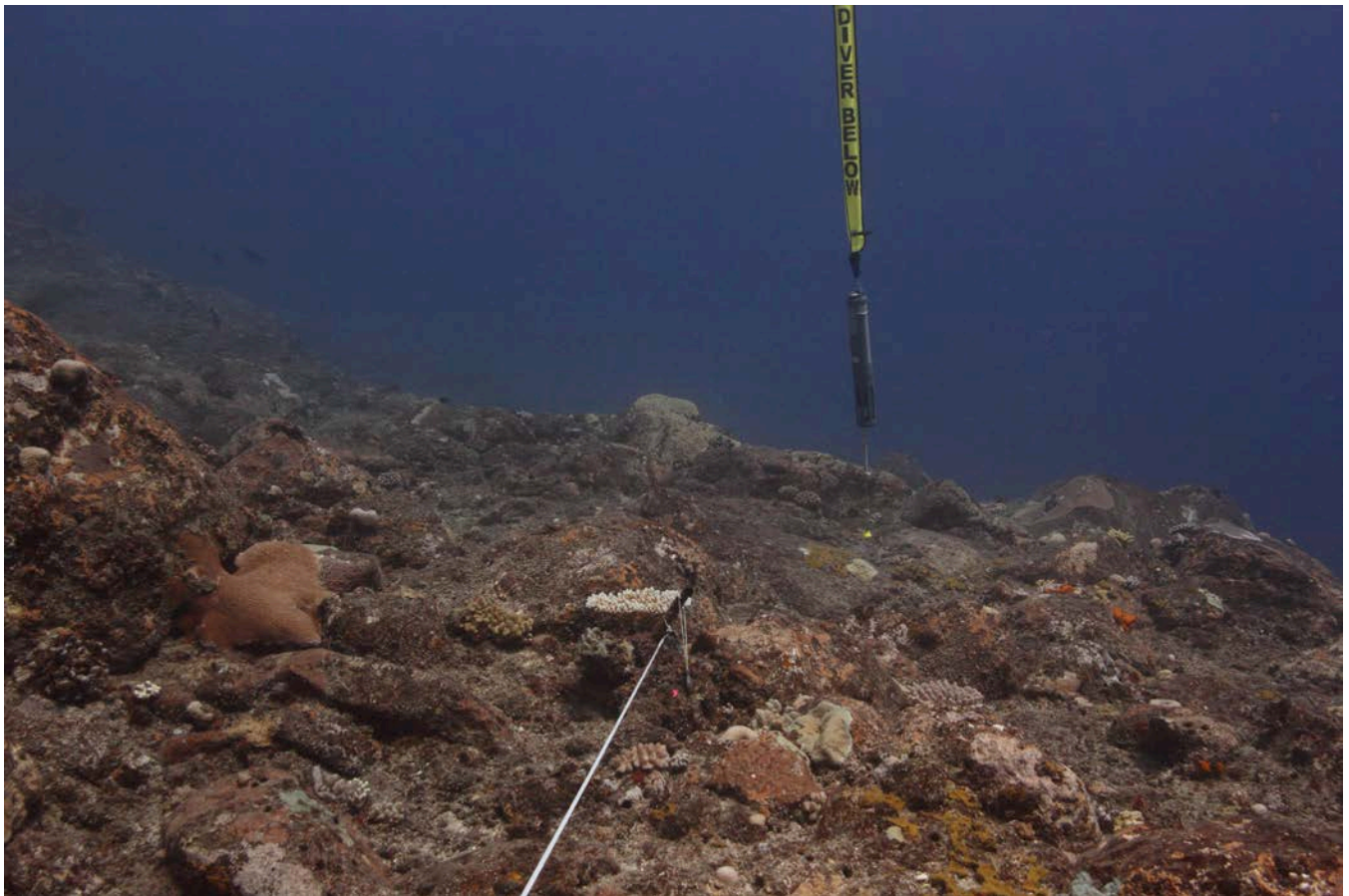




Marine Water Quality in National Park of American Samoa

Summary Report 2009-2014

Natural Resource Data Series NPS/PACN/NRDS—2017/1121



ON THE COVER

A sonde measuring water quality in National Park of American Samoa.

Photograph by: Bert Fuiava

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Abstract

This Natural Resource Data Series Report presents data collected from the marine portion of National Park of American Samoa in Tutuila and Ofu, American Samoa, USA. This is a summary or “data report” as described in the Water Quality Vital Signs Monitoring Protocol for the Pacific Island Network Version 1.0, Natural Resource Report NPS/PACN/NRR-2011/418. This report is restricted to data presentation and a limited description. The data presented in this report will be analyzed and interpreted for the establishment of expected parameter value ranges and long-term trends in future reports published in the National Park Service Natural Resource Report series. The purpose of collecting data on Vital Signs is to provide park managers information on current conditions and temporal trends in ecosystem health. Surface and bottom waters displayed similar conditions across all parameters. Sampling methods employed here were not designed to match methods used to evaluate territory water quality criteria, and were therefore not directly comparable.

Acknowledgments

We thank Tim Clark and the staff of NPSA for their cooperation and on-site logistical support.

List of Units and Acronyms

°C	Degrees Centigrade
$\mu\text{g} \cdot \text{L}^{-1}$	Micrograms per Liter
μm	Micrometer
HAVO	Hawai'i Volcanoes National Park
I&M	Inventory and Monitoring Program of the National Park Service
m	Meter
ml	Milliliter
$\text{mg} \cdot \text{L}^{-1}$	Milligrams per Liter
$\text{mS} \cdot \text{cm}^{-1}$	Milli-Siemens per Centimeter
n	Number of measurements or samples
nd	No data
NO_2	Nitrite
NO_3	Nitrate
NPS	National Park Service
NPSA	National Park of American Samoa
NRDS	Natural Resource Data Series Report
NRR	Natural Resource Report
NTU	Nephelometric Turbidity Units
ODO	Optical Dissolved Oxygen
ODOsat	Optical Dissolved Oxygen in terms of saturation
PACN	Pacific Island Network, Inventory and Monitoring Division
PN	Particulate Nitrogen
PP	Particulate Phosphorus
ppt	Parts Per Thousand
SD	Standard Deviation
SE	Standard Error
SpC	Specific conductivity
TDN	Total Dissolved Nitrogen
TDP	Total Dissolved Phosphorus
TN	Total Nitrogen
TP	Total Phosphorus
UHH	University of Hawai'i at Hilo

Introduction

Water quality is widely used as an indicator of aquatic ecosystem condition. The National Park Service (NPS) has designated water quality as a “Vital Sign,” or an indicator of physical, chemical, biological elements or ecosystem processes selected to represent the overall health or condition of natural resources within parks. Water quality is one Vital Sign monitored by the NPS Inventory and Monitoring (I&M) Division Pacific Island Network (PACN). This report presents data collected under the PACN water quality protocol (Jones et al. 2011) in the marine portion of National Park of American Samoa (NPSA) in Tutuila and Ofu, American Samoa, USA, between 2008 and 2014.

This report is a Natural Resource Data Series Report (NRDS), defined by the NPS as an annual or periodic data summary report for long-term monitoring projects. NRDSs are intended only for the release of basic data sets and summaries, with minimal interpretation. This report is one part of the I&M reporting process. Data presented in this report will be incorporated into future I&M trend-analysis reports to be published as NPS Natural Resource Reports (NRR).

The purpose of collecting data on Vital Signs is to provide park managers with information on current conditions and temporal trends in ecosystem health. Park managers can use this information to respond to resource conditions and evaluate management actions. The mission of the I&M Division is to provide data to inform management decisions and support the NPS mission of preserving the natural resources of parks unimpaired for the enjoyment of future generations (16 U.S.C. §1).

The areas sampled here were open coastal waters. Water quality criteria for American Samoa are defined in the American Samoa Water Quality Standards (AS-EPA 2013, Table 1). Criteria are defined for turbidity, total nitrogen, total phosphorus, chlorophyll-a, and light penetration, in terms of medians. Nutrients can be classified as particulate or dissolved. Total nitrogen (TN) is the sum of particulate nitrogen (PN) and TDN, total phosphorus (TP) is the sum of particulate phosphorus (PP) and TDP.

Table 1. Territory of American Samoa water quality criteria for open coastal waters (AS-EPA 2013).

Parameter	Unit	Median mean not to exceed
Total Nitrogen	$\mu\text{gN} \cdot \text{L}^{-1}$	130
Total Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	15
Light Penetration	ft	130
Chlorophyll-a	$\mu\text{g} \cdot \text{L}^{-1}$	0.25
Turbidity	NTU	0.25

Methods

Water was collected for nutrient analyses, a sonde was used to measure limnological parameters, and weather conditions were recorded. Data were collected using methods described in version 1.0 of the PACN water quality protocol (Jones et al. 2011).

Sample Sites

NPSA is located in the territory of American Samoa on the islands of Tutuila, Ofu, Ta'u where there are extensive coral reefs. Marine water quality is sampled in the park waters of Tutuila and Ofu (Figures 1 and 2).

Site names used by PACN were formatted to designate fixed or temporary sites ("F" or "T" respectively), park (NPSA), a number (e.g. 01), and habitat type ("mr" for marine); e.g. "FNPSA01_mr". Names for temporary sites were based on the date of sampling. The marine portion of the park was sampled 14 times from October 2009 to September 2013. Samples were not collected at Tutuila in 2012, nor at Tutuila and Ofu in 2014. A combination of fixed sites (sampled on more than one occasion) and temporary sites (chosen at random and sampled only once) were sampled for water samples and limnological parameters during each trip. Additional limnological parameter readings were taken at fixed and temporary sites during annual benthic marine community surveys (Brown et al., 2011).

Sample site locations were chosen based on safety and support of other PACN protocols. Sample sites could not be located closer to shore due to shallowness and surf-breaks. Sites corresponded to the location of sites of benthic marine community surveys conducted by SCUBA, which themselves were limited to a specific depth contour for safety.

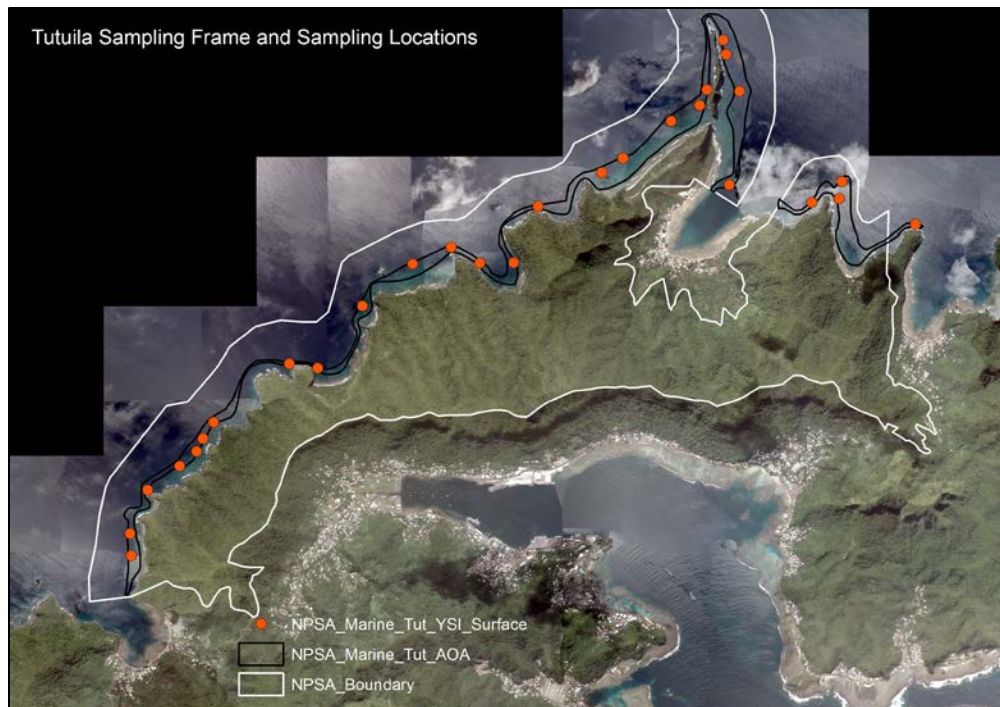


Figure 1. Marine water quality sample sites in NPSA at Tutuila.

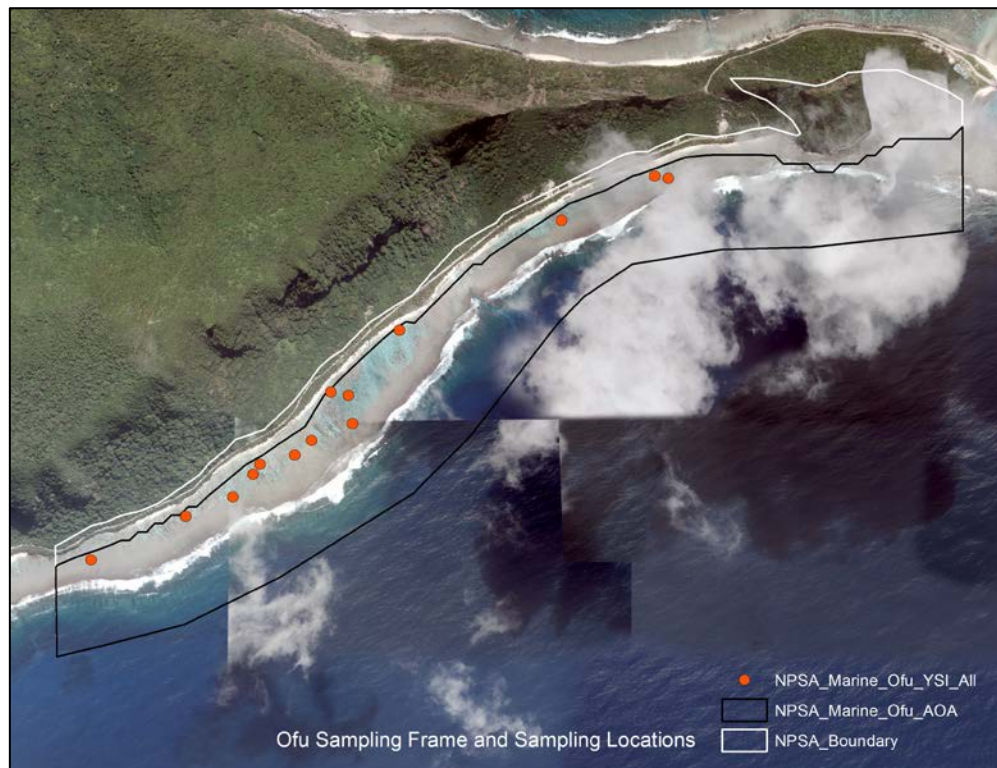


Figure 2. Marine water quality sample sites in NPSA at Ofu.

Water Collection

A Niskin bottle was used to sample water from a depth of 1 m (surface sample), and a separate sample was taken 2-3 m above the bottom substrate (bottom sample). Water was dispensed from the Niskin bottle directly into a new or acid-washed 140 milliliter (ml) syringe, or acid washed filter tower. Water was filtered in the field using an in-line filter holder and a 0.7 μm GF/F filter, and 140 ml of sample water was filtered into each sample bottle. Three 140 ml samples were taken at each sample site and placed on ice in the field inside a cooler. Samples were transferred to a freezer on the day of collection until delivery to the EPSCoR Analytical Laboratory at the University of Hawai'i at Hilo (UHH) Marine Science Department for chemical analysis. Samples were analyzed for TDP, TDN, and $\text{NO}_3 + \text{NO}_2$. Minimum analytical detection limits were 15.0 micrograms per liter ($\mu\text{g} \cdot \text{L}^{-1}$) for TDP, 0.070 milligrams per liter ($\text{mg} \cdot \text{L}^{-1}$) for TDN, and 1.0 $\mu\text{g} \cdot \text{L}^{-1}$ for $\text{NO}_3 + \text{NO}_2$.

Limnological Parameters and General Conditions

A YSI 6600 multiparameter sonde was calibrated within a few days before commencing field sampling. The sonde was used to measure depth (m), temperature ($^{\circ}\text{C}$), specific conductivity (SpC) in milli-Siemens per centimeter ($\text{mS} \cdot \text{cm}^{-1}$), pH, optical dissolved oxygen (ODO) in $\text{mg} \cdot \text{L}^{-1}$, chlorophyll in $\mu\text{g} \cdot \text{L}^{-1}$, and turbidity in nephelometric turbidity units (NTU). The sonde also reported salinity in ppt calculated from SpC, and dissolved oxygen in percent saturation (% ODOsat) calculated from ODO and temperature. The sonde was set to record readings every 30 seconds prior to leaving the dock. The sonde was lowered to a depth of 1 m and allowed to log readings for at least five minutes, then lowered to 2 to 3 m above the bottom and allowed to log readings for at least five minutes, at each site. Between sites the sonde was stored with probes immersed in freshwater. The mean and variance of stable values, isolated by depth, is reported. Average wind speed over three minutes and wind direction were measured using a Kestrel wind speed device. Global positioning system coordinates were recorded. Photographs of sample sites were also taken.

Data Analysis, Management, and Quality Control

Environmental parameters, habitat descriptions, and general observations were recorded on datasheets in the field. Datasheets were stored at PACN offices within Hawai'i Volcanoes National Park (HAVO), scanned, and uploaded to PACN servers. All data including laboratory results were entered into PACN databases. Data were downloaded from the YSI 650 control unit and readings from surface and bottom depths isolated and uploaded to databases. Accuracy of data entry into databases was verified by comparing database entries to the original datasheets by a person who did not enter the data into databases. Data were then certified by the PACN freshwater program lead at the time, either Tazhay Jones or David Raikow. Data determined to be unreliable due to instrument or sampling errors were flagged in databases and removed from further consideration. Data were explored visually by plotting time-series. Outlying data and data that deviated from regular temporal patterns were identified. Corroboration between related parameters and field notes was used to identify possible causes of deviation from regular temporal patterns.

Measurements from a series of water samples or sonde readings taken at an individual site within minutes of each other were expected to be normally distributed around the true value of the parameter, because the parameter should not change appreciably over the short time required to take

multiple samples or readings. Variation in sample values should be most influenced by external factors. Therefore, the arithmetic mean and the standard error are reported for individual sampling events, because the accuracy of the estimate of the mean is of interest. Non-normal distributions, however, are generally expected when summarizing limnological conditions over a time period such as a year due to censoring (values cannot drop below zero or have a minimum analytical detection limit) and positive skewness (having infrequent high values) (Helsel and Hirsch 2002). Therefore the median and standard deviation are reported for annual summaries because the variance of the parameter over the study period is of interest (Tables 3-13). The median equals the mean in normally-distributed parameters.

For the purposes of descriptive statistics, values below detection limits were assigned values equal to one-half of the detection limit. Mean values of chlorophyll that were less than zero are reported with a value of zero, i.e. as non-detects.

Turbidity probes can return negative values when conditions are at or near zero turbidity. Negative turbidity readings were set to 0.1, the lowest value above zero for the probe. Resetting very low turbidity values to 0.1 NTU is based on the assumption that natural water, while often visually indistinguishable from transparent deionized (distilled) water, can never be particulate-free.

Spatial Analysis

Data was plotted spatially in ArcMap 10.3.1. The spatial distribution of parameter values at the surface across the marine portion of the park was plotted using the Inverse Distance Weighting (IDW) spatial analyst tool. IDW is based on the principle that values close to one another are more alike than those that are farther apart. We used a variable search radius with 12 points. Such settings, along with the number and dispersion of sample points, affect the appearance of interpolations.

Sample locations were not chosen to optimize spatial analysis. Hence the sample sites fell generally on a transect line running north to south. Thus interpolation along the east-west axis was less reliable than along the north-south axis. Based on this, a power option of seven was chosen, which decreases the significance of surrounding points and produced a horizontal (east-west) visual banding effect. We also limited the interpolation to an area within 250 m of all sample points, to avoid displaying results in areas where no samples were taken. The color ramp used in the display of spatial interpolations blends five distinct colors. This method was chosen to aid interpretation. The colors correspond to points along the scale regardless of absolute values: black = 0% of the scale, blue = 25%, green = 50%, yellow = 75%, and white = 100%.

Results

Because data from all sites were collected over a variable number of consecutive days, typically one to three, results are presented as summaries by quarter. Medians of surface data by year are presented in comparison to state water quality criteria. Results are presented below as summaries of all replicate samples by parameter, plots of arithmetic means over time, and spatial interpolations. Surface and bottom parameter spatial distributions are presented using the same result range to allow direct comparison.

Total Dissolved Phosphorus

Non-detects are presented at $7.5 \mu\text{g} \cdot \text{L}^{-1}$, or half the detection limit, and treated as such for calculation of the mean. Very little TDP was detected across all years, with the exception of 2013 when there was a spike in TDP across both areas (Tables 2-3, Figures 3-7).

Table 2. Total dissolved phosphorus ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	24	7.5	7.5	7.5	0.0
	1	Bottom	24	7.5	7.5	7.5	0.0
2010	1	Surface	30	7.5	7.5	7.5	0.0
	1	Bottom	18	7.5	7.5	21.0	4.2
2011	3	Surface	6	7.5	7.5	7.5	0.0
	3	Bottom	15	7.5	7.5	7.5	0.0
2011	4	Surface	12	7.5	7.5	7.5	0.0
	4	Bottom	12	7.5	7.5	7.5	0.0
2013	1	Surface	11	7.5	19.0	24.0	5.3
	1	Bottom	8	7.5	20.0	23.0	4.9

Table 3. Total dissolved phosphorus ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	9	7.5	7.5	7.5	0.0
	4	Surface	24	7.5	7.5	7.5	0.0
2010	1	Surface	24	7.5	7.5	7.5	0.0
	2	Surface	21	7.5	7.5	7.5	0.0
	3	Surface	21	7.5	7.5	7.5	0.0
2011	2	Surface	12	7.5	7.5	7.5	0.0
	4	Surface	12	7.5	7.5	7.5	0.0
2012	2	Surface	12	7.5	7.5	7.5	0.0
	4	Surface	6	7.5	7.5	7.5	0.0
	4	Bottom	6	7.5	7.5	7.5	0.0
2013	2	Surface	12	7.5	7.5	7.5	0.0
	3	Surface	6	7.5	11.8	17.0	5.0

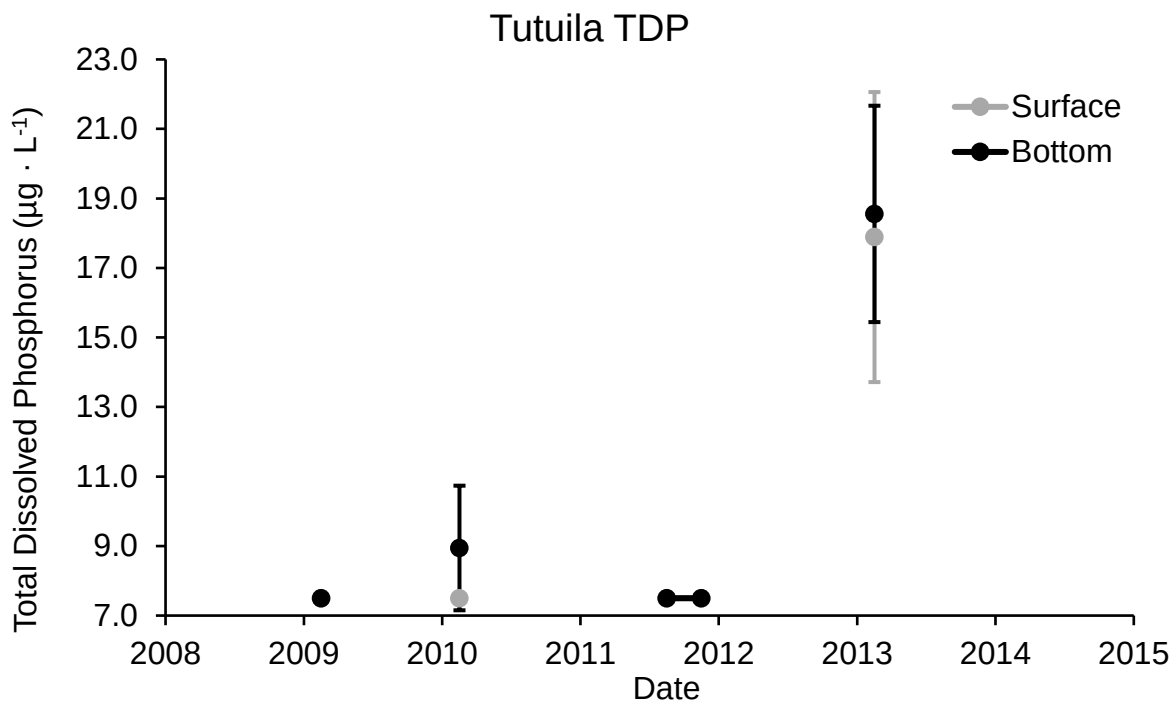


Figure 3. Total dissolved phosphorus in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals. Non-detects are presented as half the detection limit, and treated as such for calculation of the mean.

