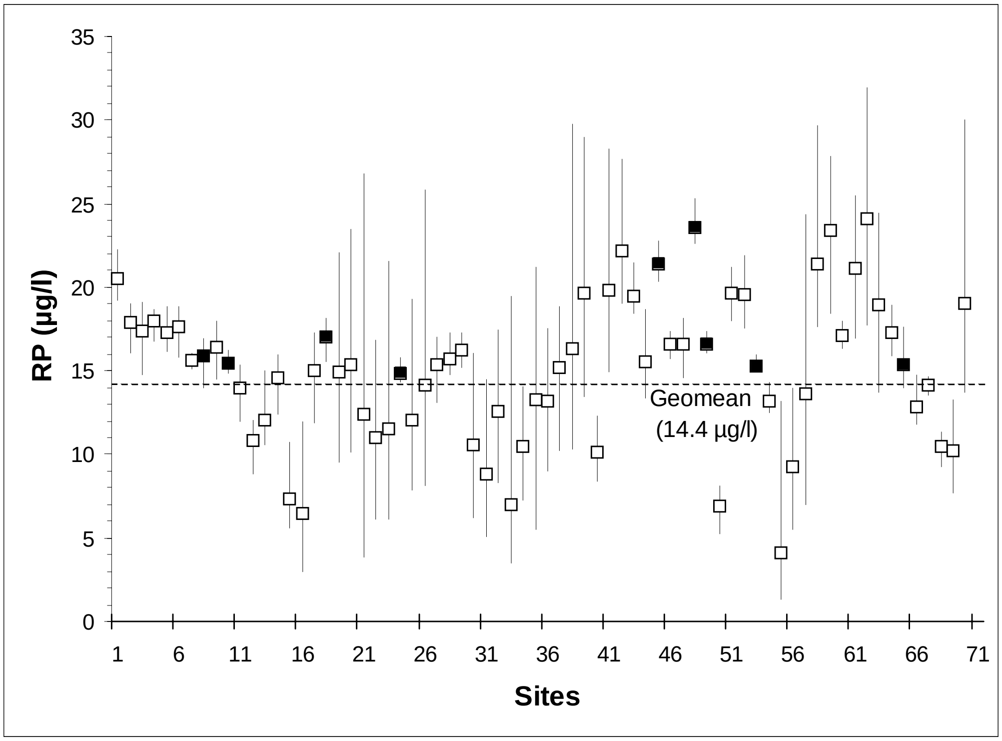

Figure 2: Geometric mean reactive P levels in spring (filled squares) and seep (open squares) samples from Tumon Bay, Guam. Vertical bars indicate range of monthly values for June-August 2000. Dashed line represents the geometric mean of all data sets.

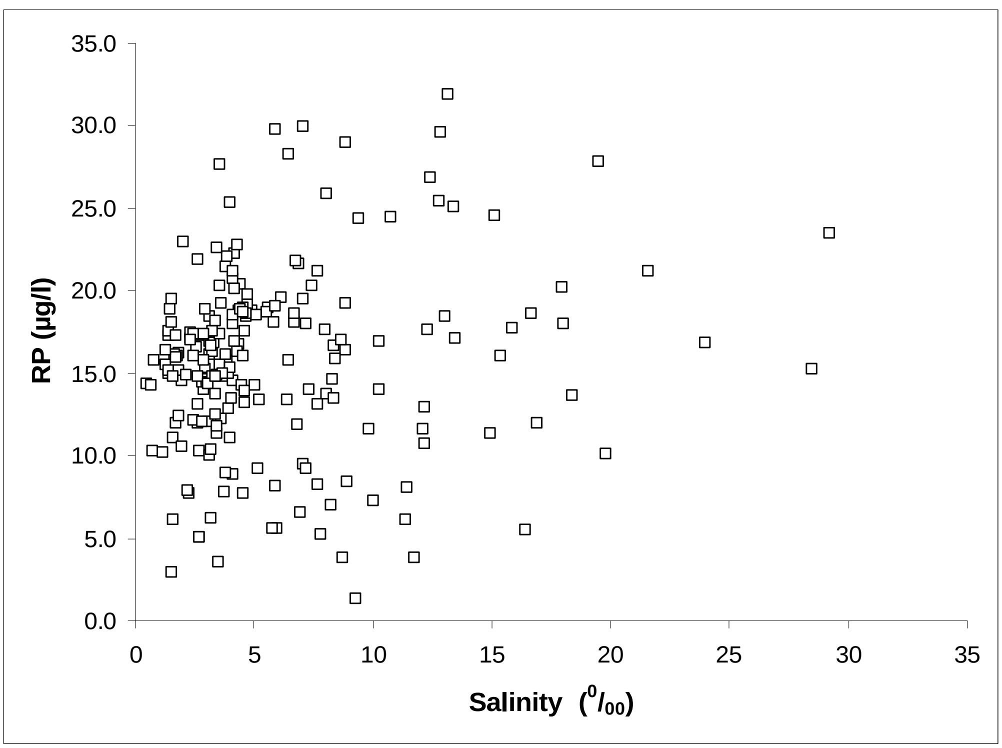

Figure 3: Reactive P concentrations in spring and seep samples from Tumon Bay plotted against salinity

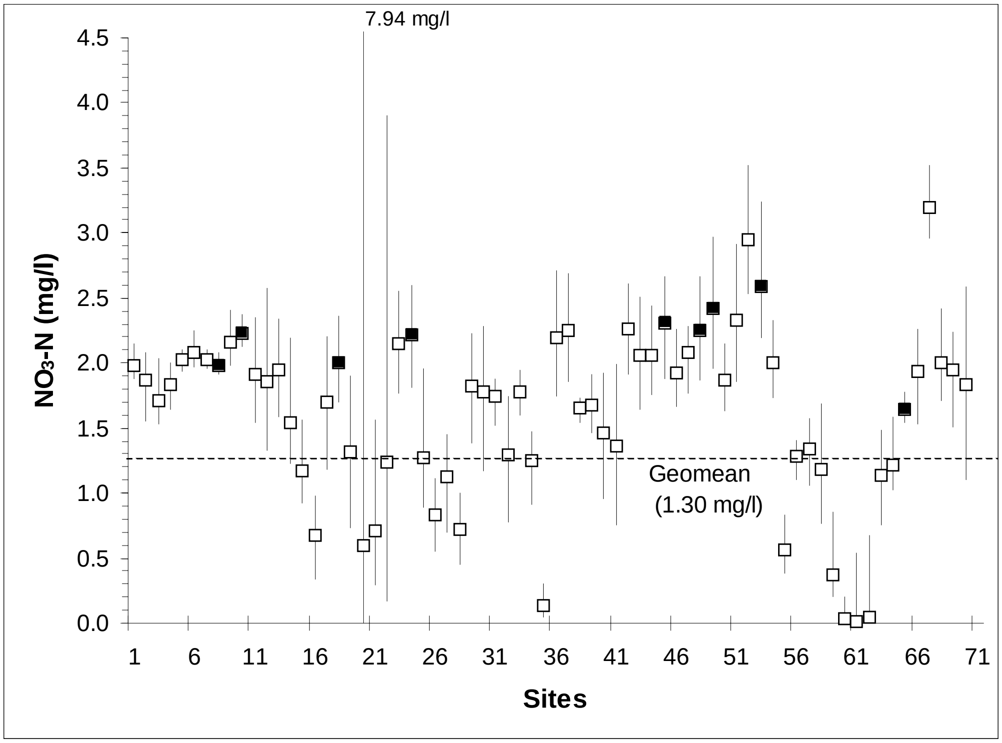

Figure 4: Geometric mean nitrate-N levels in spring (filled squares) and seep (open squares) samples from Tumon Bay, Guam. Vertical bars indicate range of monthly values for June-August 2000. Dashed line represents the geometric mean of all data sets.

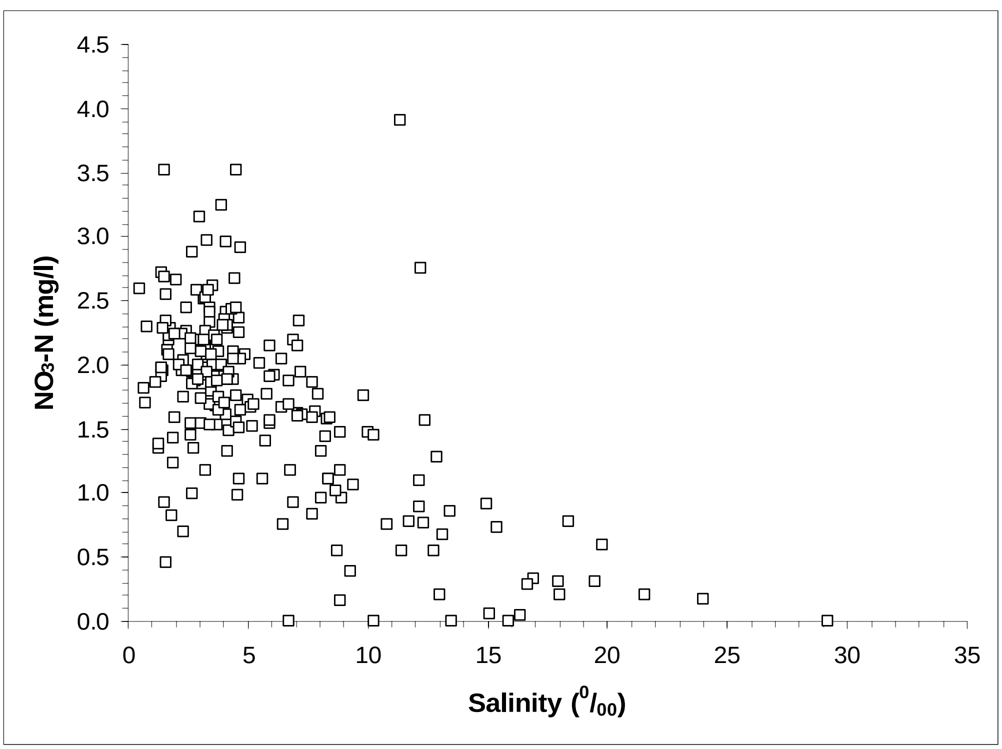

Figure 5: Nitrate-N concentrations in spring and seep samples from Tumon Bay plotted against salinity

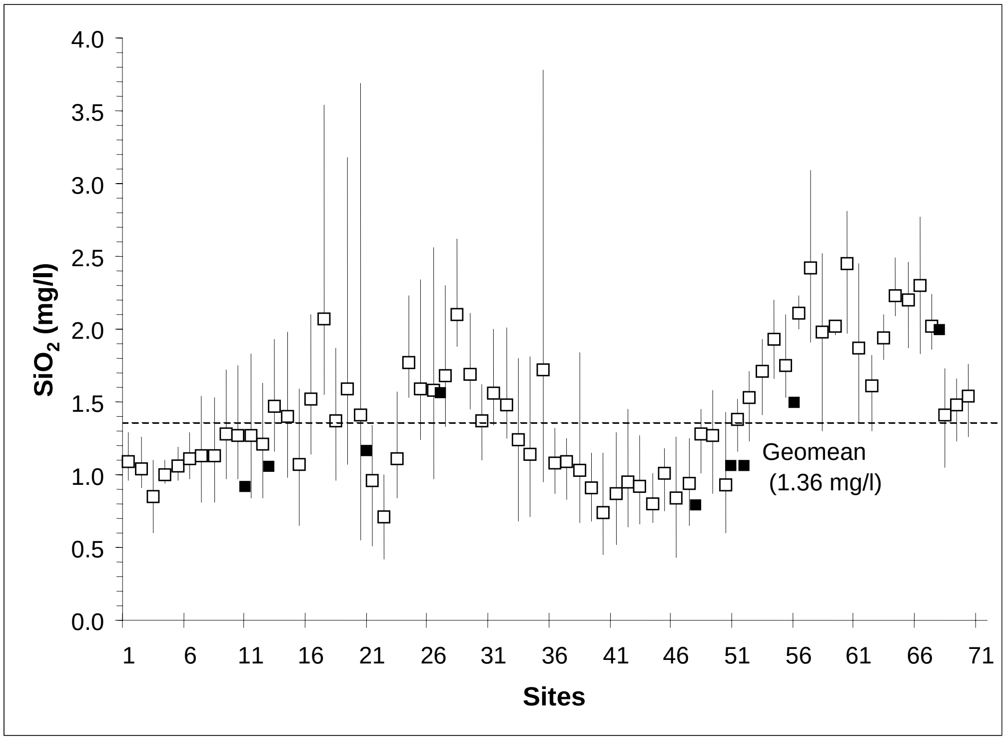

Figure 6: Geometric mean silica levels in spring (filled squares) and seep (open squares) samples from Tumon Bay, Guam. Vertical bars indicate range of monthly values for June-August 2000. Dashed line represents the geometric mean of all data sets.

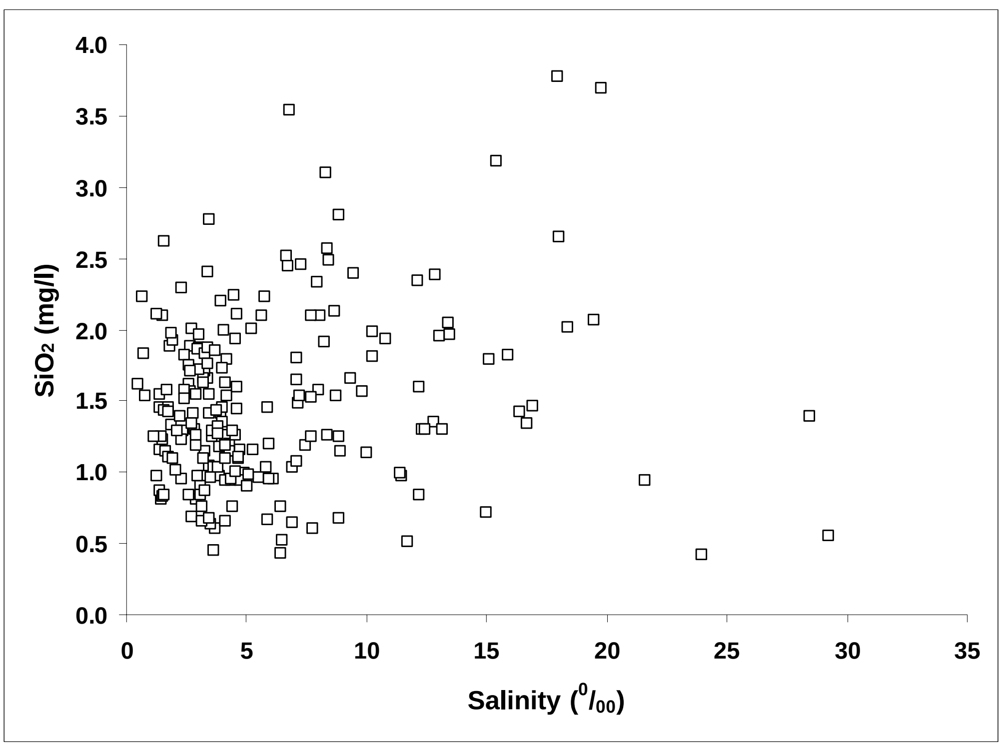

Figure 7: Silica concentrations in spring and seep samples from Tumon Bay plotted against salinity

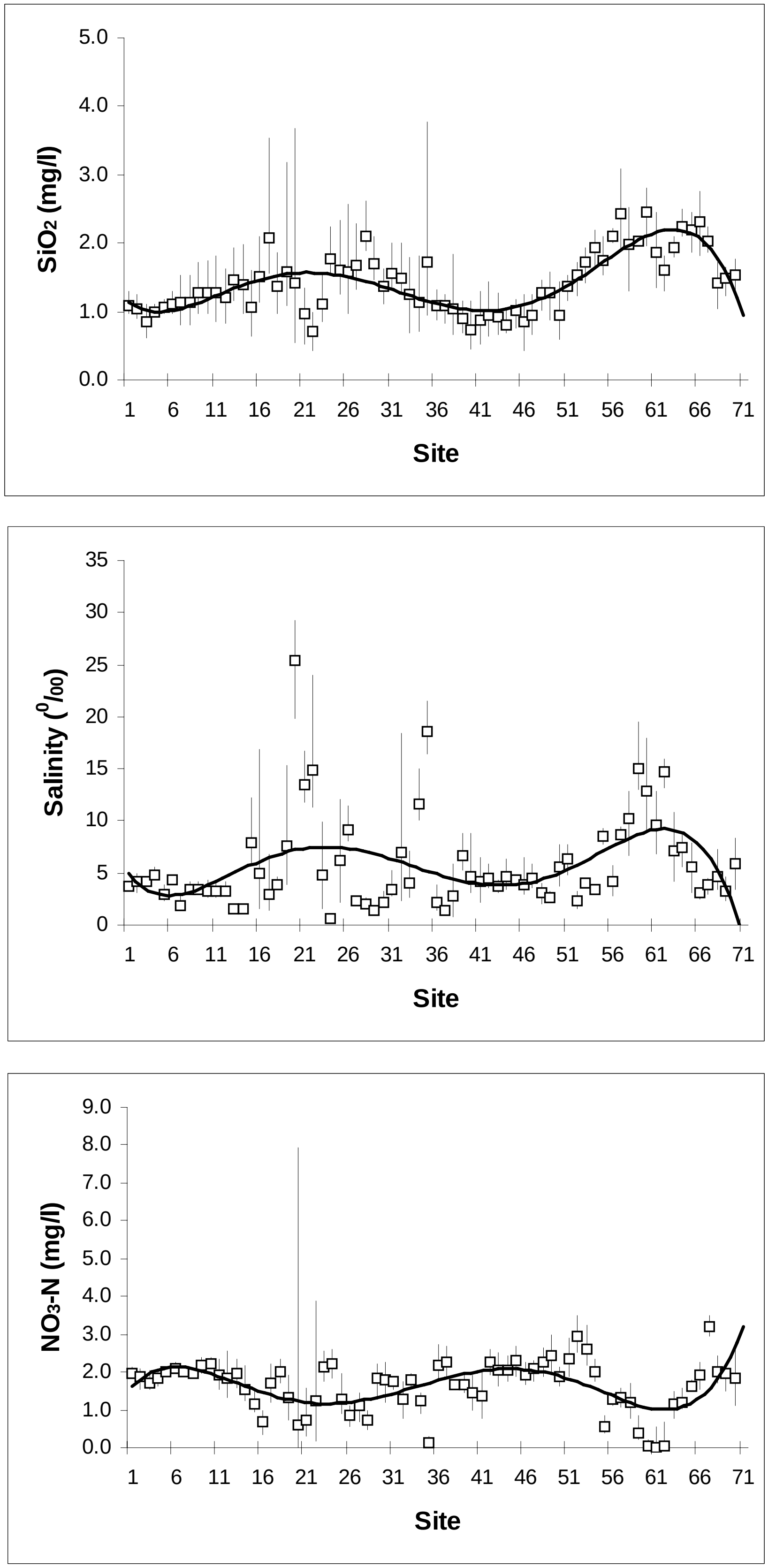

Figure 8: Polynomial regression analysis of (a) silica, (b) salinity and (c) nitrate-N against site (space)

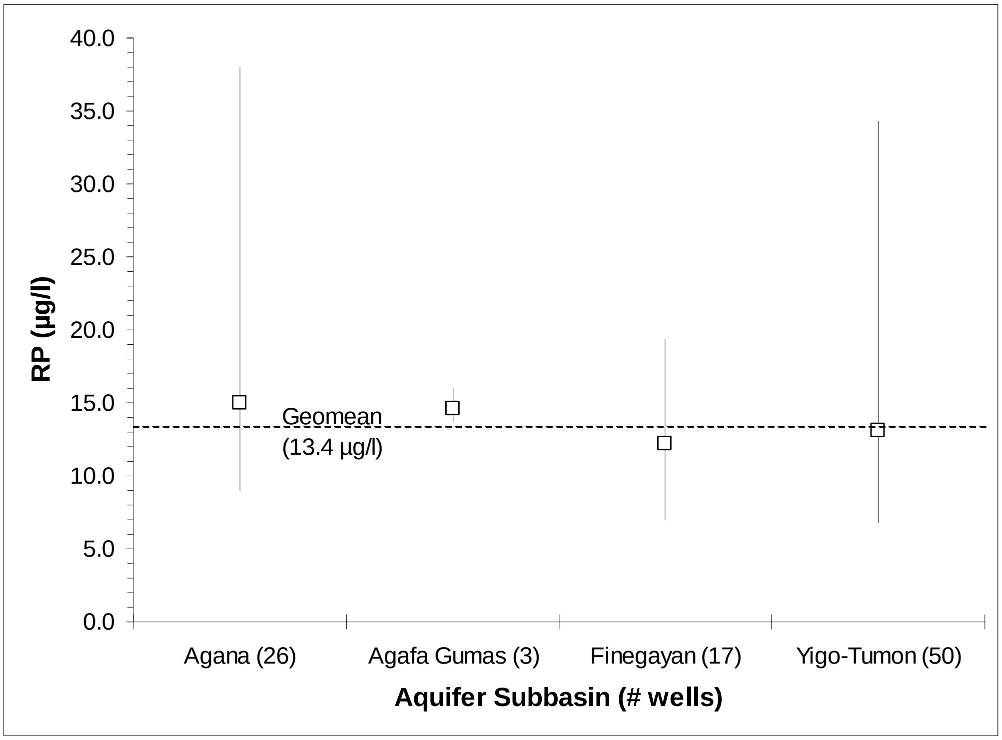

Figure 9: Geometric mean reactive P levels in drinking water production wells from four different subbasins in northern Guam. Vertical bars indicate range of values.

