



Marine Water Quality in War in the Pacific National Historical Park

Summary Report 2009-2014

Natural Resource Data Series NPS/PACN/NRDS—2017/1122



ON THE COVER

Coastline of Agat marine area in War in the Pacific National Historical Park.

Photograph by: Amanda McCutcheon

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Abstract

This Natural Resource Data Series Report presents data collected from the marine portion of War in the Pacific National Historical Park in Asan and Agat, Guam, 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. 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 Mike Gawel and the staff of War in the Pacific National Historical Park 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
NO_2	Nitrite
NO_3	Nitrate
NPS	National Park Service
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
WAPA	War in the Pacific National Historical Park

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 War in the Pacific National Historical Park (WAPA) in Asan and Agat, Guam, 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).

Marine areas in WAPA are category M-1Excellent marine waters (GEPA 1997). Water quality criteria are defined for pH, orthophosphate, nitrate, oxygen saturation, salinity, suspended solids, and turbidity (Table 1).

Table 1. Territory of Guam water quality criteria for M-1 marine waters (GEPA 1997).

Parameter	Unit	Criteria excluding natural phenomena
pH	n/a	Range 6.5 - 8.5
Orthophosphate (PO ₄)	mgP · L ⁻¹	Not to exceed 0.025
Nitrates (NO ₃)	mgN · L ⁻¹	Not to exceed 0.10
Oxygen Saturation	%	Not to fall below 75%
Salinity	%	Not to vary past ± 10% of ambient conditions
Suspended solids	mg · L ⁻¹	Not to exceed 5
Turbidity	NTU	Not to exceed 0.5

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

WAPA is located in the territory of Guam and includes two marine units in Asan and Agat (Figure 1). Marine water quality is sampled in both marine areas.

Site names used by PACN were formatted to designate fixed or temporary sites (“F” or “T” respectively), park (WAPA), a number (e.g. 01), and habitat type (“mr” for marine); e.g. “FWAPA01_mr”. Names for temporary sites were based on the date of sampling. The marine portion of the park was sampled nine times from March 2009 to September 2014. Four fixed sites (FWAPA02, -05, -10, and -15, Table 2) and a unique set of four (two in Asan, two in Agat) temporary sites chosen at random 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).

Table 2. Fixed marine sample site locations at War in the Pacific National Historical Park that are sampled at during each trip.

PACN site designation	Location	Decimal Degrees Latitude	Decimal Degrees Longitude
FWAPA02_mr	Asan	13.482261	144.723496
FWAPA05_mr	Asan	13.478204	144.711624
FWAPA10_mr	Agat	13.394444	144.654031
FWAPA15_mr	Agat	13.376842	144.644125

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.

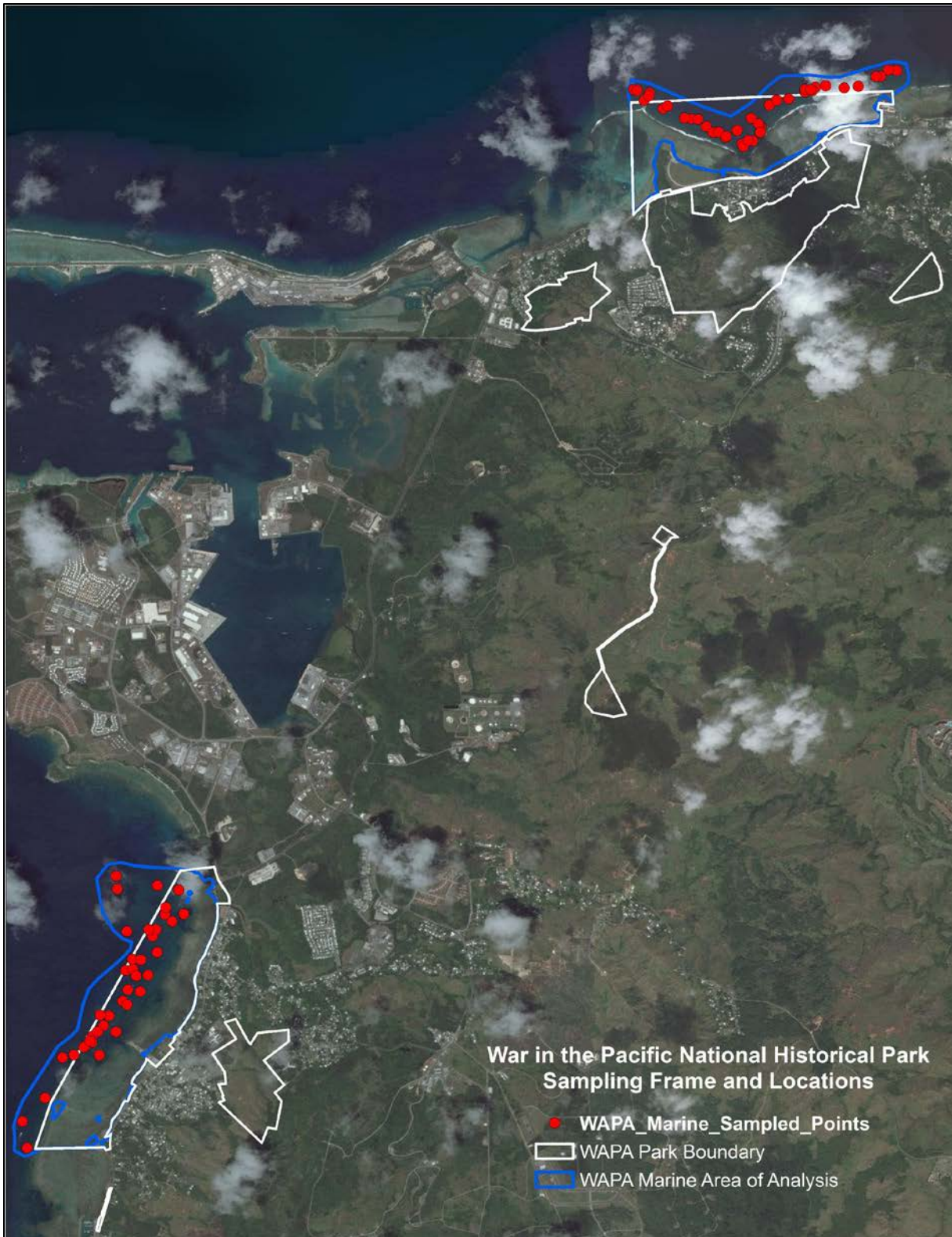


Figure 1. Marine water quality sample sites at War in the Pacific National Historical Park in Asan and Agat.

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. 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. Spatial distributions of bottom nutrients are presented using result ranges observed in bottom samples. Territory water quality standards were not violated.

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 most measurements being non-detects (Tables 3-4, Figures 2-7).

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

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	9	7.5	7.5	7.5	0
	2	Bottom	9	7.5	7.5	7.5	0
	3	Surface	18	7.5	7.5	45	8.8
	3	Bottom	6	7.5	7.5	7.5	0
	4	Surface	12	7.5	7.5	7.5	0
	4	Bottom	12	7.5	7.5	7.5	0
2010	1	Surface	15	7.5	7.5	7.5	0
	1	Bottom	9	7.5	7.5	7.5	0
	2	Surface	9	7.5	7.5	7.5	0
	2	Bottom	9	7.5	7.5	7.5	0
	3	Surface	12	7.5	7.5	7.5	0
	3	Bottom	12	7.5	7.5	17.6	2.9
2011	3	Surface	6	7.5	7.5	7.5	0
	3	Bottom	6	7.5	7.5	7.5	0
2014	2	Surface	12	7.5	7.5	23	5
	2	Bottom	11	7.5	7.5	21	4.1

Table 4. Total dissolved phosphorus ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	7.5	7.5	7.5	0.0
	2	Bottom	15	7.5	7.5	7.5	0.0
	3	Surface	12	7.5	7.5	7.5	0.0
	3	Bottom	12	7.5	7.5	7.5	0.0

Table 4 (continued). Total dissolved phosphorus ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	4	Surface	12	7.5	7.5	7.5	0.0
(continued)	4	Bottom	12	7.5	7.5	7.5	0.0
2010	1	Surface	15	7.5	7.5	7.5	0.0
	1	Bottom	9	7.5	7.5	7.5	0.0
	2	Surface	14	7.5	7.5	7.5	0.0
	2	Bottom	14	7.5	7.5	7.5	0.0
	3	Surface	12	7.5	7.5	7.5	0.0
	3	Bottom	12	7.5	7.5	7.5	0.0
2011	3	Surface	6	7.5	7.5	7.5	0.0
	3	Bottom	6	7.5	7.5	7.5	0.0
2014	2	Surface	12	7.5	7.5	28.0	5.9
	2	Bottom	12	7.5	7.5	17.0	2.7

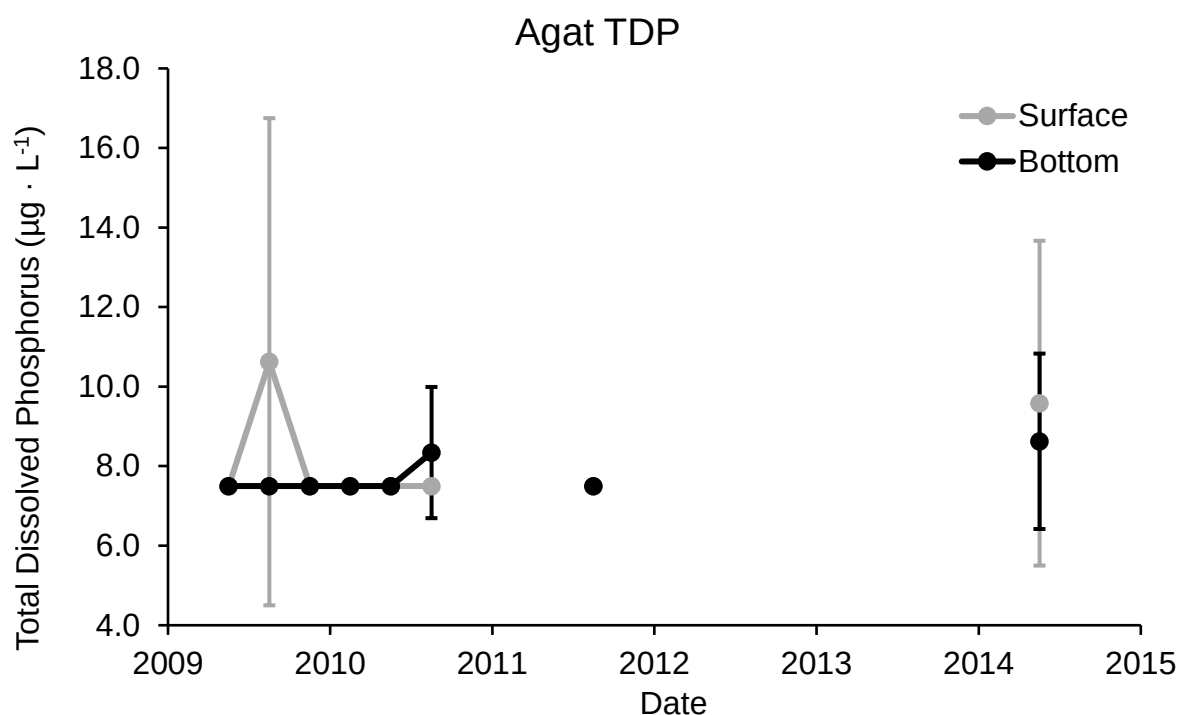


Figure 2. Total Dissolved Phosphorus in marine waters of WAPA in Agat. Data are means and 95% confidence intervals. Non-detects are presented as half the detection limit, and treated as such for calculation of the mean.