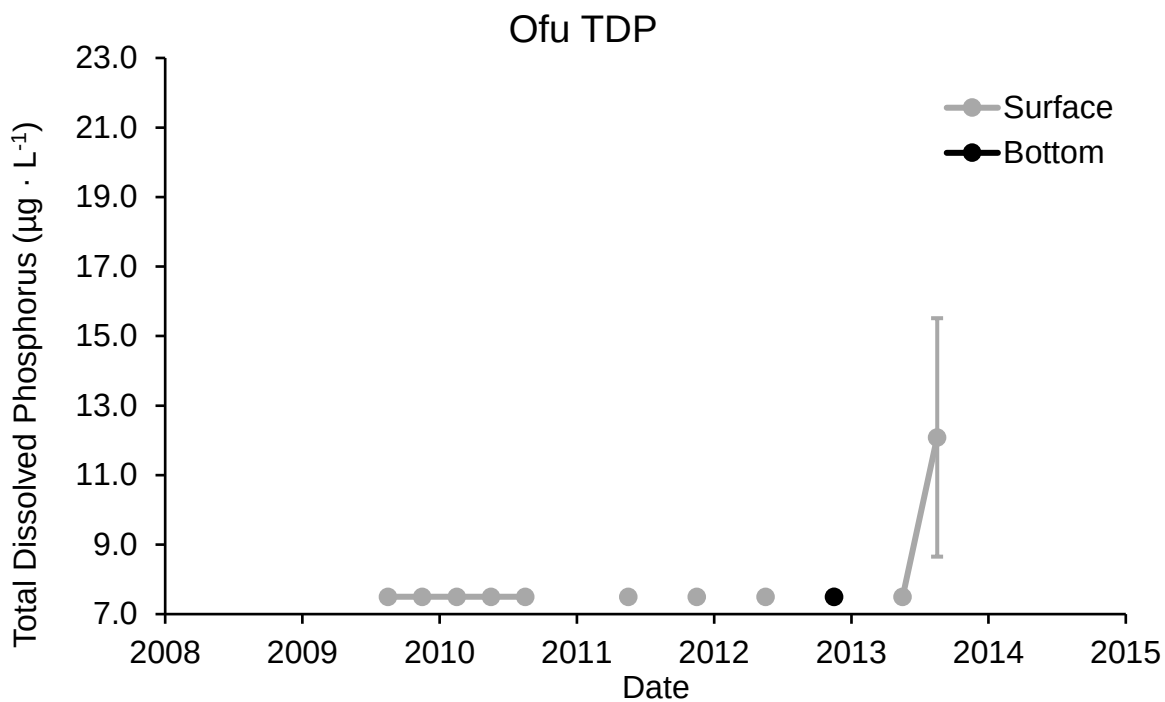


Figure 4. Total dissolved phosphorus in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals. Non-detects are presented as half the detection limit, and treated as such for calculation of the mean.

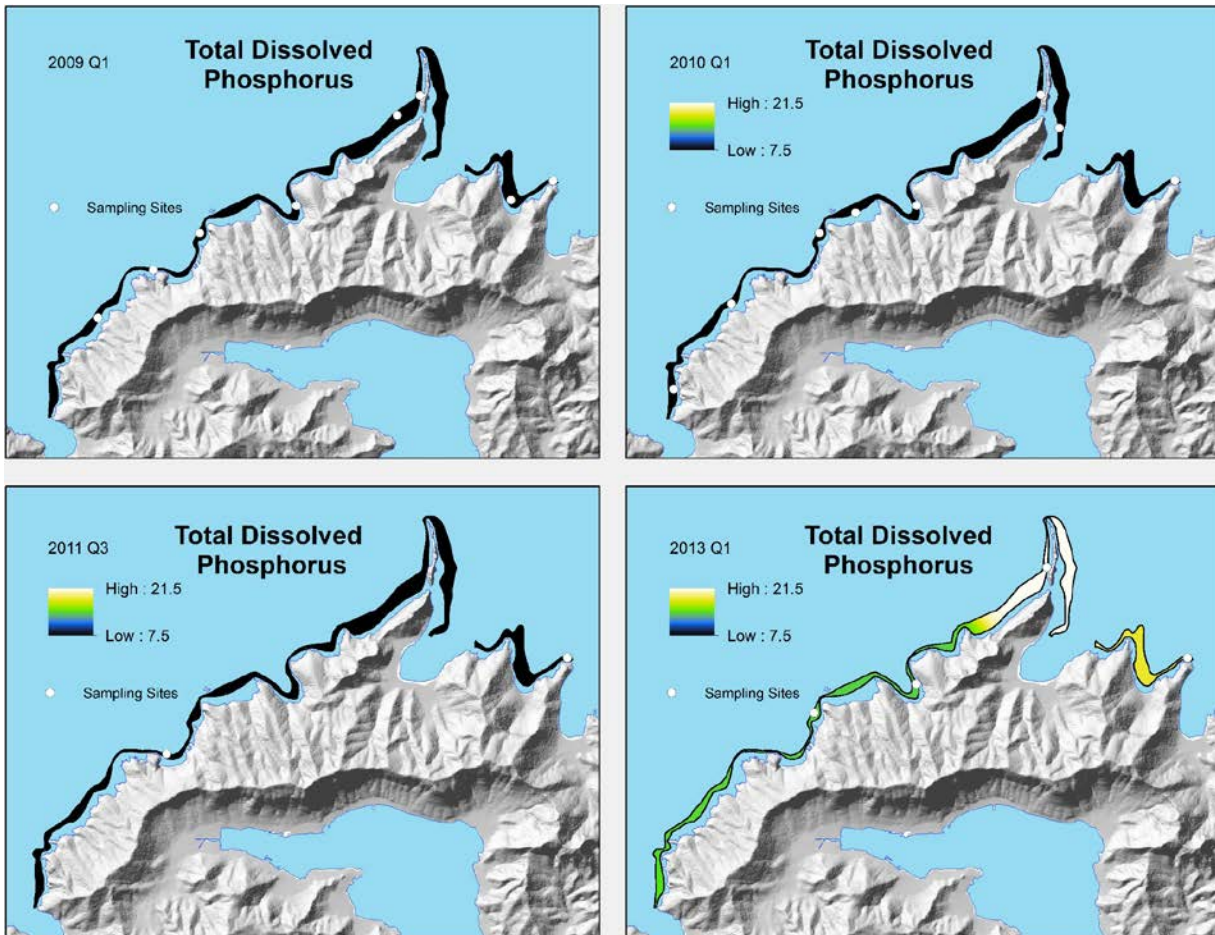


Figure 5. Spatial distribution of surface total dissolved phosphorus in marine waters of NPSA in Tutuila using the total range of results observed (lowest to highest data values) in surface and bottom samples.

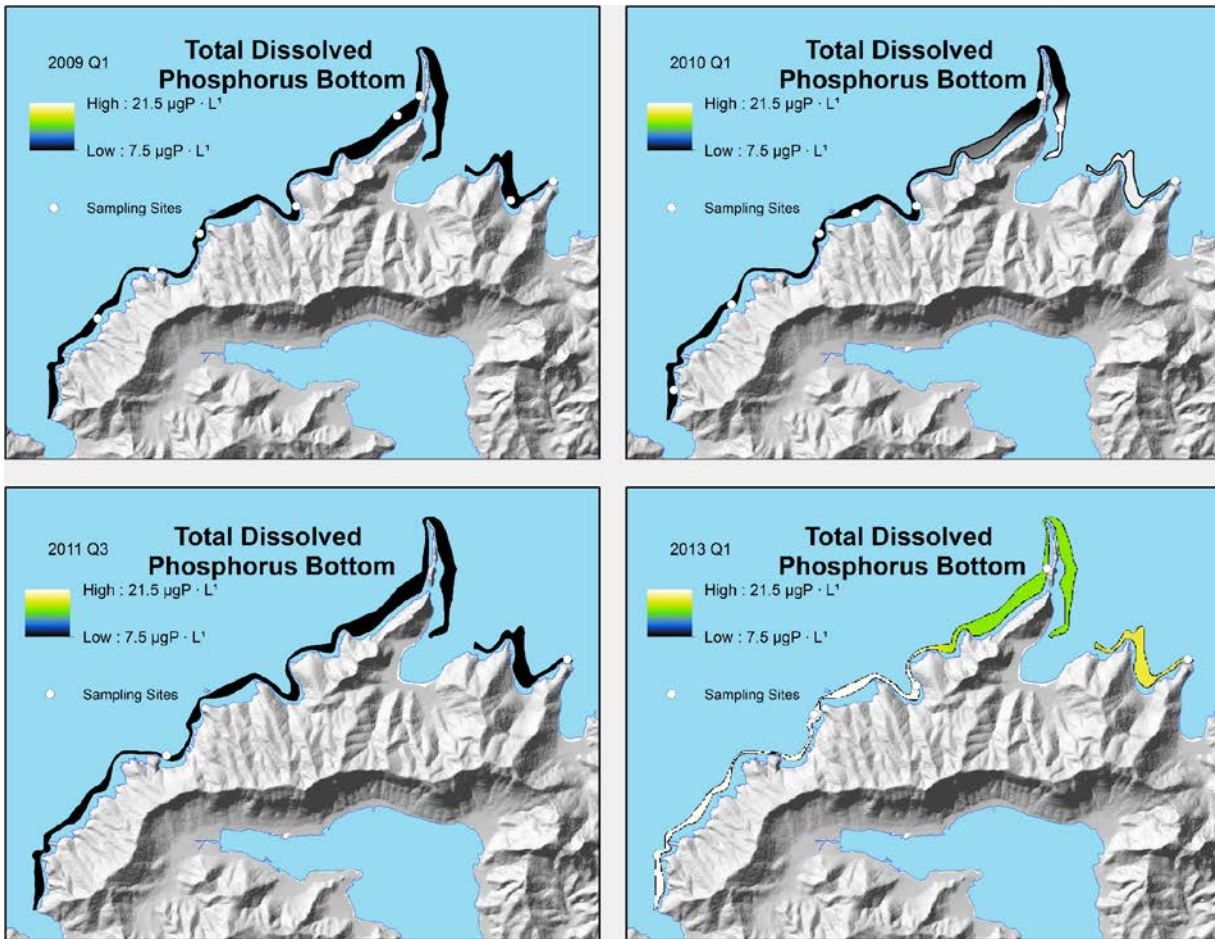


Figure 6. Spatial distribution of bottom total dissolved phosphorus in marine waters of NPSA in Tutuila using the total range of results observed (lowest to highest data values) in surface and bottom samples.

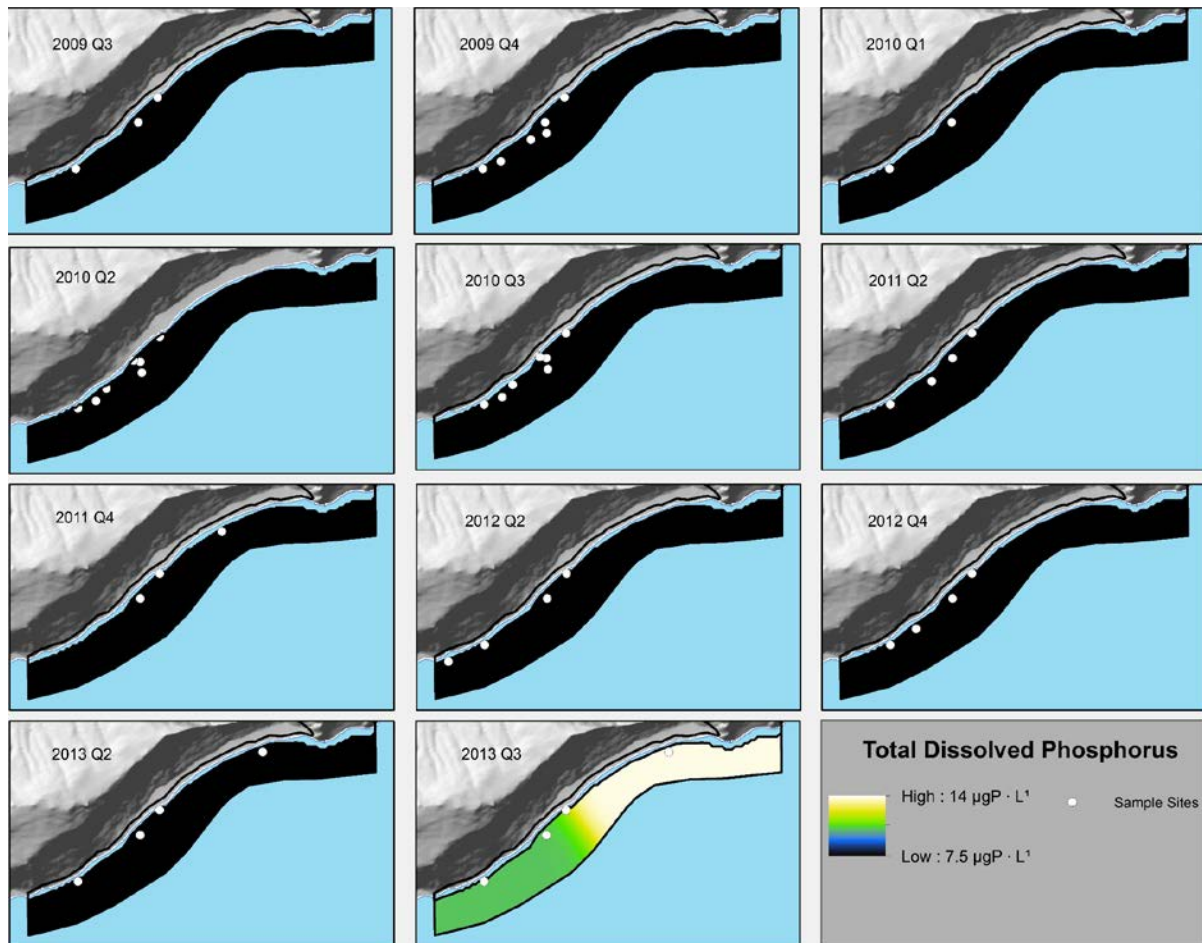


Figure 7. Spatial distribution of surface total dissolved phosphorus in marine waters of NPSA in Ofu using the total range of results observed (lowest to highest data values) in surface and bottom samples.

Total Dissolved Nitrogen

Concentrations of TDN also spiked in 2013 in Tutuila, but were relatively constant throughout the whole time period in Ofu (Tables 3-4, Figures 8-12).

Table 4. Total dissolved nitrogen ($\text{mg} \cdot \text{L}^{-1}$) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	24	0.072	0.103	0.128	0.015
	1	Bottom	24	0.074	0.098	0.147	0.019
2010	1	Surface	30	0.035	0.118	0.348	0.052
	2	Bottom	18	0.074	0.118	0.156	0.021
2011	3	Surface	6	0.084	0.123	0.179	0.036
	3	Bottom	15	0.035	0.098	0.156	0.039
2011	4	Surface	12	0.128	0.137	0.302	0.062
	4	Bottom	12	0.133	0.165	0.312	0.055
2013	1	Surface	15	0.183	0.273	0.791	0.181
	1	Bottom	9	0.123	0.217	0.363	0.082

Table 5. Total dissolved nitrogen ($\text{mg} \cdot \text{L}^{-1}$) in marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	9	0.035	0.073	0.094	0.027
	4	Surface	24	0.035	0.121	0.230	0.046
2010	1	Surface	24	0.093	0.118	0.178	0.019
	2	Surface	21	0.078	0.119	0.192	0.033
	3	Surface	21	0.035	0.093	0.257	0.047
2011	2	Surface	12	0.035	0.079	0.201	0.040
	4	Surface	12	0.070	0.137	0.153	0.026
2012	2	Surface	12	0.077	0.101	0.137	0.021
	4	Surface	6	0.076	0.086	0.119	0.015
	4	Bottom	6	0.084	0.103	0.125	0.015
2013	2	Surface	12	0.078	0.107	0.286	0.071
	3	Surface	6	0.088	0.117	0.169	0.029

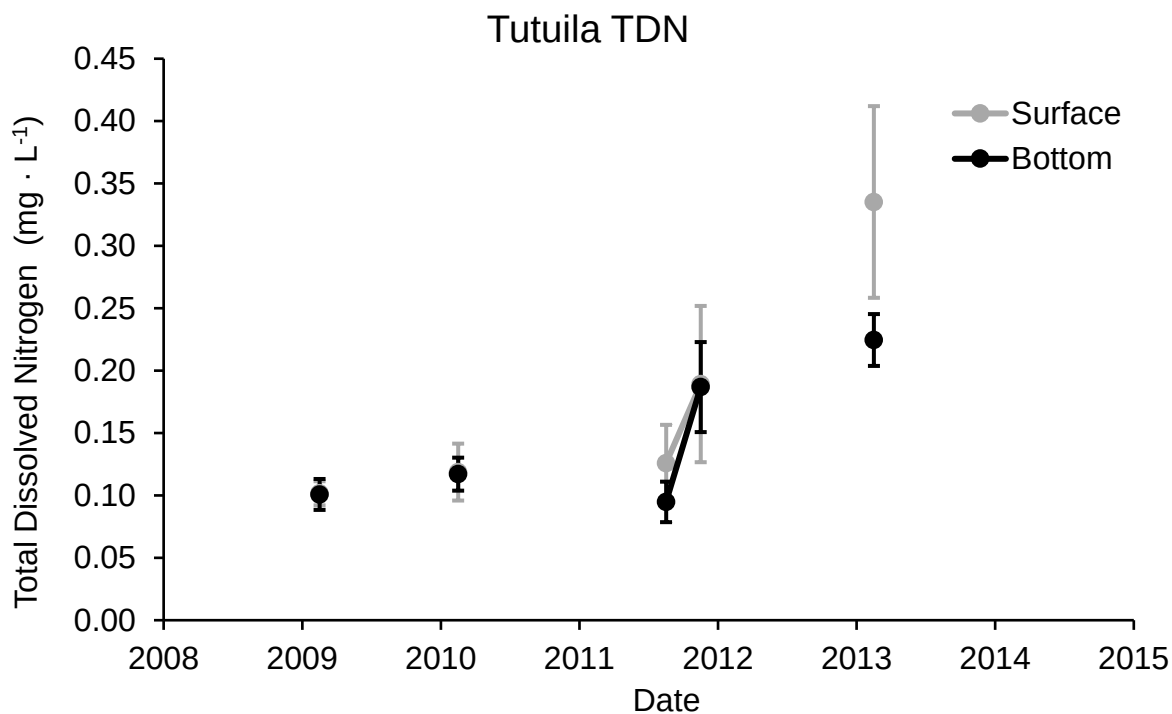


Figure 8. Total dissolved nitrogen in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals of eight sites.

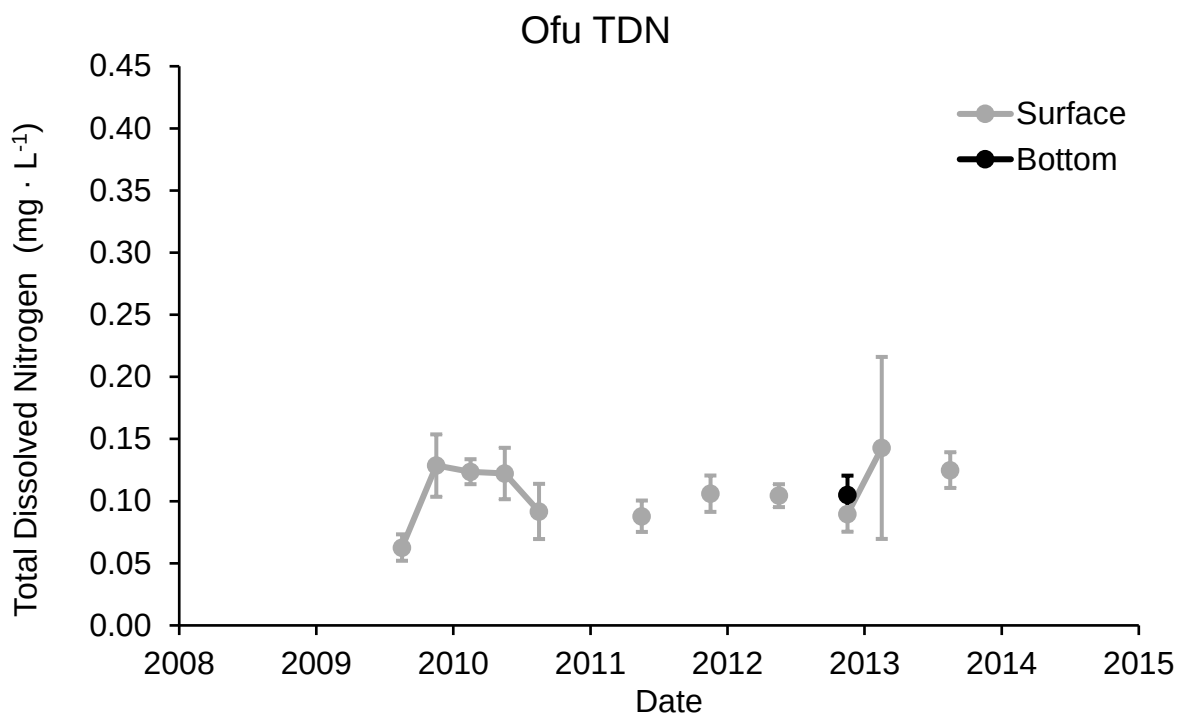


Figure 9. Total dissolved nitrogen in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals of eight sites.