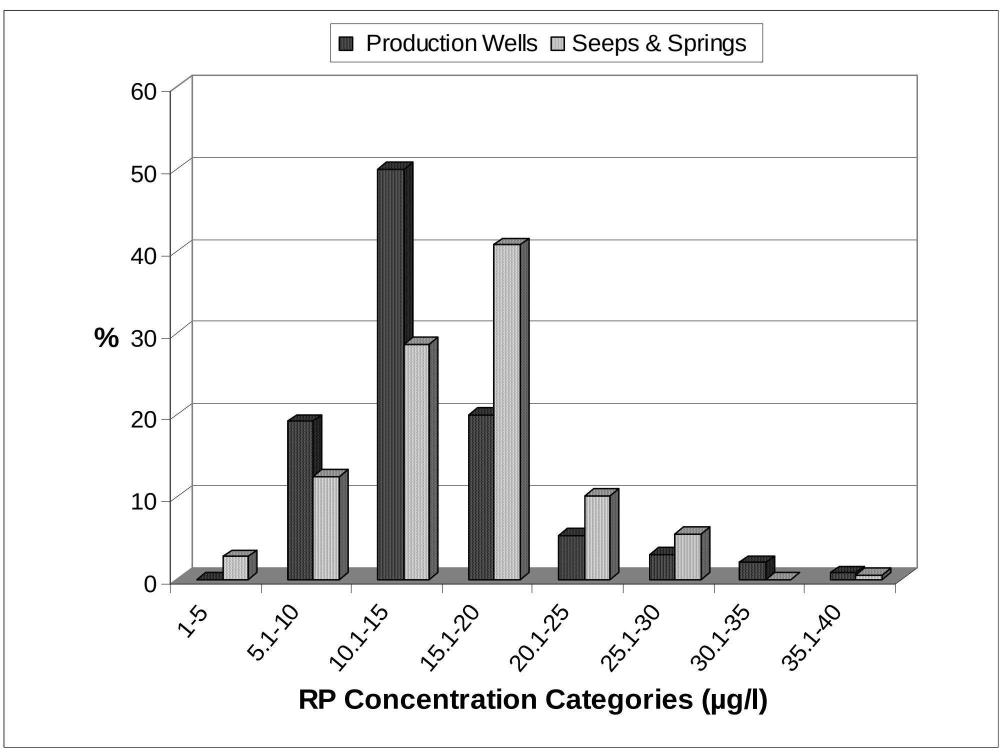

Figure 10: Histograms for reactive P in Tumon Bay seeps and springs and in GWA production wells.

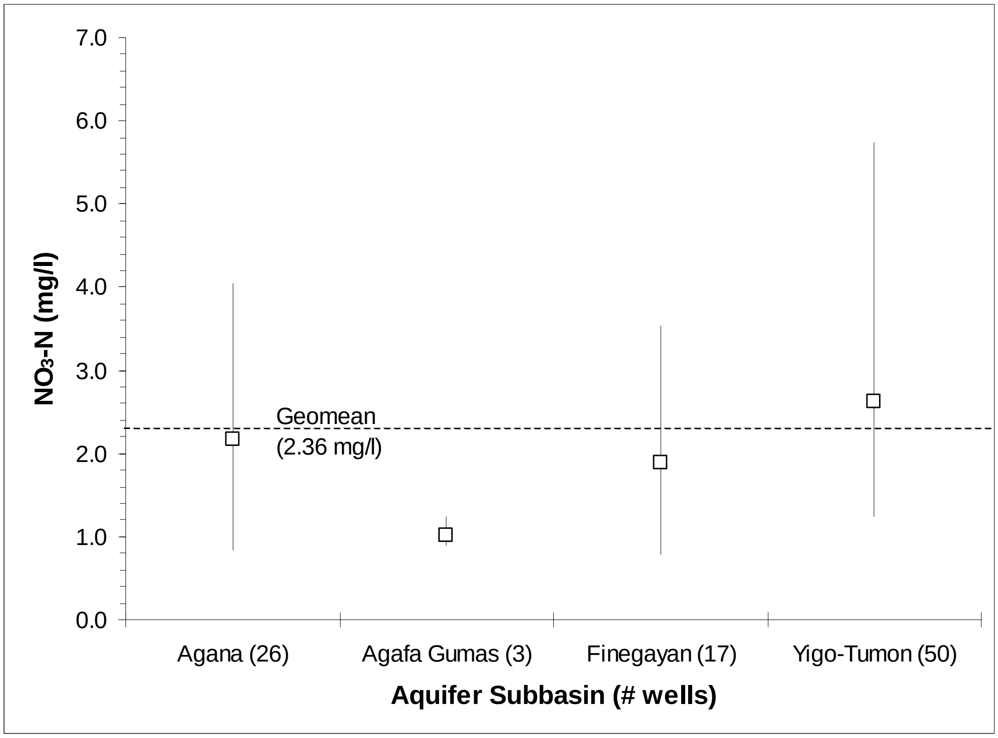

Figure 11: Geometric mean nitrate-N levels in drinking water production wells from four different subbasins in northern Guam. Vertical bars indicate range of values

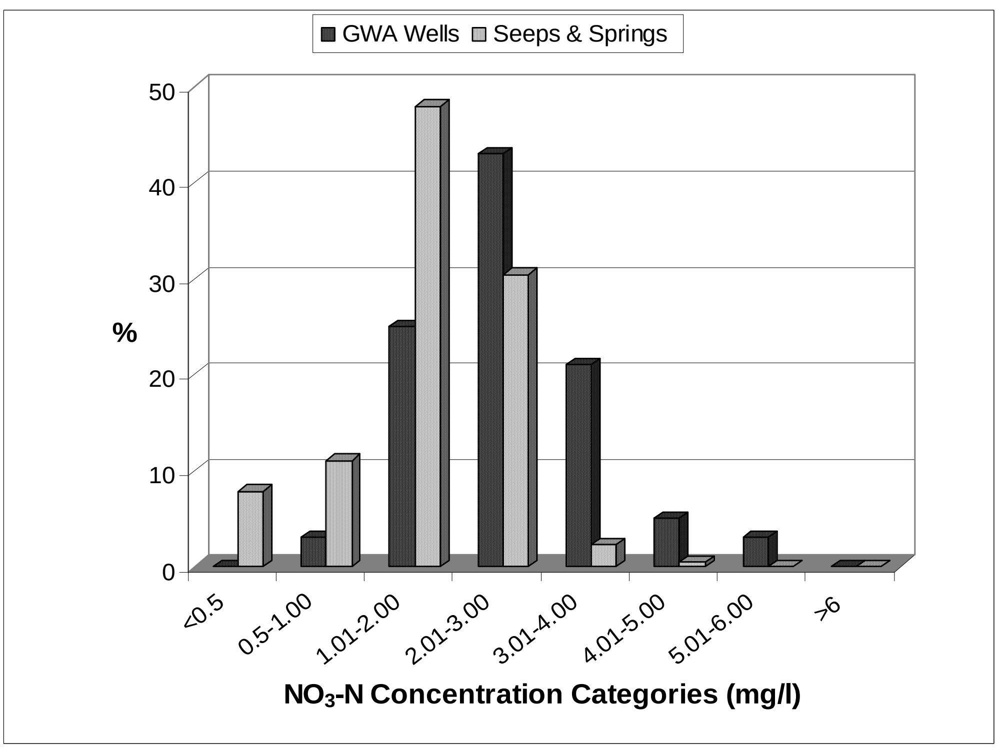

Figure 12: Histograms for nitrate-N in Tumon Bay seeps and springs and in GWA production wells.

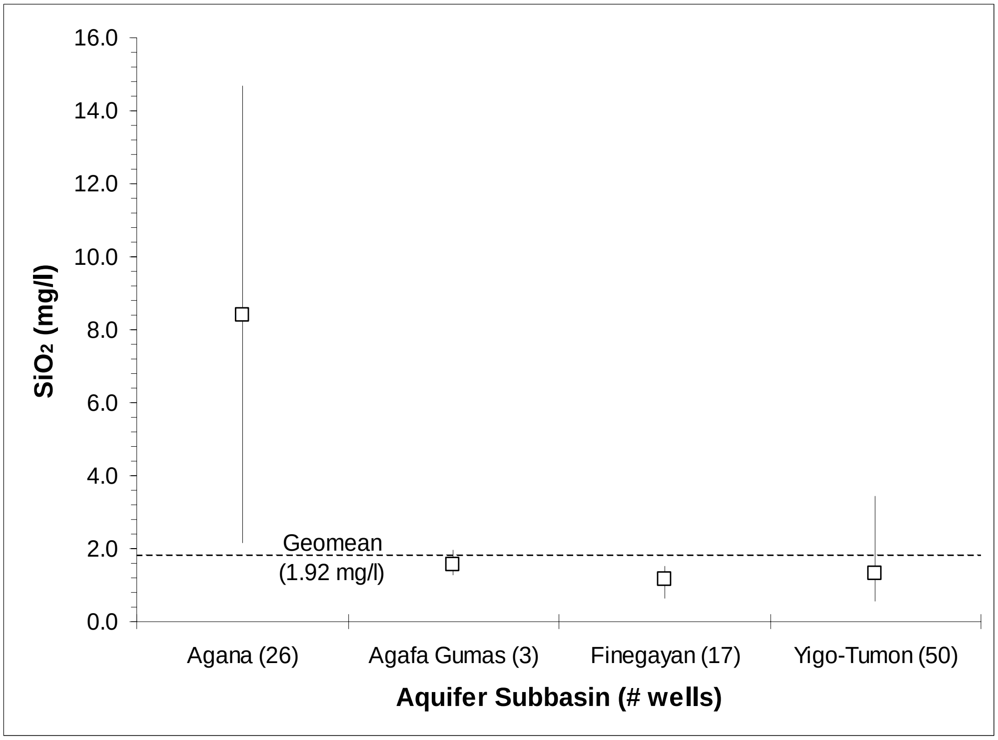

Figure 13: Geometric mean silica levels in drinking water production wells from four different subbasins in northern Guam. Vertical bars indicate range of values

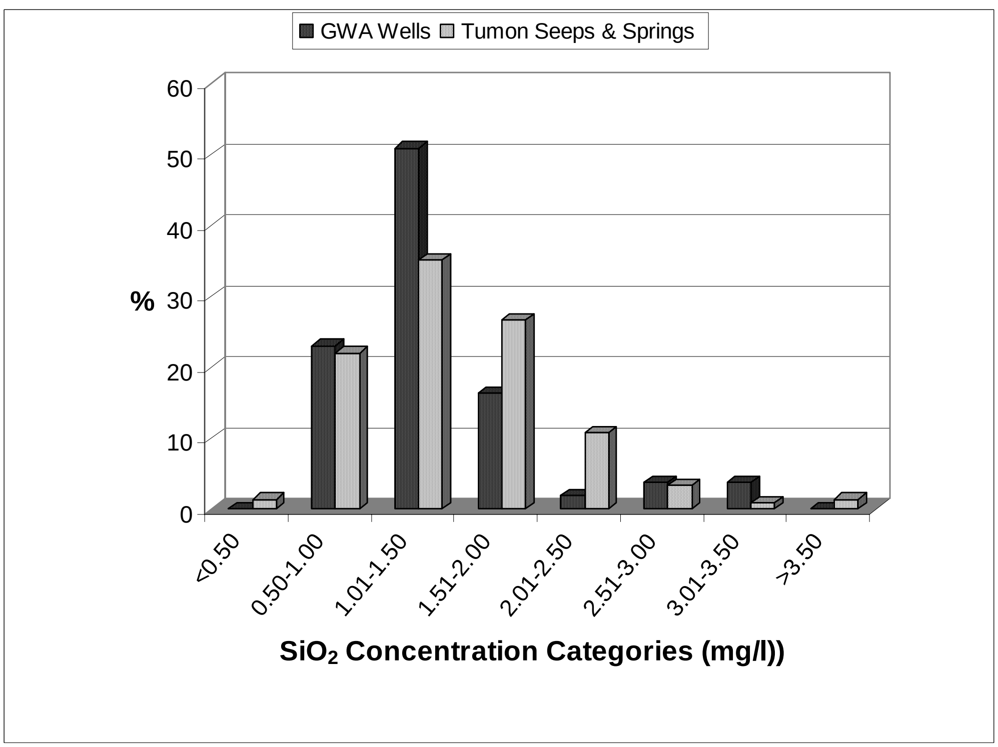

Figure 14: Frequency distribution histograms for silica in Tumon Bay seeps and springs and in Guam's drinking water production wells (excluding wells from the Agana subbasin).

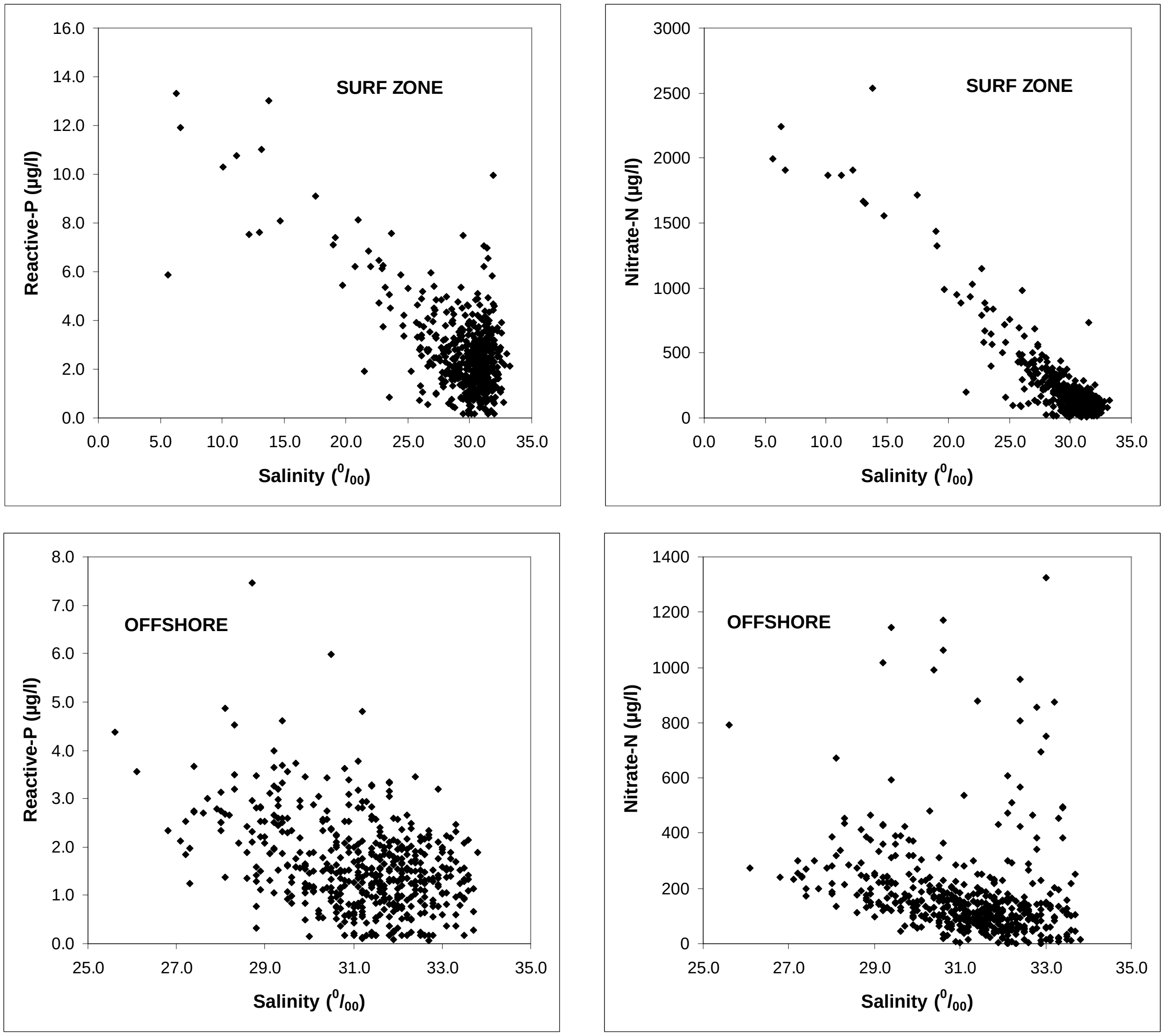

Figure 15: Daily concentrations of reactive P and nitrate-N plotted against salinity of seawater from the surf (mixing) zone and ~50 m offshore in Tumon Bay (February-May 2001)

CONCLUSIONS AND RECOMMENDATIONS

Coastal waters receiving groundwater inputs from limestone watersheds are typically DIN enriched (Matson, 1993; Lapoint, 2004). The comparatively high DIN levels found in groundwater entering Tumon Bay are, therefore, not unusual. It has been suggested from field observations that DIN threshold concentrations required to promote macroalgae blooms in coral reef waters are in the order of ~70 µg/l (Lapointe, 1997; 1999; Lapointe and Thacker, 2002). Considering that algae require N:P molar ratios of ~10:1 (Bell 1992), the corresponding threshold concentration for RP was estimated to lie somewhere between 1.5-3.0 µg/l (Lapointe, 2004). These critical values are certainly within the range of concentrations determined for each nutrient in nearshore waters of Tumon Bay during the present study. In fact, 80% of samples taken ~50 m offshore contained DIN concentrations >70 µg/l. In contrast, only 8% had RP levels in excess of 3 µg/l and 49% yielded values of less than 1.5 µg/l. Thus, while N is generally present in oversupply in this region of the bay, P levels are frequently limiting. This could explain why *E. clathrata* does not extend far beyond the intertidal zone. It also highlights the dramatic effect relatively small anthropogenic inputs of RP could have on the distribution and abundance of this species within the bay. The dense blooms of *E. clathrata* observed near the two RP enriched springs (Fig. 2) may well serve to illustrate this point.