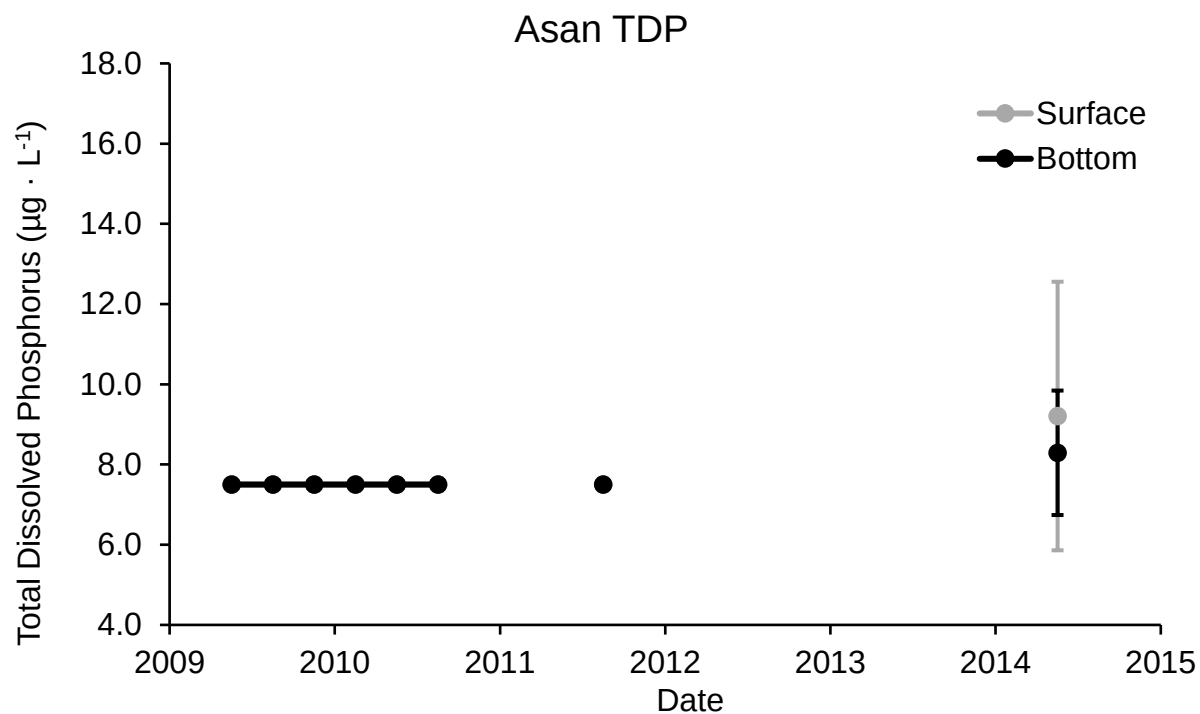


Figure 3. Total Dissolved Phosphorus in marine waters of WAPA in Asan. Data are means and 95% confidence intervals. Non-detects are presented as half the detection limit, and treated as such for calculation of the mean.

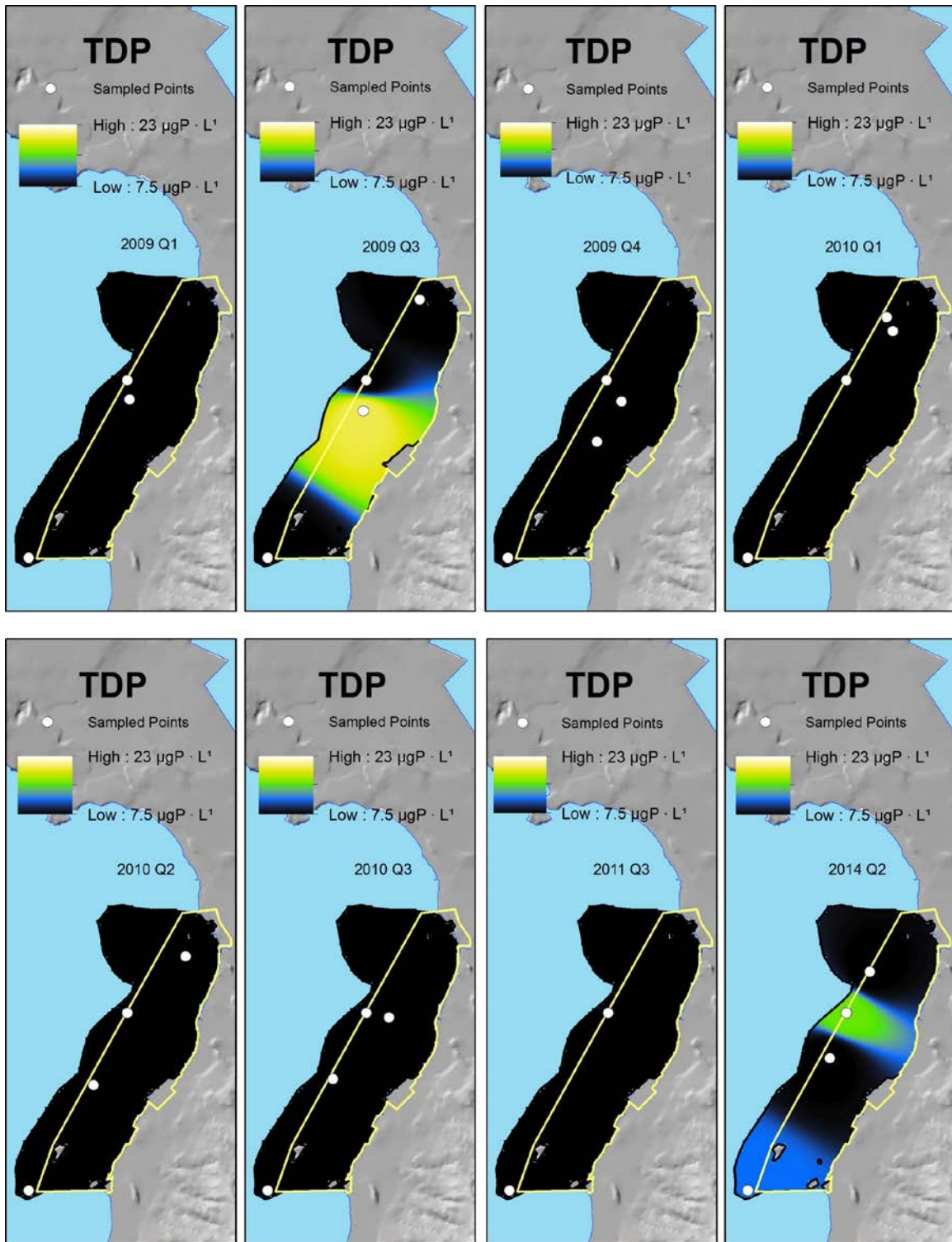


Figure 4. Spatial distribution of surface TDP marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

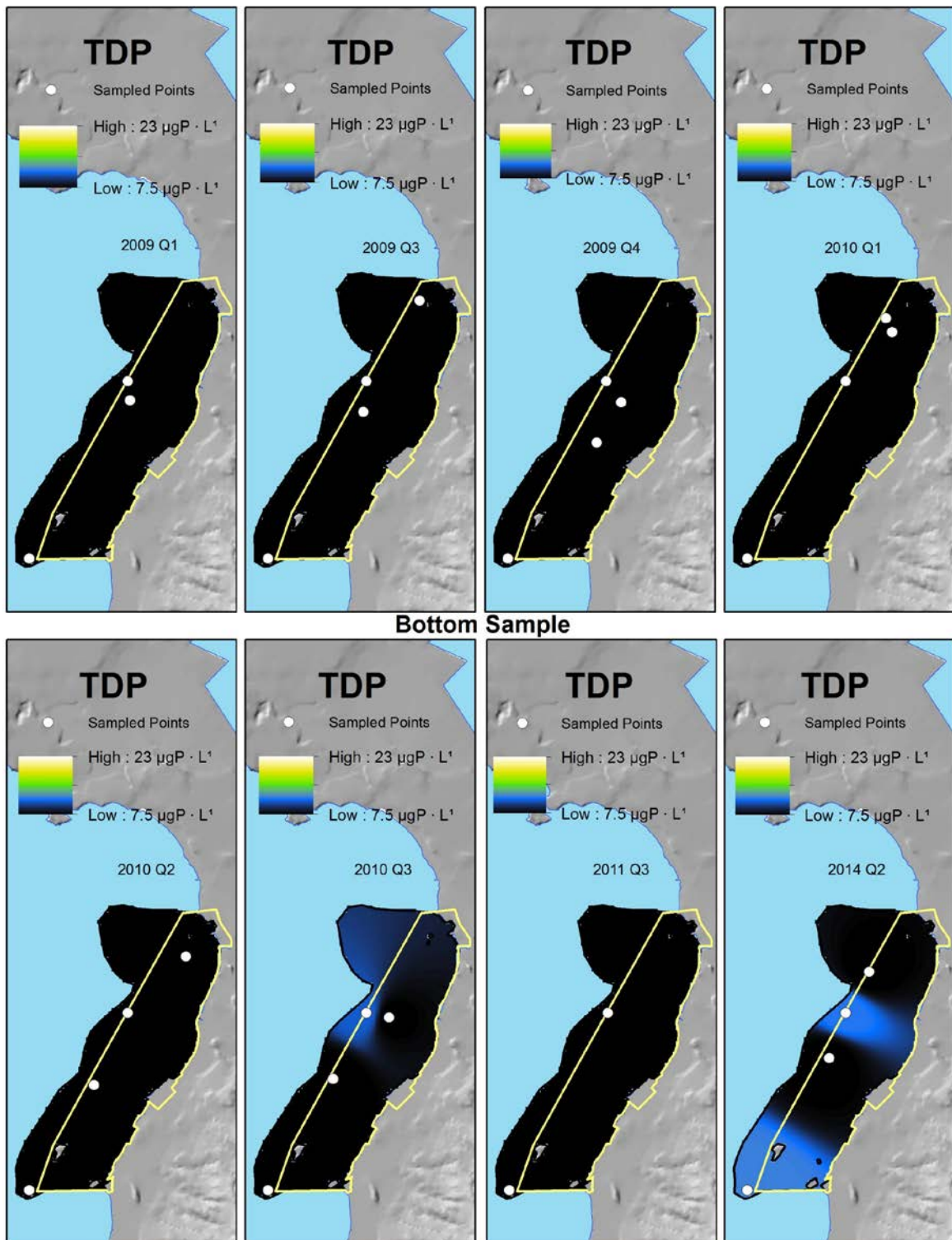


Figure 5. Spatial distribution of bottom TDP marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