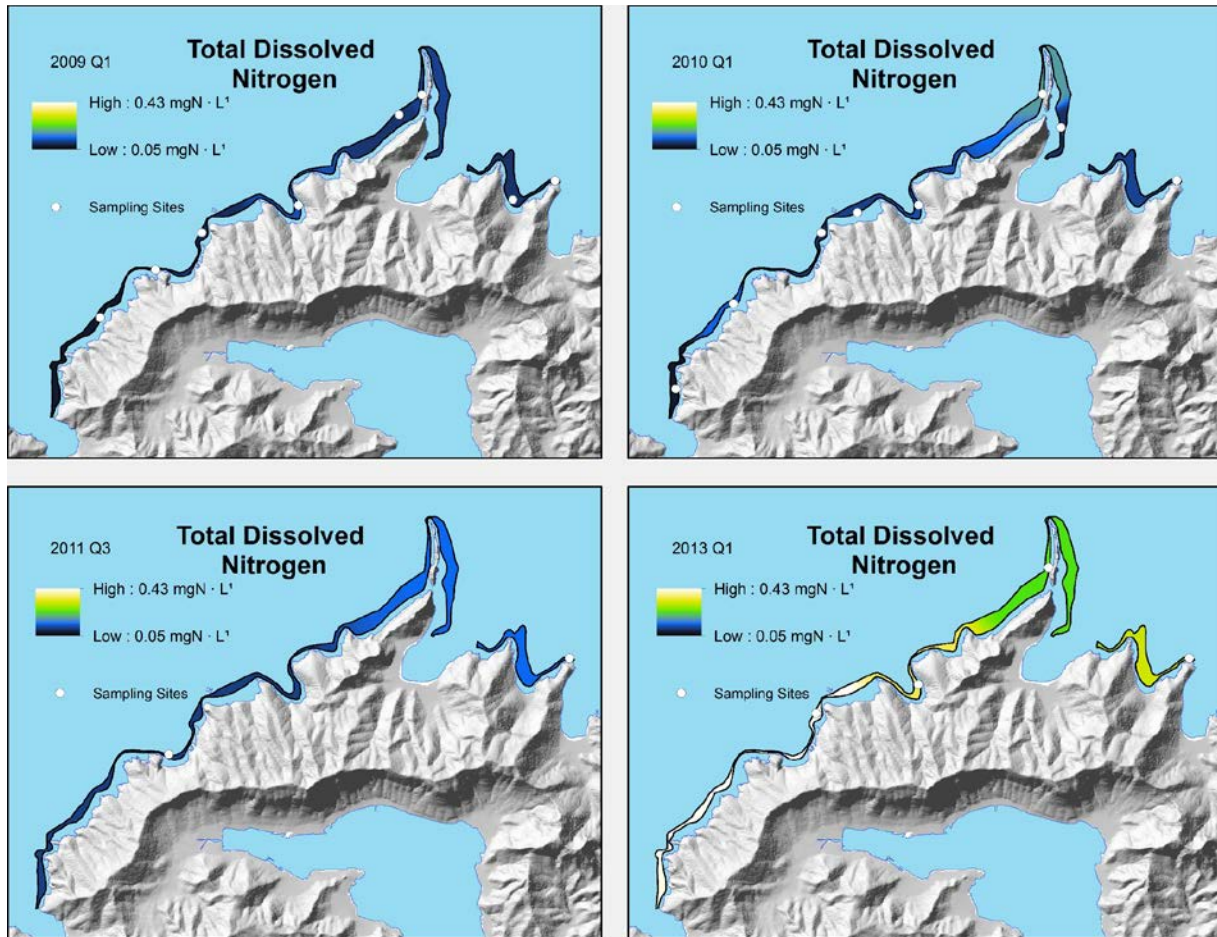


Figure 10. Spatial distribution of surface total dissolved nitrogen in marine waters of NPSA in Tutuila using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

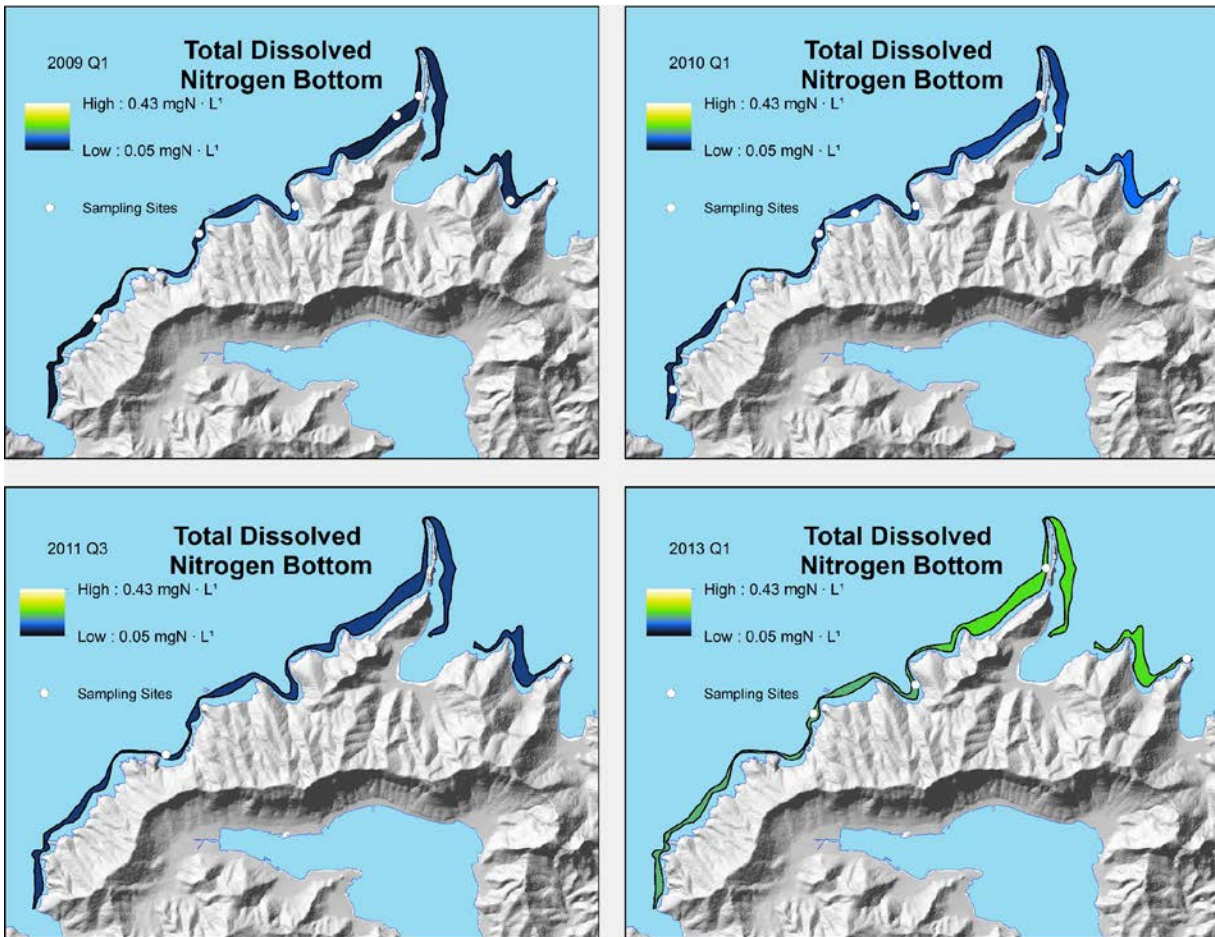


Figure 11. Spatial distribution of bottom total dissolved nitrogen in marine waters of NPSA in Tutuila using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

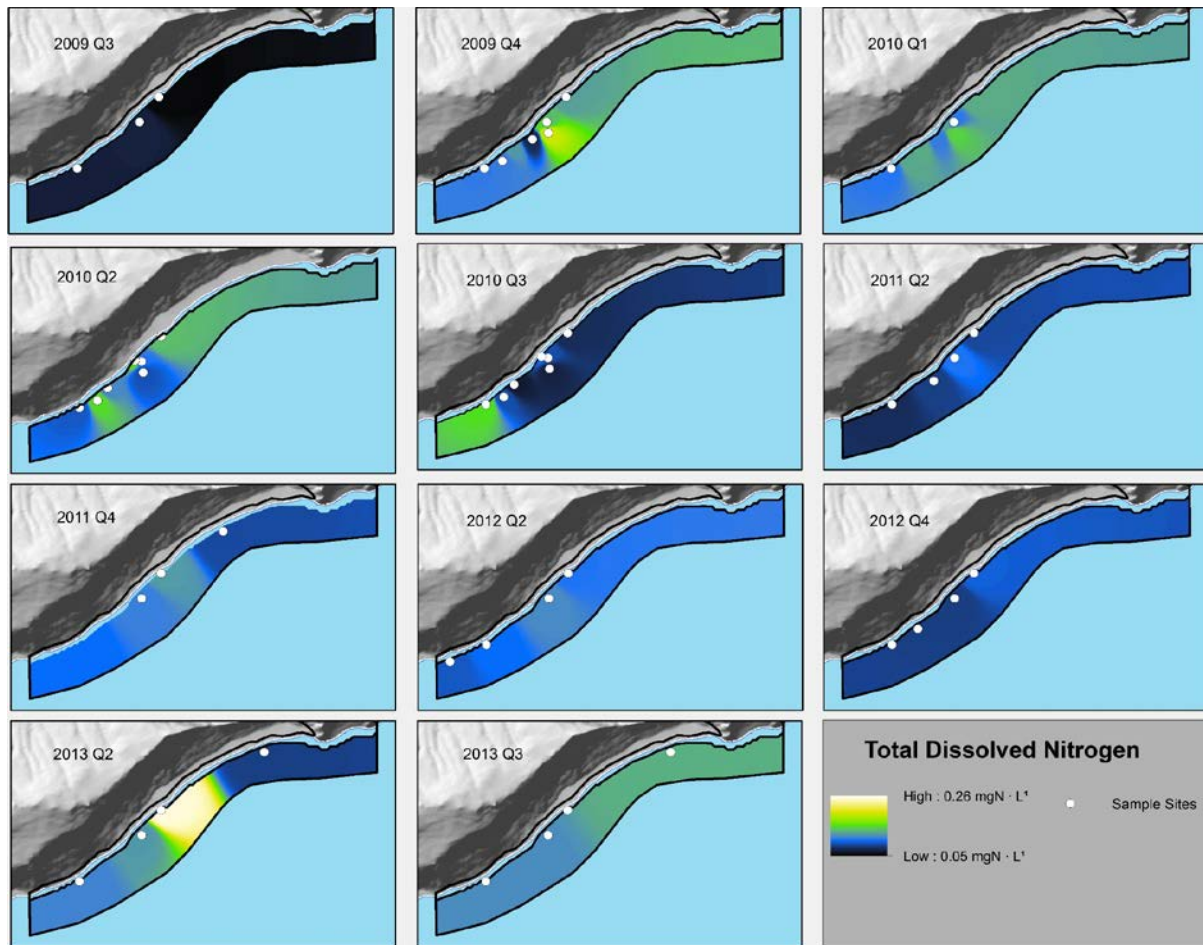


Figure 12. Spatial distribution of surface total dissolved nitrogen in marine waters of NPSA in Ofu using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

Nitrate + Nitrite

Concentrations of $\text{NO}_2 + \text{NO}_3$ were variable over the monitoring period and were generally greater in Ofu than in Tutuila. Surface waters also displayed more variability in $\text{NO}_2 + \text{NO}_3$ (Tables 6-7, Figures 13-17).

Table 6. Nitrate + nitrite ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	24	0.0	3.0	10.0	3.8
	1	Bottom	24	0.0	4.5	10.0	4.1
2010	1	Surface	30	0.5	0.5	0.5	0.0
	1	Bottom	18	0.5	0.5	4.0	1.4
2011	3	Surface	6	4.0	5.5	5.9	0.7
	3	Bottom	15	4.7	6.3	8.9	1.2
2013	1	Surface	15	0.5	3.2	22.3	5.5
	1	Bottom	9	0.5	1.5	4.0	1.1

Table 7. Nitrate + nitrite ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	9	0.5	5.1	13.9	4.1
	4	Surface	24	3.0	11.5	37.0	8.4
2010	1	Surface	24	11.0	0.5	31.0	6.3
	2	Surface	21	4.0	12.0	31.0	8.0
	3	Surface	21	3.0	9.0	28.0	5.9
2011	2	Surface	12	3.8	5.9	7.2	1.1
	4	Surface	12	8.4	9.3	10.4	0.6
2012	4	Surface	6	10.7	11.4	12.4	0.7
	4	Bottom	6	10.6	14.7	19.8	4.2
2013	2	Surface	12	7.0	10.0	17.0	3.5
	3	Surface	6	3.0	5.5	8.0	2.3

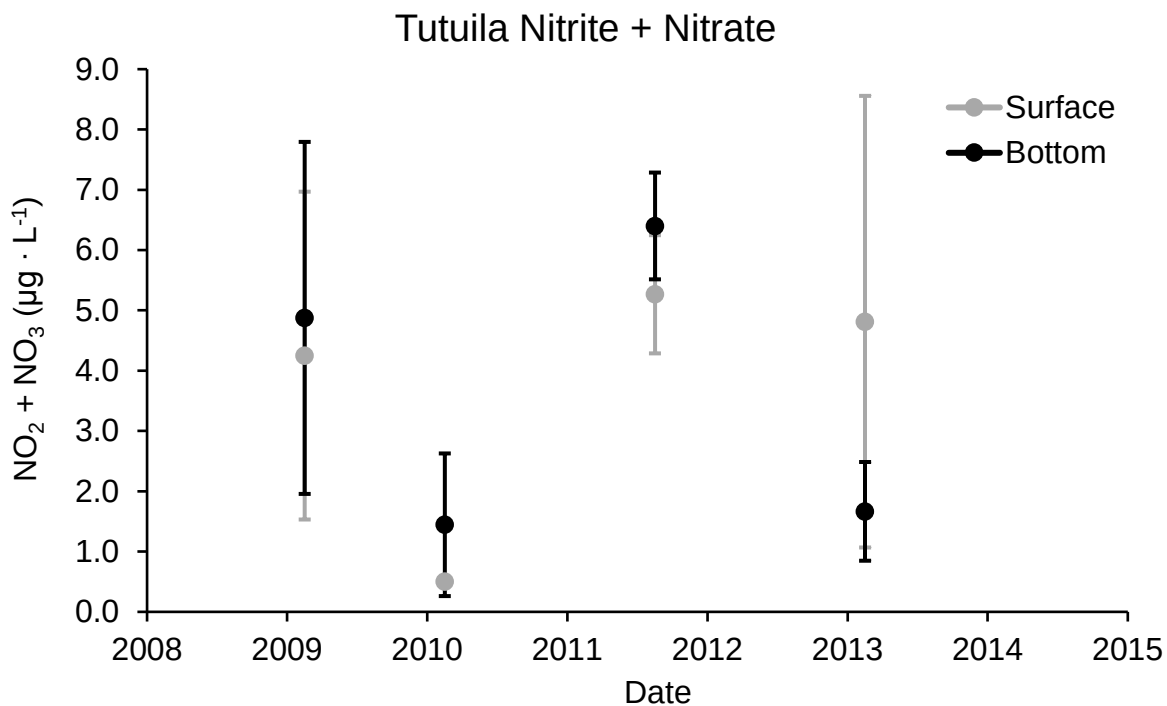


Figure 13. Nitrite + nitrate in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals of eight sites.

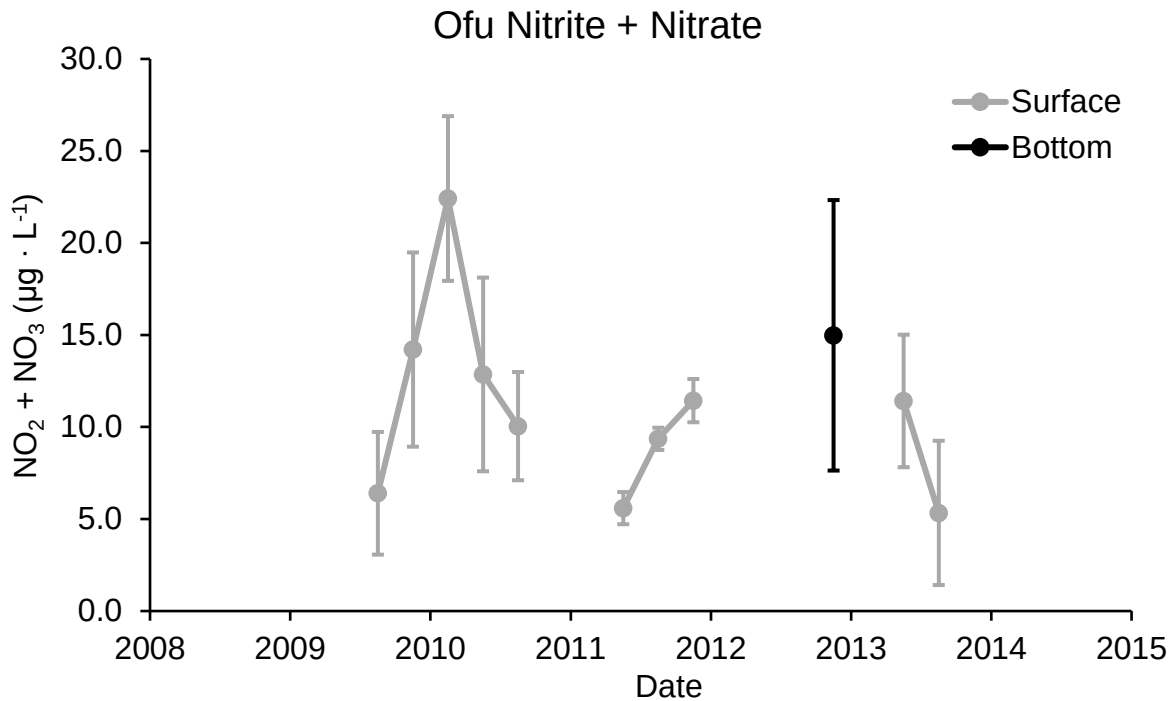


Figure 14. Nitrite + nitrate in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals of eight sites.

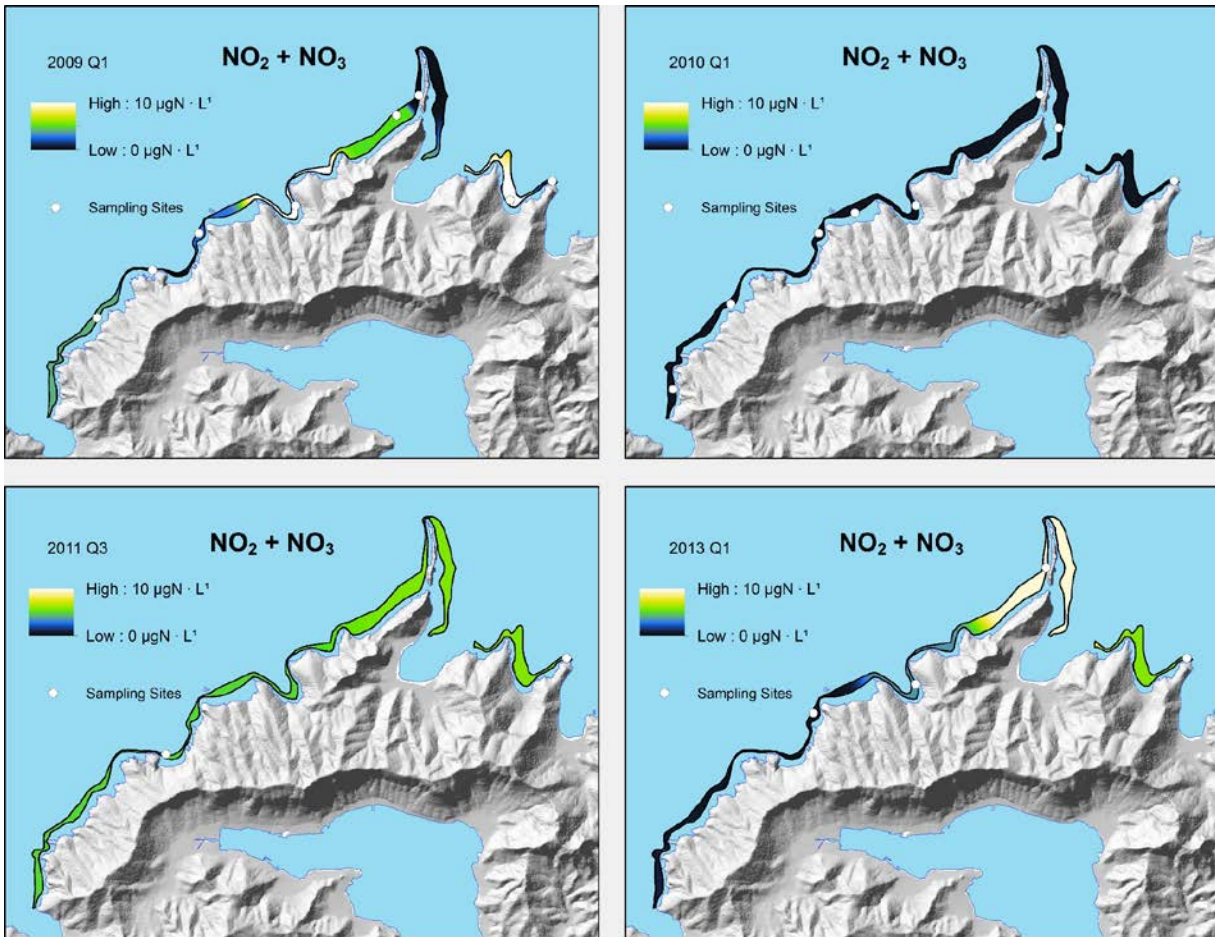


Figure 15. Spatial distribution of surface nitrite + nitrate in marine waters of NPSA in Tutuila using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

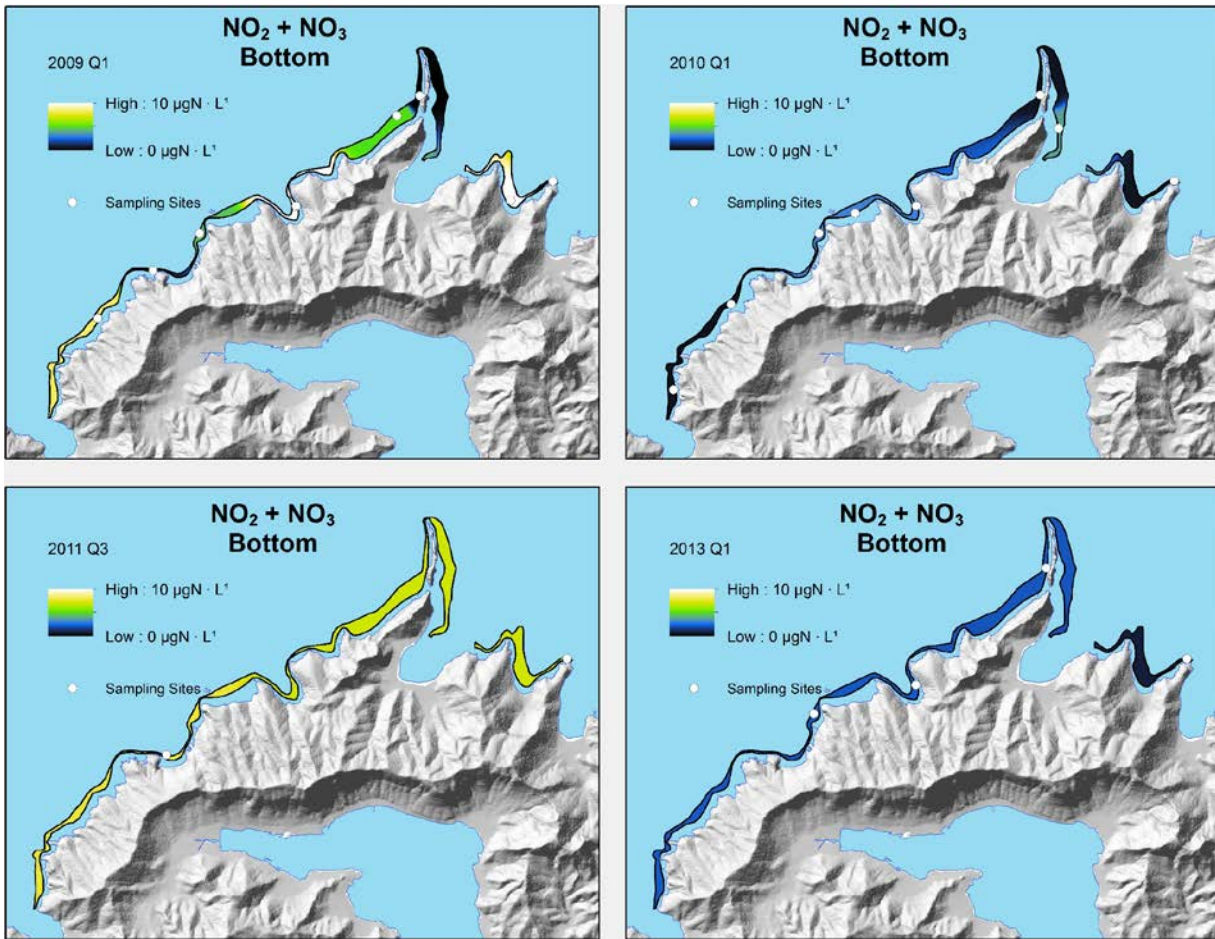


Figure 16. Spatial distribution of bottom Nitrite + Nitrate in marine waters of NPSA in Tutuila using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