Studies on the Australian Great Barrier Reef suggest that algae do not do particularly well in waters where RP concentrations are less than 0.1 µg/l (Furnas *et al.*, 1995). Likewise, DIN concentrations of <10 µg/l are equally limiting to algal growth (Lapointe, 2004). Based on the current study and some earlier data from Guam (Nadeau and Denton, in prep), it would appear that oceanic waters circulating the island are limiting in both nutrients. The absence of conspicuous macroalgae growth seaward of the reef crest, in Tumon Bay and elsewhere around the coast, supports this contention.

The question remains as to whether hotel landscaping activities, or other anthropogenic source of RP, have exacerbated the green algae problem in Tumon Bay in recent years. The findings presented here reveal very little overall difference between average RP concentrations in emergent seeps and springs, and levels present in the aquifer further inland. This infers nutrient contributions from waterfront sources were insignificant at the time of our study. Nevertheless, the possibility of discrete pulses of nutrient enriched waters entering the intertidal zone of the bay from adjacent landscaped areas remains, and seems highly likely, in light of current management practices that exercise little control over excessive irrigation and fertilizer applications. Past evidence tends to support this line of thinking. For example, Marsh (1977) discovered occasionally high RP concentrations (up to 388 µg/l) in runoff from the parking lots and gardens of two of the seven hotels that fronted Tumon Bay at the time of his study. Surprisingly, this researcher failed to make any connection between these data and the prolific growth of *E. clathrata* reported earlier in Tumon Bay by FitzGerald (1976). However, he did note that the Guam Environmental Protection Agency had occasionally observed similarly high levels of RP in hotel runoff, although no data was given.

More recently, Matson (1991) examined several aquifer beach seeps and springs at the northern end of Tumon Bay between two major hotels. He reported average NO_3-N levels of 1.39-1.74 mg/l, which is not unusual for Guam's groundwater. However, average RP levels ranged from

17.1-40.3 μg/l, appreciably higher than the 7-8 μg/l recorded by FitzGerald (1976) several years earlier. In a later study, Matson (1996) focused on interstitial waters from an additional six intertidal sites in Tumon Bay. This time, even higher levels of RP were measured (37.2-55.8 μg/l) whereas NO_3-N levels remained fairly typical of local groundwater discharges (0.74-4.14 mg/l).

It could be argued that the intermittent flows of drainage water from hotels are too variable to provide a reliable source of nutrients for sustained *E. clathrata* growth. However, the recent work of Schaffelke and Klumpp (1998) indicates that marine algae have the capacity to rapidly accumulate and store P in their tissues under conditions of short-term (1 h) nutrient enrichment. These nutrient stores are then used to sustain enhanced growth and net photosynthesis rates for about a week, once conditions return to normal. Clearly then, episodic nutrient inputs, associated with hotel landscaping activities, may very well play a highly significant role in maintaining the chronic algal problem that is present in Tumon Bay today.

Current US EPA doctrine dictates that RP levels in excess of 25 µg/l can promote nuisance algal growth (US EPA, 1986). Unfortunately, this threshold value is based largely on experiences in freshwater rather than the marine environment where RP is naturally less abundant. In all probability, most marine algae are better adapted to nutrient impoverished environments than their freshwater counterparts and, as such, can be induced to grow to nuisance proportions at RP levels much lower than 25 µg/l. The fact that sustained RP concentrations of 1.5-3 µg/l have been shown to initiate macroalgae blooms in coral reef waters elsewhere in the world certainly lends weight to this argument, and suggests that the current standard for Guam's cleanest marine waters (GEPA 2001) should be lower than it is today. This notwithstanding, the threshold concentration of RP necessary to induce blooms of *E. clathratus* remains to be determined and may, in fact, be higher than other marine algae given the propensity of this species for brackish water. In any event, it is clear that RP levels presently found in groundwater intruding into Tumon Bay occasionally exceed the conventional 25 µg/l benchmark (Fig. 2) and leave little room for additional contributions from fertilizers, or any other potential sources of this nutrient.

Approximately 40 million gallons of fresh water flow from the aquifer into Tumon Bay each day (Jocson, 1998). Thus, a little over 2 kg of P entering the bay from anthropogenic sources would effectively double daily inputs from the aquifer alone (assuming background RP concentrations average ~14 µg/l). Hotel managers are, therefore, advised to pay close attention to the landscaping activities that go on in their grounds in order to eliminate, or at least minimize excess fertilizer and water applications to their lawns and gardens.

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APPENDICES

Site Descriptions and Raw Data Sets

APPENDIX A

Site Descriptions and Nutrient Data Sets for Agana Bay Seeps and Springs

Agana Bay Sampling Sites - Field Notes (July 2000)

Site	Distance (m)	Description
Northern Half of Bay		
1	0	Spring fed stream: ~250 m South of Alupang Beach Tower Hotel, by public parking lot and BBQ area
2	800	Dungca's Stream: by bridge
3	850	Major Spring: Dungca's Spring
4	900	Spring : by waste bin #6
5	950	Small spring
6	1050	Seep: about 10 paces N. of waste bin # 7
7	1650	Seep: in northern corner of bay, down from concrete waste bin # 11 at the back of the Onward Hotel
8	1700	Spring: flows along landward side of rocky ridge at the base of the penninsula
9	1800	Spring: beside big fig tree at base of the penninsula by some steps

Analytes Measured in Agana Bay Seeps and Springs - July 2001

Site	Chloride (mg/l)	Salinity ($^0/_{00}$)	Total N (µg/l)	NO_3-N (µg/l)	NO_2-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Total P (µg/l)	RP (µg/l)	SiO_2 (µg/l)
1	360	0.6	2837	2442	4.50	20.2	2467	21.8	22.5	3770
2	283	0.5	1474	1335	13.6	23.4	1372	18.2	21.7	3593
3	**259**	**0.5**	**2132**	**2150**	**<1.3**	**<1.06**	**2150**	**13.8**	**16.0**	**3032**
4	208	0.4	2310	2315	<1.3	<1.06	2315	20.9	21.8	2773
5	262	0.5	3264	3170	7.53	2.92	3180	12.3	12.7	2732
6	1970	3.5	2079	2071	4.46	<1.06	2075	14.7	15.4	2709
7	612	1.1	3111	2565	<1.3	<1.06	2565	16.4	18.2	3819
8	1558	2.8	3201	3123	2.38	<1.06	3126	16.9	17.8	3231
9	1262	2.3	3927	4014	<1.3	<1.06	4014	29.3	30.6	5471

bold type indicates major (Dungca's) spring

APPENDIX B

Site Descriptions and Nutrient Data Sets for Tumon Bay Seeps and Springs

Tumon Bay Sampling Sites - Field Notes (June 2000)

Site	Distance (m)	Description
Penninsula		Separating Gun beach from Tumon Bay; moving from the point towards N. end of Tumon Bay
1	0	Spring: in 'Boonie Dog' cave in headland below Nikko Hotel (Gagna Beach)
2	51	Large seep: heavy flow, W. side of cave, 166' from 'Boonie Dog' cave, below Nikko Hotel
3	91	Major seep: in small cave; large boulder in water; water skaters in abundance
4	152	Seep: cave - fractures
5	200	Seep: W. side of recess in rock face. Last Nikko headland site before Okura beach
Beach		
6	0	Spring: at N. end of Tumon bay (Okura Beach), btwn lge bolder & seagrape tree
7	50	Spring: 164' from northern end of Tumon Bay, in front of Okura (preserve sign)
8	86	**Major spring: still in front of Okura Hotel**
9	166	no details recorded
10	180	**Major spring: in front of Westin Hotel; fast flowing, ~ 6 m across (5-10 MGD) photo taken**
11	240	Spring: in front of Westin Hotel safety information board
12	300	Small seep
13	344	Spring: Reef Hotel beach, N. end
14	396	Spring: Reef Hotel beach, S. end, down from large boulder
15	450	In front of Sails (north end of bar area)
16	496	Southern end of Sails
17	570	In front of steps of Outrigger Hotel
18	600	**Major spring (Wet Willies): Northern end of Outrigger deck**
19	654	Down from # 40 concrete trash bin; N. end of vacant lot
20	700	Small brackish seep: S. end of vacant lot next to Outrigger
21	750	Small brackish seep: down from (-->) # 39 concrete trash bin
22	800	Small (induced diffussive) brackish seep: down from Hyatt Hotel
23	850	Small beech seep: S. side of Hyatt Hotel
24	908	**Major spring: (Hyatt Spring?) Uson beach (private lot)**
25	953	Small brackish seep
26	1003	no details recorded
27	1053	Seep
28	1104	Seepy-spring: between 2 duplexes on N. end of Swavely property
29	1170	Spring: S. end of Swavely property
30	1206	Spring: down from Fujita beach bar steps between 2-3 anchor blocks. Lots of *Enteromorpha*
31	1251	Seep: in front of turquois property beside Fujita Hotel. Lots of *Enteromorpha*
32	1301	Spring: N. end of condo beside ranch style fence. Lots of *Enteromorpha*
33	1350	Small spring: 7 spaces between posts of ranch style fence, N. end by tall coconut tree. No *Enteromorpha*
34	1400	Small brackish seep: 20' E. of # 33 concrete trash bin. No *Enteromorpha*
35	1400	Very salty (induced diffusive) seep: down from Royal Palms Hotel demolition site
36	1461	Small seep: N. end of Blue Lagoon Apartments
37	1500	Seep: in front of 'Cushing Zoo' sign; middle of extensive seep field (100m)
38	1550	Seep: mildly brackish, down from concrete trash bin # 30 (Matapang beach park)
39	1600	Seep: mildly brackish down from concrete tank, 30' from N. boundary of Tropicana Hotel
40	1650	Small seep: 30' S. of totum pole at N. end of Dai-ichi Hotel (now known as the Fiesta Hotel) buildings
41	1700	Small seep: mildly brackish, 15' S. of Dai-ichi Hotel steps
42	1752	Seep: down from ~ centre of tallest Dai-ichi building (southern end of property)
43	1800	Seep down from Dai-ichi Hotel refreshment hut; S. end of 200 m seep field
44	1850	Seep: down from Seahorse Restaurant car park
45	1899	**Major spring: down from Seahorse Restaurant (in between last two windows at S. end)**
46	1962	Seep: at end of private apartments next to Seahorse Restuarant - lots of *Entero*
47	2000	Seep: 22' N. of concrete trash bin # 25 - lots of *Enteromorpha* for next 200m (gravelly substrate)
48	2051	**Major spring: down from vacant lot N. of Pacific Star; 44' N. of trash bin # 24**
49	2104	**Major spring: down from PacStar recreational sports station (PacStar spring?)**
50	2151	Spring: midway along S. wall of Pacific Star (Marriott) Hotel
51	2207	Small spring: midway around rocky outcrop separating Pacific Star Hotel from Pacific Island Club (PIC)
52	2250	Small spring: 30' S. of coral bunker
53	2299	**Major spring: 15' S. of bin # 23; N. boarder of PIC - some *Enteromorpha***
54	2348	Spring: 14' S of steps on N. side of PIC - some *Enteromorpha*
55	2406	Mildly brackish seep: down from main steps of PIC
56	2453	Small seep: down from tall PIC tower - some *Enteromorpha*
57	2503	Small FW seep; 11' S. of bin # 22 - some *Enteromorpha*
58	2549	Mildly brackish (induced diffusive) seep: dug hole in beach, 6 fence posts left of twin trees by Guma Mami
59	2599	Brackish (induced diffusive) seep: dug hole 2/3 of way down wire fence - Guma Mami S. boarder
60	2649	Mildly brackish (induced diffusive) seep: dug hole 50' N. of Ypao beach boarder
61	2699	Brackish (induced diffusive) seep: dug hole down from Tumon Bay preserve sign, N. end Ypao beach
62	2749	Salty (induced diffusive) seep: dug hole down from bin #19, Ypao Beach Park
63	2805	Small seep 18' S. of Lifeguard Station, Ypao beach
64	2849	Small seep: down from bin # 16 Ypao Beach park
65	2872	**Major spring: (Hilton Beach spring?) at N. end of rocky outcrop, N. of Hilton Hotel**
66	2904	Small spring: midway between bin 14 and 13
67	2949	Small spring: down from Pavillion "G" (Ypao Beach park)
68	2999	Small spring: down from Hilton Tower (Ypao Beach park)
69	3050	Small spring: 20' north of concrete ramp in Hilton Hotel sea wall
70	3099	Small, mildly brackish seep: 23' south of last steps in Hilton Hotel sea wall

Analytes Measured in Tumon Bay Seeps and Springs - June 2000

Site	Chloride (mg/l)	Salinity ($^0/_{00}$)	Total N (µg/l)	NO_3-N (µg/l)	NO_2-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Total P (µg/l)	RP (µg/l)	SiO_2 (µg/l)
1	2287.7	4.2	2297.6	1881.9	16.9	24.9	1923.6	18.3	22.3	956
2	1710	3.1	2106	1997	<1.3	5.5	2002.5	16.3	16.1	906
3	2043	3.7	1945	1534	<1.3	<1.1	1534.0	16.7	14.8	602
4	2417	4.4	2075	1887	<1.3	<1.1	1887.4	15.5	16.8	938
5	1271	2.3	2057	2037	<1.3	<1.1	2037.5	16.7	17.1	956
6	2148	3.9	2151	1966	<1.3	<1.1	1966.4	13.9	15.8	971
7	817	1.5	2139	1958	<1.3	<1.1	1957.6	13.8	15.1	809
8	**1593**	**2.9**	**1919**	**1909**	**<1.3**	**<1.1**	**1909.5**	**13.2**	**14.0**	**812**
9	1741	3.2	2015	1975	<1.3	**<1.1**	**1974.8**	17.8	16.9	971
10	**1629**	**3.0**	**2330**	**2190**	**<1.3**	**<1.1**	**2189.5**	**14.2**	**15.2**	**974**
11	1445	2.6	1574	1538	<1.3	<1.1	1538.3	11.5	11.9	838
12	1707	3.1	1942	1856	<1.3	<1.1	1855.8	12.3	12.0	836
13	773	1.4	2161	1978	<1.3	<1.1	1977.9	13.1	15.0	1156
14	695	1.3	1485	1345	<1.3	<1.1	1344.6	12.8	15.5	976
15	3812	6.9	988	928	57.8	6.0	991.8	5.8	6.5	647
16	2517	4.6	1144	980	7.0	40.2	1027.5	6.4	7.8	1142
17	783	1.4	2162	1903	7.1	<1.1	1910.0	13.5	17.3	1547
18	**1950**	**3.5**	**2308**	**2000**	**<1.3**	**<1.1**	**1999.9**	**12.3**	**15.6**	**961**
19	2146	3.9	1998	1906	<1.3	<1.1	1905.6	23.7	22.1	1178
20	16071	29.2	232	0.53	<1.3	387.1	387.7	23.8	23.4	548
21	6445	11.7	888	780	14.5	31.2	826.1	3.6	3.8	510
22	13187	24.0	325	174	59.2	48.6	282.1	17.5	16.9	420
23	3804	6.9	2373	2193	34.3	21.5	2249.2	23.9	21.6	1033
24	**442**	**0.8**	**2685**	**2298**	**<1.3**	**<1.1**	**2297.9**	**13.5**	**15.8**	**1531**
25	4882	8.9	1325	1178	23.1	5.6	1207.2	20.4	19.3	1243
26	6295	11.4	695	552	48.1	11.5	611.4	7.7	8.1	974
27	1029	1.9	1625	1425	18.0	10.9	1454.4	14.7	16.2	1327
28	1480	2.7	1073	998	9.7	14.5	1022.1	17.7	17.3	1879
29	766	1.4	2099	1971	<1.3	12.1	1983.3	17.7	15.2	1452
30	978	1.8	2464	2282	<1.3	<1.1	2282.0	17.3	16.1	1451
31	1543	2.8	2201	1878	5.2	<1.1	1882.7	12.0	14.5	1413
32	1288	2.3	1851	1749	<1.3	<1.1	1749.2	18.2	17.4	1291
33	1488	2.7	2226	1944	2.9	<1.1	1947.3	5.2	5.1	682
34	8226	15.0	1168	911	19.7	1.7	932.4	10.3	11.3	714
35	11864	21.6	337	205	33.0	2.2	240.6	20.9	21.2	946
36	778	1.4	2798	2715	2.5	8.6	2726.5	17.2	17.6	869
37	832	1.5	2837	2684	<1.3	3.1	2687.5	16.9	18.1	833
38	3245	5.9	2086	1537	13.1	11.9	1562.0	29.5	29.8	668
39	4881	8.9	1863	1468	20.1	30.1	1518.0	28.2	29.0	678
40	2006	3.6	2045	1679	12.4	8.1	1699.4	11.0	12.3	455
41	3554	6.5	917	750	22.7	25.4	797.9	29.7	28.3	517
42	1951	3.5	2694	2611	2.3	1.6	2615.3	29.4	27.6	636
43	1739	3.2	2532	2512	5.2	2.3	2519.7	19.6	18.5	657
44	1892	3.4	2443	2441	<1.3	3.1	2444.3	13.6	14.9	674
45	**2440**	**4.4**	**2672**	**2668**	**3.0**	**5.7**	**2676.6**	**19.2**	**20.4**	**753**
46	3539	6.4	2152	1670	1.5	2.5	1674.3	14.5	15.7	430
47	2279	4.1	2276	2282	2.2	3.3	2287.9	13.0	14.6	651
48	**1121**	**2.0**	**2654**	**2664**	**<1.3**	**3.9**	**2667.8**	**20.6**	**22.9**	**1010**
49	**1798**	**3.3**	**2888**	**2974**	**<1.3**	**<1.1**	**2974.0**	**13.0**	**16.3**	**865**
50	4287	7.8	1968	1632	9.1	6.7	1647.5	2.4	5.3	599
51	2602	4.7	2839	2915	<1.3	2.0	2916.8	15.7	19.8	1157
52	844	1.5	3500	3519	<1.3	3.8	3522.5	16.4	19.5	1230
53	**2163**	**3.9**	**3161**	**3241**	**<1.3**	**<1.1**	**3241.2**	**12.1**	**15.0**	**1408**
54	1865	3.4	2287	2334	<1.3	2.0	2335.5	8.6	12.5	1662
55	4790	8.7	726	549	9.0	7.2	564.8	0.4	3.8	1535
56	1503	2.7	1624	1352	19.8	7.0	1378.9	7.9	10.3	2001
57	4535	8.2	1699	1439	9.7	12.5	1461.6	4.0	7.0	1915
58	6783	12.3	997	770	<1.3	2.8	772.6	13.7	17.6	1299
59	7167	13.0	519	200	<1.3	3.4	203.4	21.6	18.4	1957
60	4866	8.8	311	156	<1.3	233.6	389.1	13.6	16.4	2807
61	7029	12.8	723	545	<1.3	<1.1	544.6	23.5	25.4	1355
62	7234	13.2	892	676	1.8	5.8	683.8	31.5	31.9	1296
63	2302	4.2	1765	1481	4.6	11.3	1496.6	17.0	20.1	1794
64	3090	5.6	1293	1106	<1.3	10.0	1115.6	17.1	19.0	2093
65	**1673**	**3.0**	**1842**	**1546**	**3.2**	**10.5**	**1560.0**	**12.3**	**14.7**	**1873**
66	1349	2.5	2287	2262	<1.3	4.0	2266.4	8.3	12.2	1826
67	1651	3.0	3117	3149	1.5	5.3	3156.1	10.7	14.6	1861
68	1893	3.4	2420	2414	4.4	7.8	2425.7	8.8	11.4	1048
69	1257	2.3	2509	2235	5.6	12.1	2252.3	4.9	7.7	1232
70	4606	8.4	1286	1103	15.0	72.7	1191.1	15.0	16.7	1263