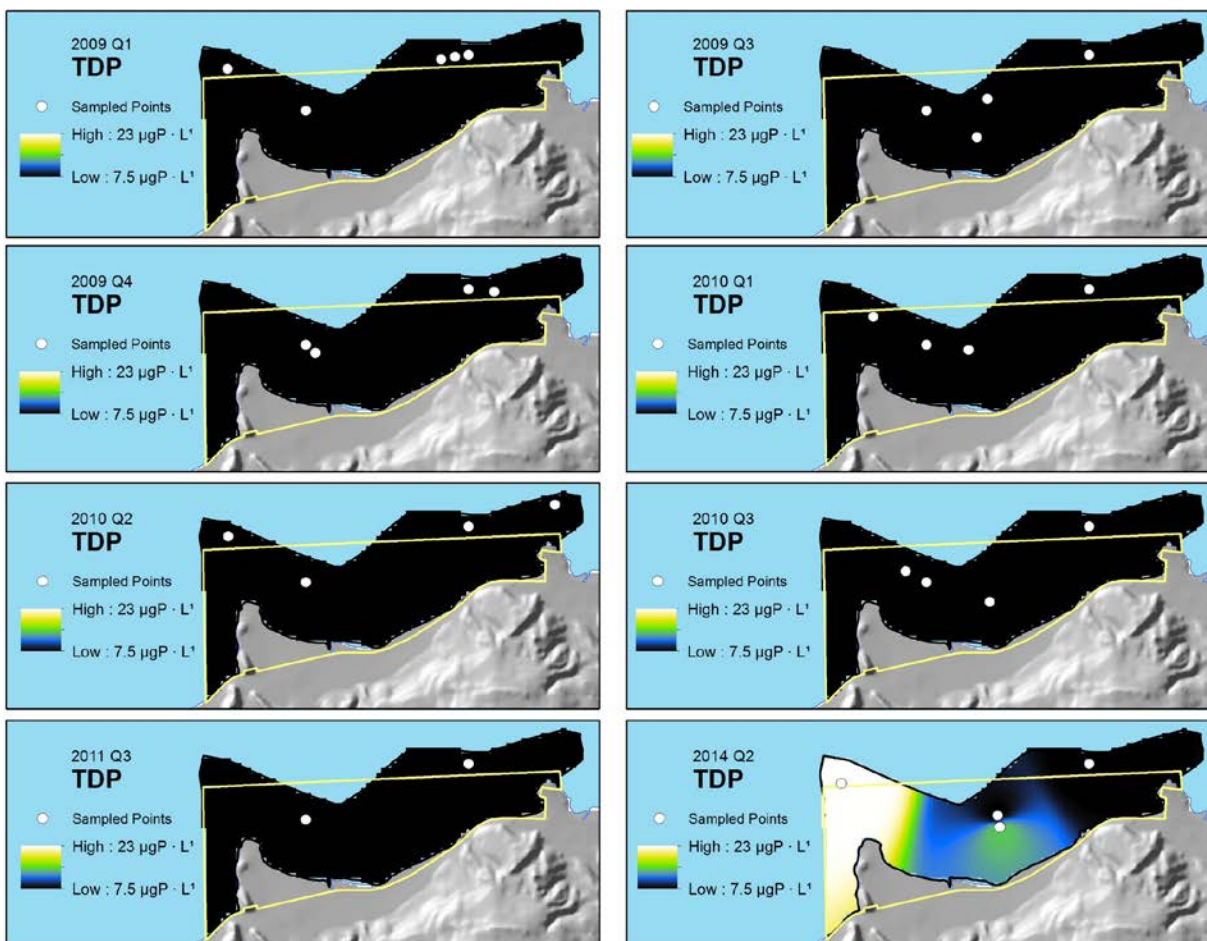


Figure 6. Spatial distribution of surface TDP marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

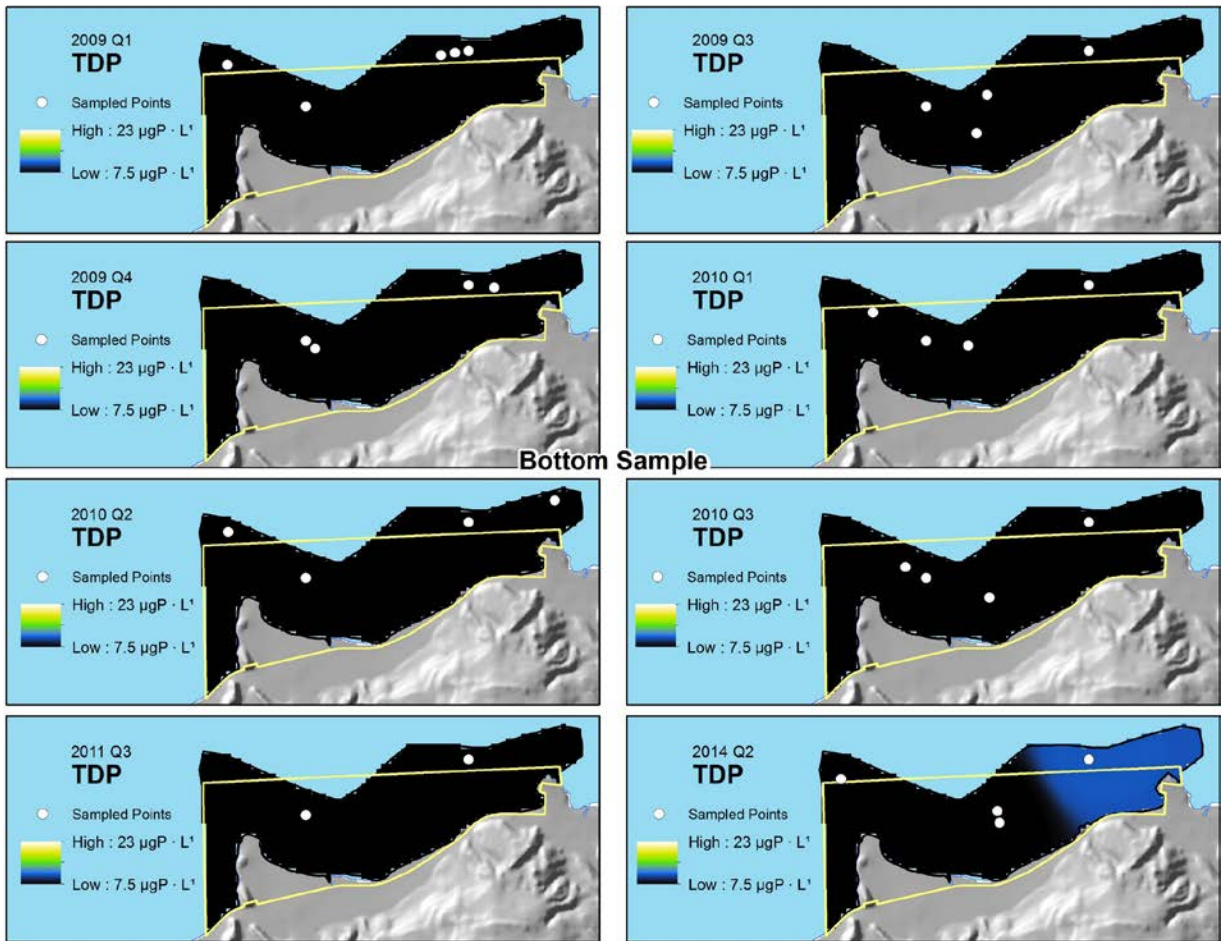


Figure 7. Spatial distribution of bottom TDP marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

Total Dissolved Nitrogen

Concentrations of TDN were relatively constant over the monitoring period. Surface waters had slightly higher concentrations than bottom waters (Tables 5-6, Figures 8-9). The highest measurements of TDN were usually taken in Agat (Figures 10-13).

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

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	9	0.035	0.082	0.103	0.019
	2	Bottom	9	0.035	0.076	0.097	0.024
	3	Surface	18	0.079	0.110	1.144	0.245
	3	Bottom	6	0.075	0.100	0.260	0.067
	4	Surface	12	0.035	0.089	0.125	0.023
	4	Bottom	12	0.035	0.089	0.172	0.042
2010	1	Surface	15	0.035	0.085	0.095	0.025
	1	Bottom	9	0.035	0.081	0.349	0.101
	2	Surface	9	0.035	0.077	0.109	0.021
	2	Bottom	9	0.035	0.078	0.168	0.045
	3	Surface	12	0.035	0.096	0.152	0.036
	3	Bottom	12	0.035	0.092	0.151	0.038
2011	3	Surface	6	0.086	0.088	0.114	0.012
	3	Bottom	6	0.035	0.090	0.146	0.044
2014	2	Surface	8	0.035	0.070	0.197	0.050
	2	Bottom	6	0.035	0.035	0.096	0.027

Table 6. Total dissolved nitrogen ($\text{mg} \cdot \text{L}^{-1}$) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	0.064	0.082	0.124	0.016
	2	Bottom	15	0.070	0.076	0.106	0.011
	3	Surface	12	0.101	0.110	0.126	0.008
	3	Bottom	12	0.081	0.100	0.174	0.029
	4	Surface	12	0.035	0.089	0.136	0.025
	4	Bottom	12	0.035	0.089	0.116	0.026
2010	1	Surface	15	0.035	0.085	0.131	0.022
	1	Bottom	9	0.035	0.081	0.201	0.060
	2	Surface	14	0.035	0.077	0.170	0.039
2010	2	Bottom	14	0.035	0.078	0.236	0.047
	3	Surface	12	0.077	0.096	0.248	0.047
	3	Bottom	12	0.071	0.092	0.199	0.039

Table 6 (continued). Total dissolved nitrogen ($\text{mg} \cdot \text{L}^{-1}$) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2011	3	Surface	6	0.035	0.088	0.148	0.044
	3	Bottom	6	0.073	0.090	0.124	0.017
2014	2	Surface	9	0.035	0.070	0.100	0.027
	2	Bottom	5	0.070	0.035	0.112	0.020

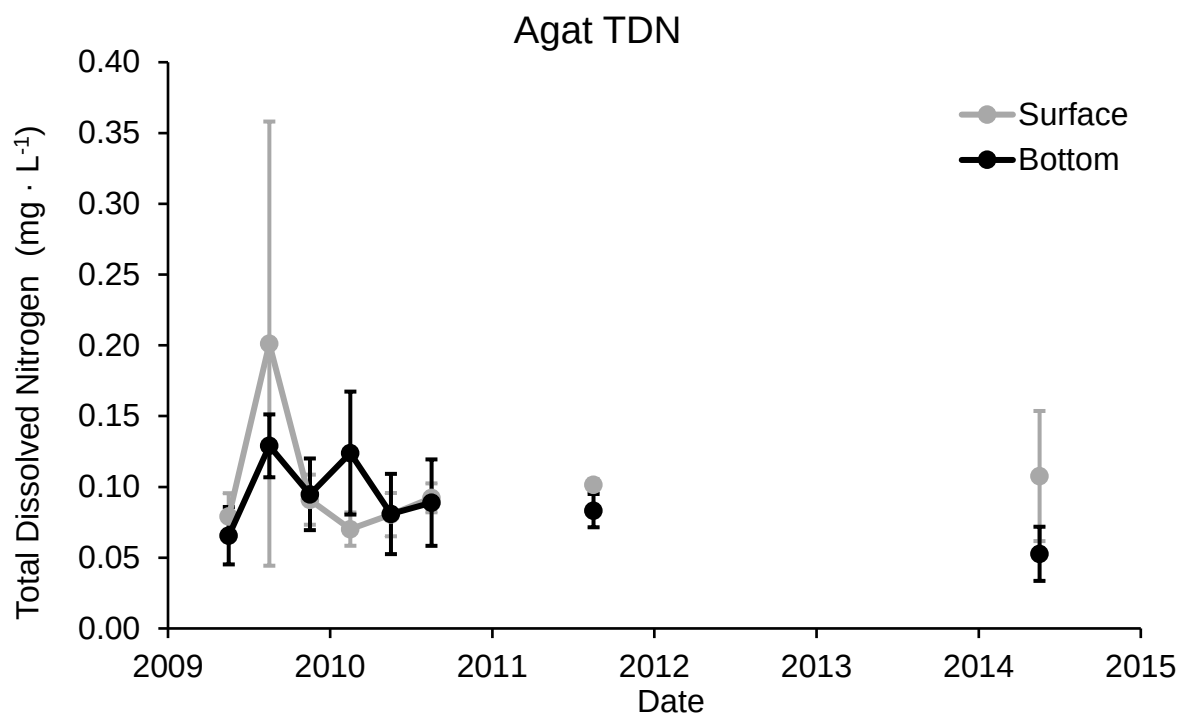


Figure 8. Total dissolved nitrogen in marine waters of WAPA in Agat. Data are means and 95% confidence intervals of four sites.