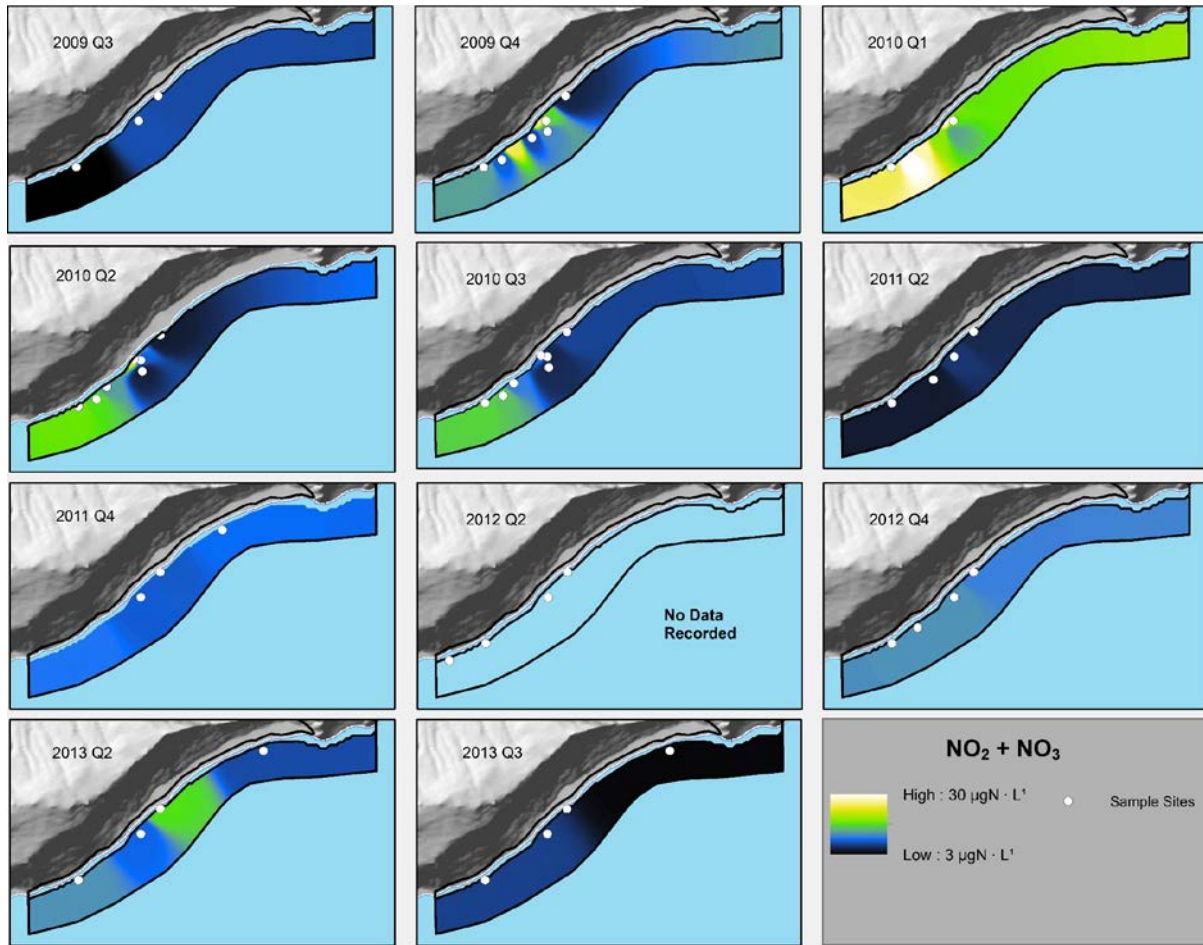


Figure 17. Spatial distribution of surface nitrite + nitrate in marine waters of NPSA in Ofu using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

Chlorophyll

Isolated spikes in chlorophyll concentration were observed during the monitoring period (Tables 8-9, Figures 18-22).

Table 8. Chlorophyll ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	21	0.0	0.2	4.6	1.1
	1	Bottom	23	0.1	0.2	4.7	1.3
2011	3	Bottom	1	0.1	0.1	0.1	NA
2013	1	Surface	4	0.3	0.9	1.5	0.5
	2	Bottom	19	0.0	0.0	0.5	0.1

Table 9. Chlorophyll ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	3	0.1	0.1	0.1	0.0
	4	Surface	5	0.1	0.9	1.3	0.5
2010	1	Surface	2	0.0	0.1	0.1	0.1
	3	Surface	6	0.1	0.1	0.1	0.0
2011	2	Surface	4	0.5	0.6	0.9	0.2
	4	Surface	3	0.1	0.1	0.1	0.0
2012	2	Surface	1	1.4	1.4	1.4	NA
	2	Bottom	2	0.3	1.0	1.7	1.0
	4	Surface	2	0.1	0.1	0.1	0.0
	4	Bottom	2	0.1	0.1	0.1	0.0

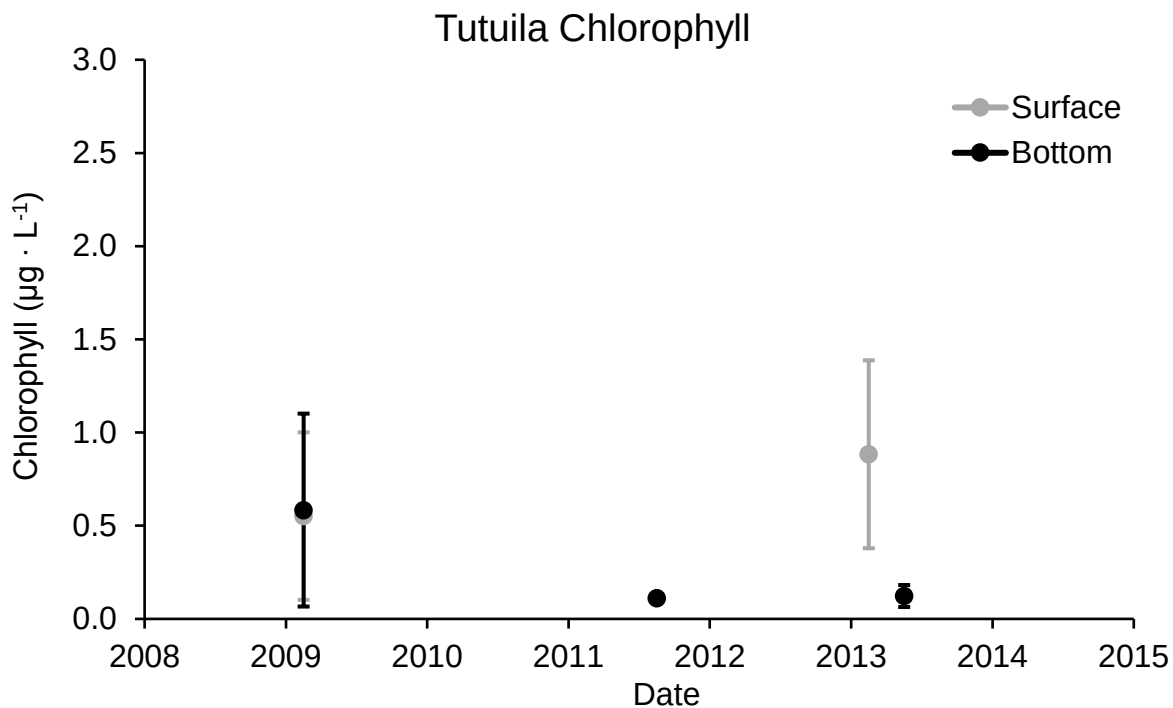


Figure 18. Chlorophyll in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals.

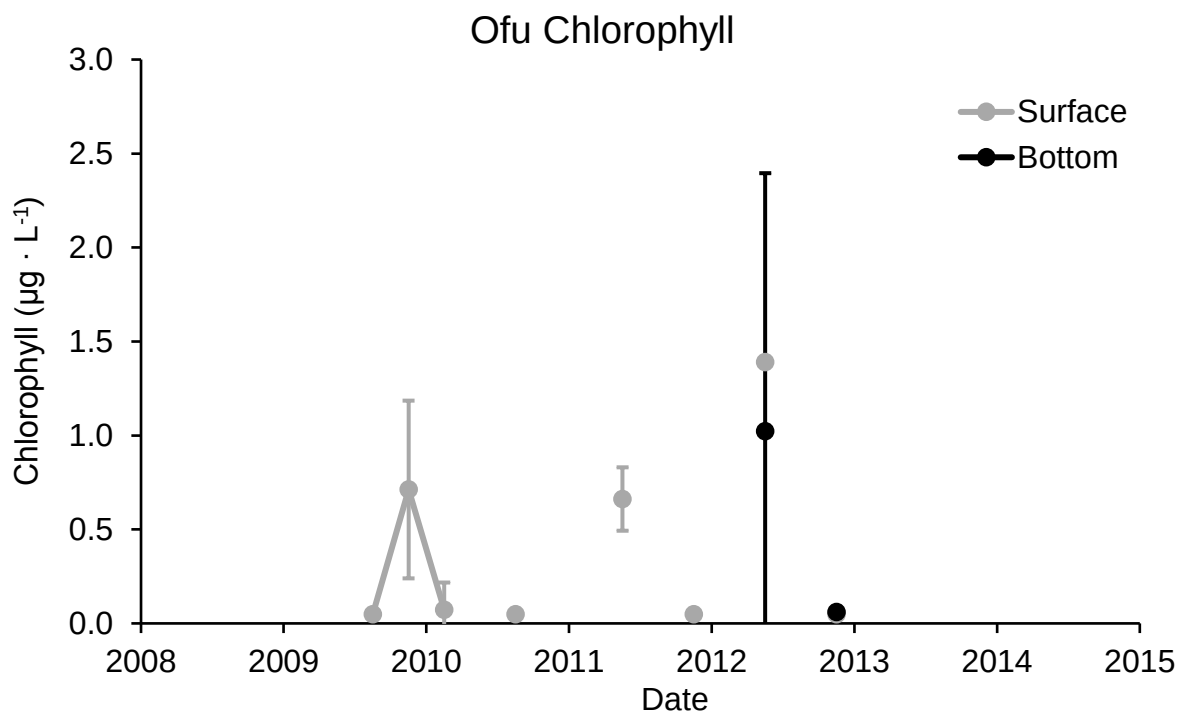


Figure 19. Chlorophyll in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals.

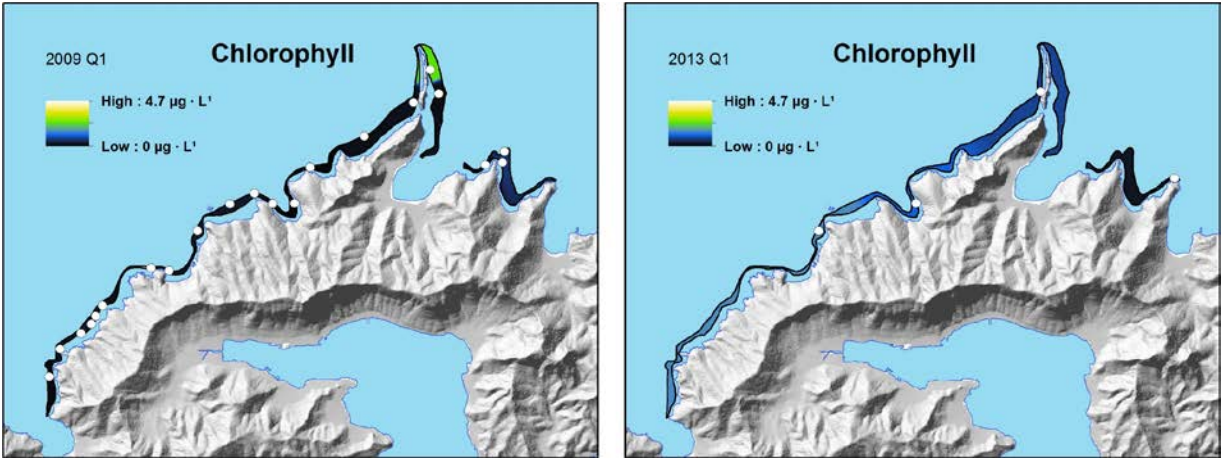


Figure 20. Spatial distribution of surface chlorophyll in surface marine waters of NPSA in Tutuila for selected quarters using the total range of results observed in surface and bottom samples.

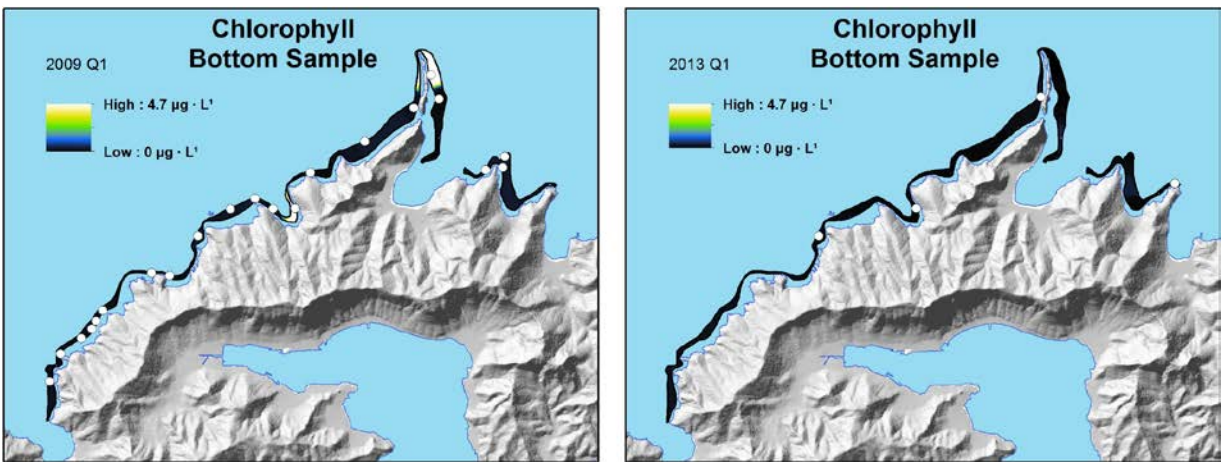


Figure 21. Spatial distribution of bottom chlorophyll in surface marine waters of NPSA in Tutuila for selected quarters using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

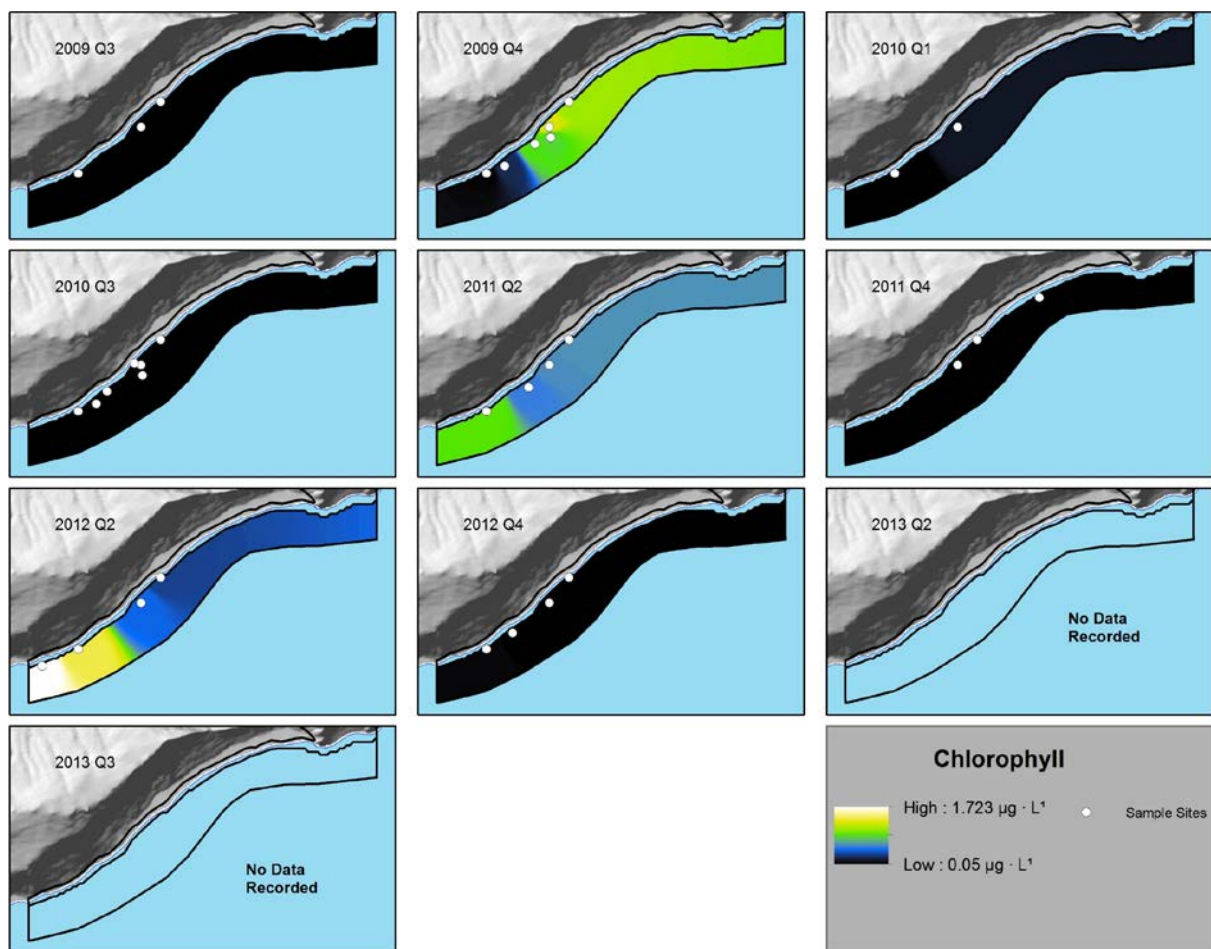


Figure 22. Spatial distribution of surface chlorophyll in surface marine waters of NPSA in Ofu using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

Dissolved Oxygen Concentration and Saturation

Dissolved oxygen concentrations were generally consistent between years in both areas (Tables 10-11, Figures 23-24 and 27-30). Dissolved oxygen saturation was also consistent between years (Tables 12-13, Figures 25-30).

Table 10. Dissolved oxygen concentration ($\text{mg} \cdot \text{L}^{-1}$) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	27	6.0	6.3	6.7	0.1
	1	Bottom	27	5.9	6.3	6.5	0.1
2011	3	Bottom	1	6.4	6.4	6.4	NA
2013	1	Surface	4	7.1	7.3	7.4	0.1
	2	Bottom	19	7.4	7.8	8.1	0.2

Table 11. Dissolved oxygen concentration ($\text{mg} \cdot \text{L}^{-1}$) in marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	3	7.8	8.3	8.5	0.4
	4	Surface	1	10.3	10.3	10.3	NA
2010	1	Surface	2	5.8	7.2	8.6	1.9
	3	Surface	7	7.0	8.1	8.6	0.6
2011	2	Surface	4	0.6	6.1	6.7	2.9
2012	2	Surface	1	6.5	6.5	6.5	NA
	2	Bottom	2	11.8	9.1	6.4	3.8
	4	Surface	2	7.9	8.0	8.1	0.2
	4	Bottom	2	10.4	9.3	8.3	1.5
2013	2	Bottom	2	7.2	7.8	8.9	1.1

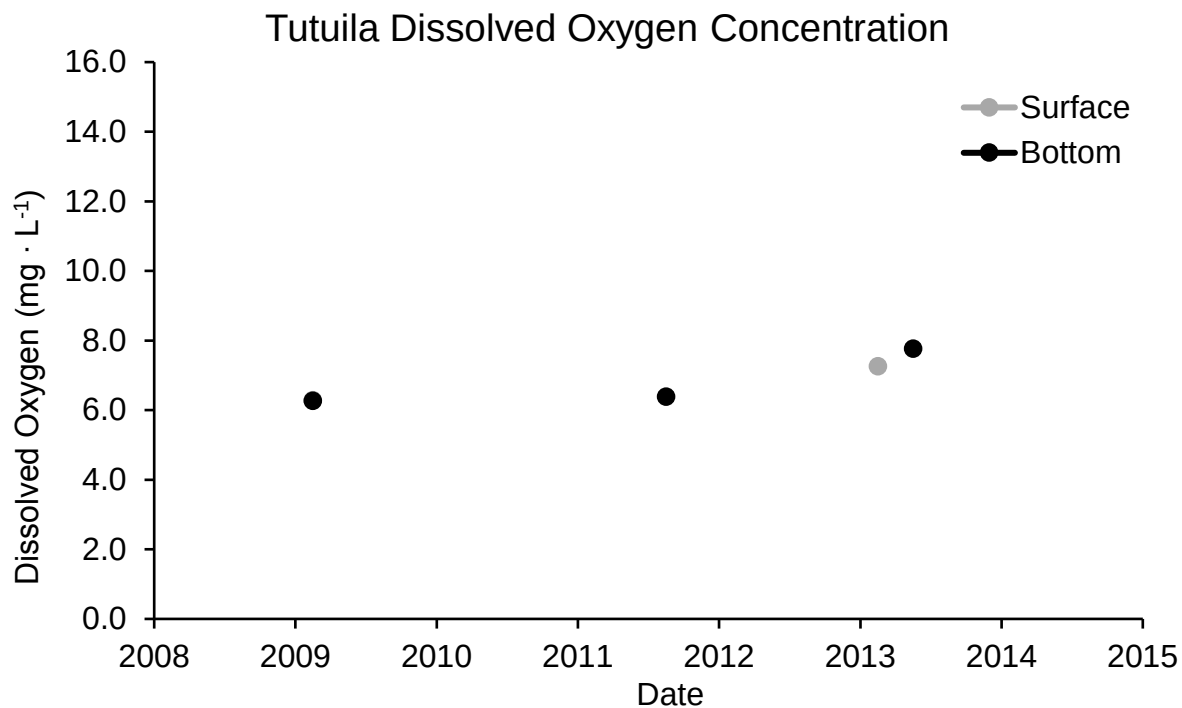


Figure 23. Dissolved oxygen concentration in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals.