Bold type indicates major springs

Analytes Measured in Tumon Bay Seeps and Springs - July 2000

Site	Chloride (mg/l)	Salinity ($^0/_{00}$)	Total N (µg/l)	NO_3-N (µg/l)	NO_2-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Total P (µg/l)	RP (µg/l)	SiO_2 (µg/l)
1	2001	3.6	2153	2145	<1.3	<1.1	2145.0	20.4	19.2	1037
2	2704	4.9	2034	2082	<1.3	<1.1	2081.9	20.8	18.8	997
3	2594	4.7	2010	2041	<1.3	<1.1	2040.8	19.9	19.1	944
4	3036	5.5	1943	2006	<1.3	<1.1	2005.6	17.8	18.7	961
5	2098	3.8	2089	2104	1.5	<1.1	2105.8	16.3	16.1	1036
6	2560	4.7	2046	2254	1.4	<1.1	2255.5	13.7	18.5	1093
7	908	1.7	2382	2108	<1.3	<1.1	2107.9	14.4	16.1	1144
8	**1818**	**3.3**	**2257**	**2084**	**<1.3**	**<1.1**	**2084.2**	**16.2**	**16.8**	**1151**
9	2265	4.1	2846	2408	<1.3	<1.1	2407.7	17.3	17.9	1262
10	**2383**	**4.3**	**2372**	**2379**	**<1.3**	**<1.1**	**2378.7**	**20.1**	**16.3**	**1201**
11	2213	4.0	2333	2356	<1.3	<1.1	2356.4	21.1	15.3	1346
12	1571	2.9	2786	2579	2.2	<1.1	2580.9	12.1	12.1	1300
13	864	1.6	2352	2336	<1.3	<1.1	2336.0	12.2	11.1	1431
14	951	1.7	2197	2194	2.6	<1.1	2196.5	17.1	16.0	1424
15	3266	5.9	1648	1563	44.9	<1.1	1607.7	5.0	5.6	1197
16	838	1.5	1460	928	17.2	<1.1	945.6	2.6	2.9	2095
17	1434	2.6	2217	2204	3.8	<1.1	2208.1	18.4	16.6	1617
18	**2545**	**4.6**	**2348**	**2363**	**1.3**	**<1.1**	**2364.4**	**22.5**	**17.6**	**1439**
19	3900	7.1	1757	1618	16.8	<1.1	1634.9	10.6	9.5	1075
20	15650	28.5	8498	7942	414	2	8357.3	16	15	1390
21	6833	12.4	1721	1567	34.9	<1.1	1602.1	48.9	26.8	1300
22	6703	12.2	3355	2758	317.7	2.4	3078.2	15.8	12.9	843
23	871	1.6	2826	2552	26.6	<1.1	2578.4	6.4	6.1	840
24	**270**	**0.5**	**2686**	**2598**	**5.8**	**<1.1**	**2603.4**	**12.0**	**14.4**	**1621**
25	1231	2.2	2076	1958	46.4	<1.1	2004.8	5.6	7.9	1393
26	4420	8.0	1147	959	73.2	18.5	1051.1	28.8	25.9	1570
27	1458	2.7	1523	1448	30.5	<1.1	1478.8	10.9	13.1	1565
28	1017	1.8	890	825	48.1	<1.1	872.8	13.5	15.2	1885
29	944	1.7	2372	2226	1.5	<1.1	2227.8	17.2	17.3	1577
30	953	1.7	2333	2083	15.2	<1.1	2097.9	8.6	12.0	1103
31	1494	2.7	2095	1845	24.2	3.4	1872.7	1.6	5.1	1336
32	4227	7.7	1737	1586	11.9	2.2	1600.5	5.5	8.3	1246
33	1918	3.5	1951	1794	15.6	<1.1	1809.5	0.5	3.5	1550
34	5504	10.0	1613	1469	7.1	<1.1	1476.6	4.6	7.3	1139
35	9017	16.4	139	40	3.9	5.6	49.7	4.9	5.5	1418
36	1075	2.0	2497	2236	2.7	<1.1	2238.8	11.3	14.5	1094
37	804	1.5	2633	2286	3.1	<1.1	2289.0	11.9	18.8	1250
38	2770	5.0	2045	1728	27.1	<1.1	1754.6	12.7	14.3	899
39	3369	6.1	2181	1917	18.2	<1.1	1934.9	17.6	19.6	951
40	1737	3.2	2192	1923	3.3	<1.1	1926.3	6.4	10.0	762
41	2817	5.1	1807	1670	11.8	<1.1	1681.8	16.9	18.5	982
42	2273	4.1	2368	2304	7.2	<1.1	2310.8	20.2	20.8	942
43	2402	4.4	2361	2104	4.4	<1.1	2108.8	17.9	18.7	951
44	3526	6.4	2302	2040	8.5	<1.1	2048.4	11.7	13.4	753
45	**2378**	**4.3**	**2434**	**2435**	**3.2**	**<1.1**	**2437.7**	**16.8**	**22.8**	**1143**
46	1766	3.2	2853	2260	2.0	<1.1	2262.1	14.1	16.6	1099
47	1969	3.6	2762	2225	1.8	<1.1	2226.8	15.2	17.4	1246
48	**2189**	**4.0**	**2829**	**2307**	**<1.3**	**<1.1**	**2306.8**	**24.2**	**25.4**	**1453**
49	**1341**	**2.4**	**3132**	**2441**	**<1.3**	**<1.1**	**2441.3**	**15.3**	**17.3**	**1577**
50	3261	5.9	2447	2144	14.0	<1.1	2158.5	8.3	8.1	952
51	3947	7.2	2889	2342	1.5	<1.1	2343.9	18.4	18.0	1483
52	1787	3.2	3499	2526	5.2	<1.1	2531.0	18.1	17.5	1711
53	**2499**	**4.5**	**3276**	**2445**	**3.1**	**<1.1**	**2447.8**	**19.5**	**16.0**	**1929**
54	2166	3.9	2249	2002	<1.3	<1.1	2002.4	10.1	12.9	2202
55	5123	9.3	492	385	22.3	2.1	408.9	0.5	1.3	1661
56	3166	5.8	1729	1402	19.7	<1.1	1421.6	5.3	5.5	2226
57	4563	8.3	1930	1577	20.2	9.8	1607.2	12.1	14.6	3095
58	7079	12.9	1412	1280	3.7	<1.1	1284.0	30.0	29.6	2387
59	10720	19.5	445	309	2.3	<1.1	311.0	28.6	27.8	2063
60	9898	18.0	160	200	23.0	26.4	249.5	20.0	18.0	2652
61	3707	6.7	449	1.2	<1.3	6.0	7.2	16.8	21.8	2449
62	8737	15.9	195	2.5	<1.3	66.7	69.2	17.8	17.7	1818
63	4439	8.1	1429	1326	15.6	1.1	1342.8	16.3	13.7	2095
64	4623	8.4	1729	1582	19.0	5.4	1606.6	12.7	15.9	2489
65	**4012**	**7.3**	**1638**	**1608**	**8.5**	**7.0**	**1623.9**	**15.2**	**14.0**	**2455**
66	1907	3.5	2154	2080	2.5	<1.1	2082.7	19.5	11.8	2768
67	2484	4.5	3393	3517	6.5	<1.1	3523.1	21.0	14.3	2238
68	3965	7.2	1889	1936	6.9	<1.1	1942.8	4.2	9.2	1537
69	1762	3.2	2211	2189	5.6	2.2	2196.3	10.7	10.4	1662
70	3900	7.1	2159	2152	23.5	7.7	2183.3	29.0	30.0	1651

Bold type indicates major springs

Analytes Measured in Tumon Bay Seeps and Springs - August 2000

Site	Chloride (mg/l)	Salinity $(^0/_{00})$	Total N (µg/l)	NO_3-N (µg/l)	NO_2-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Total P (µg/l)	RP (µg/l)	SiO_2 (µg/l)
1	1971	3.6	2271	1913	2.0	<1.1	1914.6	19.1	20.3	1293
2	2497	4.5	2127	1554	1.6	<1.1	1555.1	16.4	19.0	1260
3	2259	4.1	2151	1613	1.5	<1.1	1614.0	17.0	18.5	1097
4	2581	4.7	2066	1640	1.5	<1.1	1641.9	16.7	18.6	1103
5	1608	2.9	2292	1937	15.0	<1.1	1952.0	14.6	18.8	1187
6	2419	4.4	2396	2041	<0.9	<1.1	2041.0	16.8	18.9	1291
7	1604	2.9	2132	2002	<0.9	<1.1	2001.6	15.4	15.8	1544
8	**2304**	**4.2**	**2103**	**1938**	**<0.9**	**<1.1**	**1938.0**	**17.1**	**16.9**	**1531**
9	1666	3.0	2276	2107	<0.9	<1.1	2106.9	12.8	14.5	1717
10	**1448**	**2.6**	**2314**	**2130**	**<0.9**	**<1.1**	**2129.8**	**14.4**	**14.8**	**1752**
11	1802	3.3	2246	1943	<0.9	<1.1	1943.4	15.1	14.8	1828
12	2271	4.1	1813	1327	2.5	<1.1	1329.5	8.2	8.9	1629
13	1066	1.9	2150	1590	<0.9	<1.1	1589.9	9.3	10.6	1926
14	1031	1.9	1697	1230	12.2	<1.1	1242.0	10.2	12.4	1978
15	6691	12.2	1613	1100	27.5	2.4	1130.0	6.3	10.7	1594
16	9295	16.9	818	334	25.2	1.6	360.6	11.8	12.0	1468
17	3744	6.8	1555	1179	15.5	5.6	1199.7	11.5	11.8	3542
18	**1876**	**3.4**	**2230**	**1693**	**<0.9**	**<1.1**	**1693.4**	**17.5**	**18.2**	**1869**
19	8467	15.4	1040	731	57.8	<1.1	789.2	15.6	16.0	3182
20	10880	19.8	950	595	38.8	<1.1	633.7	9.9	10.1	3689
21	9180	16.7	471	287	45.5	<1.1	333.0	19.8	18.6	1341
22	6257	11.4	4310	3902	99.7	2.4	4004.1	5.3	6.1	997
23	5412	9.8	2399	1763	36.7	16.1	1815.4	11.0	11.6	1567
24	**374**	**0.7**	**2389**	**1813**	**<0.9**	**<1.1**	**1813.3**	**14.9**	**14.3**	**2230**
25	6676	12.1	1182	893	88.0	<1.1	980.6	5.8	11.6	2341
26	4593	8.4	1503	1109	43.7	<1.1	1153.1	15.4	13.4	2563
27	1284	2.3	939	694	33.1	<1.1	726.8	16.1	17.0	2295
28	880	1.6	646	454	39.9	<1.1	493.4	15.3	14.8	2618
29	696	1.3	1879	1385	1.4	<1.1	1385.9	16.6	16.4	2109
30	1773	3.2	1654	1176	80.6	88.5	1344.6	6.0	6.2	1623
31	2855	5.2	2007	1517	2.9	6.9	1526.5	8.3	9.2	2002
32	10106	18.4	987	773	36.1	<1.1	809.4	12.5	13.7	2015
33	3904	7.1	2182	1601	1.4	<1.1	1602.8	21.7	19.5	1801
34	5647	10.3	2016	1446	6.2	<1.1	1452.6	14.5	14.0	1807
35	9863	17.9	497	306	52.8	19.3	378.1	19.9	20.2	3778
36	2089	3.8	2668	1745	1.7	<1.1	1746.5	7.7	9.0	1321
37	628	1.1	2713	1859	2.2	<1.1	1861.2	9.3	10.2	1249
38	409	0.7	2274	1704	6.2	15.6	1725.8	10.2	10.3	1836
39	2889	5.3	2228	1687	10.7	<1.1	1698.0	12.9	13.4	1152
40	4897	8.9	1335	961	5.0	2.2	968.4	7.5	8.4	1149
41	1167	2.1	2986	1993	3.9	<1.1	1997.2	15.4	14.9	1291
42	3242	5.9	2858	1912	38.5	3.1	1953.8	17.0	19.0	1448
43	2095	3.8	2254	1641	1.6	<1.1	1642.8	18.9	21.4	1265
44	2487	4.5	2504	1755	1.8	<1.1	1756.9	19.1	18.7	1007
45	**2268**	**4.1**	**2620**	**1884**	**2.1**	**<1.1**	**1885.7**	**21.3**	**21.2**	**1184**
46	1597	2.9	2622	1890	<0.9	<1.1	1890.0	17.3	17.4	1259
47	3200	5.8	2489	1766	6.0	2.2	1774.3	19.0	18.1	1038
48	**1905**	**3.5**	**2731**	**1866**	**<0.9**	**<1.1**	**1866.1**	**23.4**	**22.6**	**1412**
49	**1350**	**2.5**	**2877**	**1953**	**<0.9**	**<1.1**	**1953.1**	**14.1**	**16.1**	**1513**
50	2055	3.7	2805	1876	3.5	<1.1	1879.7	5.7	7.8	1429
51	4229	7.7	2700	1861	<0.9	<1.1	1861.2	19.5	21.2	1523
52	1462	2.7	3586	2880	1.5	<1.1	2881.2	20.4	21.9	1712
53	**2046**	**3.7**	**3101**	**2189**	**<0.9**	**<1.1**	**2188.9**	**14.5**	**14.9**	**1847**
54	1675	3.0	2217	1731	1.0	<1.1	1731.9	15.3	14.3	1965
55	4226	7.7	1068	836	4.7	<1.1	841.2	12.3	13.1	2101
56	2552	4.6	1510	1103	9.6	10.0	1122.5	15.5	13.9	2105
57	5188	9.4	1464	1060	1.1	<1.1	1061.0	22.6	24.4	2389
58	3685	6.7	2068	1689	2.7	<1.1	1691.8	20.7	18.6	2521
59	7376	13.4	1200	859	22.8	5.0	886.4	26.6	25.1	2048
60	7418	13.5	222	0.80	<0.9	100.7	101.5	20.3	17.1	1968
61	5644	10.3	194	1.33	<0.9	82.9	84.2	17.2	16.9	1985
62	8306	15.1	232	62	11.0	19.7	93.2	24.7	24.6	1787
63	5937	10.8	1128	752	2.8	<1.1	755.0	23.9	24.5	1932
64	4777	8.7	1252	1021	3.3	<1.1	1024.3	16.3	17.0	2127
65	**4381**	**8.0**	**2147**	**1775**	**3.1**	**<1.1**	**1778.5**	**16.3**	**17.6**	**2328**
66	1877	3.4	2215	1535	1.4	<1.1	1536.3	14.5	14.8	2409
67	2236	4.1	3738	2954	3.0	<1.1	2956.8	12.9	13.5	1993
68	2202	4.0	2279	1705	3.2	<1.1	1708.5	8.5	11.0	1732
69	2551	4.6	2088	1502	5.5	<1.1	1507.5	10.9	13.2	1595
70	1859	3.4	3372	2585	8.4	6.8	2600.8	12.9	13.7	1760