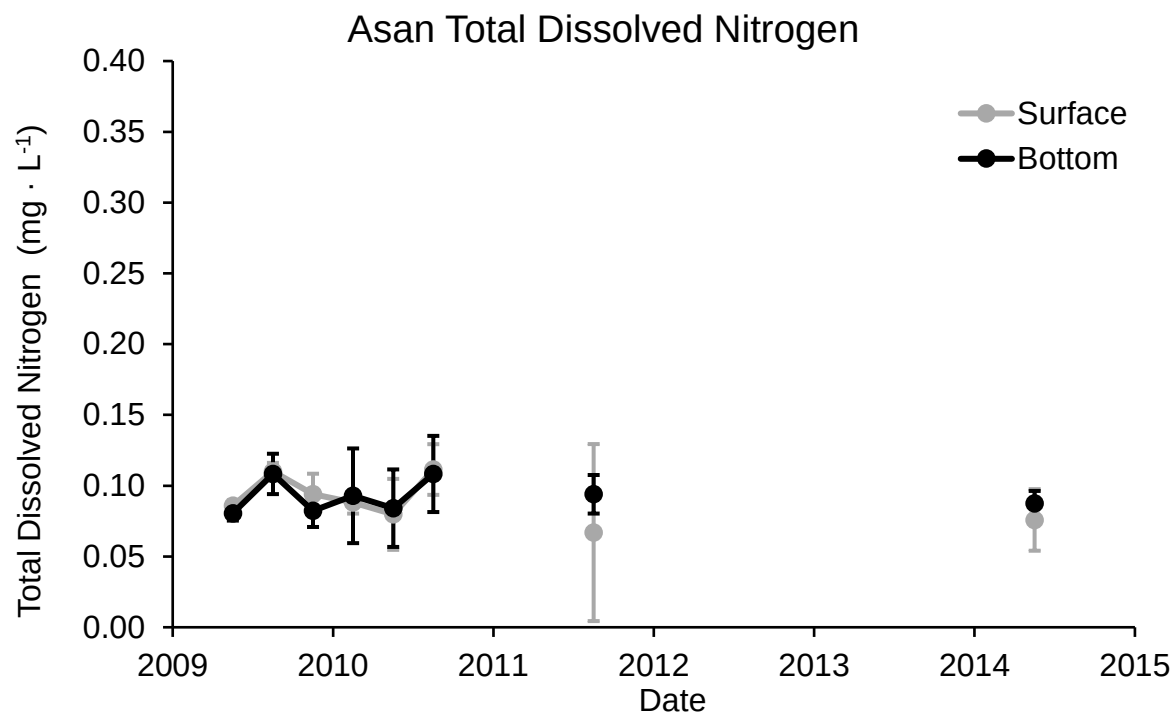


Figure 9. Total dissolved nitrogen in marine waters of WAPA in Asan. Data are means and 95% confidence intervals of four sites.

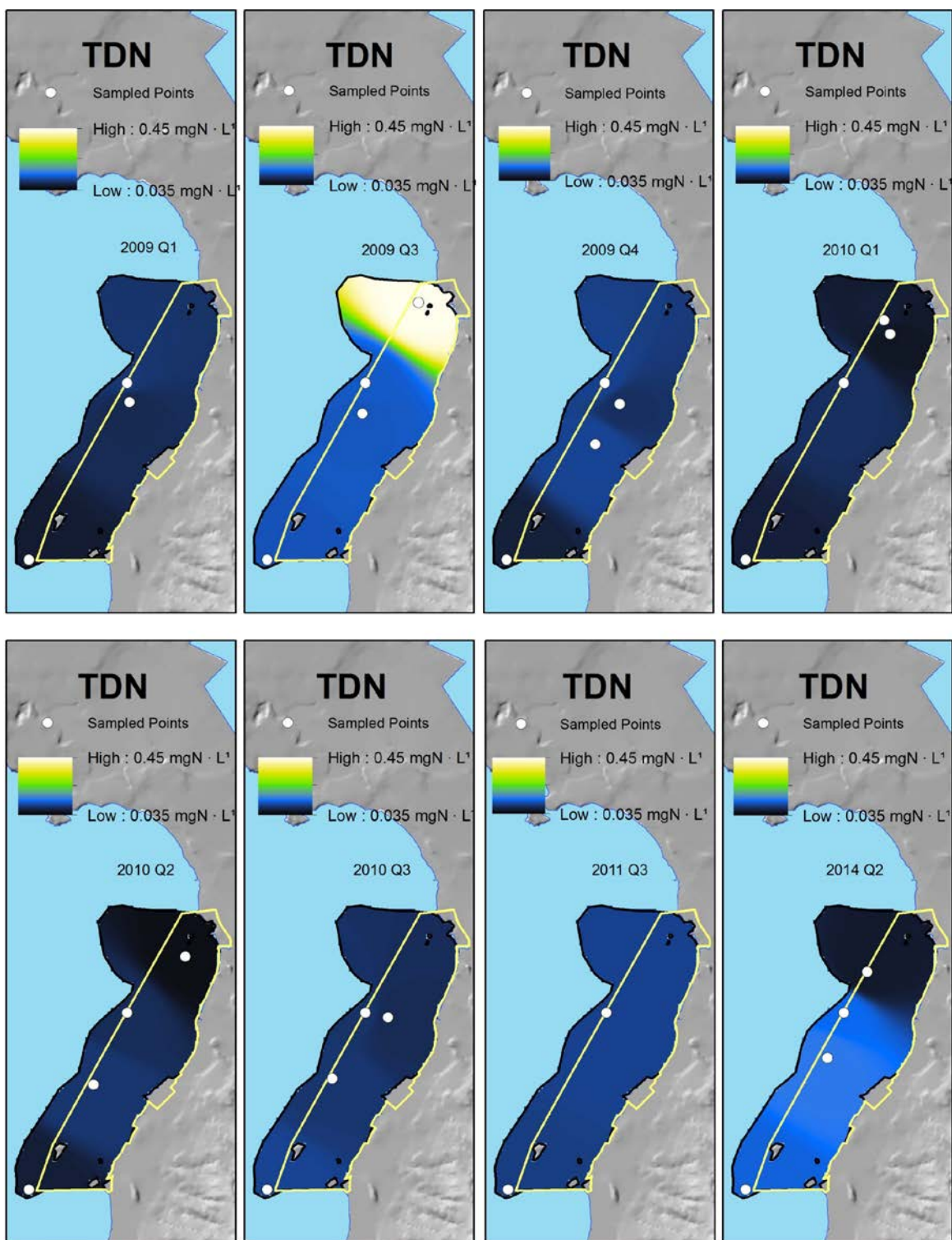


Figure 10. Spatial distribution of surface in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

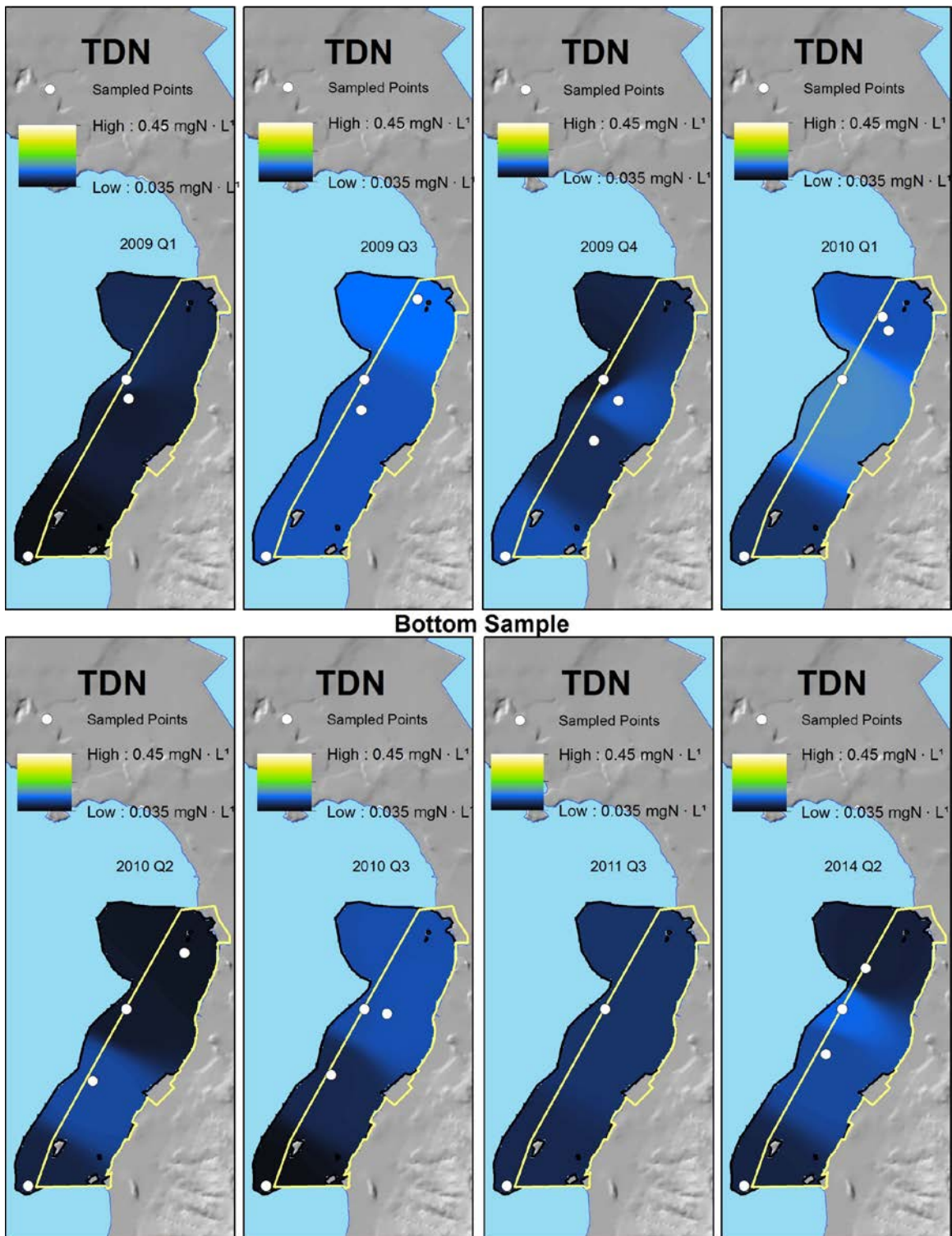


Figure 11. Spatial distribution of bottom total dissolved nitrogen in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

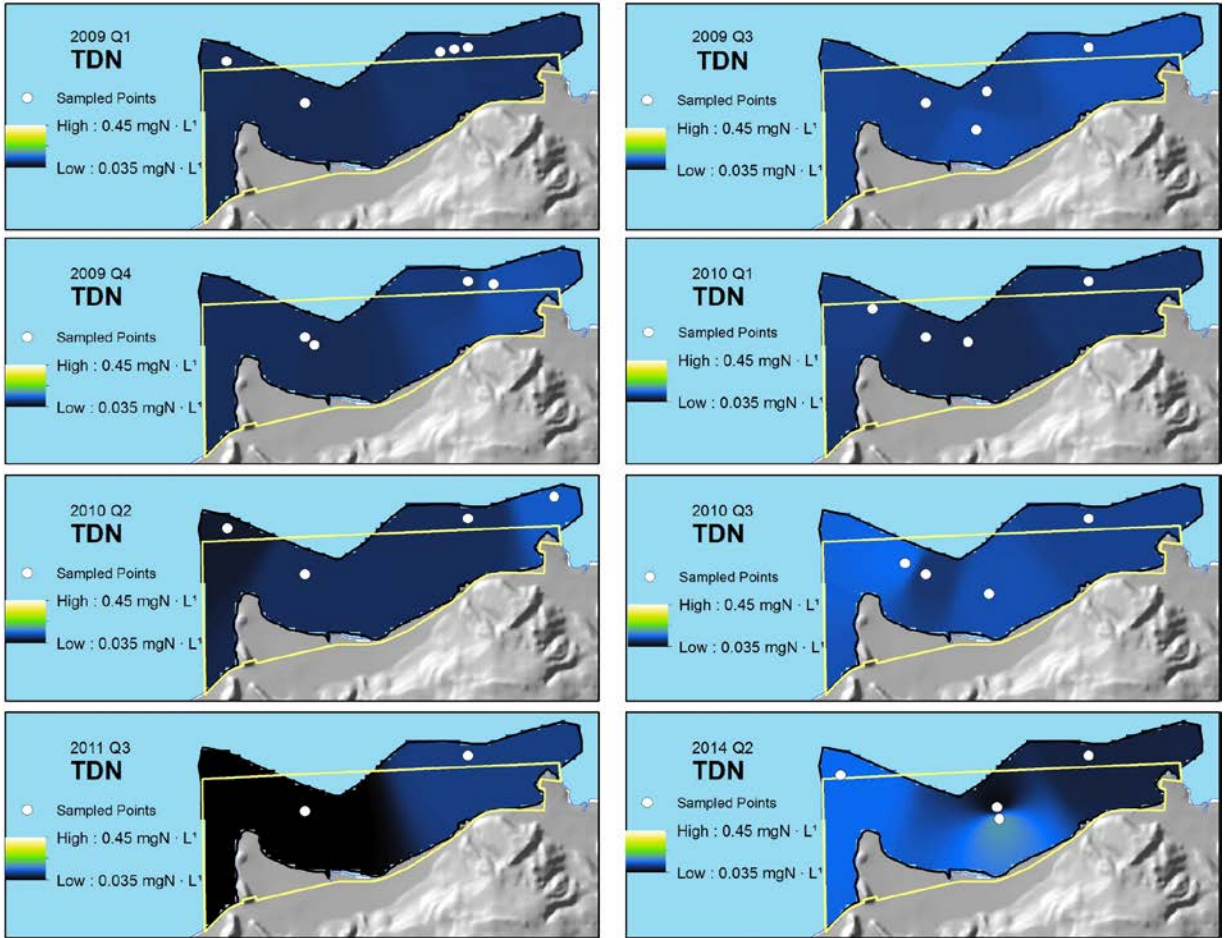


Figure 12. Spatial distribution of surface total dissolved nitrogen in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