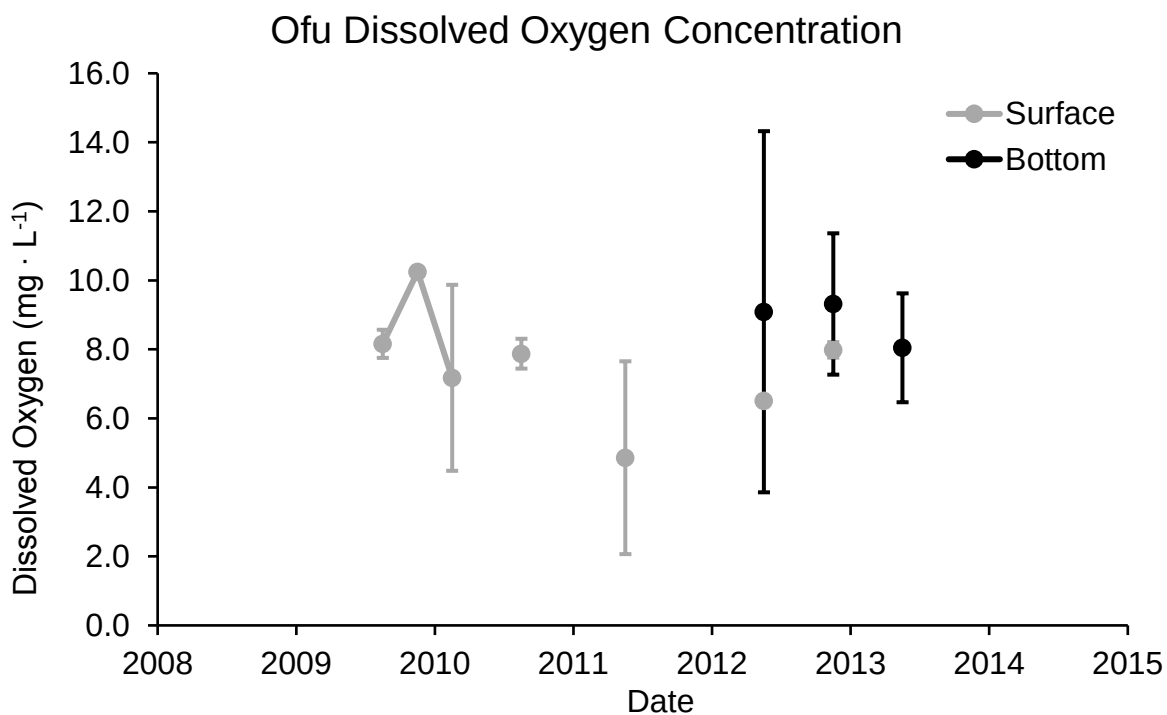


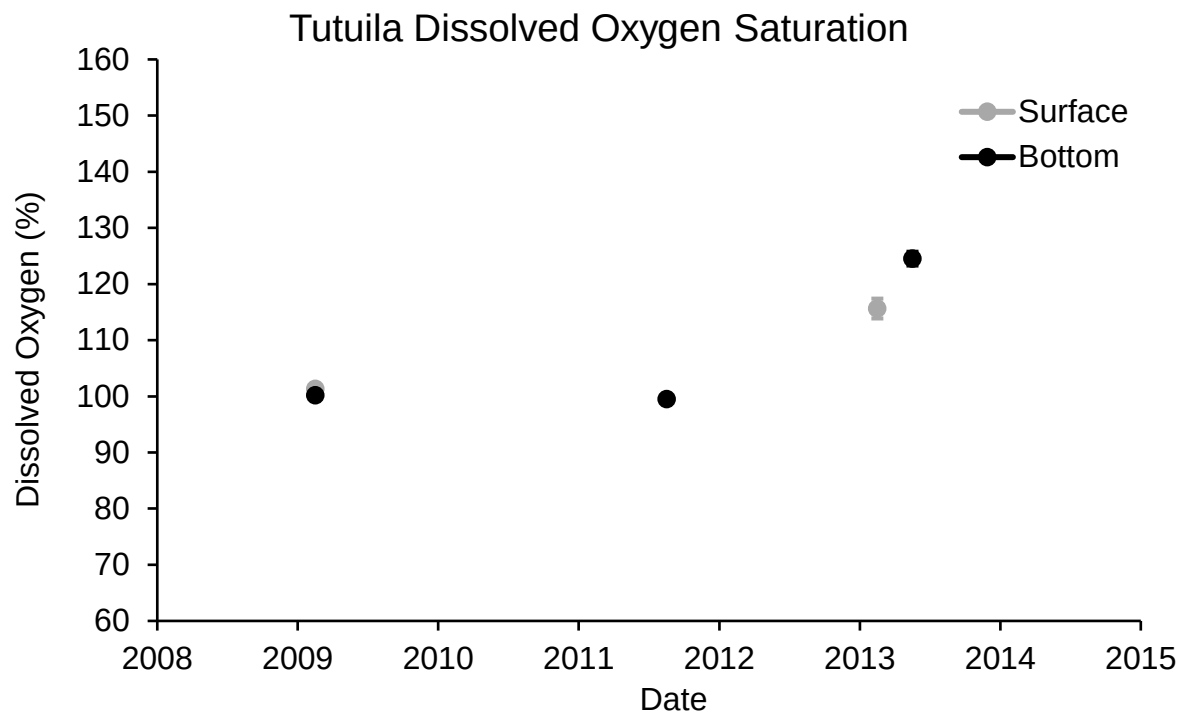
Figure 24. Dissolved oxygen concentration in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals.

Table 12. Dissolved oxygen saturation (%) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	27	100.1	101.6	100.0	1.5
	1	Bottom	27	100.0	100.4	100.0	1.9
2011	3	Bottom	1	99.5	99.5	99.5	NA
2013	1	Surface	4	113.3	116.1	117.1	1.8
	2	Bottom	19	118.8	124.2	129.3	2.7

Table 13. Dissolved oxygen saturation (%) in marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	3	120.3	128.7	132.1	6.1
	4	Surface	1	158.6	158.6	158.6	NA
2010	1	Surface	2	137.3	114.8	92.2	31.9
	3	Surface	6	110.5	122.9	134.0	9.4
2011	2	Surface	4	106.6	103.3	99.9	7.0
2012	2	Surface	1	103.8	103.8	103.8	NA
	2	Bottom	1	102.4	102.4	102.4	NA
2013	2	Bottom	1	115.9	115.9	115.9	NA

**Figure 25.** Dissolved oxygen saturation in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals.

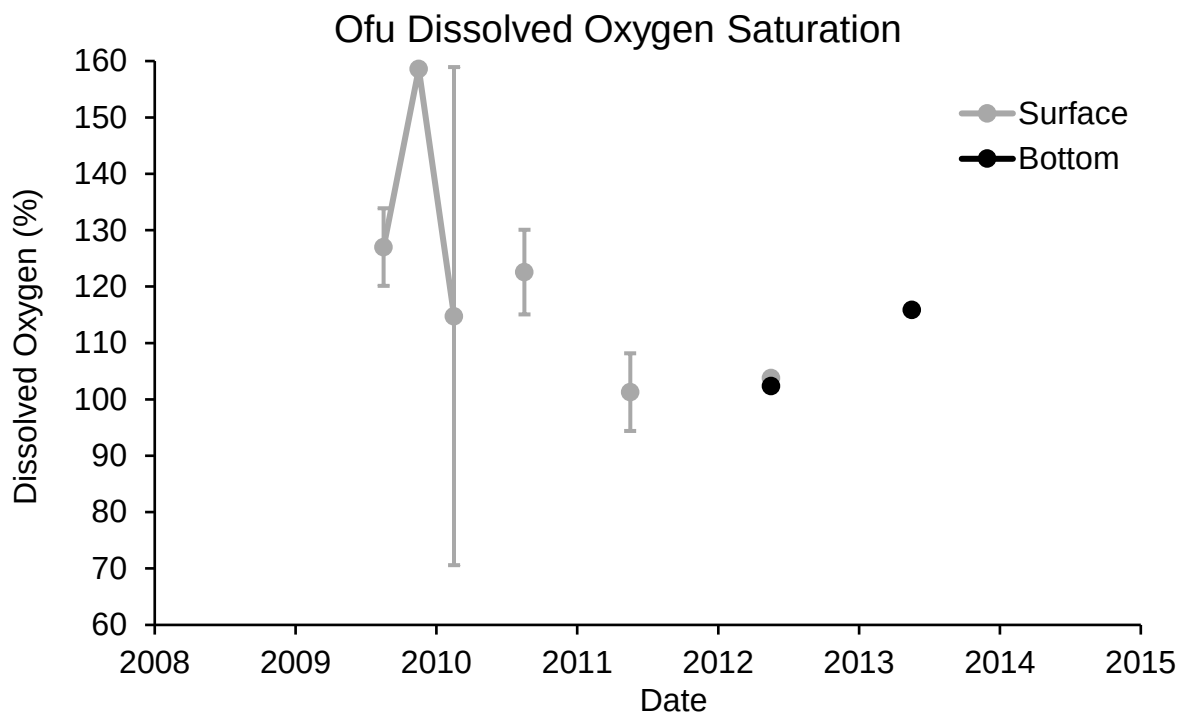


Figure 26. Dissolved oxygen saturation in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals.

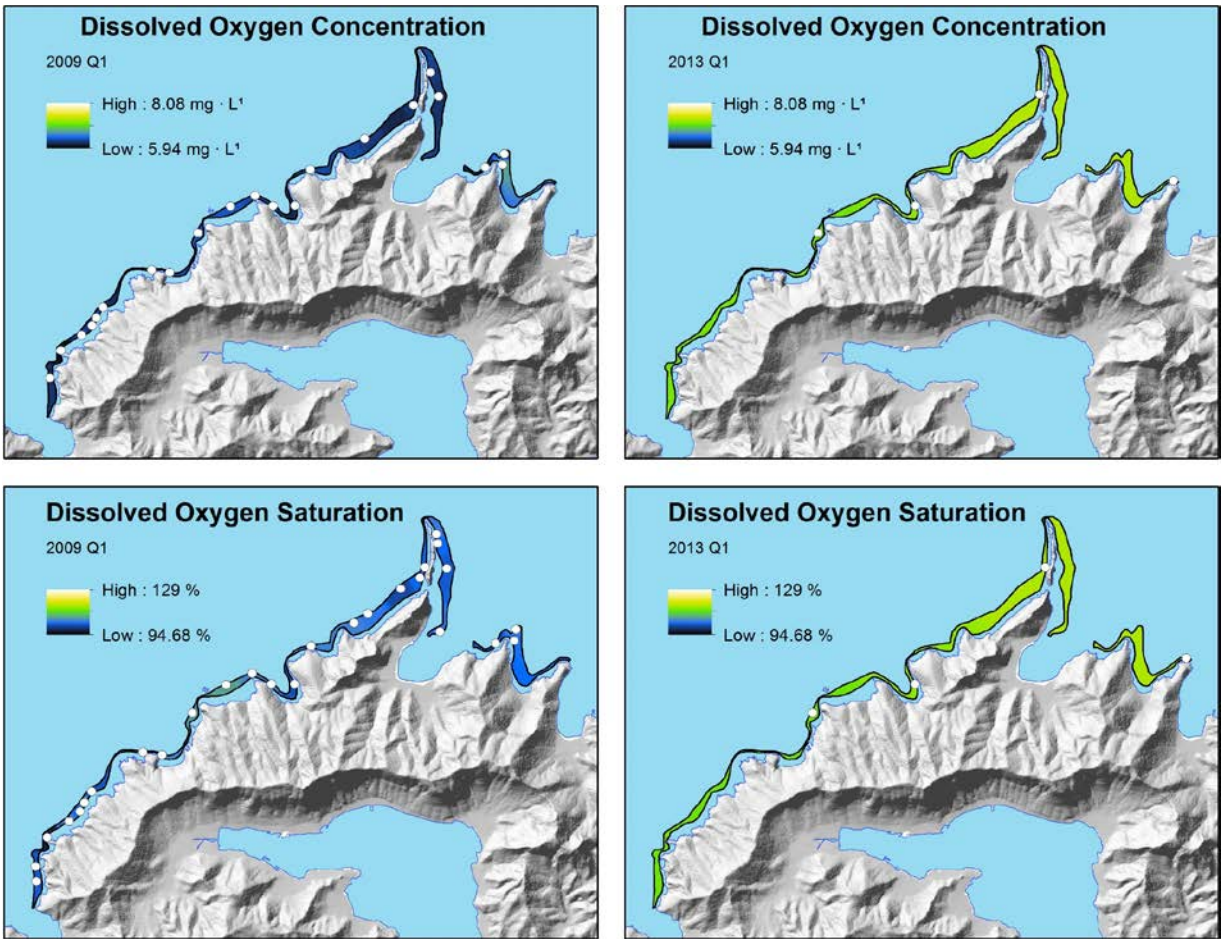


Figure 27. Spatial distribution of surface dissolved oxygen concentration and saturation in marine waters of NPSA in Tutuila using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

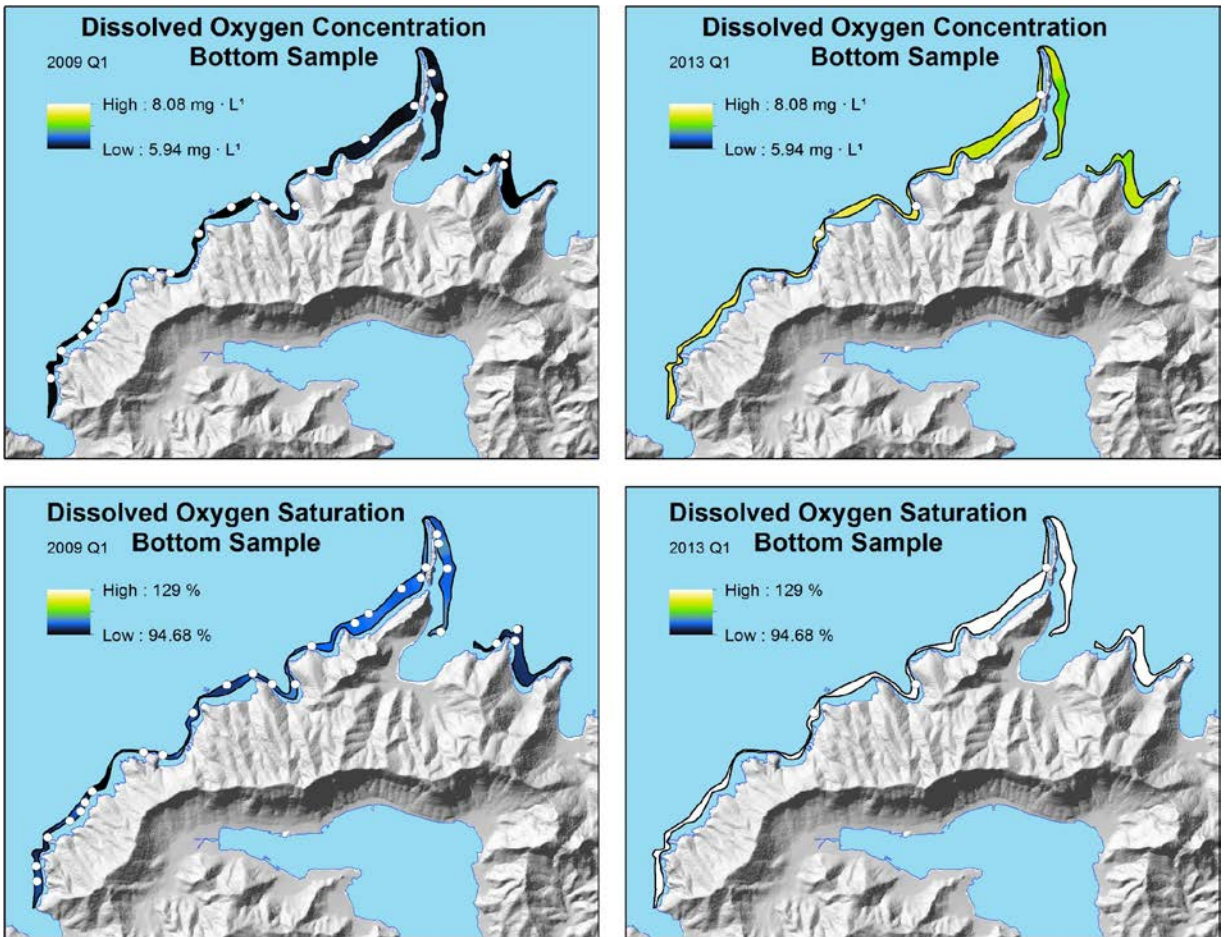


Figure 28. Spatial distribution of bottom dissolved oxygen concentration and saturation in marine waters of NPSA in Tutuila using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

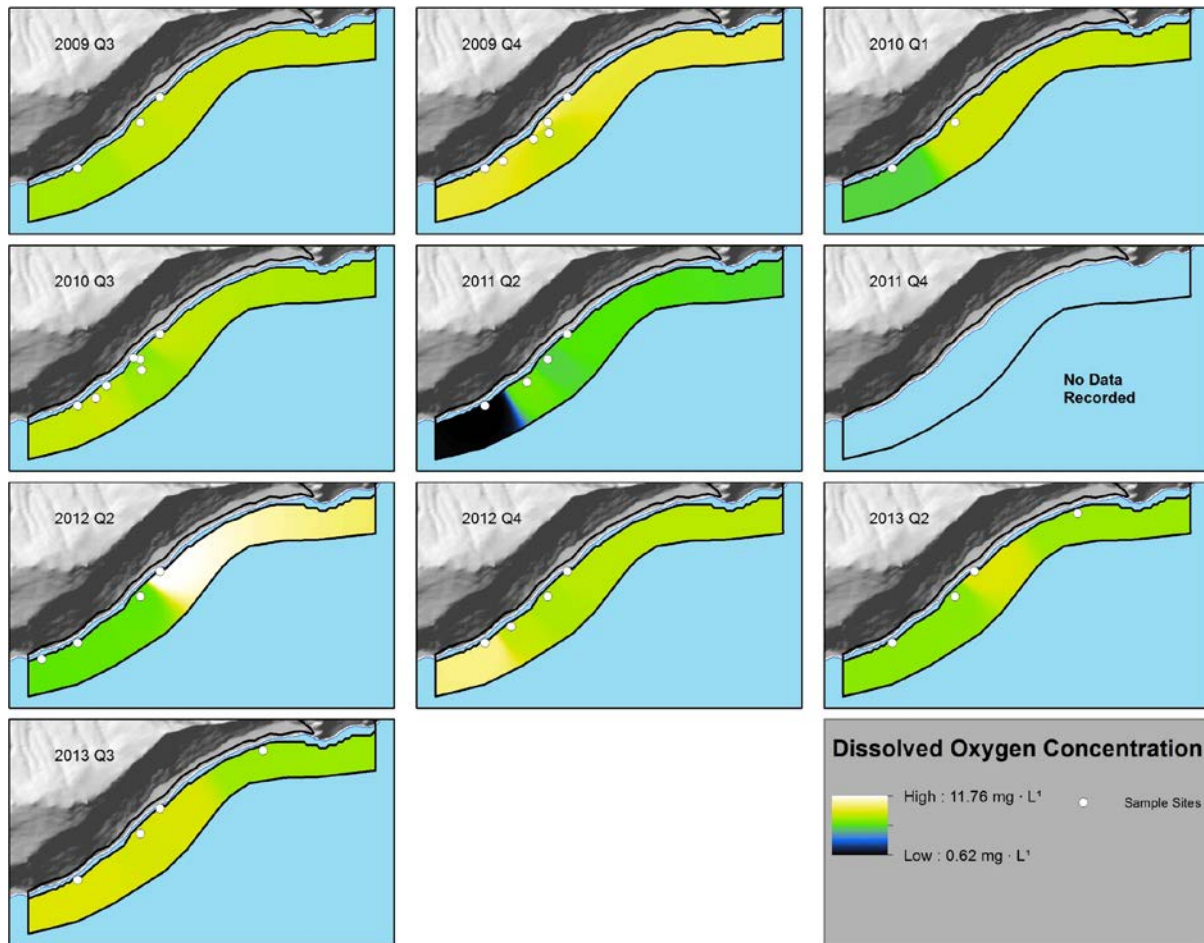


Figure 29. Spatial distribution of surface dissolved oxygen concentration in marine waters of NPSA in Ofu using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

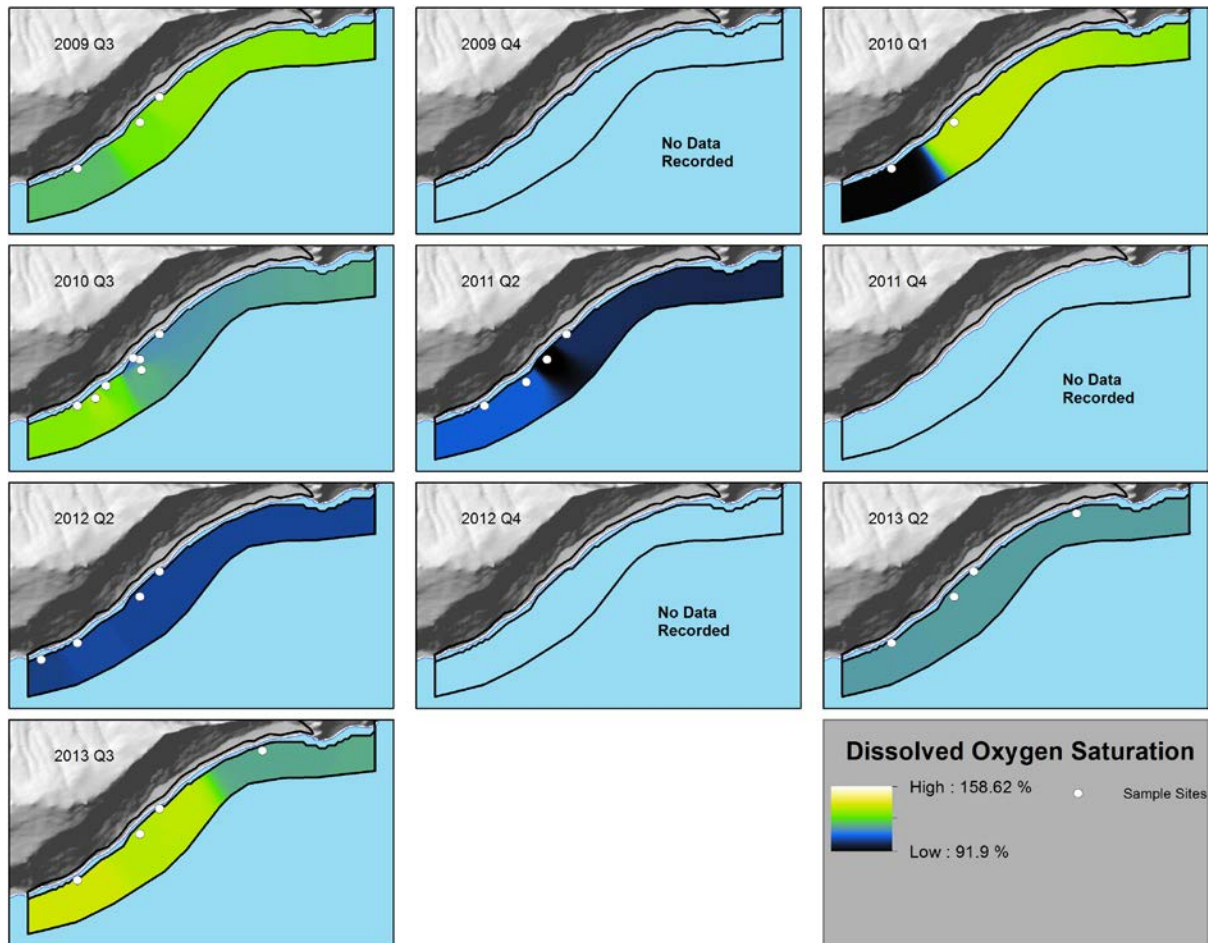


Figure 30. Spatial distribution of surface dissolved oxygen saturation in marine waters of NPSA in Ofu using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

pH

Surface and bottom waters displayed inconsistent patterns in pH (Tables 14-15, Figures 31-35).