Bold type indicates major springs

APPENDIX C

Nutrient Data Sets for GWA Production Wells

Analytes Measured in GWA Production Wells - June 2000 - March 2001

Subbasin	Well i.d.	Chloride (mg/l)	Salinity (0/00)	Total N (µg/l)	NO_3-N (µg/l)	NO_2-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Total P (µg/l)	RP (µg/l)	SiO_2 (µg/l)
Agafa Gumas	AG-1	36.0	0.07	nd	892	<0.68	<1.12	892	nd	16.0	1430
Agafa Gumas	AG-2A	10.9	0.02	nd	1244	<0.68	<1.12	1244	nd	14.2	1298
Agafa Gumas	HGC-2	12.2	0.02	nd	964	<0.68	<1.12	964	nd	13.7	1979
Agana	A-1	6.90	0.01	1374	1324	<0.68	<1.12	1324	16.3	12.5	14975
Agana	A-2	9.56	0.02	3482	3094	<0.68	<1.12	3094	16.1	11.3	7103
Agana	A-3	7.59	0.01	1006	833	<0.68	<1.12	833	16.8	13.0	14302
Agana	A-4	49.9	0.09	3158	2782	<0.68	<1.12	2782	13.1	15.9	7632
Agana	A-5	7.58	0.01	1823	1713	<0.68	<1.12	1713	14.9	10.6	10451
Agana	A-6	14.72	0.03	2236	2128	<0.68	<1.12	2128	16.3	12.5	9400
Agana	A-7	8.31	0.02	2669	2623	<0.68	<1.12	2623	8.34	11.2	6159
Agana	A-8	7.06	0.01	1947	1889	<0.68	<1.12	1889	8.63	11.0	6657
Agana	A-9	182	0.33	1531	1505	<0.68	<1.12	1505	22.4	25.2	11525
Agana	A-10	208	0.38	2617	2381	<0.68	<1.12	2381	21.2	22.1	8937
Agana	A-12	6.54	0.01	1460	1333	<0.68	<1.12	1333	17.4	14.2	14594
Agana	A-13	154	0.28	2081	1929	<0.68	<1.12	1929	19.4	18.5	7669
Agana	A-14	308	0.56	2290	2140	<0.68	<1.12	2140	19.5	21.1	9636
Agana	A-15	171	0.31	3835	3635	<0.68	<1.12	3635	18.2	16.8	6000
Agana	A-17	520	0.95	2833	2719	<0.68	<1.12	2719	21.6	22.1	5968
Agana	A-19	462	0.84	3305	3191	<0.68	<1.12	3191	20.5	19.6	8288
Agana	A-21	410	0.75	1910	1766	<0.68	<1.12	1766	31.3	38.0	7777
Agana	A-21	408	0.74	1983	1753	<0.68	<1.12	1753	13.5	21.7	8570
Agana	A-23	13.7	0.02	3033	2950	<0.68	<1.12	2950	15.8	10.7	8561
Agana	A-25	41.6	0.08	3318	3179	<0.68	<1.12	3179	15.4	9.0	6353
Agana	A-26	94.8	0.17	4257	4040	<0.68	<1.12	4040	8.33	10.0	4986
Agana	A-28	176	0.32	2276	2149	<0.68	<1.12	2149	14.3	16.2	7464
Agana	A-29	32.7	0.06	2216	2098	<0.68	<1.12	2098	16.1	10.9	10102
Agana	A-30	56.1	0.10	2377	2183	<0.68	<1.12	2183	9.08	10.9	10510
Agana	A-31	17.5	0.03	2560	2312	<0.68	<1.12	2312	15.9	16.5	14685
Agana	A-32	10.7	0.02	3264	2970	<0.68	<1.12	2970	14.0	12.8	13581
Agana	NAS-1	74.4	0.14	2140	1905	<0.68	<1.12	1905	13.5	17.5	2175
Finegayan	F-1	133	0.24	1732	1540	<0.68	<1.12	1540	9.89	11.5	1103
Finegayan	F-2	145	0.26	nd	1337	<0.68	<1.12	1337	nd	10.0	1432
Finegayan	F-3	109	0.20	nd	1529	<0.68	<1.12	1529	nd	10.2	1258
Finegayan	F-4	235	0.43	nd	795	<0.68	<1.12	795	nd	11.2	655
Finegayan	F-5	165	0.30	nd	2685	<0.68	<1.12	2685	10.7	12.2	959
Finegayan	F-6	409	0.74	2838	2742	<0.68	<1.12	2742	15.7	19.4	1270
Finegayan	F-7	93.0	0.17	3136	2940	<0.68	<1.12	2940	10.7	13.2	1180
Finegayan	F-8	30.3	0.06	3425	3332	<0.68	<1.12	3332	6.52	9.30	1173
Finegayan	F-9	94.5	0.17	2715	2199	<0.68	<1.12	2199	8.19	11.6	811
Finegayan	F-10	303	0.55	1790	1603	<0.68	<1.12	1603	9.19	11.8	1452
Finegayan	F-11	192	0.35	1416	1304	<0.68	<1.12	1304	9.00	12.6	1526
Finegayan	F-12	25.5	0.05	3749	3541	<0.68	<1.12	3541	10.9	12.3	1220
Finegayan	F-13	312	0.57	3399	3197	<0.68	<1.12	3197	5.02	7.0	915
Finegayan	F-15	21.3	0.04	1419	1316	<0.68	<1.12	1316	11.8	13.4	1535
Finegayan	F-16	16.9	0.03	1381	1322	<0.68	<1.12	1322	10.9	12.3	1323
Finegayan	F-17	15.2	0.03	1426	1298	<0.68	<1.12	1298	12.2	14.2	1240
Finegayan	H-1	184	0.33	2148	2044	<0.68	<1.12	2044	11.5	15.9	928
Finegayan	H-1(repeat)	22.4	0.04	2164	2364	<0.68	11.42	2375	16.1	18.0	1053
Yigo-Tumon	D-1	57.7	0.10	1929	1938	<0.68	<1.12	1938	9.75	13.6	1207
Yigo-Tumon	D-1(repeat)	42.5	0.08	2031	2046	<0.68	7.91	2054	12.1	15.1	1274
Yigo-Tumon	D2	23.3	0.04	2446	2333	<0.68	7.83	2341	12.6	13.4	1337
Yigo-Tumon	D-3	24.2	0.04	2456	2468	<0.68	<1.12	2468	6.80	10.0	1402
Yigo-Tumon	D-3(repeat)	12.5	0.02	3963	3053	<0.68	9.68	3063	9.19	12.4	1442
Yigo-Tumon	D-4	29.0	0.05	2123	2131	<0.68	<1.12	2131	8.39	11.7	1293
Yigo-Tumon	D-4(repeat)	13.1	0.02	2414	2471	<0.68	7.00	2478	11.3	13.3	1347
Yigo-Tumon	D-5	48.0	0.09	1998	2004	<0.68	<1.12	2004	5.55	7.75	809
Yigo-Tumon	D-5(repeat)	18.8	0.03	2190	2337	<0.68	9.48	2346	6.05	8.4	898
Yigo-Tumon	D-6	42.3	0.08	2222	2278	<0.68	<1.12	2278	6.35	9.70	1248
Yigo-Tumon	D-6(repeat)	27.0	0.05	2287	2424	<0.68	7.39	2431	7.48	10.0	1306
Yigo-Tumon	D-7	58.6	0.11	2115	2158	<0.68	<1.12	2158	6.35	10.1	1638
Yigo-Tumon	D-7(repeat)	16.6	0.03	2209	2469	<0.68	8.97	2477	8.88	11.4	1749
Yigo-Tumon	D-8	338	0.61	1394	1452	<0.68	<1.12	1452	7.90	9.88	933
Yigo-Tumon	D-8(repeat)	79.5	0.14	1376	1644	<0.68	9.28	1653	7.56	9.57	908
Yigo-Tumon	D-9	162	0.29	2061	2099	<0.68	<1.12	2099	6.69	10.1	1446
Yigo-Tumon	D-10	32.7	0.06	2215	2252	<0.68	<1.12	2252	7.13	10.9	1685
Yigo-Tumon	D-10(repeat)	11.9	0.02	2634	2685	<0.68	8.27	2694	9.29	12.1	1578
Yigo-Tumon	D-11	92.6	0.17	2207	2291	<0.68	<1.12	2291	6.12	9.38	1458
Yigo-Tumon	D-11(repeat)	88.1	0.16	2133	2416	<0.68	9.35	2425	8.85	11.2	1292

All repeat samples taken at different times; nd = not determined

Analytes Measured in GWA Production Wells - June 2000 - March 2001 (cont.)

Subbasin	Well i.d.	Chloride (mg/l)	Salinity $(^0/_{00})$	Total N (µg/l)	NO_3-N (µg/l)	NO_2-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Total P (µg/l)	RP (µg/l)	SiO_2 (µg/l)
Yigo-Tumon	D-12	15.9	0.03	1209	1235	<0.68	<1.12	1235	4.63	6.84	727
Yigo-Tumon	D-12(repeat)	12.0	0.02	1302	1390	<0.68	8.58	1399	6.30	7.8	748
Yigo-Tumon	D-13	573	1.04	1453	1519	<0.68	<1.12	1519	6.75	9.59	660
Yigo-Tumon	D-13(repeat)	40.7	0.07	1587	1644	<0.68	11.7	1655	7.85	10.6	562
Yigo-Tumon	D-14	69.5	0.13	2555	2621	<0.68	<1.12	2621	8.56	13.0	1595
Yigo-Tumon	D-14(repeat)	16.2	0.03	2974	3126	<0.68	11.0	3137	12.9	15.3	1813
Yigo-Tumon	D-15	19.9	0.04	2866	2920	<0.68	29.7	2950	11.1	13.5	1763
Yigo-Tumon	D-16	90.5	0.16	3069	3113	<0.68	<1.12	3113	8.94	12.3	1878
Yigo-Tumon	D-16(repeat)	20.0	0.04	3824	3492	<0.68	7.41	3500	12.6	14.1	1912
Yigo-Tumon	D-17	199	0.36	3029	3170	<0.68	<1.12	3170	19.4	27.4	1503
Yigo-Tumon	D-17(repeat)	57.7	0.10	3631	3769	<0.68	7.40	3777	31.1	34.3	1475
Yigo-Tumon	D-18	65.7	0.12	3017	3188	<0.68	7.63	3196	12.5	15.3	1349
Yigo-Tumon	D-19	64.2	0.12	1948	2082	<0.68	<1.12	2082	5.23	6.90	1069
Yigo-Tumon	D-19(repeat)	58.5	0.11	2070	2093	<0.68	5.00	2098	6.67	8.6	1048
Yigo-Tumon	D-20	73.9	0.13	2035	2174	<0.68	<1.12	2174	5.55	9.80	1359
Yigo-Tumon	D-20(repeat)	23.8	0.04	2475	2573	<0.68	9.57	2582	13.5	10.0	1468
Yigo-Tumon	D-21	69.3	0.13	2772	2924	<0.68	<1.12	2924	5.75	9.01	1440
Yigo-Tumon	D-21(repeat)	16.9	0.03	3384	3571	<0.68	10.1	3581	9.35	10.6	1486
Yigo-Tumon	D-24	65.3	0.12	2672	2770	<0.68	<1.12	2770	5.03	8.69	1097
Yigo-Tumon	D-(repeat)24	31.7	0.06	2857	3169	<0.68	8.47	3177	6.61	8.09	1103
Yigo-Tumon	EX-5	34.8	0.06	2183	2193	<0.68	<1.12	2193	7.99	12.9	1246
Yigo-Tumon	EX-5(repeat)	13.8	0.03	2394	2741	<0.68	7.90	2749	10.7	14.7	1419
Yigo-Tumon	EX-11	23.8	0.04	4692	4257	<0.68	<1.12	4257	10.8	11.9	1725
Yigo-Tumon	EX-11(repeat)	12.0	0.02	5190	5734	<0.68	8.32	5742	18.2	12.7	1438
Yigo-Tumon	EX-11(3)	25.1	0.05	4408	4245	<0.68	<1.12	4245	8.39	11.2	1144
Yigo-Tumon	G-501	133	0.24	nd	2663	<0.68	<1.12	2663	nd	7.73	2311
Yigo-Tumon	M-1	140	0.25	3243	3342	<0.68	<1.12	3342	8.75	10.8	1149
Yigo-Tumon	M-1(repeat)	48.5	0.09	3404	3815	<0.68	10.1	3825	10.8	12.9	1168
Yigo-Tumon	M-2	156	0.28	3105	3140	<0.68	<1.12	3140	9.48	11.2	1021
Yigo-Tumon	M-2(repeat)	17.1	0.03	3457	3839	<0.68	6.09	3845	11.6	14.2	1131
Yigo-Tumon	M-3	22.1	0.04	3740	3885	<0.68	1.95	3887	7.14	9.0	1125
Yigo-Tumon	M-3(repeat)	11.5	0.02	4203	4727	<0.68	7.69	4735	8.5	10.9	1301
Yigo-Tumon	M-4	19.0	0.03	4097	4217	<0.68	<1.12	4217	10.9	13.1	1026
Yigo-Tumon	M-4(repeat)	10.5	0.02	4932	5610	<0.68	7.92	5618	15.3	18.2	1164
Yigo-Tumon	M-5	51.4	0.09	1497	1460	<0.68	<1.12	1460	16.6	20.3	849
Yigo-Tumon	M-5(repeat)	15.2	0.03	1604	1750	<0.68	9.32	1760	22.3	25.3	954
Yigo-Tumon	M-6	181	0.33	1723	1654	<0.68	<1.12	1654	11.4	13.0	928
Yigo-Tumon	M-6(repeat)	40.5	0.07	1926	2005	<0.68	9.33	2014	14.4	17.8	974
Yigo-Tumon	M-7	11.4	0.02	2140	2360	<0.68	9.02	2369	24.5	31.6	1069
Yigo-Tumon	M-8	10.5	0.02	9646	5022	<0.68	13.0	5035	11.2	13.5	830
Yigo-Tumon	M-14	32.4	0.06	3839	3926	<0.68	<1.12	3926	20.8	25.0	1647
Yigo-Tumon	M-14(repeat)	12.0	0.02	4173	4645	<0.68	8.40	4653	28.1	29.8	1577
Yigo-Tumon	M-15(repeat)	16.1	0.03	2520	2829	<0.68	11.6	2841	17.3	20.0	957
Yigo-Tumon	M-15	74.9	0.14	2426	2430	<0.68	<1.12	2430	13.3	16.7	866
Yigo-Tumon	M-17A	79.9	0.15	2425	2417	<0.68	<1.12	2417	10.5	13.5	1049
Yigo-Tumon	M-17A(repeat)	12.5	0.02	2525	2740	<0.68	12.0	2752	14.6	17.1	978
Yigo-Tumon	M-17B	68.4	0.12	2431	2403	<0.68	<1.12	2403	10.2	12.8	900
Yigo-Tumon	M-17B(repeat)	13.7	0.02	2672	2957	<0.68	9.57	2967	14.2	16.9	1143
Yigo-Tumon	M-18	53.8	0.10	1750	1685	<0.68	<1.12	1685	10.4	13.2	983
Yigo-Tumon	M-20	61.2	0.11	nd	2092	<0.68	<1.12	2092	14.5	16.0	1136
Yigo-Tumon	M-20(repeat)	13.7	0.02	2598	2917	<0.68	8.18	2925	13.7	19.9	893
Yigo-Tumon	M-21	117	0.21	3306	3158	<0.68	<1.12	3158	14.7	18.4	1086
Yigo-Tumon	Y-1	13.6	0.02	nd	3174	<0.68	<1.12	3174	nd	16.3	2799
Yigo-Tumon	Y-12	42.5	0.08	nd	2289	<0.68	<1.12	2289	nd	10.2	1721
Yigo-Tumon	Y-15	12.8	0.02	nd	1635	<0.68	<1.12	1635	nd	24.0	1730
Yigo-Tumon	Y-2	15.4	0.03	nd	3448	<0.68	<1.12	3448	nd	17.3	3197
Yigo-Tumon	Y-3	13.3	0.02	nd	3047	<0.68	<1.12	3047	nd	18.9	2868
Yigo-Tumon	Y-4	16.4	0.03	nd	3014	<0.68	<1.12	3014	nd	16.0	2985
Yigo-Tumon	Y-5	40.0	0.07	nd	2912	<0.68	<1.12	2912	nd	12.1	2595
Yigo-Tumon	Y-6	13.4	0.02	nd	3381	<0.68	<1.12	3381	nd	13.9	3441
Yigo-Tumon	Y-7	13.3	0.02	nd	1681	<0.68	<1.12	1681	nd	14.9	3245
Yigo-Tumon	Y-9	13.3	0.02	nd	1804	<0.68	<1.12	1804	nd	19.2	3149

All repeat samples taken at different times; nd = not determined

APPENDIX D

Site Descriptions and Nutrient Data Sets for Tumon Bay Nearshore Waters

Nearshore Sampling Sites in Tumon Bay - Field Notes (February 2001)

Site	Seep/Spring	Description
Surf Zone and ~50 m offshore:		
1	Major Spring	Okura Hotel: facing steps with drinks machine to the right
2	Major Spring	Westin Hotel: facing round concrete building in middle of property with pointed skylight
3	Small Spring	Reef Hotel: facing steps up to hotel down from public information sign
4	Seep	Sails Restaurant: facing trash can #45
5	Major Spring	Outrigger Hotel. The middle coconut tree between trash can #42 and #43 was the marker used.
6	Seep	Hyatt Hotel: facing coconut tree to right of trash can #38
7	Small Spring	Fujita Hotel: facing seventh fence post of fence (from N. end) surrounding lawn
8	Seep	Fiesta Hotel (previously Dai-ichi Hotel): facing covered way between two buildings, down from tiki torch
9	Major Spring	Marriot Hotel: facing concrete walkway down to beach
10	Major Spring	Pacific Islands Club: facing public information sign posted on beach

Nutrient Data Sets for Tumon Bay Nearshore Waters

Date	Site	Location	Surf Zone					~50 m Offshore				
			Salinity ($^0/_{00}$)	RP (µg/l)	NO_3-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Salinity ($^0/_{00}$)	RP (µg/l)	NO_3-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)
21-Feb-2001	1	Okura	29.9	0.70	175	<1.25	175	30.7	0.36	163	<1.25	163
	2	Westin	31.1	0.72	160	<1.25	160	31.8	<0.34	136	<1.25	136
	3	Reef	30.0	0.98	158	<1.25	158	29.6	0.84	120	<1.25	120
	4	Sails	31.3	1.43	116	<1.25	116	31.0	0.42	92.3	<1.25	92.3
	5	Outrigger	29.9	<0.34	74.5	<1.25	74.5	31.0	0.60	68.6	<1.25	68.6
	6	Hyatt	29.2	1.64	52.3	<1.25	52.3	31.8	0.36	86.7	<1.25	86.7
	7	Fujita	31.1	1.63	138	<1.25	138	33.5	<0.34	104.3	<1.25	104
	8	Fiesta	31.2	2.22	167	<1.25	167	32.2	0.60	49.3	<1.25	49.3
	9	Marriot	31.9	1.16	52.6	<1.25	52.6	32.2	<0.34	106	<1.25	106
	10	PIC	30.0	0.51	93.9	<1.25	93.9	32.6	0.64	2.68	<1.25	2.7
22-Feb-2001	1	Okura	30.0	2.17	195	<1.25	195	31.2	1.61	169	<1.25	169
	2	Westin	28.6	1.85	209	<1.25	209	30.5	1.08	170	<1.25	170
	3	Reef	27.9	2.78	226	<1.25	226	30.4	2.74	172	<1.25	172
	4	Sails	30.2	3.40	124	<1.25	124	30.5	2.37	98.8	<1.25	98.8
	5	Outrigger	29.8	0.85	69.3	<1.25	69	29.0	2.21	95.9	<1.25	95.9
	6	Hyatt	30.5	0.86	28.7	<1.25	29	30.9	2.87	142	<1.25	142
	7	Fujita	31.0	4.03	150	<1.25	150	31.4	2.83	91.8	<1.25	91.8
	8	Fiesta	31.4	3.33	130	<1.25	130	32.1	2.35	299	<1.25	299
	9	Marriot	27.3	4.84	552	<1.25	552	29.9	3.45	320	<1.25	320
	10	PIC	28.5	3.90	379	<1.25	379	33.1	1.53	22.3	<1.25	22.3

NO_2-N levels were consistenly below an analytical detection limit of ~2 µg/l

Nutrient Data Sets for Tumon Bay Nearshore Waters (cont.)