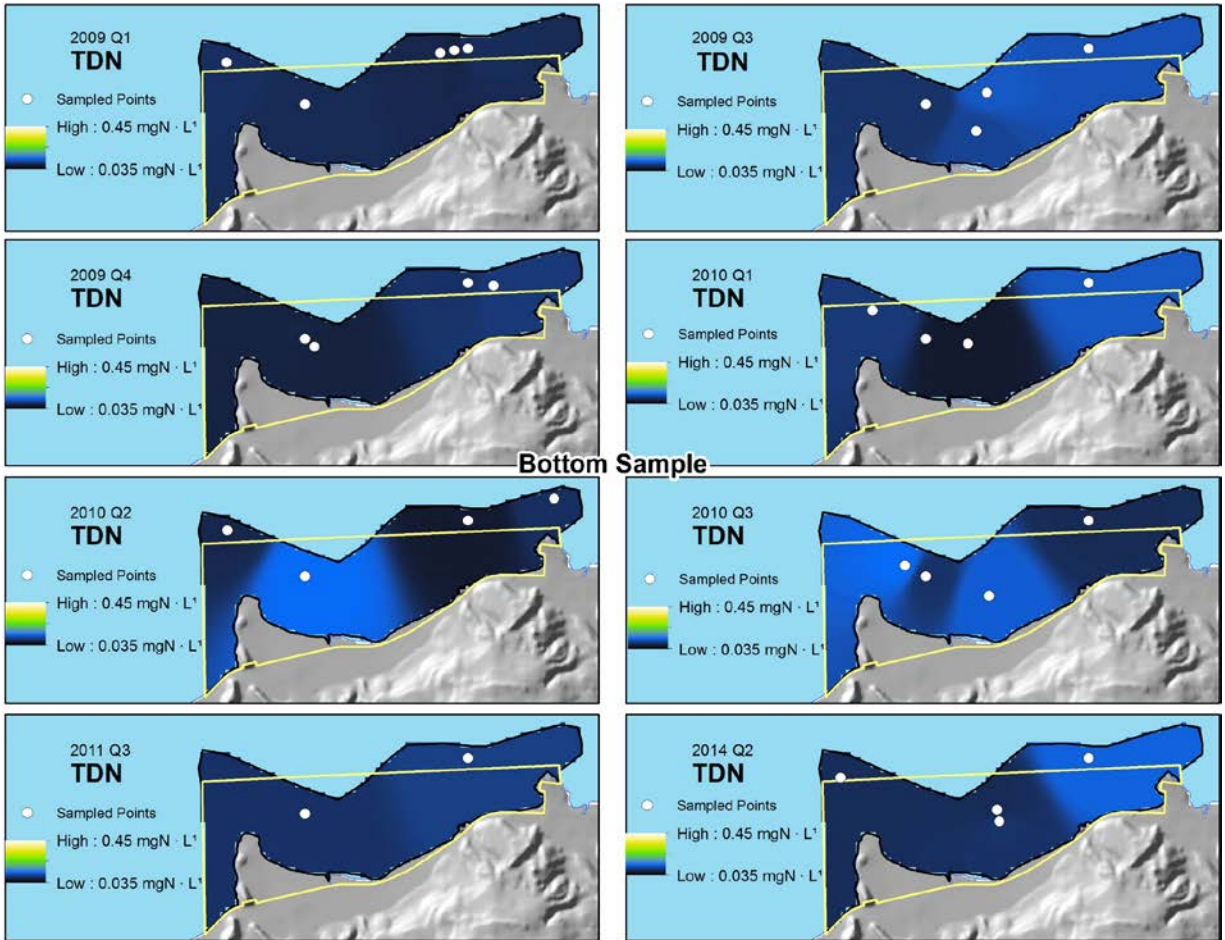


Figure 13. Spatial distribution of bottom total dissolved nitrogen in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

Nitrate + Nitrite

Concentrations of $\text{NO}_2 + \text{NO}_3$ were relatively constant over the monitoring period, but were generally lower in bottom waters than in surface waters. Surface waters also displayed more variability in $\text{NO}_2 + \text{NO}_3$ (Tables 7-8, Figures 14-15). The highest measurements of $\text{NO}_2 + \text{NO}_3$ were usually taken near stream outputs in Asan and Agat (Figures 16-19).

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

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	9	1.8	2.9	7.2	2.2
		Bottom	9	0.5	2.3	3.7	1.2
	3	Surface	18	0.5	5.0	16.0	4.8
		Bottom	6	0.5	3.0	9.0	3.6
	4	Surface	12	0.5	0.5	15.2	4.0
		Bottom	12	0.5	0.5	3.0	1.0
2010	1	Surface	15	0.5	0.5	4.0	1.0
		Bottom	9	0.5	1.3	21.0	7.3
	2	Surface	9	0.5	0.5	0.5	0.0
		Bottom	9	0.5	0.5	9.6	3.0
	3	Surface	12	0.5	0.5	3.0	1.0
		Bottom	12	0.5	0.5	0.5	0.0
2011	3	Surface	6	5.8	5.2	7.1	0.5
	3	Bottom	6	3.0	3.6	6.7	1.5

Table 8. Nitrate + nitrite ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	0.5	2.9	4.3	1.1
		Bottom	15	0.5	2.3	4.6	1.2
	3	Surface	12	2.0	5.0	15.0	4.3
		Bottom	12	0.5	3.0	5.0	1.5
	4	Surface	12	0.5	0.5	3.0	0.7
		Bottom	12	0.5	0.5	0.5	0.0
2010	1	Surface	15	0.5	0.5	3.0	0.8
		Bottom	9	0.5	1.3	13.0	4.3
	2	Surface	14	0.5	0.5	3.1	0.9
		Bottom	14	0.5	0.5	1.9	0.4
	3	Surface	12	0.5	0.5	5.2	1.7
		Bottom	12	0.5	0.5	1.7	0.3
2011	3	Surface	6	0.5	5.2	4.6	1.5
		Bottom	6	0.5	3.6	4.1	1.4
2014	2	Surface	6	0.5	0.8	8.0	3.0
		Bottom	6	0.5	0.5	5.0	1.8

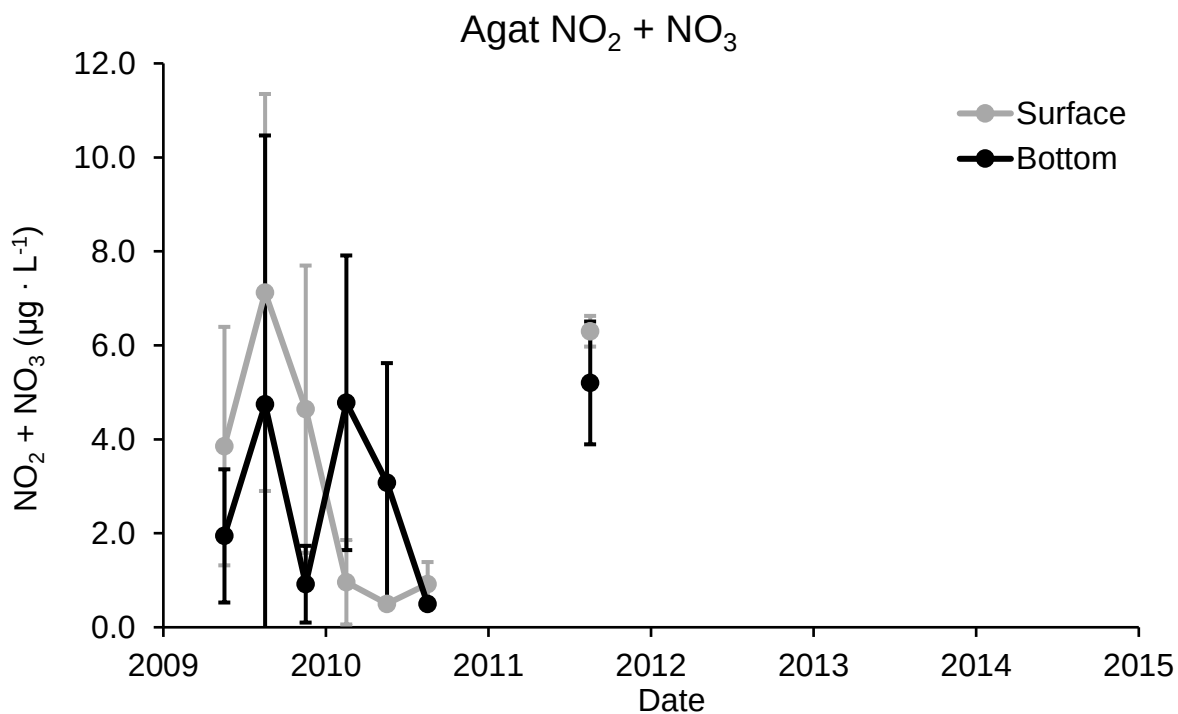


Figure 14. Nitrite + nitrate in marine waters of WAPA in Agat. Data are means and 95% confidence intervals of four sites.

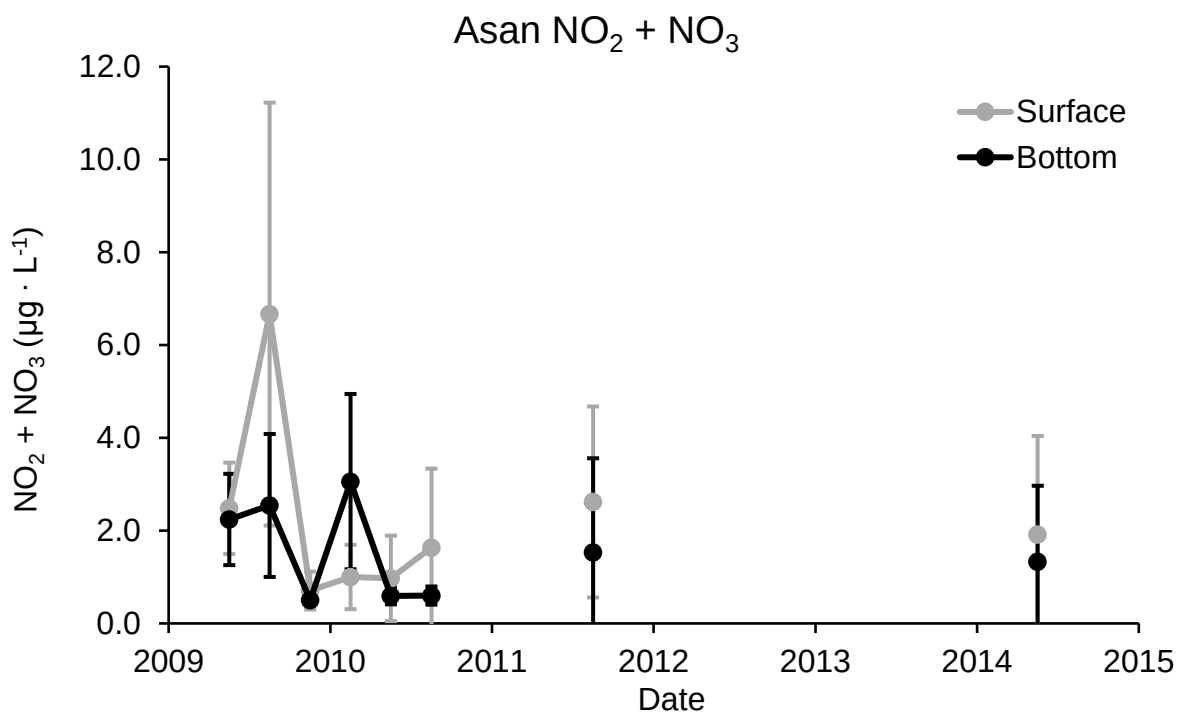


Figure 15. Nitrite + nitrate in marine waters of WAPA in Asan. Data are means and 95% confidence intervals of four sites.