Table 14. pH in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	27	8.1	8.2	8.2	0.0
	1	Bottom	27	8.2	8.2	8.2	0.0
2011	3	Bottom	1	8.4	8.4	8.4	NA
2013	1	Surface	4	8.1	8.1	8.1	0.0
2013	2	Bottom	19	8.0	8.0	8.1	0.0

Table 15. pH in marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	3	8.1	8.1	8.1	0.0
	4	Surface	7	8.1	8.1	8.2	0.0
2010	1	Surface	3	8.1	8.1	8.2	0.1
	3	Surface	7	8.1	8.1	8.1	0.0
2011	2	Surface	4	8.1	8.1	8.2	0.0
2012	2	Surface	1	8.2	8.2	8.2	NA
	2	Bottom	2	8.2	8.3	8.3	0.1
	4	Surface	2	8.1	8.1	8.1	0.0
	4	Bottom	2	8.1	8.2	8.2	0.0
2013	2	Bottom	2	8.1	8.0	8.2	0.0

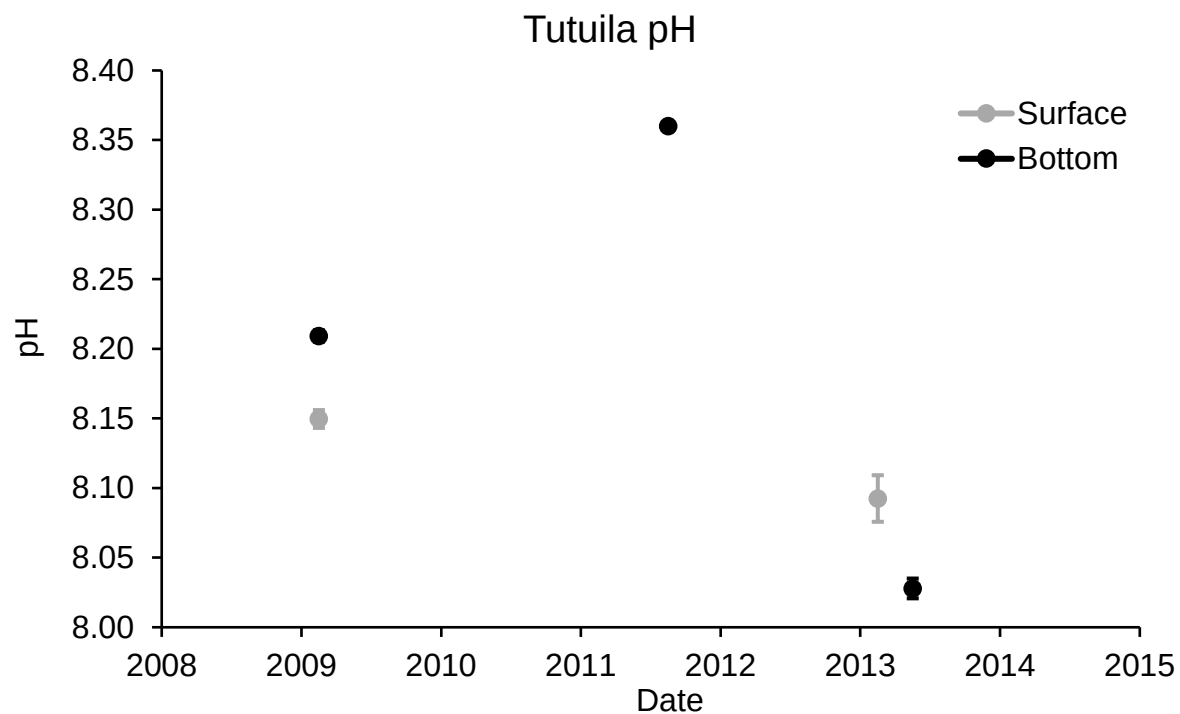


Figure 31. pH in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals.

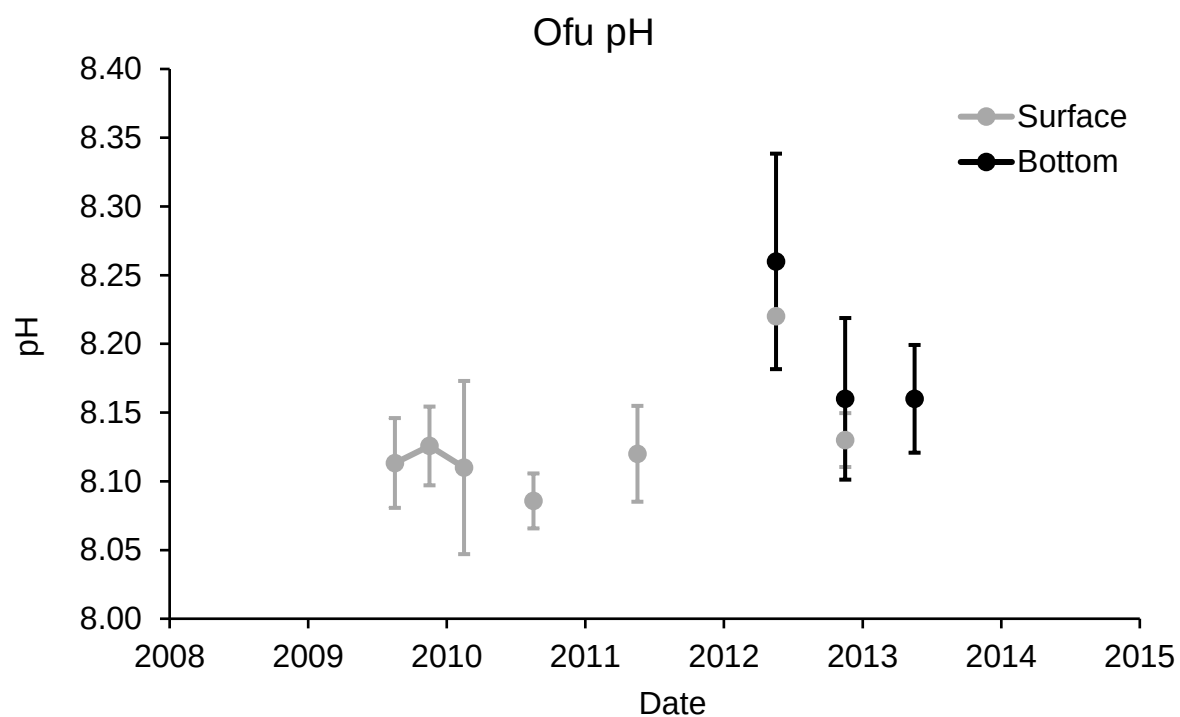


Figure 32. pH in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals.

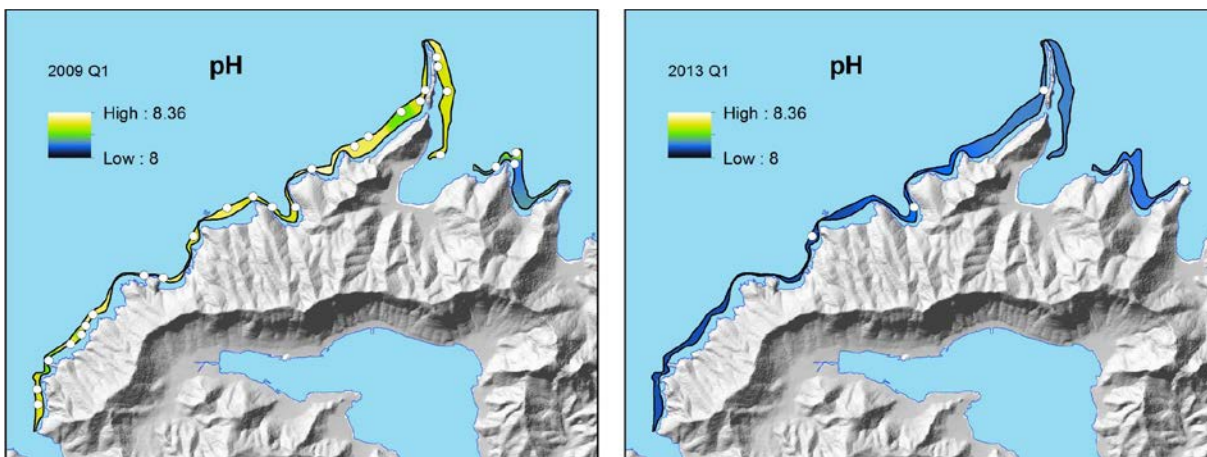


Figure 33. Spatial distribution of surface pH in marine waters of NPSA in Tutuila for selected quarters using the total range of results observed in surface and bottom samples.

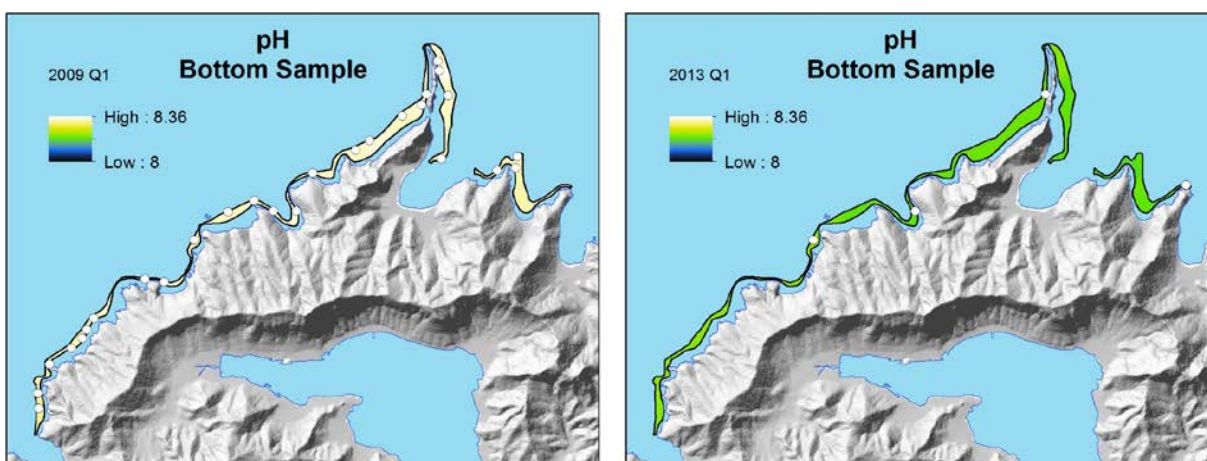


Figure 34. Spatial distribution of bottom pH in marine waters of NPSA in Tutuila for selected quarters using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

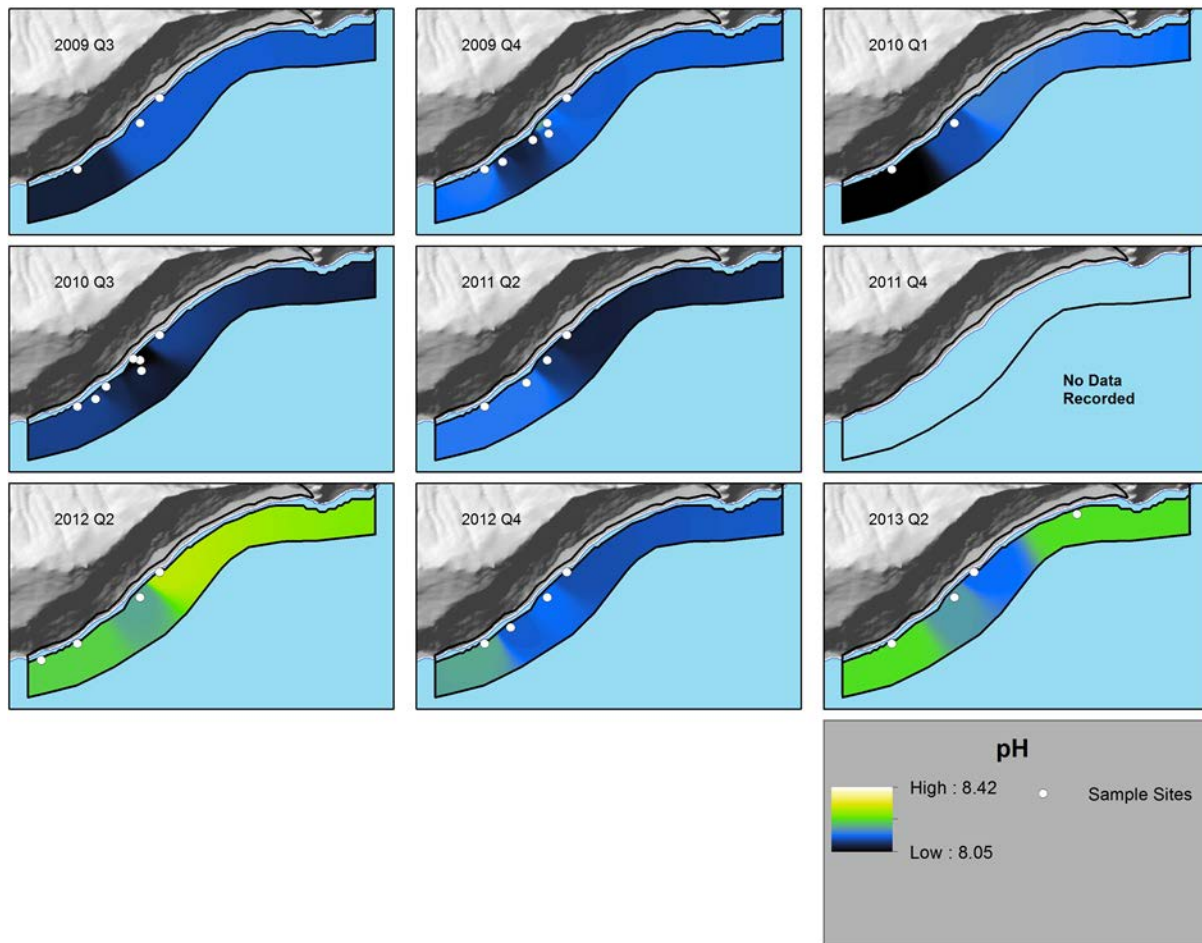


Figure 35. Spatial distribution of surface pH in marine waters of NPSA in Ofu using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

Salinity

Patterns in salinity were inconsistent in both areas (Tables 16-17, Figures 36-40).

Table 16. Salinity (ppt) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	26	36.8	36.9	37.0	0.0
	1	Bottom	27	35.3	35.6	35.7	0.1
2011	3	Bottom	1	36.2	36.2	36.2	NA
2013	1	Surface	4	35.5	35.5	35.6	0.1
	2	Bottom	19	35.5	35.8	36.0	0.1

Table 17. Salinity (ppt) in marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	3	36.1	36.2	36.3	0.1
	4	Surface	7	36.4	36.6	36.7	0.1
2010	1	Surface	2	37.0	37.0	37.1	0.0
	3	Surface	7	35.8	35.8	35.9	0.0
2011	2	Surface	4	35.5	35.6	35.7	0.1
	4	Surface	3	36.1	36.2	36.2	0.0
2012	2	Surface	1	35.7	35.7	35.7	NA
	2	Bottom	2	35.6	35.7	35.7	0.1
	4	Surface	2	33.3	33.3	33.4	0.0
	4	Bottom	2	33.4	33.4	33.4	0.0
2013	2	Bottom	2	35.5	35.8	35.7	0.1

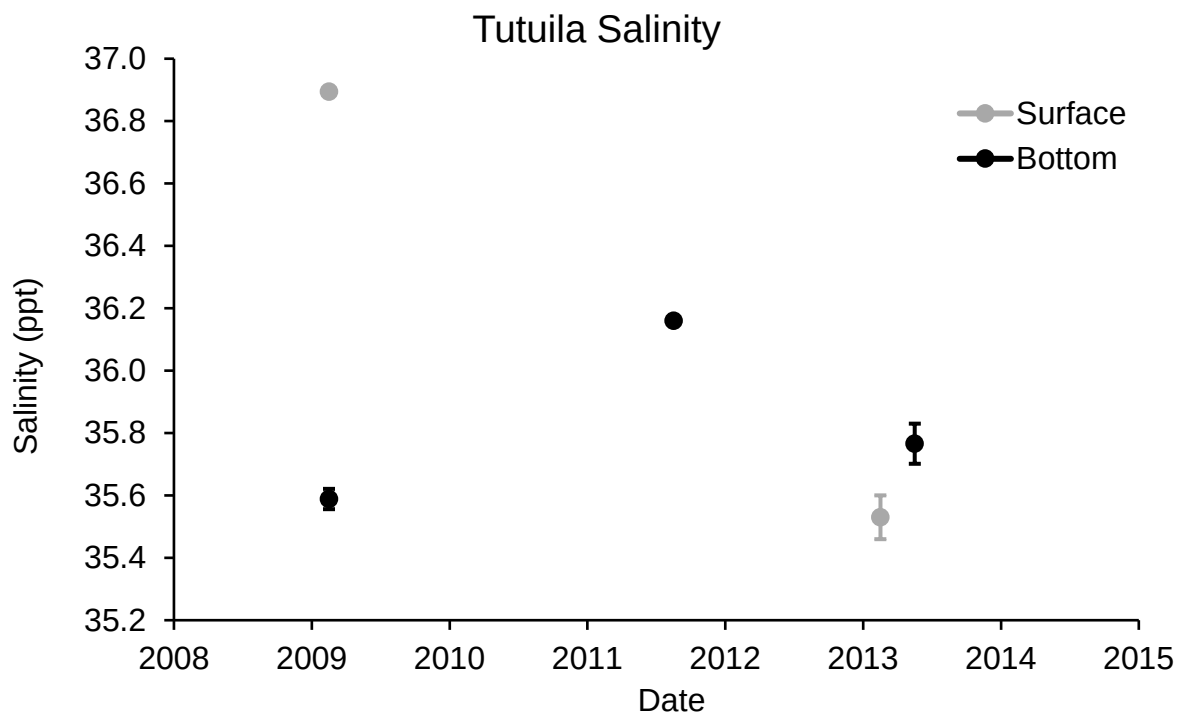


Figure 36. Salinity in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals.

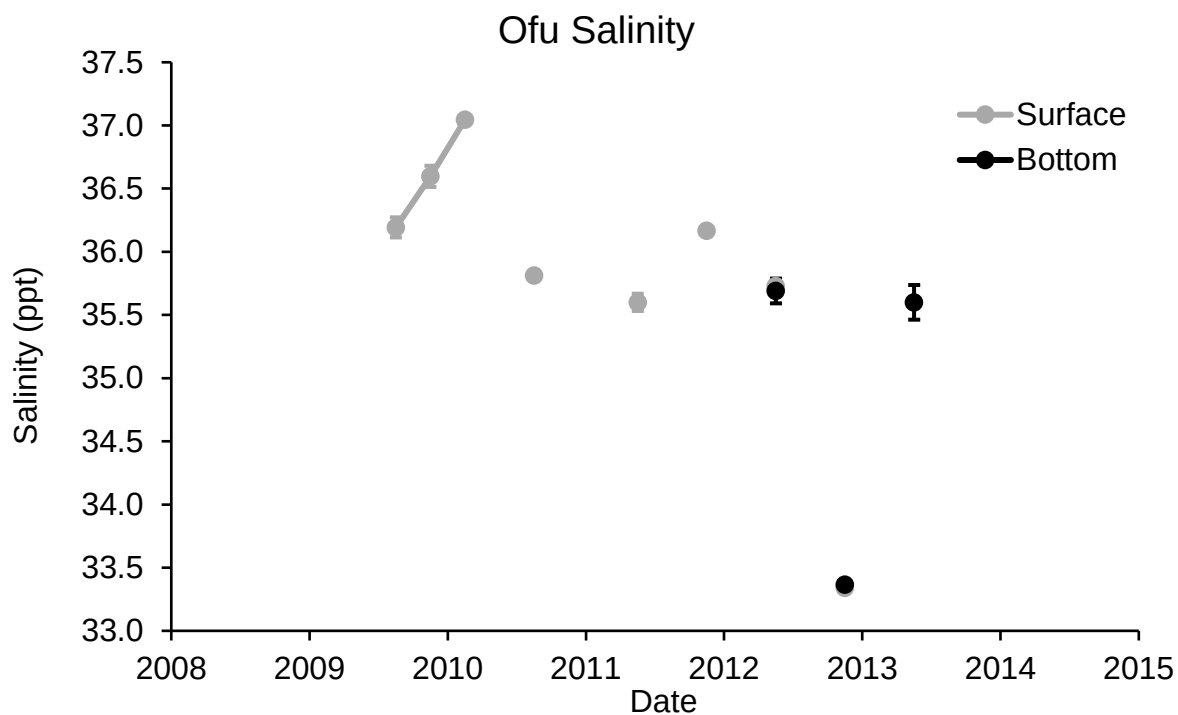


Figure 37. Salinity in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals.

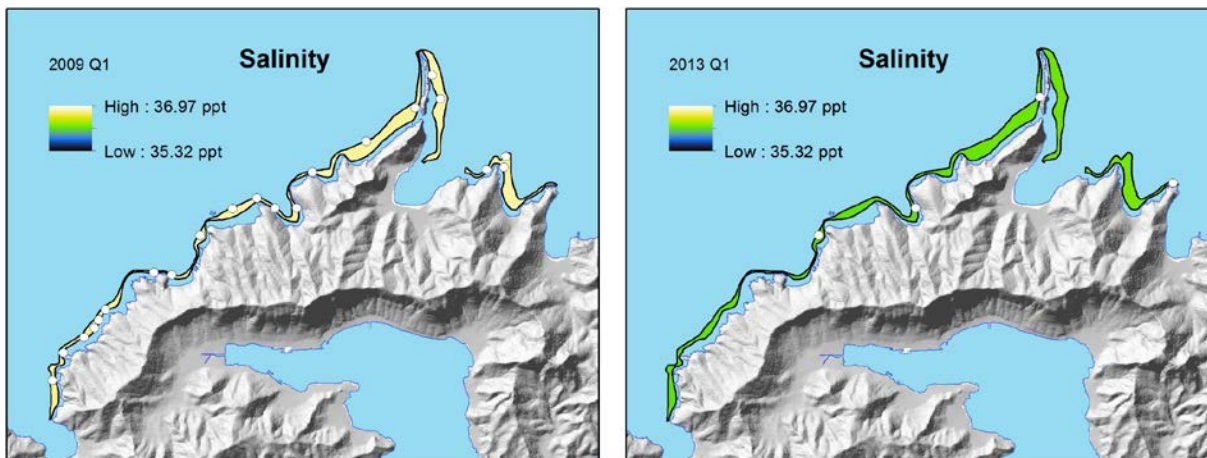


Figure 38. Spatial distribution of surface salinity in marine waters of NPSA in Tutuila for selected quarters using the total range of results observed in surface and bottom samples.