Date	Site	Location	Surf Zone Salinity ($^0/_{00}$)	Surf Zone RP (µg/l)	Surf Zone NO_3-N (µg/l)	Surf Zone NH_4-N (µg/l)	Surf Zone DIN (µg/l)	~50 m Offshore Salinity ($^0/_{00}$)	~50 m Offshore RP (µg/l)	~50 m Offshore NO_3-N (µg/l)	~50 m Offshore NH_4-N (µg/l)	~50 m Offshore DIN (µg/l)
23-Feb-2001	1	Okura	29.5	1.30	180	<1.25	180	30.7	1.79	134	<1.25	134
	2	Westin	29.6	0.89	139	<1.25	139	30.0	1.88	140	<1.25	140
	3	Reef	29.8	1.59	121	<1.25	121	30.4	1.66	133	<1.25	133
	4	Sails	29.9	3.86	124	<1.25	124	31.3	1.45	74.2	<1.25	74.2
	5	Outrigger	30.5	1.67	67.0	<1.25	67.0	31.9	2.14	79.1	<1.25	79.1
	6	Hyatt	31.2	2.22	66.6	<1.25	66.6	31.7	1.93	68.8	<1.25	68.8
	7	Fujita	31.9	2.35	53.1	<1.25	53.1	30.8	3.63	160	<1.25	160
	8	Fiesta	31.3	2.94	159	<1.25	159	32.7	2.26	219	<1.25	219
	9	Marriot	28.1	2.90	377	<1.25	377	31.8	2.03	158	<1.25	158
	10	PIC	30.4	2.49	174	<1.25	174	33.1	1.56	12.9	<1.25	12.9
26-Feb-2001	1	Okura	27.3	1.02	342	<1.25	342	31.3	<0.34	154	<1.25	154
	2	Westin	28.8	0.42	225	13.2	238	30.0	0.15	119	<1.25	119
	3	Reef	26.0	1.31	88.6	<1.25	88.6	27.3	1.25	243	<1.25	243
	4	Sails	29.4	2.24	190	<1.25	190	28.6	1.89	178	<1.25	178
	5	Outrigger	28.6	0.47	91.7	<1.25	91.7	28.1	1.37	134	<1.25	134
	6	Hyatt	29.5	<0.34	83.5	<1.25	83.5	31.2	0.56	116	<1.25	116
	7	Fujita	30.6	0.82	120	<1.25	120	31.5	0.47	62.7	<1.25	62.7
	8	Fiesta	31.3	1.00	49.3	<1.25	49	32.2	1.36	511	<1.25	511
	9	Marriot	19.7	5.45	990	<1.25	990	27.6	2.71	299	<1.25	299
	10	PIC	29.2	1.82	232	<1.25	232	30.9	0.59	97.9	<1.25	97.9
27-Feb-2001	1	Okura	26.6	2.12	407	<1.25	407	29.4	2.32	1144	<1.25	1144
	2	Westin	5.6	5.86	1997	<1.25	1997	27.2	2.54	299	<1.25	299
	3	Reef	29.0	1.66	180	<1.25	180	30.1	1.08	156	<1.25	156
	4	Sails	30.1	1.10	112	<1.25	112	30.8	2.07	118	<1.25	118
	5	Outrigger	29.7	1.38	82.5	<1.25	82.5	28.7	2.31	248	<1.25	248
	6	Hyatt	21.5	1.92	202	<1.25	202	30.3	2.54	195	<1.25	195
	7	Fujita	30.6	1.56	162	<1.25	162	31.6	1.20	106	<1.25	106
	8	Fiesta	31.8	2.00	112	<1.25	112	30.6	2.26	1064	<1.25	1064
	9	Marriot	12.2	7.54	1909	<1.25	1909	25.6	4.38	793	<1.25	793
	10	PIC	20.7	6.23	946	<1.25	946	31.1	2.81	140	<1.25	140
28-Feb-2001	1	Okura	29.0	2.05	236	<1.25	236	30.7	1.35	161	<1.25	161
	2	Westin	29.7	1.35	176	<1.25	176	31.7	1.03	108	<1.25	108
	3	Reef	29.2	1.36	139	<1.25	139	28.8	1.42	157	<1.25	157
	4	Sails	29.9	1.55	81.1	<1.25	81.1	27.1	2.13	234	<1.25	234
	5	Outrigger	27.3	0.97	117	<1.25	117	28.8	1.58	131	<1.25	131
	6	Hyatt	28.3	0.58	124	<1.25	124	31.8	<0.34	123	<1.25	123
	7	Fujita	27.8	1.88	217	<1.25	217	30.8	0.58	113	<1.25	113
	8	Fiesta	29.7	2.00	170	<1.25	170	30.7	1.16	184	<1.25	184
	9	Marriot	27.0	2.17	303	<1.25	303	29.3	1.53	202	<1.25	202
	10	PIC	30.2	1.56	139	<1.25	139	32.3	0.53	1.47	<1.25	1.47
1-Mar-2001	1	Okura	26.1	3.42	445	<1.25	445	27.9	2.79	273	<1.25	273
	2	Westin	29.0	2.80	258	<1.25	258	28.7	2.10	294	<1.25	294
	3	Reef	26.5	2.82	367	<1.25	367	24.7	4.53	398	<1.25	398
	4	Sails	28.6	3.06	191	<1.25	191	30.3	2.57	123	<1.25	123
	5	Outrigger	29.7	1.37	88.8	<1.25	88.8	30.9	2.00	192	<1.25	192
	6	Hyatt	28.4	2.16	266	<1.25	266	32.0	1.28	153	<1.25	153
	7	Fujita	28.8	3.03	262	<1.25	262	30.7	1.52	139	<1.25	139
	8	Fiesta	29.8	2.51	183	<1.25	183	31.9	1.62	433	<1.25	433
	9	Marriot	22.7	4.71	789	<1.25	789	28.0	2.52	283	<1.25	283
	10	PIC	28.0	2.29	250	<1.25	250	32.1	1.67	1.03	<1.25	1.03
2-Mar-2001	1	Okura	23.5	0.87	403	<1.25	403	29.2	1.06	1017	<1.25	1017
	2	Westin	6.6	11.92	1905	<1.25	1905	27.2	1.84	256	<1.25	256
	3	Reef	27.8	1.42	231	<1.25	231	29.9	1.25	202	<1.25	202
	4	Sails	26.8	2.32	260	<1.25	260	29.1	1.87	150	<1.25	150
	5	Outrigger	25.9	0.74	97.9	<1.25	98	29.5	0.92	172	<1.25	172
	6	Hyatt	26.2	1.07	225	<1.25	225	30.2	0.69	133	<1.25	133
	7	Fujita	28.8	1.58	190	<1.25	190	30.6	0.96	177	<1.25	177
	8	Fiesta	28.2	1.84	240	<1.25	240	30.4	1.17	992	<1.25	992
	9	Marriot	11.2	10.78	1867	<1.25	1867	29.9	1.14	234	<1.25	234
	10	PIC	28.4	1.78	319	<1.25	319	31.2	0.75	16.0	<1.25	16.0

NO_2-N levels were consistenly below an analytical detection limit of ~2 µg/l

Nutrient Data Sets for Tumon Bay Nearshore Waters (cont.)

Date	Site	Location	Surf Zone Salinity (‰)	Surf Zone RP (µg/l)	Surf Zone NO_3-N (µg/l)	Surf Zone NH_4-N (µg/l)	Surf Zone DIN (µg/l)	~50 m Offshore Salinity (‰)	~50 m Offshore RP (µg/l)	~50 m Offshore NO_3-N (µg/l)	~50 m Offshore NH_4-N (µg/l)	~50 m Offshore DIN (µg/l)
6-Mar-2001	1	Okura	28.0	1.78	113	<1.25	113	31.0	0.83	159	<1.25	159
	2	Westin	28.2	1.96	268	<1.25	268	29.9	1.16	131	<1.25	131
	3	Reef	29.7	1.77	134	<1.25	134	30.1	1.10	60.0	<1.25	60.0
	4	Sails	30.0	0.71	43.4	<1.25	43.4	30.5	0.95	63.1	<1.25	63.1
	5	Outrigger	31.9	1.14	48.7	<1.25	48.7	30.7	0.73	29.0	<1.25	29.0
	6	Hyatt	28.9	1.80	12.9	<1.25	12.9	31.1	1.42	129	<1.25	129
	7	Fujita	30.5	2.05	150	<1.25	150	31.1	0.84	110	<1.25	110
	8	Fiesta	29.9	2.65	167	<1.25	167	31.7	0.90	241	<1.25	241
	9	Marriot	27.0	2.16	417	<1.25	417	29.4	1.86	313	<1.25	313
	10	PIC	27.9	1.26	311	<1.25	311	30.9	0.63	7.15	<1.25	7.2
7-Mar-2001	1	Okura	31.6	4.02	48.2	<1.25	48.2	31.2	2.95	46.2	<1.25	46.2
	2	Westin	31.2	4.16	42.0	<1.25	42.0	31.0	1.70	49.3	<1.25	49.3
	3	Reef	30.6	5.13	51.5	<1.25	51.5	32.1	1.46	40.5	<1.25	40.5
	4	Sails	32.2	3.59	32.8	<1.25	32.8	32.1	1.95	29.8	<1.25	29.8
	5	Outrigger	31.1	2.60	38.2	<1.25	38.2	32.0	2.10	21.6	<1.25	21.6
	6	Hyatt	31.9	9.95	17.7	<1.25	17.7	32.0	1.14	18.2	<1.25	18.2
	7	Fujita	31.5	3.19	25.8	<1.25	25.8	31.7	1.85	22.9	<1.25	22.9
	8	Fiesta	31.5	3.53	35.0	<1.25	35.0	32.1	1.36	10.2	<1.25	10.2
	9	Marriot	31.8	1.10	12.3	<1.25	12.3	32.2	1.36	7.85	<1.25	7.9
	10	PIC	31.3	2.77	7.5	<1.25	7.5	32.2	0.90	7.41	<1.25	7.4
8-Mar-2001	1	Okura	30.9	0.54	10.0	<1.25	10.0	30.8	0.44	72.6	<1.25	72.6
	2	Westin	31.1	4.01	71.9	<1.25	71.9	31.5	0.84	56.6	<1.25	56.6
	3	Reef	30.7	2.49	72.3	<1.25	72.3	30.8	2.54	64.5	<1.25	64.5
	4	Sails	31.5	3.89	61.6	<1.25	61.6	31.2	2.13	59.8	<1.25	59.8
	5	Outrigger	31.2	2.26	54.6	<1.25	54.6	31.6	1.56	34.4	<1.25	34.4
	6	Hyatt	30.7	1.26	12.1	<1.25	12.1	31.8	1.34	37.4	<1.25	37.4
	7	Fujita	31.0	3.17	44.3	<1.25	44.3	32.3	1.24	32.3	<1.25	32.3
	8	Fiesta	29.9	2.02	44.0	<1.25	44.0	32.1	0.99	54.2	<1.25	54.2
	9	Marriot	30.0	1.16	94.7	<1.25	94.7	30.6	0.75	18.6	<1.25	18.6
	10	PIC	31.1	1.42	21.3	<1.25	21.3	32.9	0.78	0.9	<1.25	0.9
9-Mar-2001	1	Okura	28.0	1.50	125	<1.25	125	28.8	0.32	176	<1.25	176
	2	Westin	29.0	2.06	190	<1.25	190	29.6	1.37	130	<1.25	130
	3	Reef	29.1	2.21	103	<1.25	103	29.2	1.96	136	<1.25	136
	4	Sails	29.4	3.37	117	<1.25	117	29.9	1.62	114	<1.25	114
	5	Outrigger	29.8	2.63	121	<1.25	121	29.7	1.77	65.5	<1.25	65.5
	6	Hyatt	29.9	3.43	14.7	<1.25	14.7	31.1	2.06	84.6	<1.25	84.6
	7	Fujita	30.9	3.21	90.5	<1.25	91	32.1	1.37	67.5	<1.25	67.5
	8	Fiesta	32.0	2.30	87.5	<1.25	88	31.4	1.55	141	<1.25	141.4
	9	Marriot	29.0	1.62	230	<1.25	230	29.9	1.05	94.10	<1.25	94.1
	10	PIC	30.9	1.33	79.0	<1.25	79.0	32.1	0.51	3.71	<1.25	3.7
12-Mar-2001	1	Okura	30.1	1.39	126	<1.25	126	30.0	1.20	153.3	<1.25	153
	2	Westin	29.5	0.76	156	<1.25	156	29.6	1.26	152.5	<1.25	152
	3	Reef	27.1	4.53	136	<1.25	136	27.4	2.74	171.1	<1.25	171
	4	Sails	30.6	4.21	112	<1.25	112	30.5	1.33	105.9	<1.25	106
	5	Outrigger	30.4	2.12	99.0	<1.25	99.0	30.5	0.88	76.7	<1.25	76.7
	6	Hyatt	29.5	1.29	70.3	<1.25	70.3	30.7	1.47	88.4	<1.25	88.4
	7	Fujita	29.4	2.88	87.4	<1.25	87.4	30.7	1.03	77.3	<1.25	77.3
	8	Fiesta	30.4	2.23	96.5	<1.25	96.5	31.8	0.81	92.6	<1.25	92.6
	9	Marriot	30.0	1.55	138	<1.25	138	29.6	1.00	46.4	<1.25	46.4
	10	PIC	28.6	1.34	19.8	<1.25	19.8	31.0	0.75	2.72	<1.25	2.7
14-Mar-2001	1	Okura	22.9	6.14	580	<1.25	580	28.2	2.66	339	<1.25	339
	2	Westin	25.7	3.94	434	<1.25	434	29.2	2.51	220	<1.25	220
	3	Reef	26.1	3.29	297	<1.25	297	26.8	2.34	241	<1.25	241
	4	Sails	28.6	2.42	145	<1.25	145	29.9	1.62	144	<1.25	144
	5	Outrigger	24.7	4.21	163	<1.25	163	29.2	1.98	120	<1.25	120
	6	Hyatt	28.5	1.58	134	<1.25	134	28.4	2.08	285	<1.25	285
	7	Fujita	27.0	3.96	375	<1.25	375	31.5	1.81	89.1	<1.25	89.1
	8	Fiesta	30.4	1.77	123	<1.25	123	30.6	1.64	1171	<1.25	1171
	9	Marriot	6.3	13.34	2238	<1.25	2238	28.1	2.68	321	<1.25	321
	10	PIC	26.7	2.82	335	<1.25	335	31.1	1.48	38.6	<1.25	38.6

NO_2-N levels were consistenly below an analytical detection limit of ~2 µg/l

Nutrient Data Sets for Tumon Bay Nearshore Waters (cont.)

Date	Site	Location	Surf Zone Salinity ($^0/_{00}$)	Surf Zone RP (µg/l)	Surf Zone NO_3-N (µg/l)	Surf Zone NH_4-N (µg/l)	Surf Zone DIN (µg/l)	~50 m Offshore Salinity ($^0/_{00}$)	~50 m Offshore RP (µg/l)	~50 m Offshore NO_3-N (µg/l)	~50 m Offshore NH_4-N (µg/l)	~50 m Offshore DIN (µg/l)
15-Mar-2001	1	Okura	26.6	4.11	405	<1.25	405	29.0	2.09	255	<1.25	255
	2	Westin	27.7	2.89	280	<1.25	280	29.8	2.18	318	<1.25	318
	3	Reef	24.4	5.89	501	<1.25	501	28.0	2.51	186	<1.25	186
	4	Sails	29.6	2.23	139	<1.25	139	31.1	1.35	138	<1.25	138
	5	Outrigger	29.3	3.67	142	<1.25	142	26.1	3.56	274	<1.25	274
	6	Hyatt	26.6	0.54	115	<1.25	115	31.1	0.78	149	<1.25	149
	7	Fujita	29.4	3.65	250	<1.25	250	31.6	1.07	134	<1.25	134
	8	Fiesta	30.9	2.70	202	<1.25	202	31.4	1.44	878	<1.25	878
	9	Marriot	13.2	11.02	1654	<1.25	1654	28.0	2.33	388	<1.25	388
	10	PIC	26.0	2.91	425	<1.25	425	32.5	0.24	14.5	<1.25	14.5
16-Mar-2001	1	Okura	28.9	2.49	278	<1.25	278	30.6	0.52	230	<1.25	230
	2	Westin	28.7	1.91	294	<1.25	294	31.9	0.26	148	<1.25	148
	3	Reef	28.8	2.38	236	<1.25	236	29.7	1.59	167	<1.25	167
	4	Sails	30.6	1.88	125	<1.25	125	31.2	0.88	110	<1.25	110
	5	Outrigger	30.0	2.64	112	<1.25	112	30.6	1.45	111	<1.25	111
	6	Hyatt	29.6	1.75	131	<1.25	131	32.3	0.77	75	<1.25	75.4
	7	Fujita	31.6	2.36	120	<1.25	120	31.5	1.29	126	<1.25	126
	8	Fiesta	27.6	2.36	164	<1.25	164	28.9	1.13	374	<1.25	374
	9	Marriot	23.0	3.74	670	<1.25	670	29.1	1.31	222	<1.25	222
	10	PIC	27.3	2.47	270	<1.25	270	31.9	0.79	4.41	<1.25	4.4
19-Mar-2001	1	Okura	29.7	3.15	250	<1.25	250	29.1	3.12	336	<1.25	336
	2	Westin	28.0	3.80	391	<1.25	391	31.1	1.91	151	<1.25	151
	3	Reef	30.7	2.26	150	<1.25	150	31.0	2.01	153	<1.25	153
	4	Sails	30.5	2.74	166	<1.25	166	29.8	2.97	172	<1.25	172
	5	Outrigger	30.6	3.66	131	<1.25	131	30.1	2.88	101	<1.25	101
	6	Hyatt	31.4	1.48	27.0	<1.25	27.0	31.6	2.33	171	<1.25	171
	7	Fujita	31.2	3.56	193	<1.25	193	32.9	1.41	106	<1.25	106
	8	Fiesta	31.8	2.34	153	<1.25	153	32.9	1.18	694	<1.25	694
	9	Marriot	19.1	7.39	1321	<1.25	1321	28.8	2.80	387	<1.25	387
	10	PIC	28.3	2.74	358	<1.25	358	33.3	0.98	19.9	<1.25	19.9
20-Mar-2001	1	Okura	30.3	3.92	232	<1.25	232	31.3	1.02	301	<1.25	301
	2	Westin	27.1	4.26	447	<1.25	447	30.1	1.16	187	<1.25	187
	3	Reef	30.5	1.64	159	<1.25	159	31.1	0.79	142	<1.25	142
	4	Sails	30.8	4.14	157	<1.25	157	32.0	1.96	116	<1.25	116
	5	Outrigger	31.4	1.83	89.4	<1.25	89.4	31.9	0.68	70.3	<1.25	70.3
	6	Hyatt	31.8	2.13	54.5	23.7	78.1	31.9	1.80	187	<1.25	187
	7	Fujita	30.7	3.15	236	<1.25	236	33.1	0.36	135	<1.25	135
	8	Fiesta	31.3	2.75	210	<1.25	210	33.0	1.04	753	<1.25	753
	9	Marriot	19.0	7.13	1438	<1.25	1438	29.2	2.65	361	<1.25	361
	10	PIC	28.9	2.52	333	<1.25	333	33.5	1.30	35.2	<1.25	35.2
21-Mar-2001	1	Okura	30.4	3.29	137	<1.25	137	30.3	1.77	240	<1.25	240
	2	Westin	28.6	3.88	309	<1.25	309	29.3	3.19	243	<1.25	243
	3	Reef	29.3	5.36	241	<1.25	241	29.2	3.65	238	<1.25	238
	4	Sails	29.8	4.63	208	<1.25	208	29.3	2.86	221	<1.25	221
	5	Outrigger	29.7	2.99	203	<1.25	203	29.3	2.98	167	<1.25	167
	6	Hyatt	29.3	3.24	83.0	22.4	105	29.4	3.69	219	<1.25	219
	7	Fujita	31.5	4.94	164	<1.25	164	31.8	3.33	161	<1.25	161
	8	Fiesta	31.3	4.15	204	<1.25	204	32.4	3.46	424	<1.25	424
	9	Marriot	25.0	5.32	760	<1.25	760	29.2	3.98	426	<1.25	426
	10	PIC	28.1	4.34	435	<1.25	435	30.2	3.04	229	<1.25	229
22-Mar-2001	1	Okura	31.6	2.92	67.1	<1.25	67.1	30.8	1.30	176	<1.25	176
	2	Westin	30.2	4.28	237	<1.25	237	31.8	3.16	134	<1.25	134
	3	Reef	31.2	3.17	151	<1.25	151	31.2	4.80	141	<1.25	141
	4	Sails	31.2	4.39	130	<1.25	130	31.4	3.27	109	<1.25	109
	5	Outrigger	32.1	2.88	79.0	<1.25	79.0	31.6	2.40	62.3	<1.25	62
	6	Hyatt	32.2	3.69	17.9	10.7	28.6	32.9	1.76	123	<1.25	123
	7	Fujita	31.8	5.83	156	<1.25	156	33.6	2.14	103	<1.25	103
	8	Fiesta	32.0	4.60	166	<1.25	166	33.3	2.47	454	<1.25	454
	9	Marriot	23.7	7.58	840	<1.25	840	28.7	7.46	415	<1.25	415
	10	PIC	28.5	4.47	384	<1.25	384	33.8	1.89	14.8	<1.25	15

NO_2-N levels were consistenly below an analytical detection limit of ~2 µg/l

Nutrient Data Sets for Tumon Bay Nearshore Waters (cont.)