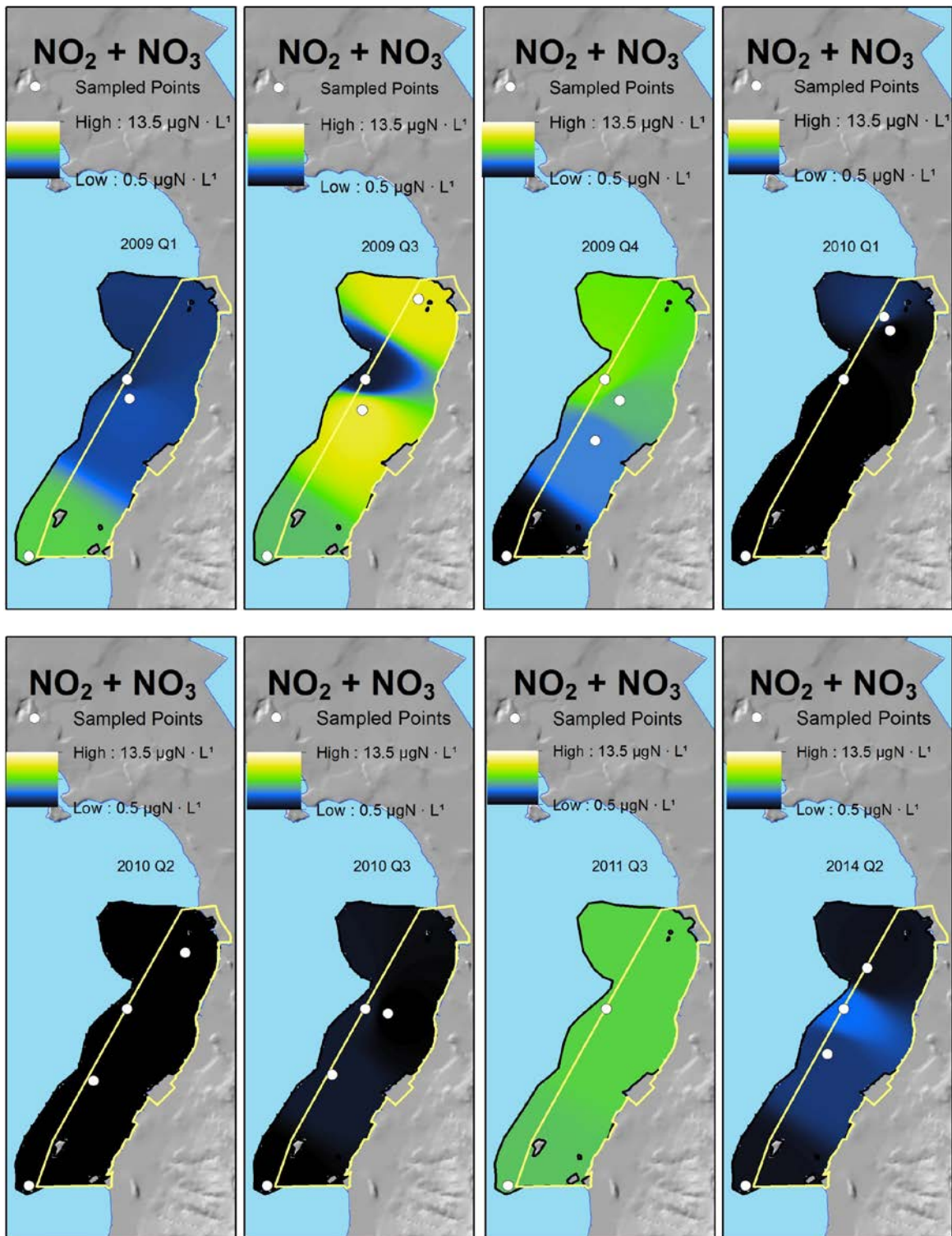


Figure 16. Spatial distribution of surface nitrite + nitrate in marine waters WAPA in Agat using the total range of results observed in both surface and bottom samples.

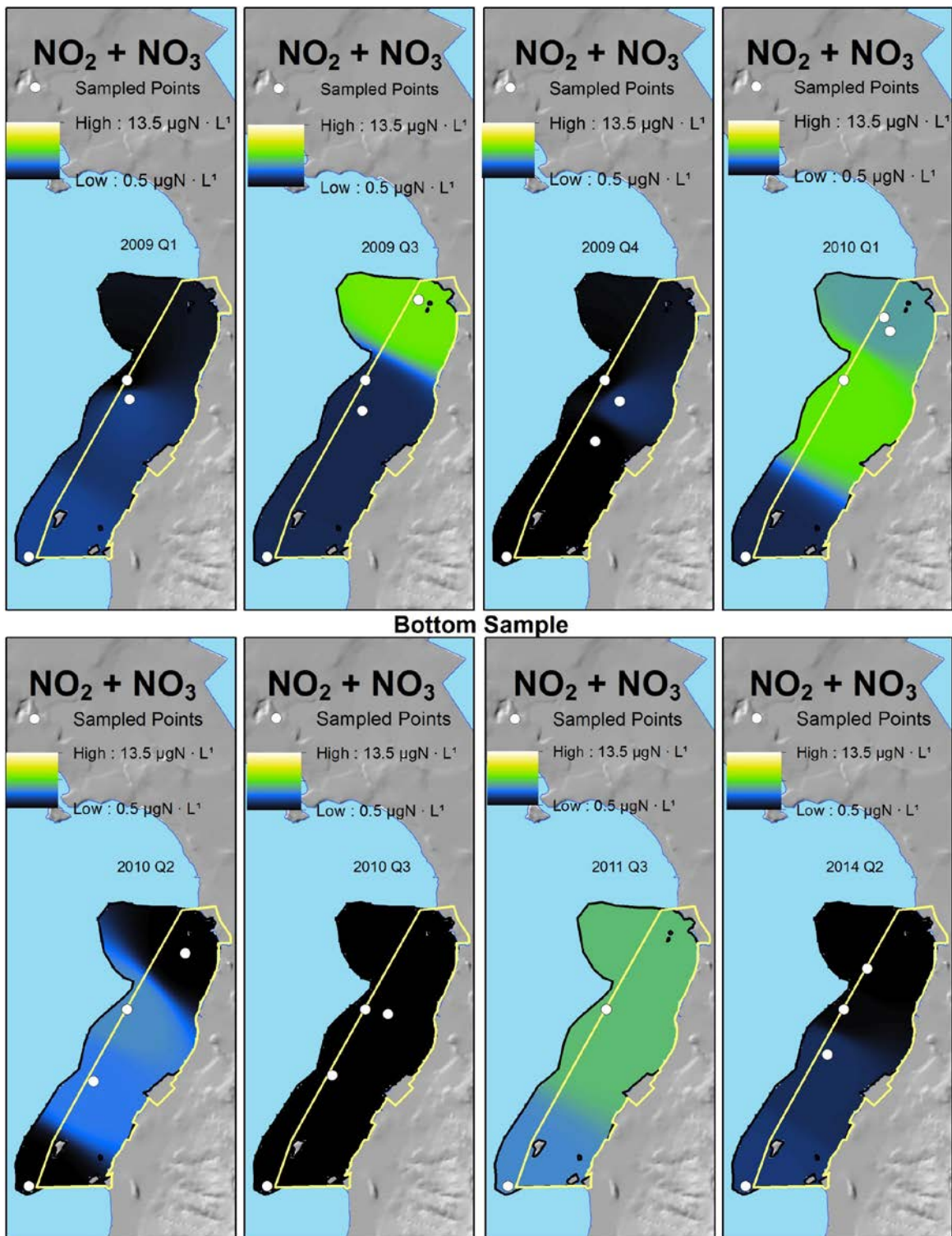


Figure 17. Spatial distribution of bottom nitrite + nitrate in marine waters WAPA in Agat using the total range of results observed in both surface and bottom samples.

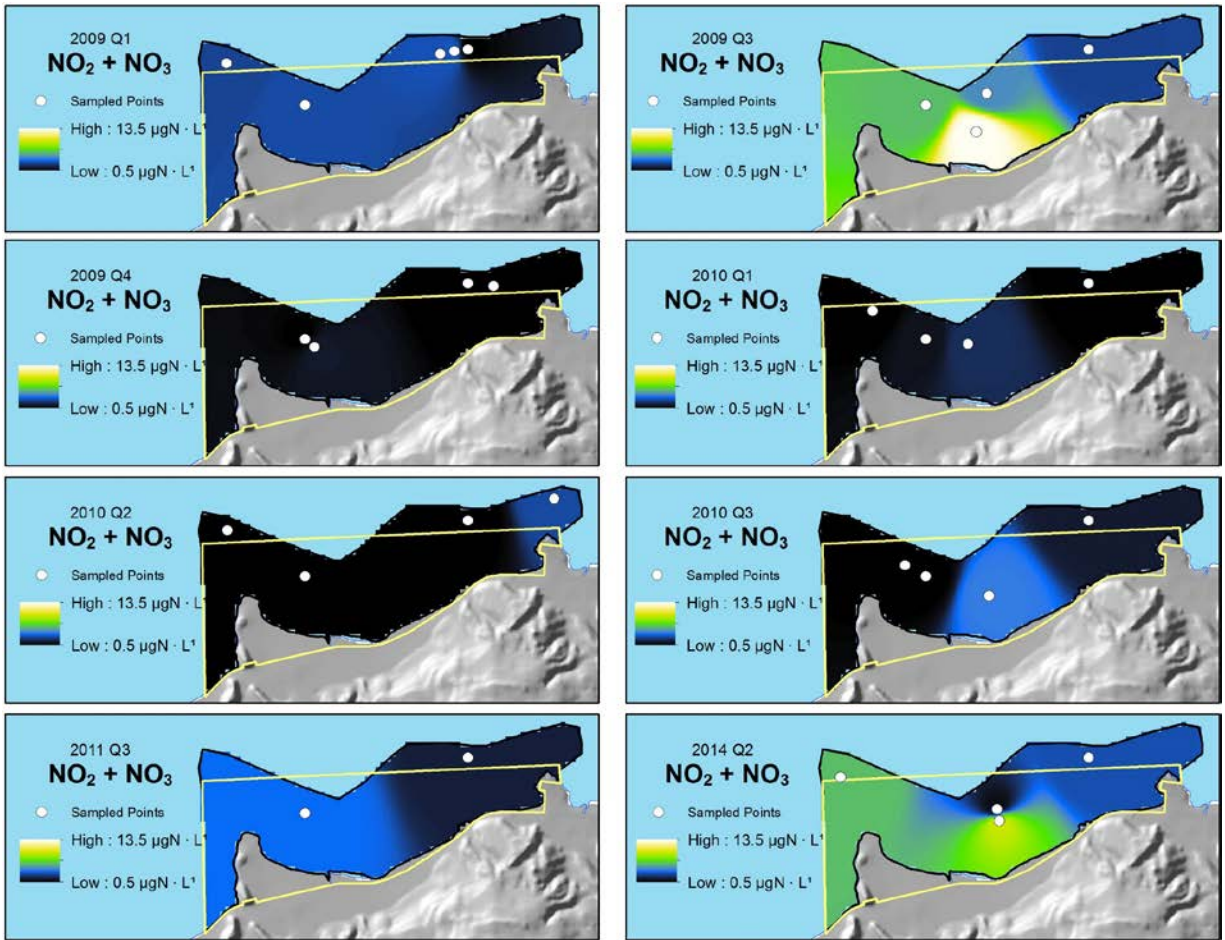


Figure 18. Spatial distribution of surface nitrite + nitrate in marine waters WAPA in Asan using the total range of results observed in both surface and bottom samples.