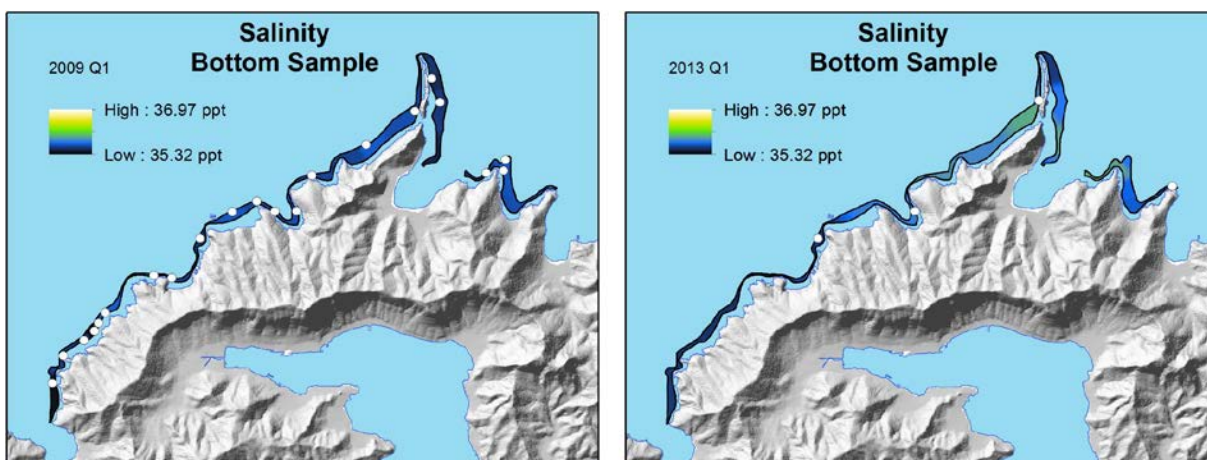


Figure 39. Spatial distribution of bottom salinity in marine waters of NPSA in Tutuila for selected quarters using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

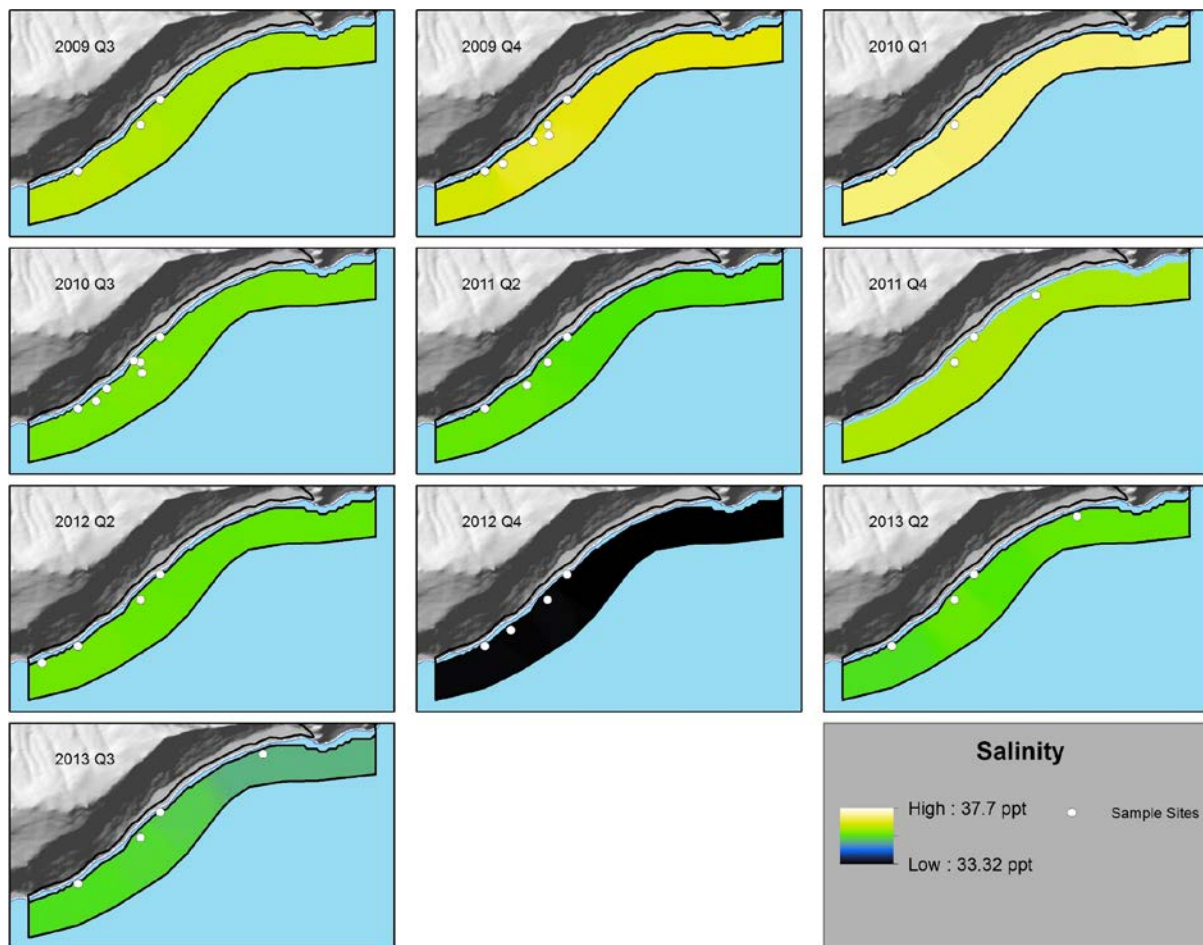


Figure 40. Spatial distribution of surface salinity in marine waters of NPSA in Ofu using the total range of results observed in (lowest to highest data values) in both surface and bottom samples.

Specific Conductance

Patterns in specific conductance were also inconsistent in both areas (Figures 41-45, Tables 17-18).

Table 18. Specific conductance ($\text{mS} \cdot \text{cm}^{-1}$) marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	26	55.7	55.8	55.9	0.0
	1	Bottom	27	53.7	54.1	54.2	0.1
2011	3	Bottom	1	54.7	54.7	54.7	NA
2013	1	Surface	4	53.8	54.0	54.1	0.1
	2	Bottom	19	53.9	54.3	54.6	0.2

Table 19. Specific conductance ($\text{mS} \cdot \text{cm}^{-1}$) marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	3	54.7	54.8	54.9	0.1
	4	Surface	7	55.2	55.5	55.5	0.1
2010	1	Surface	2	56.0	56.0	56.0	0.0
	3	Surface	7	54.2	54.3	54.4	0.1
2011	2	Surface	4	53.9	54.1	54.1	0.1
	4	Surface	3	54.7	54.8	54.8	0.1
2012	2	Surface	1	54.2	54.2	54.2	NA
	2	Bottom	2	54.2	54.2	54.2	0.1
	4	Surface	2	51.0	51.0	51.0	0.0
	4	Bottom	2	51.0	51.0	51.1	0.0
2013	2	Bottom	2	54.0	54.3	54.2	0.1

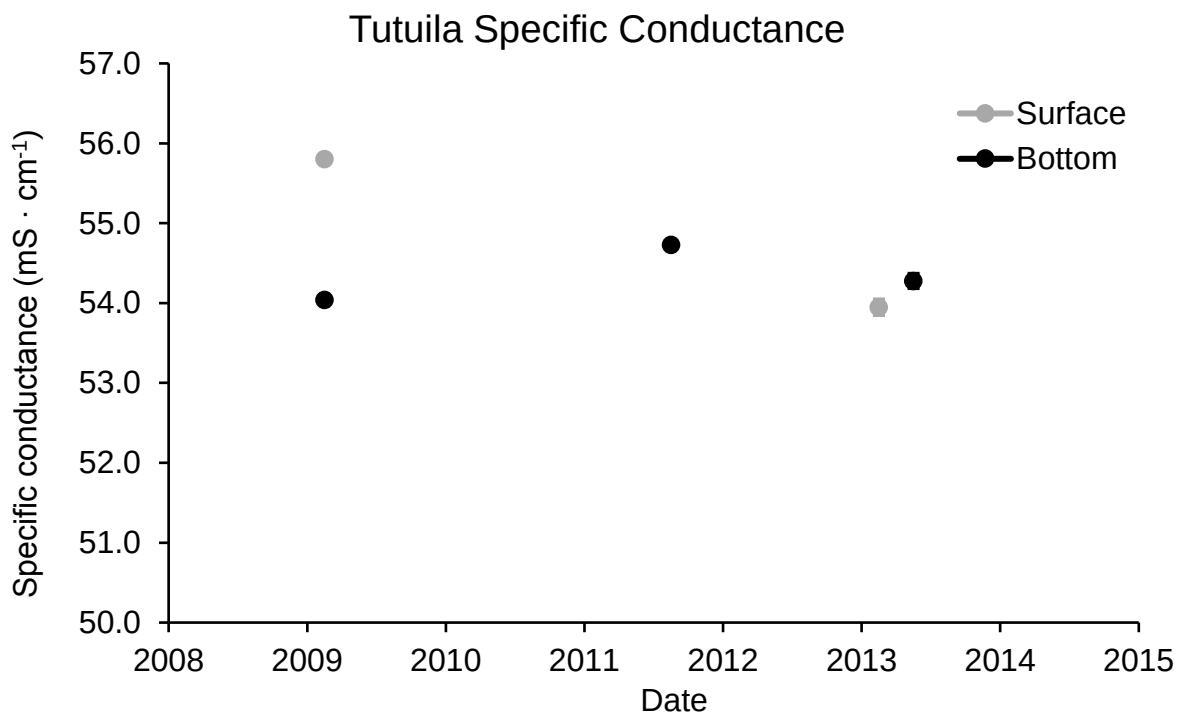


Figure 41. Specific conductance in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals.

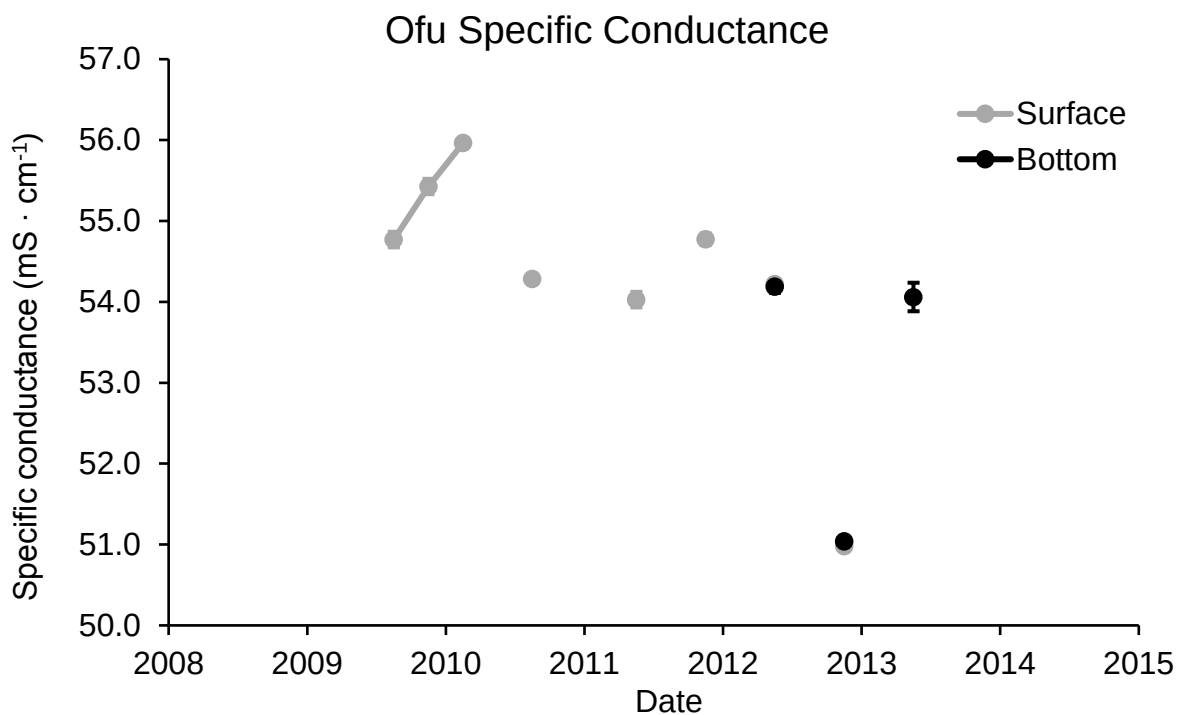


Figure 42. Specific conductance in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals.

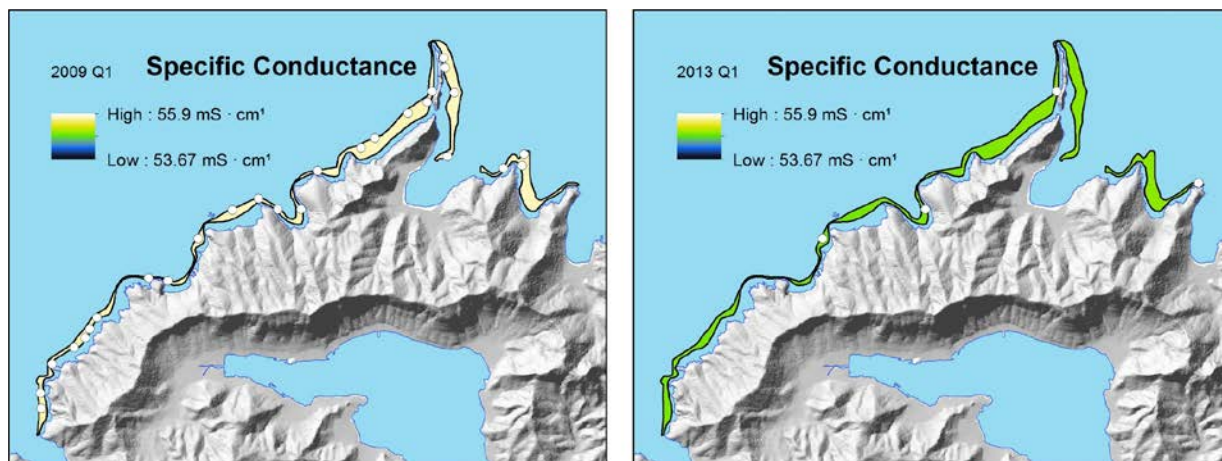


Figure 43. Spatial distribution of surface specific conductance in marine waters of NPSA in Tutuila using the total range of results observed in surface and bottom samples.

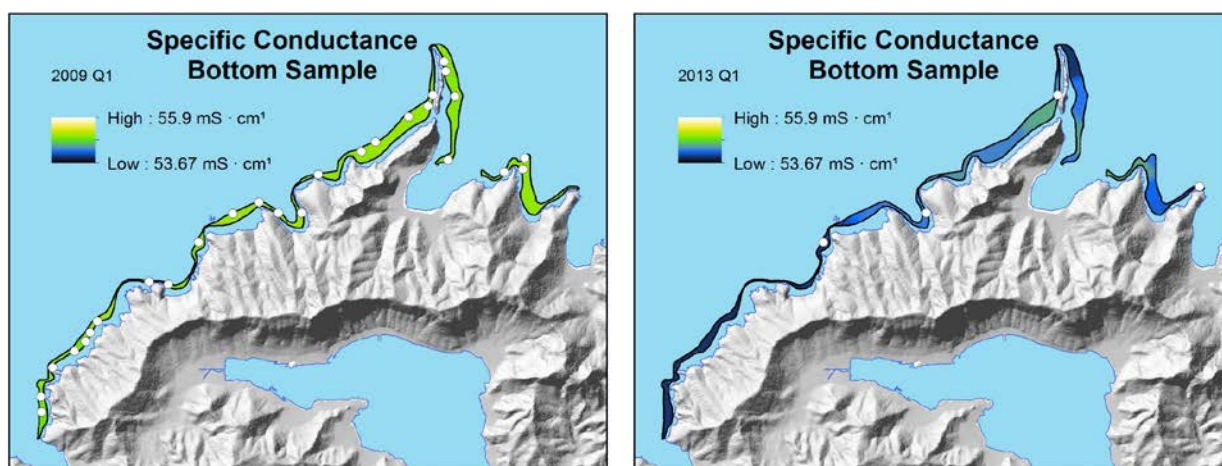


Figure 44. Spatial distribution of bottom specific conductance in marine waters of NPSA in Tutuila using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

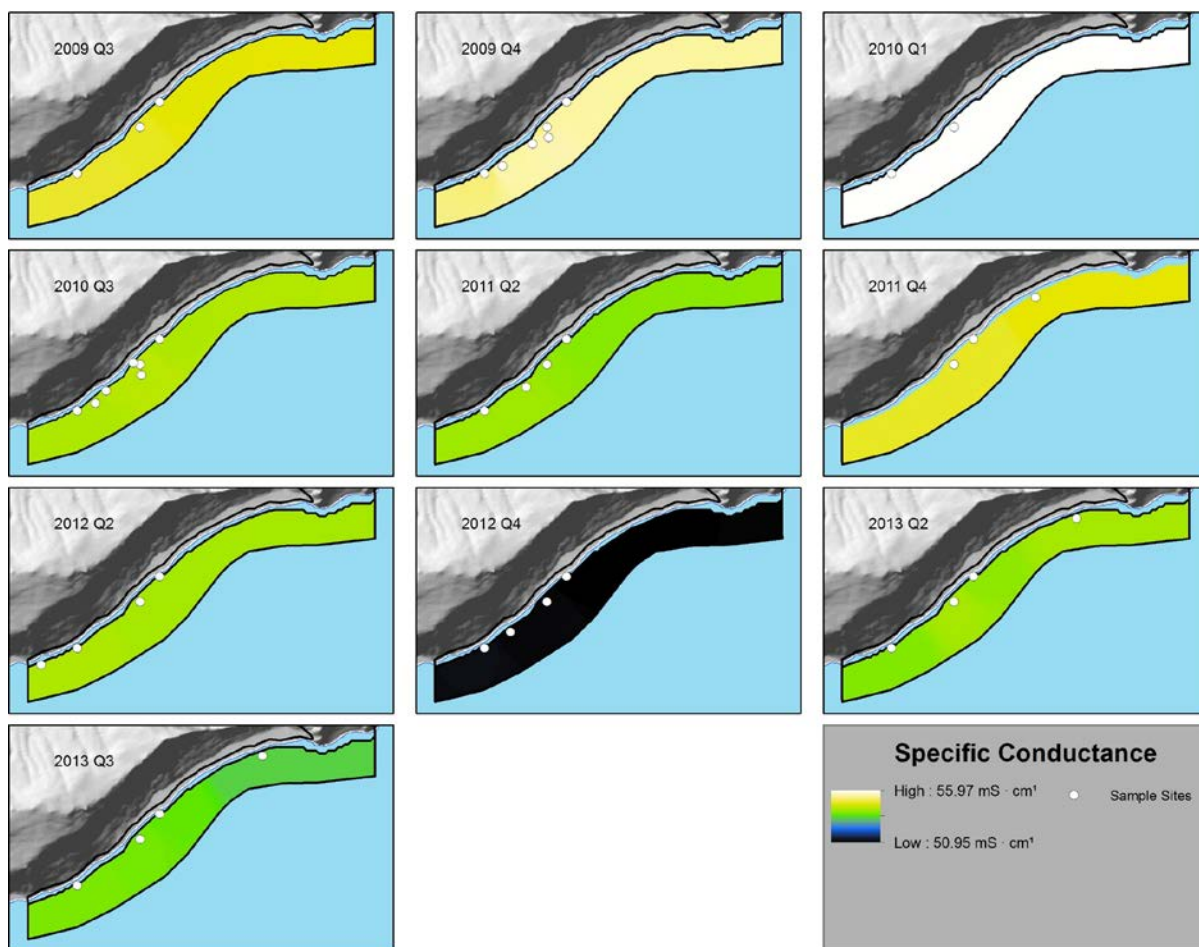


Figure 45. Spatial distribution of surface specific conductance in marine waters of NPSA in Ofu using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

Temperature

Temperatures varied during sample trips between years and depths (Tables 20-21, Figures 46-50).

Table 20. Temperature (°C) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	27	29.5	29.8	30.3	0.2
	1	Bottom	27	29.3	29.6	29.8	0.1
2011	3	Bottom	1	27.7	27.7	27.7	NA
2013	1	Surface	4	29.4	29.4	29.5	0.1
	2	Bottom	19	29.2	29.8	30.1	0.3

Table 21. Temperature (°C) in marine waters of NPSA in Ofu.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	3	27.5	27.7	28.0	0.2
	4	Surface	7	29.7	30.3	31.1	0.5
2010	1	Surface	2	28.8	29.1	29.4	0.4
	3	Surface	7	28.3	28.4	28.5	0.1
2011	2	Surface	4	29.0	29.1	29.1	0.0
	4	Surface	3	28.1	28.6	29.0	0.5
2012	2	Surface	1	29.4	29.4	29.4	NA
	2	Bottom	2	29.3	29.9	30.5	0.8
	4	Surface	2	29.1	29.1	29.1	0.0
	4	Bottom	2	29.4	29.7	29.9	0.3
2013	2	Bottom	2	29.6	29.8	29.8	0.1

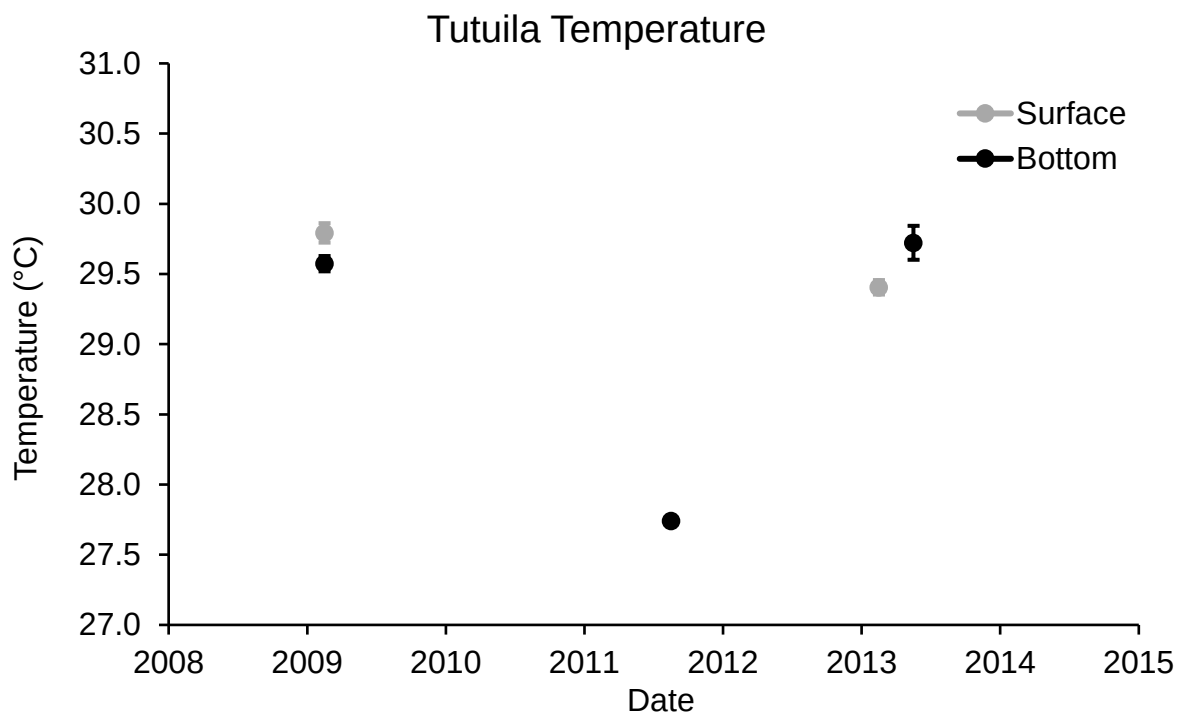


Figure 46. Temperature in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals.

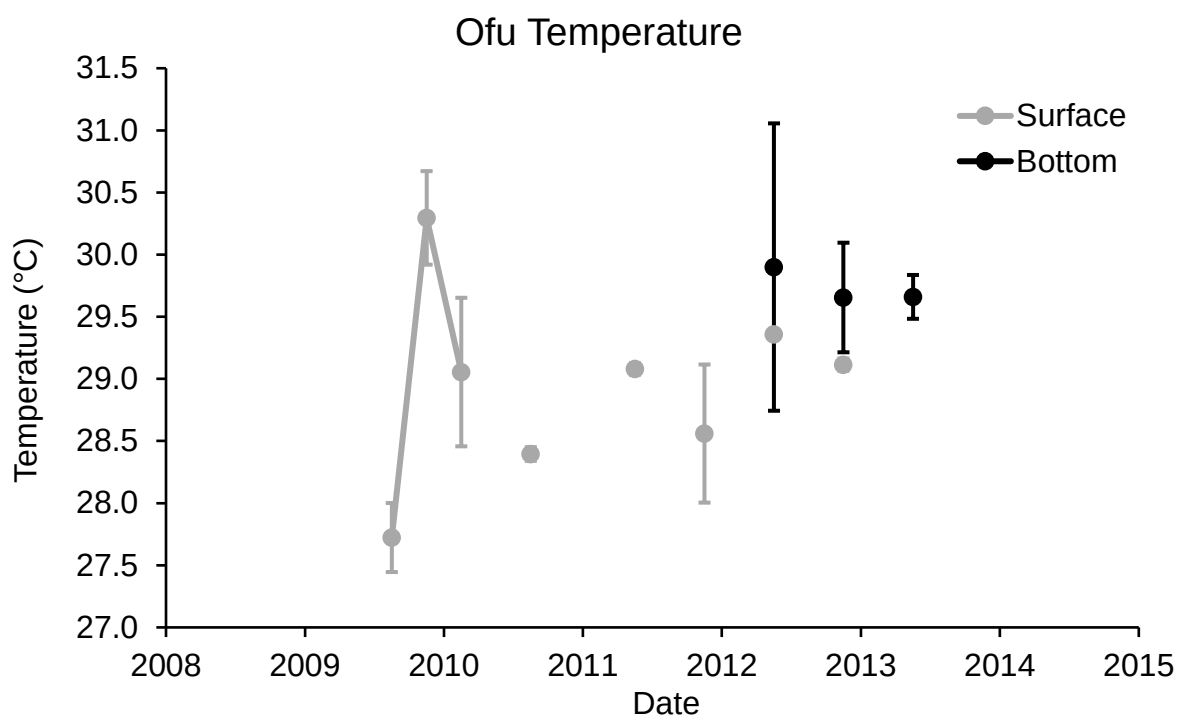


Figure 47. Temperature in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals.