Date	Site	Location	Surf Zone Salinity ($^0/_{00}$)	Surf Zone RP (µg/l)	Surf Zone NO_3-N (µg/l)	Surf Zone NH_4-N (µg/l)	Surf Zone DIN (µg/l)	~50 m Offshore Salinity ($^0/_{00}$)	~50 m Offshore RP (µg/l)	~50 m Offshore NO_3-N (µg/l)	~50 m Offshore NH_4-N (µg/l)	~50 m Offshore DIN (µg/l)
23-Mar-2001	1	Okura	31.5	3.48	85.7	<1.25	85.7	32.1	1.75	164	<1.25	164
	2	Westin	29.5	7.51	265	<1.25	265	30.4	3.44	194	<1.25	194
	3	Reef	29.6	4.21	197	<1.25	197	31.3	1.54	112	<1.25	112
	4	Sails	30.6	4.89	137	<1.25	137	31.3	2.94	95.0	<1.25	95
	5	Outrigger	30.8	3.22	92.2	<1.25	92.2	31.6	1.74	65.8	<1.25	66
	6	Hyatt	31.6	3.65	55.5	75.5	131	32.3	2.03	103	<1.25	103
	7	Fujita	31.1	7.08	136	<1.25	136	32.7	2.33	97.5	<1.25	97.5
	8	Fiesta	31.9	4.70	147	<1.25	147	32.6	2.17	288	<1.25	288
	9	Marriot	26.9	5.97	505	<1.25	505	31.8	3.05	220	<1.25	220
	10	PIC	29.0	4.75	324	<1.25	324	32.7	2.19	50.7	<1.25	50.7
9-Apr-2001	1	Okura	31.2	1.88	49.1	<1.25	49.1	30.3	1.51	187	<1.25	187
	2	Westin	30.0	3.96	201	<1.25	201	30.4	2.57	164	<1.25	164
	3	Reef	31.0	3.51	120	<1.25	120	30.6	2.01	153	15.9	168
	4	Sails	30.8	1.93	118	<1.25	118	31.2	1.76	105	<1.25	105
	5	Outrigger	31.0	1.07	65.2	<1.25	65.2	31.4	2.58	81.3	<1.25	81.3
	6	Hyatt	31.3	2.21	21.2	<1.25	21.2	32.3	2.37	93.4	<1.25	93.4
	7	Fujita	31.9	3.18	93.1	9.73	103	32.9	3.19	81.0	<1.25	81.0
	8	Fiesta	32.6	3.47	116	<1.25	116	33.2	1.54	82.7	<1.25	82.7
	9	Marriot	31.2	2.80	127	<1.25	127	33.2	1.89	96.4	<1.25	96.4
	10	PIC	31.6	3.04	148	<1.25	148	33.6	1.34	13.1	<1.25	13.1
10-Apr-2001	1	Okura	29.8	2.20	160	13.70	174	29.4	2.52	225	<1.25	225
	2	Westin	27.3	3.29	258	<1.25	258	28.9	2.81	198	<1.25	198
	3	Reef	29.0	1.97	128	<1.25	128	27.7	3.00	199	<1.25	199
	4	Sails	31.4	2.39	100	<1.25	100	31.8	1.29	57.2	<1.25	57.2
	5	Outrigger	30.2	1.26	37.0	<1.25	37.0	29.4	2.59	120	3.66	123
	6	Hyatt	29.5	1.27	38.5	14.5	53.0	31.8	1.86	84.8	<1.25	84.8
	7	Fujita	30.9	3.03	89.1	<1.25	89.1	30.9	2.16	99.9	<1.25	100
	8	Fiesta	31.6	4.35	146	15.5	162	31.9	1.70	104	<1.25	104
	9	Marriot	30.6	2.33	161	<1.25	161	31.0	<0.34	182	<1.25	182
	10	PIC	30.5	4.86	201	1.50	203	32.3	2.50	53.3	<1.25	53.3
11-Apr-2001	1	Okura	29.8	2.51	205	<1.25	205	31.4	1.98	203	<1.25	203
	2	Westin	28.7	2.04	286	12.9	299	28.8	1.28	246	10.6	256
	3	Reef	30.1	1.49	177	11.0	188	31.0	1.26	144	<1.25	144
	4	Sails	29.0	3.21	178	3.32	182	27.4	2.73	199	<1.25	199
	5	Outrigger	29.8	1.72	28.7	<1.25	28.7	28.0	3.14	180	<1.25	180
	6	Hyatt	28.0	2.51	20.8	<1.25	20.8	27.4	3.67	269	<1.25	269
	7	Fujita	31.7	2.78	138	<1.25	138	32.6	2.18	115	<1.25	115
	8	Fiesta	31.8	3.66	170	<1.25	170	32.2	2.67	293	<1.25	293
	9	Marriot	27.7	4.84	484	<1.25	484	30.5	1.93	310	<1.25	310
	10	PIC	29.5	3.64	333	<1.25	333	32.2	1.95	103	<1.25	103
12-Apr-2001	1	Okura	25.3	1.90	91.8	<1.25	92	29.8	1.89	253	<1.25	253
	2	Westin	27.2	3.37	347	<1.25	347	29.7	1.60	180	<1.25	180
	3	Reef	27.9	3.20	225	<1.25	225	28.9	2.22	150	<1.25	150
	4	Sails	30.1	2.46	76.4	<1.25	76.4	30.0	1.47	57.8	<1.25	58
	5	Outrigger	29.9	0.85	9.7	<1.25	9.7	29.9	1.65	67.9	<1.25	68
	6	Hyatt	28.5	0.77	29.6	<1.25	29.6	29.9	1.54	151	<1.25	151
	7	Fujita	30.6	2.66	142	<1.25	142	32.4	1.91	124	<1.25	124
	8	Fiesta	30.0	3.60	190	<1.25	190	31.4	1.23	201	<1.25	201
	9	Marriot	27.2	4.42	373	<1.25	373	29.0	2.53	247	<1.25	247
	10	PIC	28.7	3.27	268	<1.25	268	30.9	3.39	151	<1.25	151
16-Apr-2001	1	Okura	29.7	1.52	14.2	<1.25	14.2	31.4	3.29	253	<1.25	253
	2	Westin	28.1	4.97	357	<1.25	357	30.9	3.09	122	<1.25	122
	3	Reef	31.2	2.80	86.7	<1.25	86.7	28.3	4.52	215	<1.25	215
	4	Sails	31.3	3.27	81.4	4.27	85.7	31.4	2.64	110	<1.25	110
	5	Outrigger	31.0	2.08	88.3	<1.25	88.3	32.4	1.51	59.4	<1.25	59.4
	6	Hyatt	30.9	3.23	84.5	<1.25	84.5	31.2	2.82	171	<1.25	171
	7	Fujita	29.4	3.66	216	<1.25	216	33.3	1.69	193	<1.25	193
	8	Fiesta	28.7	4.27	340	<1.25	340	33.2	2.20	876	<1.25	876
	9	Marriot	17.5	9.12	1717	<1.25	1717	28.1	4.86	670	<1.25	670
	10	PIC	25.8	3.31	694	<1.25	694	33.0	1.05	13.9	<1.25	13.9

NO_2-N levels were consistenly below an analytical detection limit of ~2 µg/l

Nutrient Data Sets for Tumon Bay Nearshore Waters (cont.)

Date	Site	Location	Surf Zone					~50 m Offshore				
			Salinity ($^0/_{00}$)	RP (µg/l)	NO_3-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Salinity ($^0/_{00}$)	RP (µg/l)	NO_3-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)
17-Apr-2001	1	Okura	29.4	3.54	349	<1.25	349	29.7	3.73	423	<1.25	423
	2	Westin	27.3	3.42	568	<1.25	568	31.5	1.44	80.5	<1.25	80.5
	3	Reef	29.8	2.05	62.9	<1.25	63	28.6	2.43	275	<1.25	275
	4	Sails	30.6	3.51	133	6.33	139	31.6	2.23	113	<1.25	113
	5	Outrigger	30.7	2.63	126	<1.25	126	31.6	1.25	35.0	<1.25	35.0
	6	Hyatt	30.8	4.65	15.3	<1.25	15.3	31.8	3.36	223	<1.25	223
	7	Fujita	31.7	3.28	221	<1.25	221	33.1	2.24	182	<1.25	182
	8	Fiesta	31.1	6.23	288	<1.25	288	33.0	1.88	1325	<1.25	1325
	9	Marriot	13.8	13.01	2540	<1.25	2540	29.4	3.32	593	<1.25	593
	10	PIC	27.1	5.41	688	<1.25	688	33.3	2.32	8.51	<1.25	8.5
18-Apr-2001	1	Okura	30.9	2.05	76.9	14.8	91.7	30.6	2.10	187	29.7	217
	2	Westin	29.5	2.47	238.9	<1.25	239	29.5	1.62	146	<1.25	146
	3	Reef	29.8	1.64	98.0	<1.25	98.0	28.9	1.51	139	<1.25	139
	4	Sails	31.2	2.40	89.2	<1.25	89.2	30.7	1.51	59.7	<1.25	59.7
	5	Outrigger	30.1	1.29	56.2	<1.25	56.2	30.6	0.64	32.5	<1.25	32.5
	6	Hyatt	31.5	2.95	22.6	32.3	54.9	32.3	1.70	154	<1.25	154
	7	Fujita	30.3	3.81	244	<1.25	244	33.1	1.37	138	<1.25	138
	8	Fiesta	29.8	2.76	244	<1.25	244	32.1	1.53	608	<1.25	608
	9	Marriot	22.7	6.45	1148	<1.25	1148	29.5	2.30	359	<1.25	359
	10	PIC	29.2	2.00	328	<1.25	328	32.3	1.50	49.6	<1.25	49.6
19-Apr-2001	1	Okura	30.2	2.34	224	<1.25	224	30.1	1.51	304	<1.25	304
	2	Westin	29.1	2.07	376	<1.25	376	30.0	1.18	270	<1.25	270
	3	Reef	29.1	2.63	308	<1.25	308	30.8	1.50	207	<1.25	207
	4	Sails	29.9	3.04	191	<1.25	191	31.4	1.25	85.0	<1.25	85.0
	5	Outrigger	30.8	1.61	59.6	<1.25	59.6	32.0	0.73	48.4	<1.25	48.4
	6	Hyatt	31.5	1.57	55.6	87.4	143	31.8	1.50	229	<1.25	229
	7	Fujita	30.4	3.02	289	<1.25	289	32.9	2.11	228	<1.25	228
	8	Fiesta	29.7	2.95	375	9.02	384	31.1	1.61	536	<1.25	536
	9	Marriot	26.1	4.90	984	<1.25	984	30.3	2.34	482	<1.25	482
	10	PIC	26.2	5.19	628	<1.25	628	32.5	2.21	131	<1.25	131
20-Apr-2001	1	Okura	29.9	4.59	69.1	<1.25	69.1	30.7	0.89	131	<1.25	131
	2	Westin	30.1	2.73	180	<1.25	180	30.8	1.21	202	<1.25	202
	3	Reef	29.7	2.22	216	<1.25	216	30.5	1.16	165	<1.25	165
	4	Sails	30.6	2.08	111	<1.25	111	31.2	1.06	92.9	<1.25	92.9
	5	Outrigger	30.8	0.80	56.0	<1.25	56.0	31.9	0.24	46.6	<1.25	46.6
	6	Hyatt	31.5	1.65	48.7	148	197	31.9	0.10	92.8	7.30	100
	7	Fujita	31.7	2.48	120	<1.25	120	32.6	1.09	122	<1.25	122
	8	Fiesta	31.7	3.39	189	<1.25	189	33.4	1.25	382	<1.25	382
	9	Marriot	31.5	6.56	734	<1.25	734	30.6	2.23	364	<1.25	364
	10	PIC	29.2	3.41	441	<1.25	441	33.0	1.60	59.4	<1.25	59.4
23-Apr-2001	1	Okura	31.3	2.53	65.8	<1.25	65.8	31.4	1.17	103	<1.25	103
	2	Westin	31.6	3.34	99.3	<1.25	99.3	31.7	1.65	108	<1.25	108
	3	Reef	30.9	2.40	119	<1.25	119	31.6	1.14	73.9	<1.25	73.9
	4	Sails	31.5	2.10	56.7	<1.25	56.7	31.6	1.58	53.0	<1.25	53.0
	5	Outrigger	31.3	1.20	44.7	<1.25	44.7	31.8	0.95	45.6	<1.25	45.6
	6	Hyatt	31.8	1.27	52.7	10.1	62.9	32.5	1.52	44.9	<1.25	44.9
	7	Fujita	32.4	2.84	47.3	<1.25	47.3	33.7	1.14	46.6	<1.25	46.6
	8	Fiesta	32.6	3.94	86.2	34.3	120	33.2	1.39	94.0	<1.25	94.0
	9	Marriot	30.8	2.01	164	<1.25	164	32.0	1.75	119	<1.25	119
	10	PIC	-	-	-	-	-	32.9	1.23	29.7	<1.25	29.7
24-Apr-2001	1	Okura	32.2	2.52	28.9	<1.25	28.9	32.5	0.63	42.1	<1.25	42.1
	2	Westin	32.4	2.50	43.3	<1.25	43.3	32.8	0.85	56.2	<1.25	56.2
	3	Reef	32.2	1.25	77.1	<1.25	77.1	31.6	1.07	81.4	<1.25	81.4
	4	Sails	31.9	1.49	57.5	<1.25	57.5	31.4	0.97	67.2	<1.25	67.2
	5	Outrigger	32.0	0.59	41.4	<1.25	41.4	32.3	0.23	45.9	<1.25	45.9
	6	Hyatt	31.2	1.33	39.0	<1.25	39.0	32.0	0.33	58.3	<1.25	58.3
	7	Fujita	32.6	2.31	69.0	<1.25	69.0	33.1	1.06	59.9	<1.25	59.9
	8	Fiesta	33.0	2.65	77.9	<1.25	77.9	33.5	1.57	129	<1.25	129
	9	Marriot	31.4	3.64	218	<1.25	218	32.5	1.67	150	<1.25	150
	10	PIC	31.2	3.78	207	<1.25	207	31.7	2.19	124	<1.25	124

NO_2-N levels were consistenly below an analytical detection limit of ~2 µg/l; dashes indicate no data

Nutrient Data Sets for Tumon Bay Nearshore Waters (cont.)