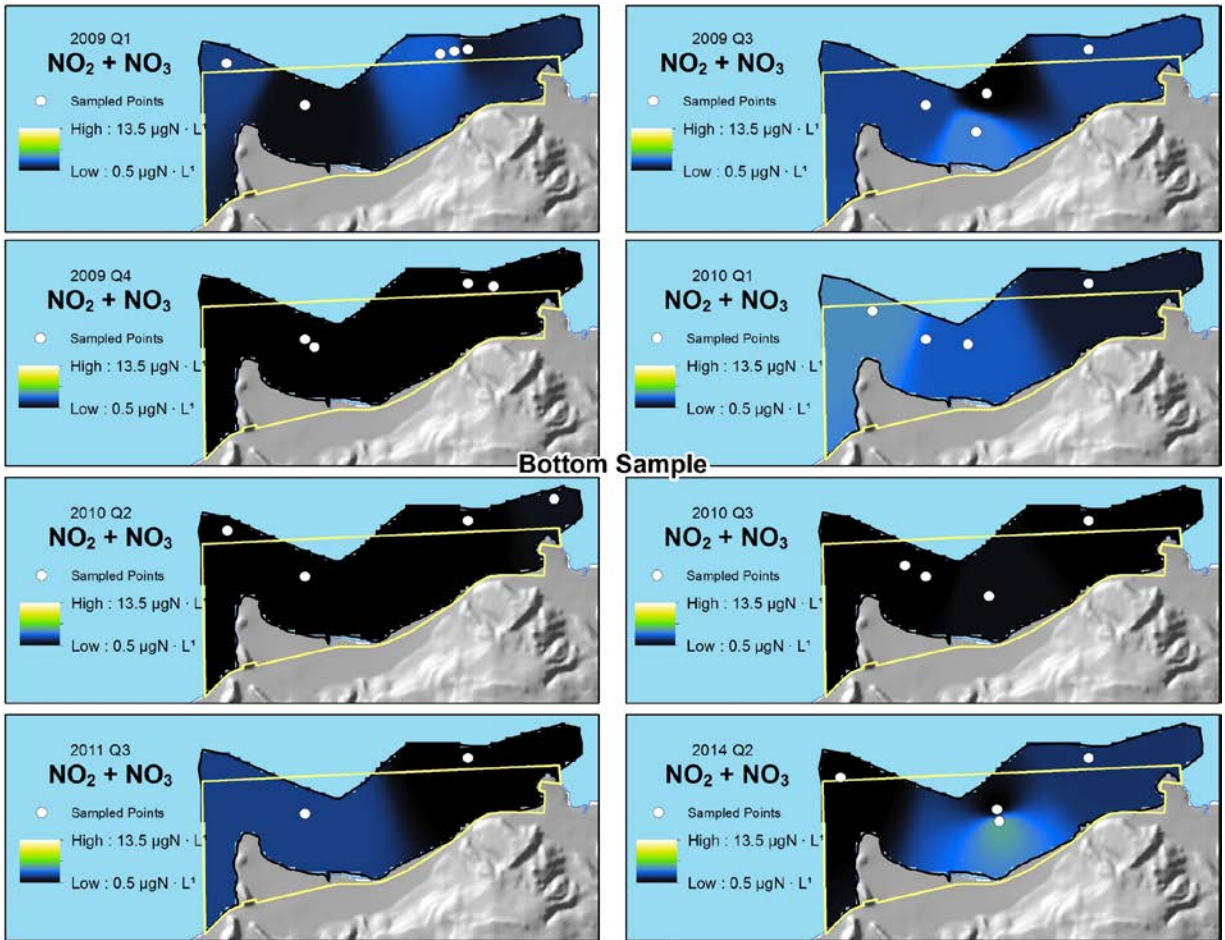


Figure 19. Spatial distribution of bottom nitrite + nitrate in marine waters WAPA in Asan using the total range of results observed in both surface and bottom samples.

Chlorophyll

Chlorophyll concentrations were low with the exception of spikes observed in both areas in 2010 (Tables 9-10, Figures 20-21). The 2010 chlorophyll spike in Agat resulted from elevated chlorophyll in waters near the Namu River input and just south of the Agat sewage treatment plant (Figures 22-25).

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

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	2	0.1	0.1	0.1	0.0
	2	Bottom	10	0.1	0.1	6.6	2.1
	3	Bottom	5	0.3	0.3	0.4	0.0
	4	Surface	4	0.2	0.3	0.4	0.1
	4	Bottom	4	0.2	0.3	0.4	0.1
2010	1	Surface	4	0.1	0.3	7.0	3.4
	1	Bottom	4	0.1	0.2	0.3	0.1
	2	Surface	7	0.1	0.1	0.3	0.1
	2	Bottom	10	0.0	0.2	3.9	1.4
	3	Surface	4	0.1	0.3	0.3	0.1
	3	Bottom	4	0.2	0.2	0.7	0.2
2011	3	Bottom	8	0.1	0.2	0.4	0.1
2014	2	Surface	9	0.0	0.1	0.2	0.0
	2	Bottom	9	0.0	0.0	0.2	0.1
	3	Surface	1	0.1	0.1	0.1	NA
	3	Bottom	1	0.3	0.3	0.3	NA

Table 10. Chlorophyll ($\mu\text{g} \cdot \text{L}^{-1}$) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	9	0.1	0.1	2.3	0.7
	2	Bottom	15	0.1	0.1	0.1	0.0
	3	Bottom	4	0.1	0.3	0.3	0.1
	4	Surface	4	0.1	0.3	0.3	0.1
	4	Bottom	4	0.1	0.3	0.3	0.1
2010	1	Surface	3	0.1	0.3	3.8	1.9
	1	Bottom	4	0.1	0.2	3.0	1.5
	2	Surface	14	0.0	0.1	3.2	0.8
	2	Bottom	12	0.1	0.2	3.0	1.1
	3	Surface	4	0.2	0.3	1.1	0.4
	3	Bottom	4	0.1	0.2	0.2	0.1
2011	3	Bottom	9	0.1	0.2	0.4	0.1
2014	2	Surface	8	0.0	0.1	0.2	0.0
		Bottom	8	0.0	0.0	0.1	0.0

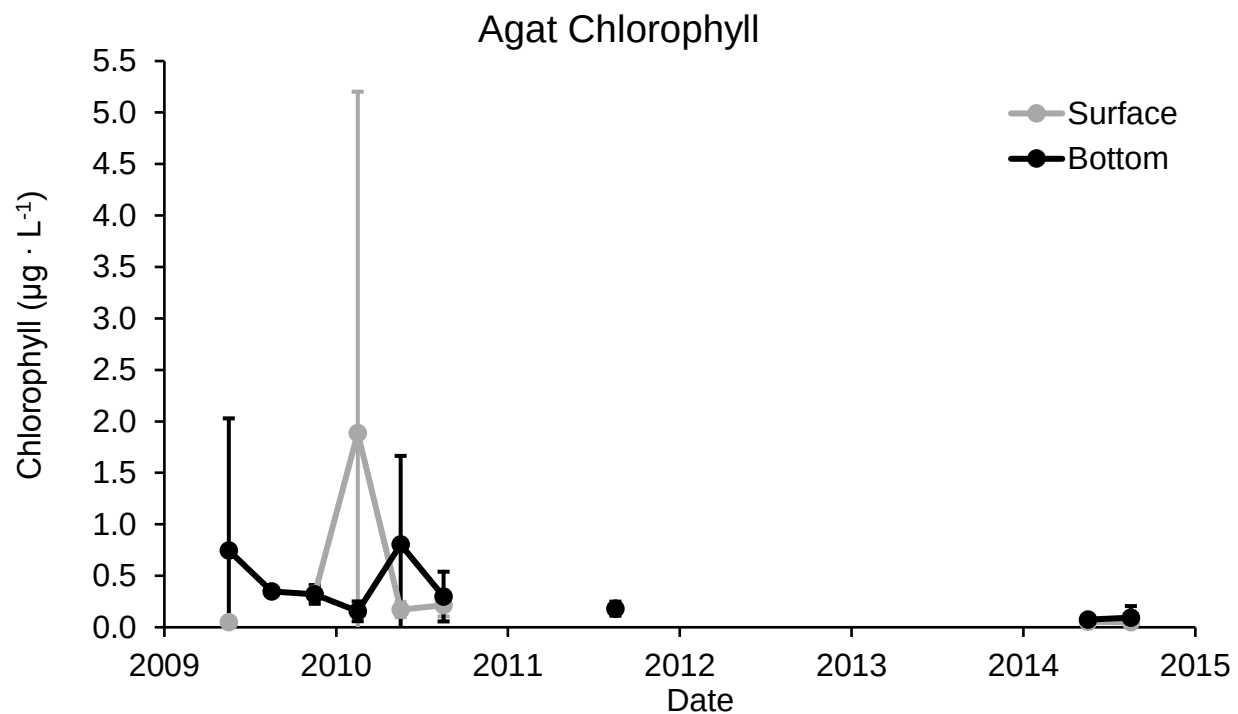


Figure 20. Chlorophyll in marine waters of WAPA in Agat. Data are means and 95% confidence intervals.

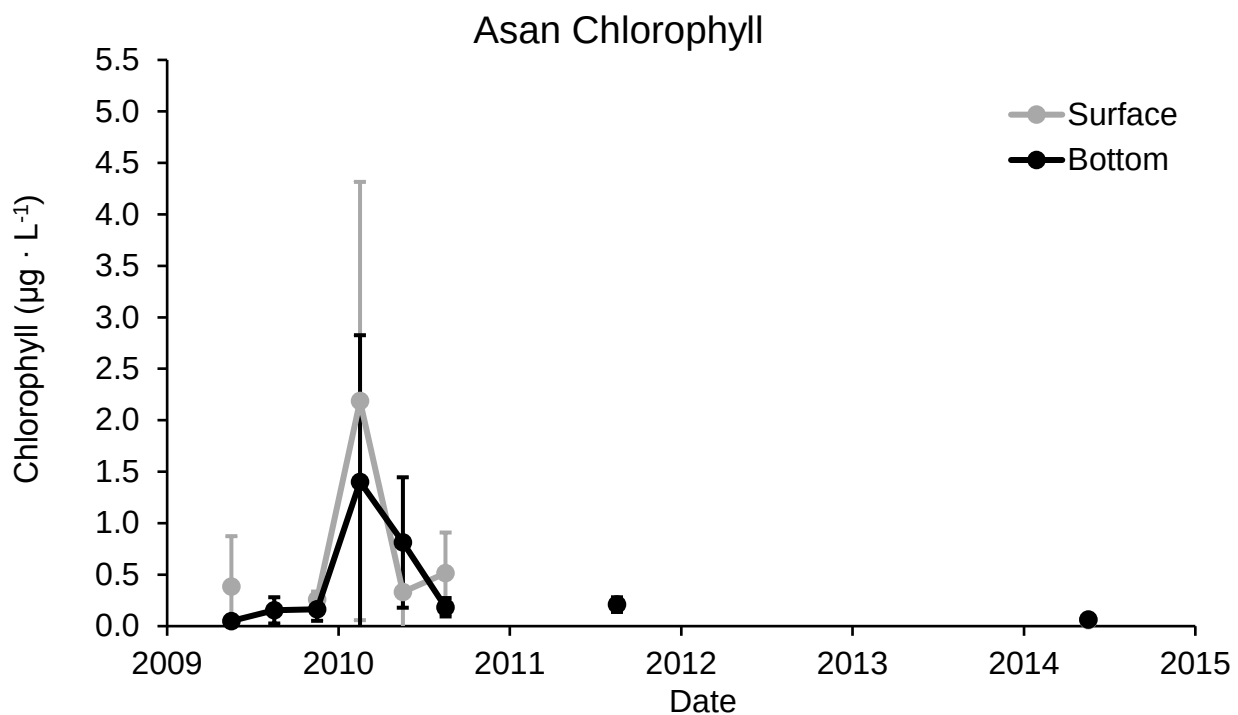


Figure 21. Chlorophyll in marine waters of WAPA in Asan. Data are means and 95% confidence intervals.