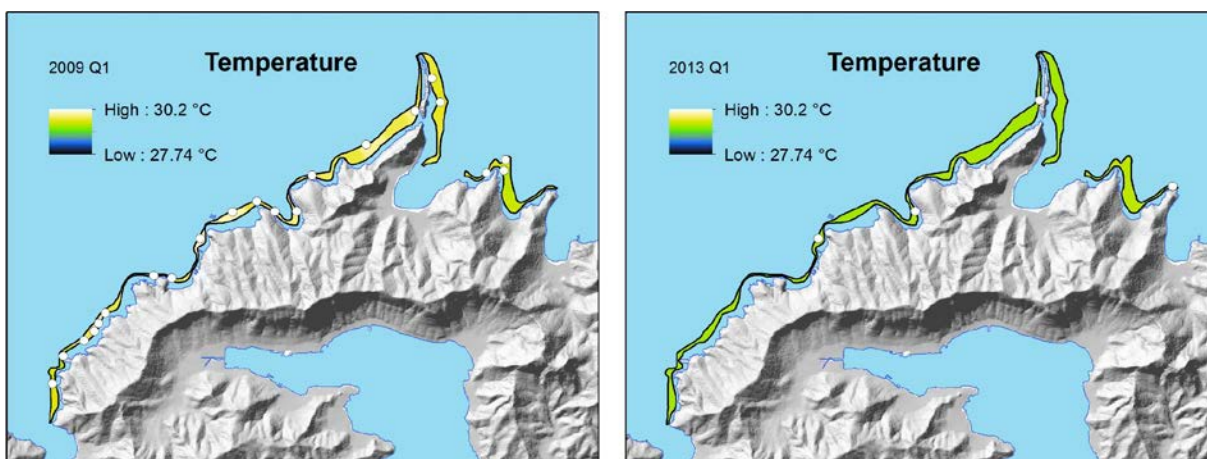


Figure 48. Spatial distribution of surface temperature in marine waters of NPSA in Tutuila for selected quarters using the total range of results observed in surface and bottom samples.

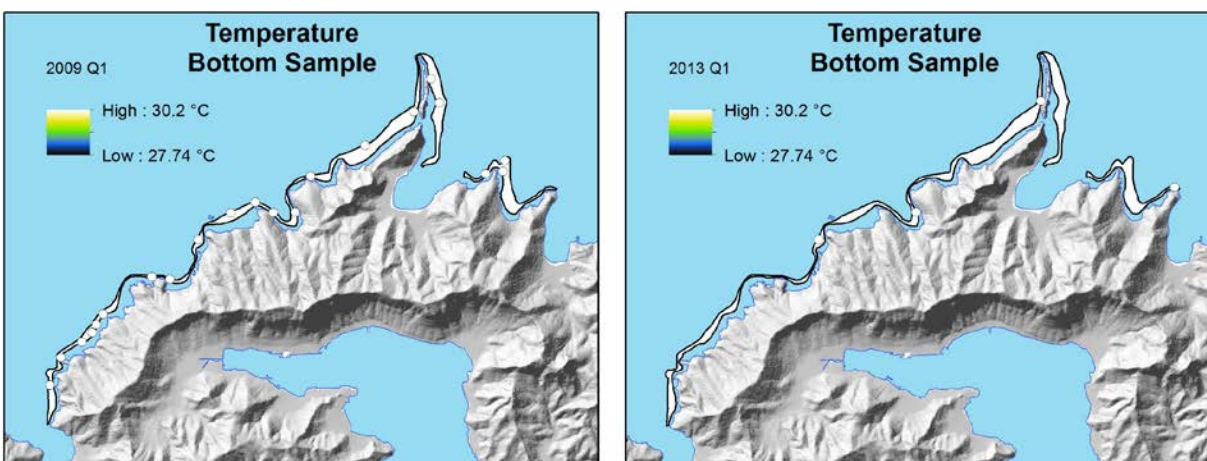


Figure 49. Spatial distribution of bottom temperature in marine waters of NPSA in Tutuila for selected quarters using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

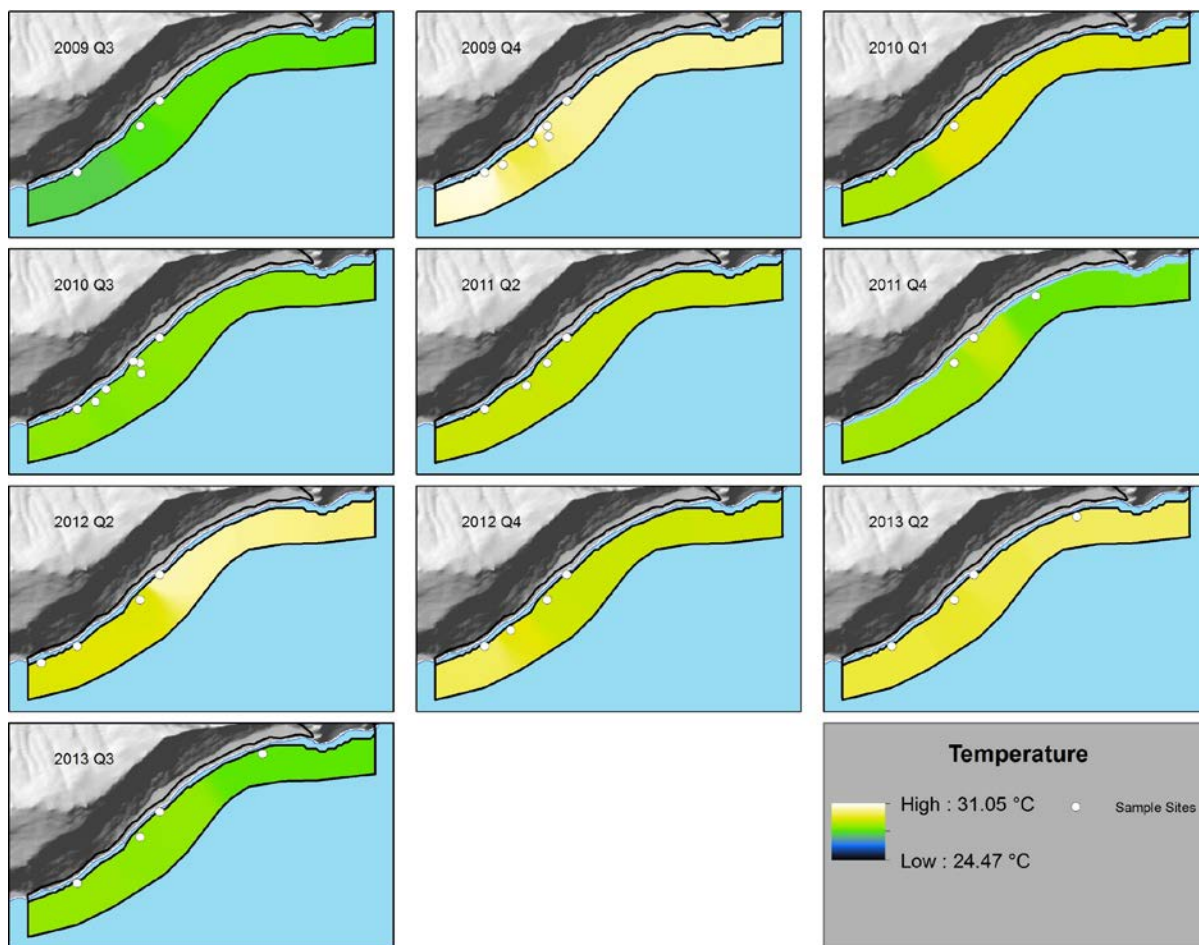


Figure 50. Spatial distribution of surface temperature in marine waters of NPSA in Ofu using the total range of results observed in (lowest to highest data values) in both surface and bottom samples.

Turbidity

Surface and bottom waters displayed very low turbidity, with the exception of a spike observed in 2010 in Ofu (Tables 22-23, Figures 51-55).

Table 22. Turbidity (NTU) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	1	Surface	26	0.1	0.1	0.1	0.0
	1	Bottom	26	0.1	0.1	0.1	0.0
2011	3	Bottom	1	2.5	2.5	2.5	NA
2013	1	Surface	4	0.1	0.1	0.1	0.0
	2	Bottom	19	0.1	0.1	1.4	0.3

Table 23. Turbidity (NTU) in marine waters of NPSA in Tutuila.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	3	Surface	3	0.1	0.1	3.9	2.2
	4	Surface	6	0.1	0.3	1.1	0.5
2010	1	Surface	2	0.1	0.1	0.1	0.0
	3	Surface	7	35.2	35.3	35.4	0.0
2011	2	Surface	4	0.1	0.1	0.1	0.0
2012	2	Surface	1	0.1	0.1	0.1	NA
	2	Bottom	2	0.1	0.1	0.1	0.0
	4	Surface	2	0.1	0.1	0.1	0.0
	4	Bottom	2	0.1	0.1	0.1	0.0
2013	2	Bottom	2	0.1	0.1	0.1	0.0

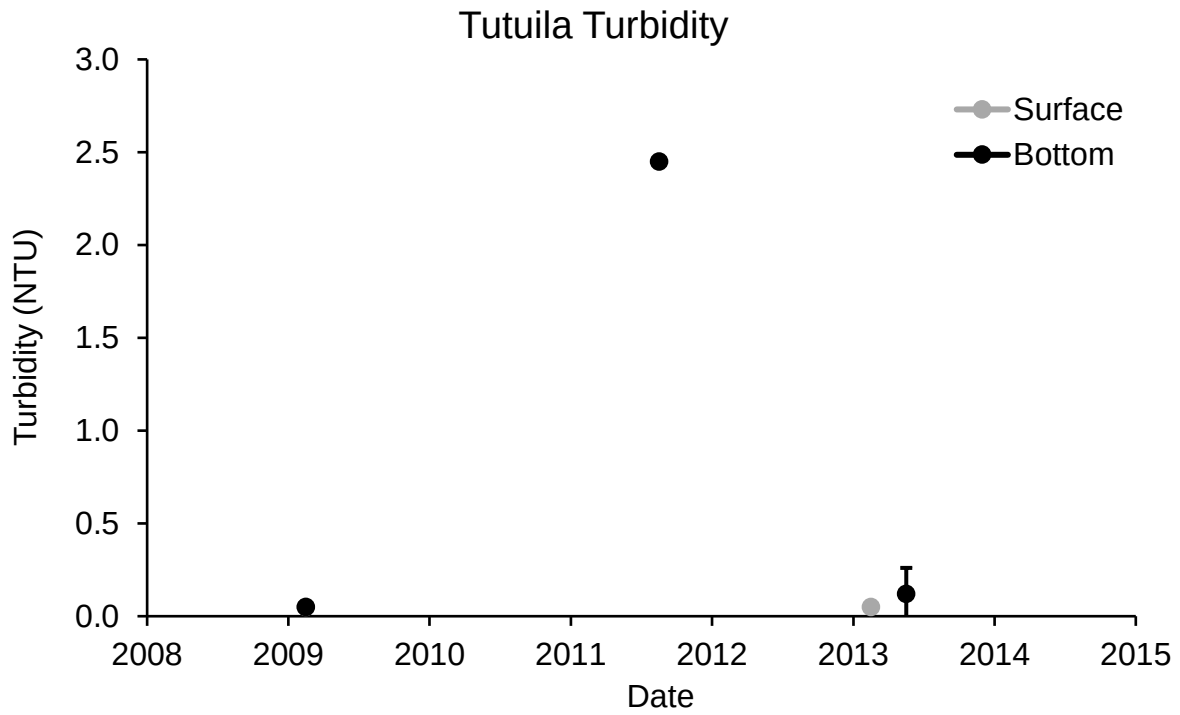


Figure 51. Turbidity in marine waters of NPSA in Tutuila. Data are means and 95% confidence intervals.

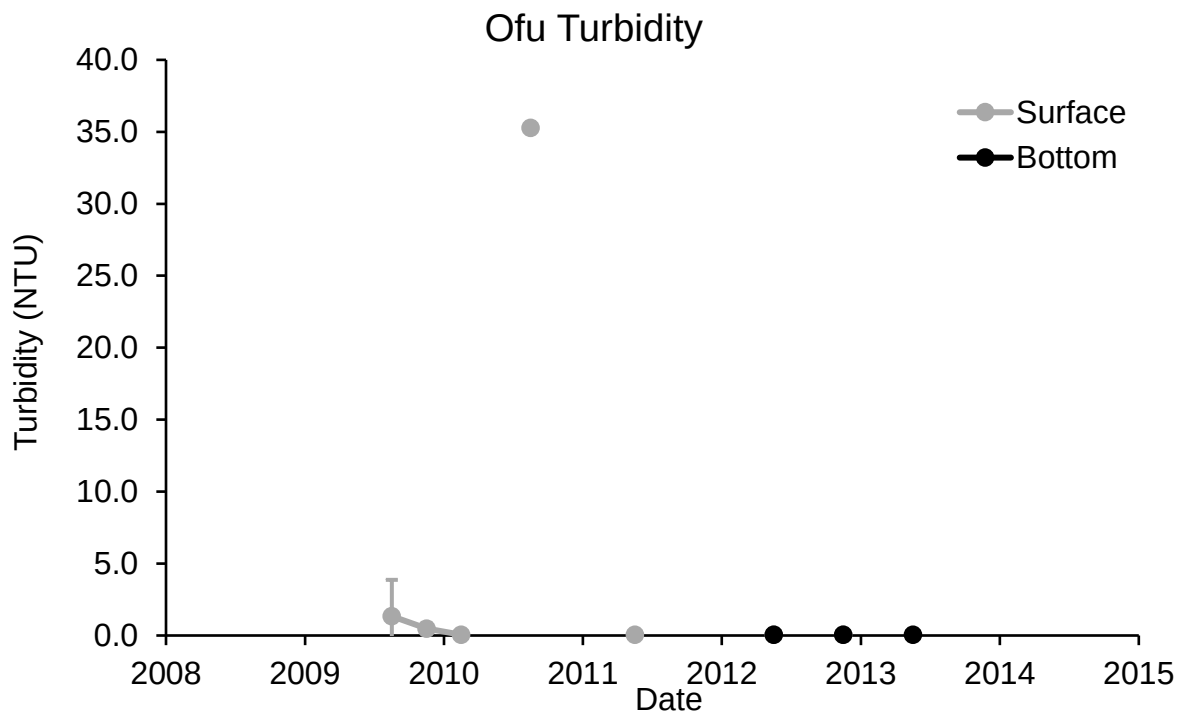


Figure 52. Turbidity in marine waters of NPSA in Ofu. Data are means and 95% confidence intervals.

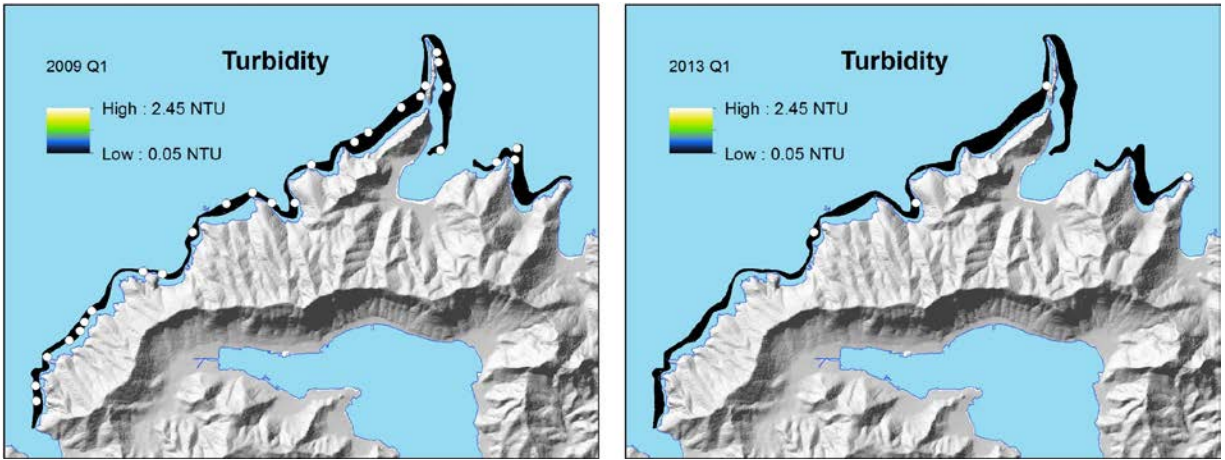


Figure 53. Spatial distribution of surface turbidity in marine waters of NPSA in Tutuila using the total range of results observed in surface and bottom samples.

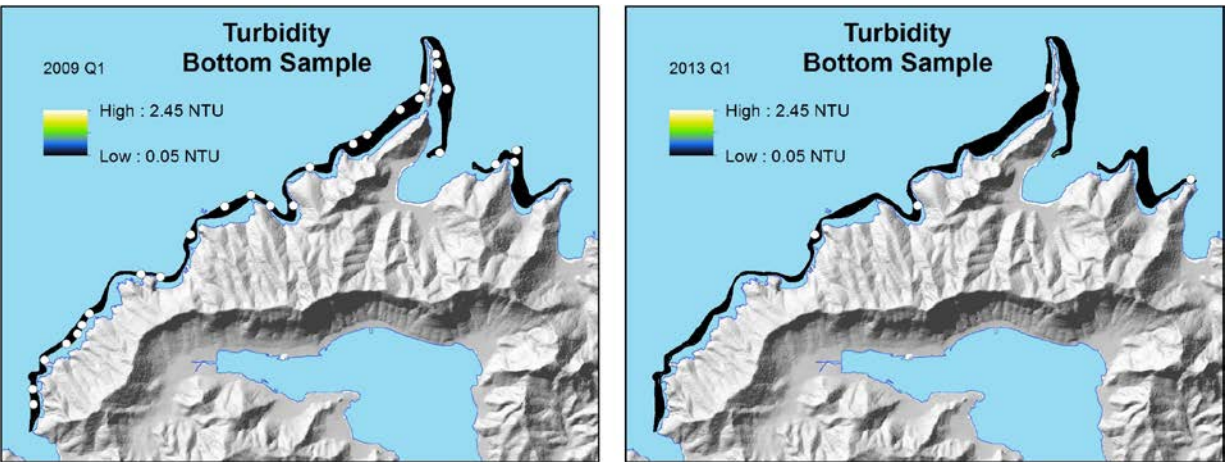


Figure 54. Spatial distribution of bottom turbidity in marine waters NPSA in Tutuila using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

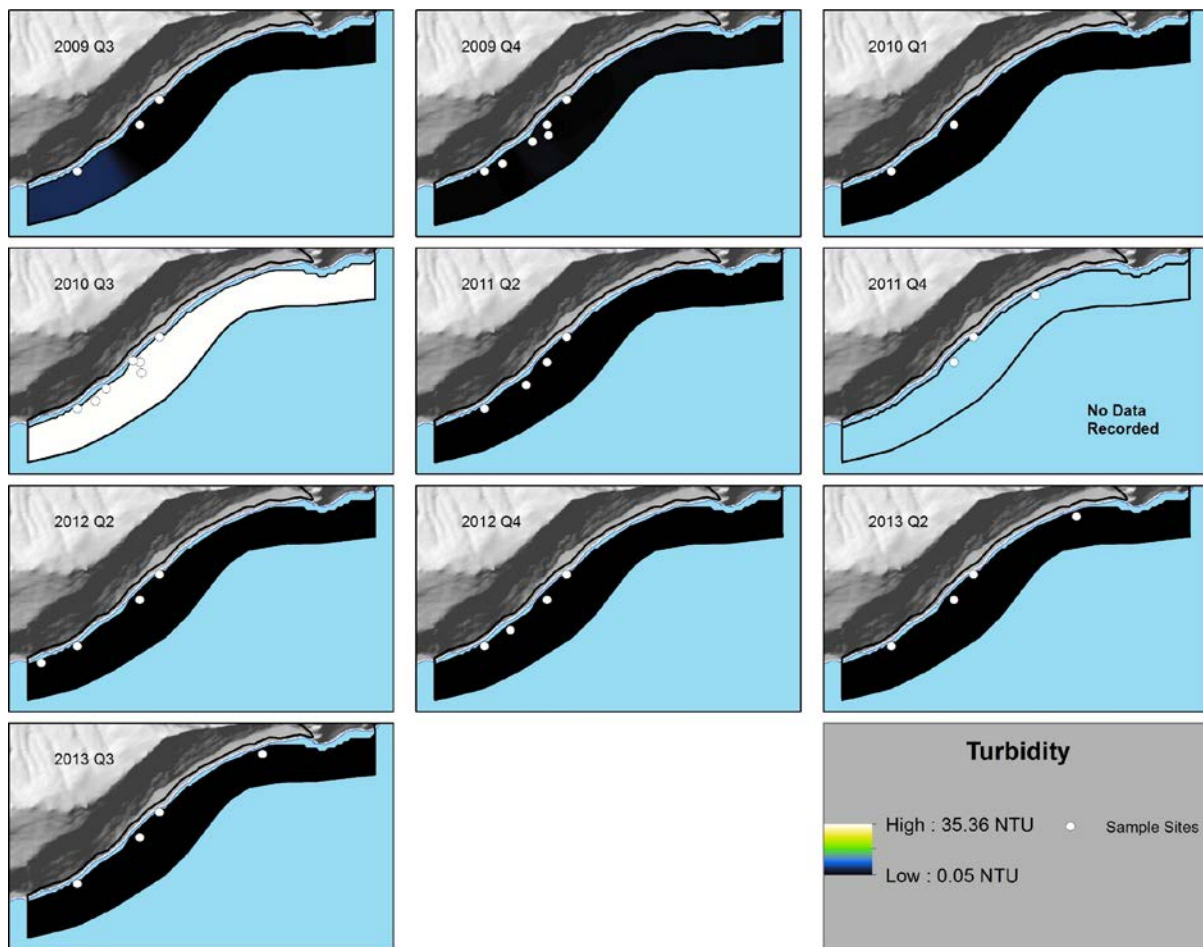


Figure 55. Spatial distribution of surface turbidity in marine waters of NPSA in Ofu using the total range of results observed (lowest to highest data values) in both surface and bottom samples.

Comparison to Territory Water Quality Criteria

Data are annual medians of surface samples (Table 24).

Table 24. Medians of water quality parameters in marine waters of National Park of American Samoa.^{A, B}

Location	Year	TDP ($\mu\text{gP} \cdot \text{L}^{-1}$)	TDN ($\text{mgN} \cdot \text{L}^{-1}$)	$\text{NO}_2 + \text{NO}_3$ ($\mu\text{gN} \cdot \text{L}^{-1}$)	Chlorophyll ($\mu\text{g} \cdot \text{L}^{-1}$)	Turbidity (NTU)
Tutuila	2009	7.50	0.10	3.33	0.22	0.05
	2010	7.50	0.11	0.50	nd	nd
	2011	7.50	0.16^B	5.27	nd	nd
	2013	18.33	0.34^B	4.61	0.09	0.05
Ofu	2009	7.50	0.11	9.00	0.15	0.25
	2010	7.50	0.11	15.17	0.05	35.25^B
	2011	7.50	0.09	7.75	0.53^B	0.05
	2012	7.50	0.10	11.43	0.05	0.05
	2013	7.50	0.12	8.67	nd	nd

^A nd = no data

^B Instances of criteria exceedance (also bolded)

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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