Date	Site	Location	Surf Zone Salinity ($^0/_{00}$)	Surf Zone RP (µg/l)	Surf Zone NO_3-N (µg/l)	Surf Zone NH_4-N (µg/l)	Surf Zone DIN (µg/l)	~50 m Offshore Salinity ($^0/_{00}$)	~50 m Offshore RP (µg/l)	~50 m Offshore NO_3-N (µg/l)	~50 m Offshore NH_4-N (µg/l)	~50 m Offshore DIN (µg/l)
25-Apr-2001	1	Okura	32.2	2.68	65.2	<1.25	65	31.6	1.81	98.9	<1.25	99
	2	Westin	32.5	2.91	70.6	<1.25	71	32.6	1.30	108	<1.25	108
	3	Reef	31.1	3.02	140	<1.25	140	31.2	1.37	78.4	<1.25	78.4
	4	Sails	31.3	1.74	33.3	<1.25	33.3	31.4	1.21	66.7	<1.25	66.7
	5	Outrigger	31.5	1.57	68.5	<1.25	68.5	32.1	1.34	67.2	<1.25	67.2
	6	Hyatt	30.8	2.81	32.9	35.8	68.6	31.6	1.54	105	<1.25	105
	7	Fujita	31.9	3.60	117	<1.25	117	32.1	2.00	86.7	<1.25	86.7
	8	Fiesta	32.4	2.77	104	<1.25	104	33.2	1.75	203	<1.25	203
	9	Marriot	29.4	4.53	358	<1.25	358	32.0	2.57	229	<1.25	229
	10	PIC	29.9	3.85	318	<1.25	318	32.4	1.75	138	<1.25	138
26-Apr-2001	1	Okura	32.0	1.38	126	<1.25	126	32.5	2.13	168	<1.25	168
	2	Westin	30.9	1.95	223	<1.25	223	31.3	1.06	181	<1.25	181
	3	Reef	30.7	3.76	194	<1.25	194	31.7	1.21	124	<1.25	124
	4	Sails	31.8	1.95	98.5	<1.25	98.5	32.7	1.32	91.3	<1.25	91.3
	5	Outrigger	32.7	0.65	89.5	<1.25	89.5	32.6	1.47	86.5	<1.25	86
	6	Hyatt	31.2	1.44	84.7	<1.25	84.7	32.9	0.78	148	<1.25	148
	7	Fujita	32.1	1.80	171	<1.25	171	33.7	0.67	106	<1.25	106
	8	Fiesta	33.2	2.12	135	<1.25	135	33.5	0.95	159	<1.25	159
	9	Marriot	31.4	6.96	230	<1.25	230	32.8	1.52	141	<1.25	141
	10	PIC	32.8	2.18	129	<1.25	129	33.6	1.09	49.1	<1.25	49.1
27-Apr-2001	1	Okura	31.8	2.67	135	<1.25	135	31.5	2.09	190	<1.25	190
	2	Westin	30.6	2.91	214	<1.25	214	30.5	5.99	153	<1.25	153
	3	Reef	31.9	4.41	93.1	<1.25	93.1	31.8	2.10	128	<1.25	128
	4	Sails	31.6	1.28	98.1	<1.25	98.1	30.9	1.29	100	<1.25	100
	5	Outrigger	31.6	1.42	81.4	<1.25	81.4	30.4	1.56	106	<1.25	106
	6	Hyatt	31.9	1.26	61.7	<1.25	61.7	32.6	1.24	140	<1.25	140
	7	Fujita	31.8	2.62	166	<1.25	166	33.5	2.09	113	<1.25	113
	8	Fiesta	32.4	2.81	153	<1.25	153	33.6	1.42	218	<1.25	218
	9	Marriot	29.5	1.66	342	<1.25	342	31.8	1.54	231	<1.25	231
	10	PIC	30.3	2.58	258	<1.25	258	32.5	1.39	124	<1.25	124
30-Apr-2001	1	Okura	30.6	0.98	221	<1.25	221	31.5	0.98	253	<1.25	253
	2	Westin	27.1	2.48	333	<1.25	333	28.8	3.48	238	<1.25	238
	3	Reef	31.3	1.14	140	<1.25	140	30.1	1.19	155	<1.25	155
	4	Sails	32.2	1.86	91.3	5.11	96.4	32.0	0.80	93.2	<1.25	93.2
	5	Outrigger	31.9	0.70	69.1	<1.25	69.1	33.0	0.59	56.5	<1.25	56.5
	6	Hyatt	30.4	1.39	50.7	<1.25	50.7	32.1	1.95	154	<1.25	154
	7	Fujita	32.0	3.01	161	<1.25	161	33.4	1.01	122	<1.25	122
	8	Fiesta	32.2	2.08	159	<1.25	159	33.4	0.79	490	<1.25	490
	9	Marriot	23.0	6.25	888	<1.25	888	29.5	2.59	318	<1.25	318
	10	PIC	30.3	1.83	256	<1.25	256	32.0	1.54	159	<1.25	159
1-May-2001	1	Okura	30.3	2.43	204	16.4	220	30.5	1.51	197	<1.25	197
	2	Westin	28.5	1.73	255	<1.25	255	28.0	2.74	217	<1.25	217
	3	Reef	32.3	1.63	101	<1.25	101	31.1	1.72	124	<1.25	124
	4	Sails	31.3	1.12	56.8	4.83	61.7	30.6	2.04	98.5	12.3	111
	5	Outrigger	30.7	0.85	61.7	<1.25	61.7	32.0	1.75	123	<1.25	123
	6	Hyatt	31.2	1.88	147	65.7	213	31.6	2.04	187	<1.25	187
	7	Fujita	30.4	2.50	241	<1.25	241	32.4	1.82	138	2.39	141
	8	Fiesta	31.1	2.30	194	31.8	225	32.7	2.02	466	<1.25	466
	9	Marriot	23.2	5.38	840	86.8	927	29.2	3.25	430	0.75	431
	10	PIC	26.1	2.55	485	<1.25	485	31.5	2.57	149	<1.25	149
2-May-2001	1	Okura	30.1	1.65	182	<1.25	182	30.5	2.37	211	<1.25	211
	2	Westin	29.1	3.53	251	<1.25	251	28.7	2.97	193	<1.25	193
	3	Reef	30.9	2.59	120	<1.25	120	31.7	2.01	91.3	<1.25	91.3
	4	Sails	31.5	2.77	70.4	<1.25	70.4	31.4	1.85	65.8	<1.25	65.8
	5	Outrigger	31.4	1.46	36.0	<1.25	36.0	32.2	1.52	70.9	<1.25	70.9
	6	Hyatt	31.2	2.44	97.3	<1.25	97.3	32.2	2.16	165	<1.25	165
	7	Fujita	30.4	3.14	235	<1.25	235	32.6	1.85	110	<1.25	110
	8	Fiesta	31.0	2.84	161	<1.25	161	32.4	1.68	566	<1.25	566
	9	Marriot	22.0	6.20	1028	<1.25	1028	29.5	3.56	389	<1.25	389
	10	PIC	27.9	2.62	382	<1.25	382	31.9	2.60	126	<1.25	126

NO_2-N levels were consistenly below an analytical detection limit of ~2 µg/l

Nutrient Data Sets for Tumon Bay Nearshore Waters (cont.)

Date	Site	Location	Surf Zone					~50 m Offshore				
			Salinity ($^0/_{00}$)	RP (µg/l)	NO_3-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Salinity ($^0/_{00}$)	RP (µg/l)	NO_3-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)
3-May-2001	1	Okura	30.5	1.49	132	<1.25	132	30.7	1.13	155	<1.25	155
	2	Westin	28.6	4.01	193	<1.25	193	29.1	1.87	141	<1.25	141
	3	Reef	30.2	1.59	121	<1.25	121	28.6	1.35	112	<1.25	112
	4	Sails	31.2	0.92	84.9	<1.25	84.9	31.0	0.65	87.3	<1.25	87.3
	5	Outrigger	30.5	1.20	76.8	<1.25	76.8	31.3	0.43	91.6	<1.25	91.6
	6	Hyatt	30.1	1.48	106	20.4	126	31.5	0.55	111	<1.25	111
	7	Fujita	30.5	2.55	142	<1.25	142	32.1	2.02	149	<1.25	149
	8	Fiesta	30.5	3.04	205	<1.25	205	32.1	1.65	472	<1.25	472
	9	Marriot	21.0	8.14	884	<1.25	884	28.3	3.19	455	<1.25	455
	10	PIC	23.6	4.53	564	<1.25	564	32.4	1.20	95.5	<1.25	95.5
4-May-2001	1	Okura	30.9	3.40	125	<1.25	125	31.1	3.18	214	5.28	220
	2	Westin	28.3	2.96	283	<1.25	283	29.4	4.61	181	13.2	195
	3	Reef	29.9	1.39	141	<1.25	141	31.4	0.25	118	<1.25	118
	4	Sails	29.6	1.04	130	<1.25	130	31.2	0.60	86.9	<1.25	86.9
	5	Outrigger	30.1	<0.34	54.4	<1.25	54.4	29.9	0.50	97.3	<1.25	97.3
	6	Hyatt	31.2	0.37	121	<1.25	121	31.4	0.17	149	<1.25	149
	7	Fujita	30.4	1.91	169	<1.25	169	32.2	0.54	128	<1.25	128
	8	Fiesta	31.4	1.98	176	<1.25	176	32.6	0.79	266	<1.25	266
	9	Marriot	27.5	2.49	450	<1.25	450	30.3	1.13	211	<1.25	211
	10	PIC	29.0	1.87	209	<1.25	209	32.3	0.50	73.8	<1.25	73.8
7-May-2001	1	Okura	32.2	1.62	26.4	<1.25	26.4	32.0	0.96	43.1	<1.25	43.1
	2	Westin	31.9	3.06	56.2	<1.25	56.2	32.4	1.12	64.7	<1.25	64.7
	3	Reef	31.3	2.06	68.7	<1.25	68.7	32.0	1.29	58.0	<1.25	58.0
	4	Sails	31.0	1.69	61.7	<1.25	61.7	31.1	1.90	57.4	<1.25	57.4
	5	Outrigger	31.4	1.32	51.9	<1.25	51.9	31.2	1.26	63.4	<1.25	63.4
	6	Hyatt	31.5	1.84	75.3	<1.25	75.3	32.2	1.57	59.6	<1.25	59.6
	7	Fujita	31.4	2.97	83.2	<1.25	83.2	31.5	1.37	44.8	<1.25	44.8
	8	Fiesta	29.8	2.53	68.5	<1.25	68.5	33.0	1.95	144.4	<1.25	144
	9	Marriot	32.0	3.20	253	<1.25	253	33.0	1.99	149.3	<1.25	149
	10	PIC	30.1	2.96	180	<1.25	180	32.9	1.36	12.8	<1.25	12.8
8-May-2001	1	Okura	32.5	1.05	37.7	<1.25	37.7	32.7	0.08	54.0	<1.25	54.0
	2	Westin	30.9	2.23	74.1	<1.25	74.1	31.2	0.13	74.4	8.14	82.5
	3	Reef	31.2	0.75	80.5	<1.25	80.5	31.5	<0.34	63.6	<1.25	63.6
	4	Sails	31.4	0.70	70.1	<1.25	70.1	31.7	0.89	68.3	<1.25	68.3
	5	Outrigger	30.8	0.63	56.2	4.06	60.2	31.2	0.12	78.3	<1.25	78.3
	6	Hyatt	30.9	0.48	97.6	<1.25	97.6	31.9	0.84	95.1	<1.25	95.1
	7	Fujita	31.3	1.42	112	<1.25	112	31.8	0.55	88.6	<1.25	88.6
	8	Fiesta	31.2	1.81	137	<1.25	137	33.3	0.60	134	<1.25	134
	9	Marriot	30.3	1.54	222	<1.25	222	31.7	1.13	174	<1.25	174
	10	PIC	31.0	2.29	177	<1.25	177	33.3	0.36	20.7	<1.25	20.7
9-May-2001	1	Okura	31.4	1.39	90.5	<1.25	90.5	31.7	0.71	107	<1.25	107
	2	Westin	30.6	2.55	138	<1.25	138	31.2	0.67	79.7	<1.25	79.7
	3	Reef	30.0	1.10	61.5	<1.25	61.5	31.2	1.09	93.8	<1.25	93.8
	4	Sails	30.2	1.36	83.5	<1.25	83.5	30.5	1.57	81.6	<1.25	81.6
	5	Outrigger	32.1	0.85	65.5	<1.25	65.5	32.0	0.93	91.2	<1.25	91.2
	6	Hyatt	31.2	0.78	120	35.3	155	32.0	1.01	92.8	<1.25	92.8
	7	Fujita	31.2	2.20	119	<1.25	119	32.8	0.77	78.9	<1.25	78.9
	8	Fiesta	31.9	1.89	113	<1.25	113	33.1	0.81	128	<1.25	128
	9	Marriot	30.3	2.85	207	<1.25	207	31.9	1.32	110	<1.25	110
	10	PIC	32.3	1.79	94.5	<1.25	94.5	33.5	0.92	24.5	<1.25	24.5
10-May-2001	1	Okura	31.7	1.23	82.0	<1.25	82.0	31.6	1.23	146	<1.25	146
	2	Westin	30.0	2.02	191	<1.25	191.0	29.8	1.57	149	<1.25	149
	3	Reef	30.5	1.17	92.1	<1.25	92.1	31.1	1.19	103	<1.25	103
	4	Sails	31.1	1.27	78.4	<1.25	78.4	31.6	1.43	63.5	<1.25	63.5
	5	Outrigger	31.7	0.82	36.1	<1.25	36.1	32.3	0.96	88.7	<1.25	88.7
	6	Hyatt	31.1	1.23	127	<1.25	127	32.5	1.29	111	<1.25	111
	7	Fujita	31.0	2.16	157	<1.25	157	32.8	0.91	100.0	<1.25	100
	8	Fiesta	31.6	2.48	161	<1.25	161	32.8	1.36	384	<1.25	384
	9	Marriot	24.6	3.80	719	<1.25	719	29.6	2.33	391	<1.25	391
	10	PIC	25.9	3.85	479	<1.25	479	33.5	1.33	16.0	<1.25	16.0

NO_2-N levels were consistenly below an analytical detection limit of ~2 µg/l

Nutrient Data Sets for Tumon Bay Nearshore Waters (cont.)

Date	Site	Location	Surf Zone					~50 m Offshore				
			Salinity ($^0/_{00}$)	RP (µg/l)	NO_3-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)	Salinity ($^0/_{00}$)	RP (µg/l)	NO_3-N (µg/l)	NH_4-N (µg/l)	DIN (µg/l)
11-May-2001	1	Okura	30.4	2.11	220	<1.25	220	30.9	1.52	227	<1.25	227
	2	Westin	28.0	1.89	321	<1.25	321	29.5	1.63	217	<1.25	217
	3	Reef	28.8	2.18	227	<1.25	227	32.1	0.78	60.1	<1.25	60.1
	4	Sails	30.9	0.73	57.4	<1.25	57.4	31.6	1.28	49.4	<1.25	49.4
	5	Outrigger	30.9	0.66	18.7	<1.25	18.7	32.1	0.72	46.1	<1.25	46.1
	6	Hyatt	30.4	0.94	57.9	<1.25	57.9	31.8	1.82	168	<1.25	168
	7	Fujita	30.1	2.25	227	<1.25	227	32.5	1.13	109	<1.25	109
	8	Fiesta	31.1	2.53	180	<1.25	180	33.4	1.53	494	<1.25	494
	9	Marriot	21.8	6.86	933	<1.25	933	29.8	2.84	374	<1.25	374
	10	PIC	26.8	3.55	433	<1.25	433	32.2	1.85	93.9	<1.25	93.9
14-May-2001	1	Okura	29.9	2.29	226	3.23	229	31.1	3.77	282	<1.25	282
	2	Westin	26.6	2.71	411	156	567	27.3	1.97	242	18.3	260
	3	Reef	30.4	1.10	130	31.4	162	29.3	2.44	131	3.03	134
	4	Sails	30.1	0.76	18.6	2.75	21.3	30.8	<0.34	52.1	22.8	74.9
	5	Outrigger	30.4	<0.34	46.0	<1.25	46.0	28.9	2.54	180	2.35	182
	6	Hyatt	30.3	0.72	114	11.2	125	31.0	0.21	127	6.10	133
	7	Fujita	30.1	1.69	203	8.03	211	32.5	0.88	65.2	<1.25	65.2
	8	Fiesta	31.8	2.27	83.4	<1.25	83.4	32.8	1.29	856	1.33	858
	9	Marriot	13.0	7.60	1666	24.2	1690	28.9	2.83	466	22.0	488
	10	PIC	24.7	3.36	582	25.6	607	31.9	1.32	116	<1.25	116
15-May-2001	1	Okura	30.0	2.40	195	<1.25	195	30.9	2.53	284	<1.25	284
	2	Westin	26.3	3.74	420	<1.25	420	29.3	2.59	240	20.2	260
	3	Reef	28.8	2.80	232	<1.25	232	30.9	1.89	87.5	<1.25	87.5
	4	Sails	30.4	1.21	55.2	<1.25	55.2	31.4	1.44	66.9	<1.25	66.9
	5	Outrigger	31.0	1.25	45.3	<1.25	45.3	31.6	0.86	29.6	<1.25	29.6
	6	Hyatt	31.3	0.86	18.4	<1.25	18.4	31.5	0.54	250	<1.25	250
	7	Fujita	27.7	1.61	387	<1.25	387	30.9	0.82	165	<1.25	165
	8	Fiesta	30.0	2.19	201	5.41	207	32.4	1.29	956	<1.25	956
	9	Marriot	10.1	10.31	1868	15.6	1884	28.3	3.49	436	17.3	453
	10	PIC	25.8	4.65	491	<1.25	491	32.5	1.91	52.3	<1.25	52.3
16-May-2001	1	Okura	30.2	1.90	155	<1.25	155	30.6	1.05	160	<1.25	160
	2	Westin	29.3	0.82	174	<1.25	174	28.8	0.78	165	<1.25	165
	3	Reef	30.8	1.36	131	<1.25	131	30.6	0.78	129	<1.25	129
	4	Sails	30.2	0.99	111	216	327	30.2	0.62	106	<1.25	106
	5	Outrigger	31.5	<0.34	53.7	<1.25	53.7	31.6	0.61	37.6	<1.25	37.6
	6	Hyatt	30.1	0.48	27.4	<1.25	27.4	32.1	1.20	162	<1.25	162
	7	Fujita	30.1	1.52	226	<1.25	226	32.6	0.96	121	<1.25	121
	8	Fiesta	30.9	1.58	172	<1.25	172	32.4	1.03	807	<1.25	807
	9	Marriot	14.7	8.08	1554	<1.25	1554	29.9	1.64	371	<1.25	371
	10	PIC	25.9	2.80	479	<1.25	479	31.6	1.07	91.8	<1.25	91.8
17-May-2001	1	Okura	31.3	1.92	82	<1.25	82.2	31.4	1.57	106	<1.25	106
	2	Westin	29.9	0.28	100	6.56	106	29.5	1.08	152	<1.25	152
	3	Reef	30.8	0.43	109	<1.25	109	31.4	<0.34	80.7	<1.25	80.7
	4	Sails	31.4	1.03	73.9	<1.25	73.9	30.3	0.54	85.9	<1.25	85.9
	5	Outrigger	31.5	<0.34	22.2	24.0	46.2	32.5	<0.34	54.9	<1.25	54.9
	6	Hyatt	31.3	0.65	75.8	20.5	96.3	31.7	0.94	136	<1.25	136
	7	Fujita	30.6	2.39	172	7.63	180	32.8	<0.34	97.0	<1.25	97.0
	8	Fiesta	30.6	1.91	157	<1.25	157	32.8	0.57	343	<1.25	343
	9	Marriot	23.5	5.06	649	<1.25	649	30.1	1.88	226	<1.25	226
	10	PIC	29.3	0.85	211	7.49	219	31.0	0.52	93.6	<1.25	93.6
18-May-2001	1	Okura	30.8	2.60	86.3	<1.25	86.3	31.4	1.90	180	<1.25	180
	2	Westin	28.2	2.85	263	<1.25	263	29.9	0.83	101	<1.25	101
	3	Reef	31.7	0.28	49.7	<1.25	49.7	30.2	0.54	88.9	<1.25	88.9
	4	Sails	31.2	0.36	51.6	<1.25	51.6	31.5	<0.34	42.1	<1.25	42.1
	5	Outrigger	32.0	<0.34	30.5	<1.25	30.5	32.7	<0.34	45.9	<1.25	45.9
	6	Hyatt	31.4	0.30	57.5	8.84	66.4	31.5	<0.34	81.4	<1.25	81.4
	7	Fujita	32.6	1.18	90.0	<1.25	90.0	32.6	<0.34	90.3	<1.25	90.3
	8	Fiesta	30.7	1.82	151	<1.25	151	33.7	0.27	250	11.32	261
	9	Marriot	28.0	3.25	463	15.3	479	32.1	<0.34	181	<1.25	181
	10	PIC	29.5	1.45	244	<1.25	244	31.4	<0.34	64.1	<1.25	64.1

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