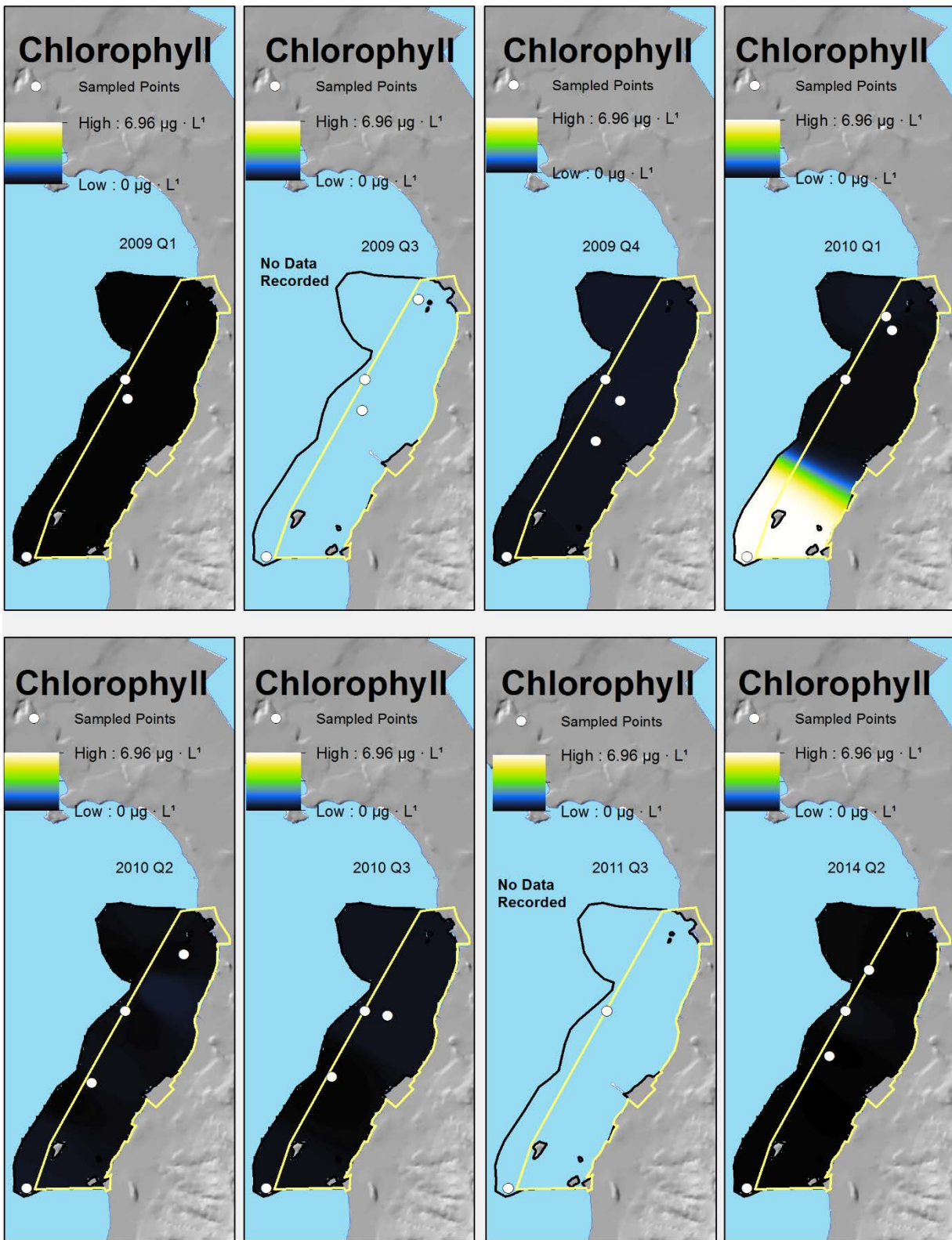


Figure 22. Spatial distribution of surface chlorophyll in surface marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

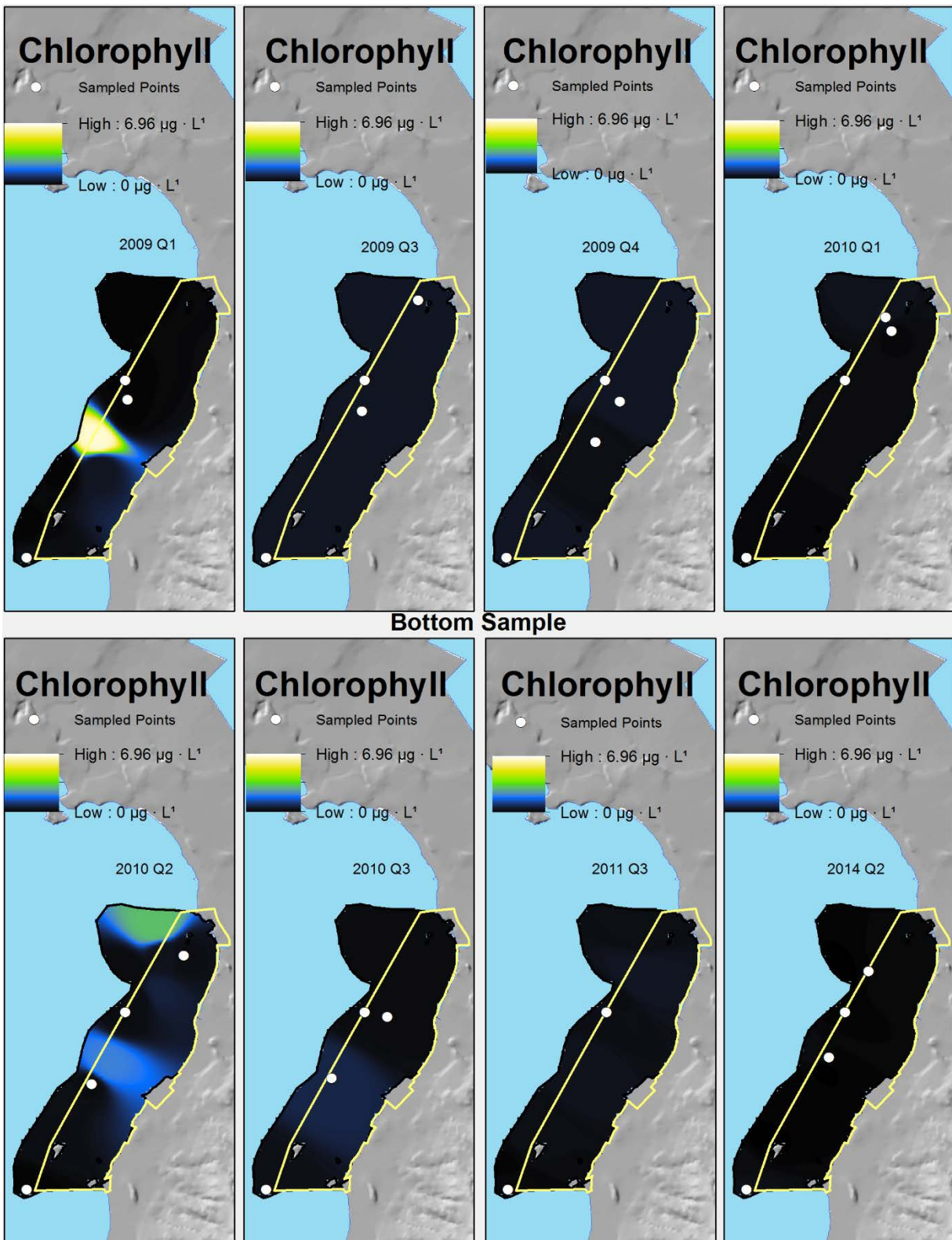


Figure 23. Spatial distribution of bottom chlorophyll in surface marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

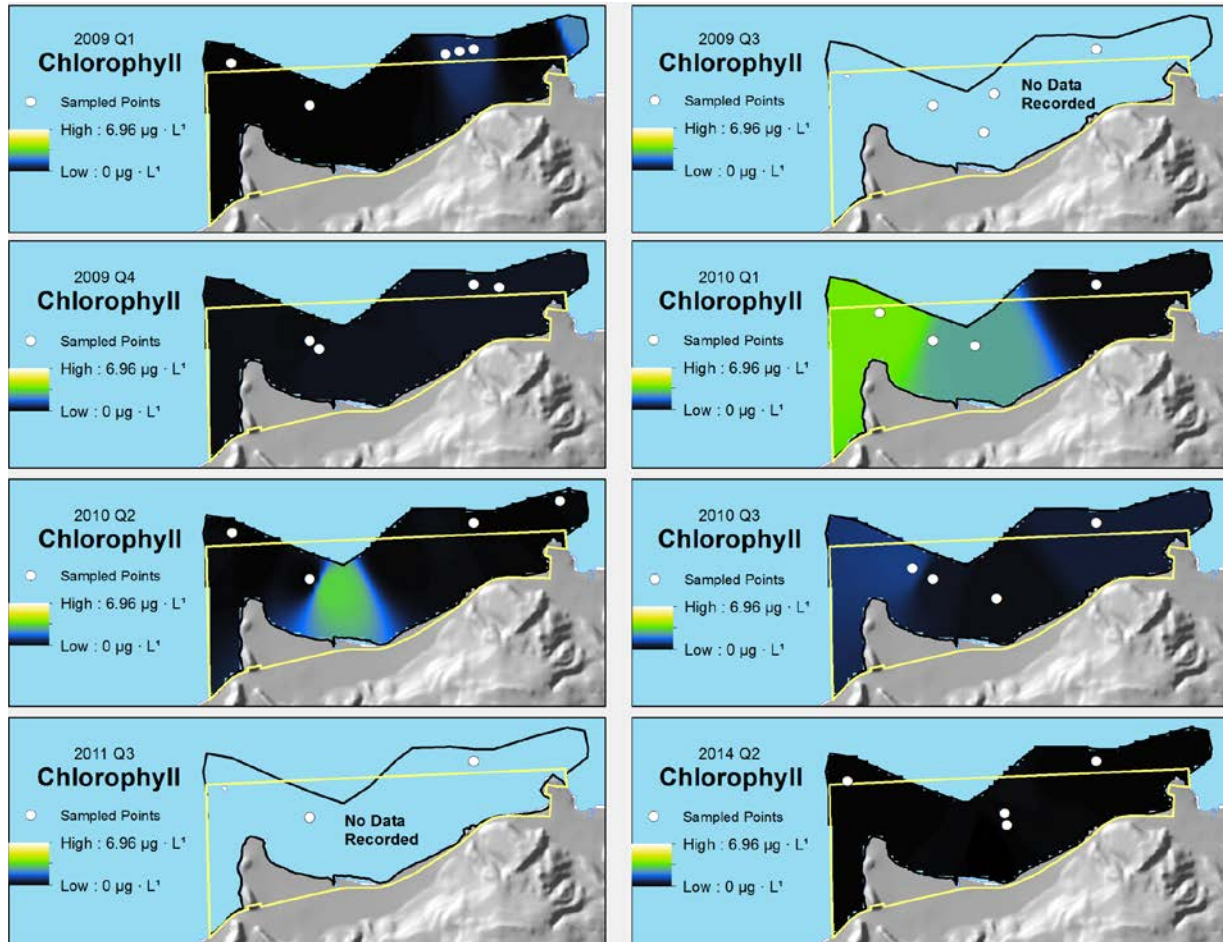


Figure 24. Spatial distribution of bottom chlorophyll in surface marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

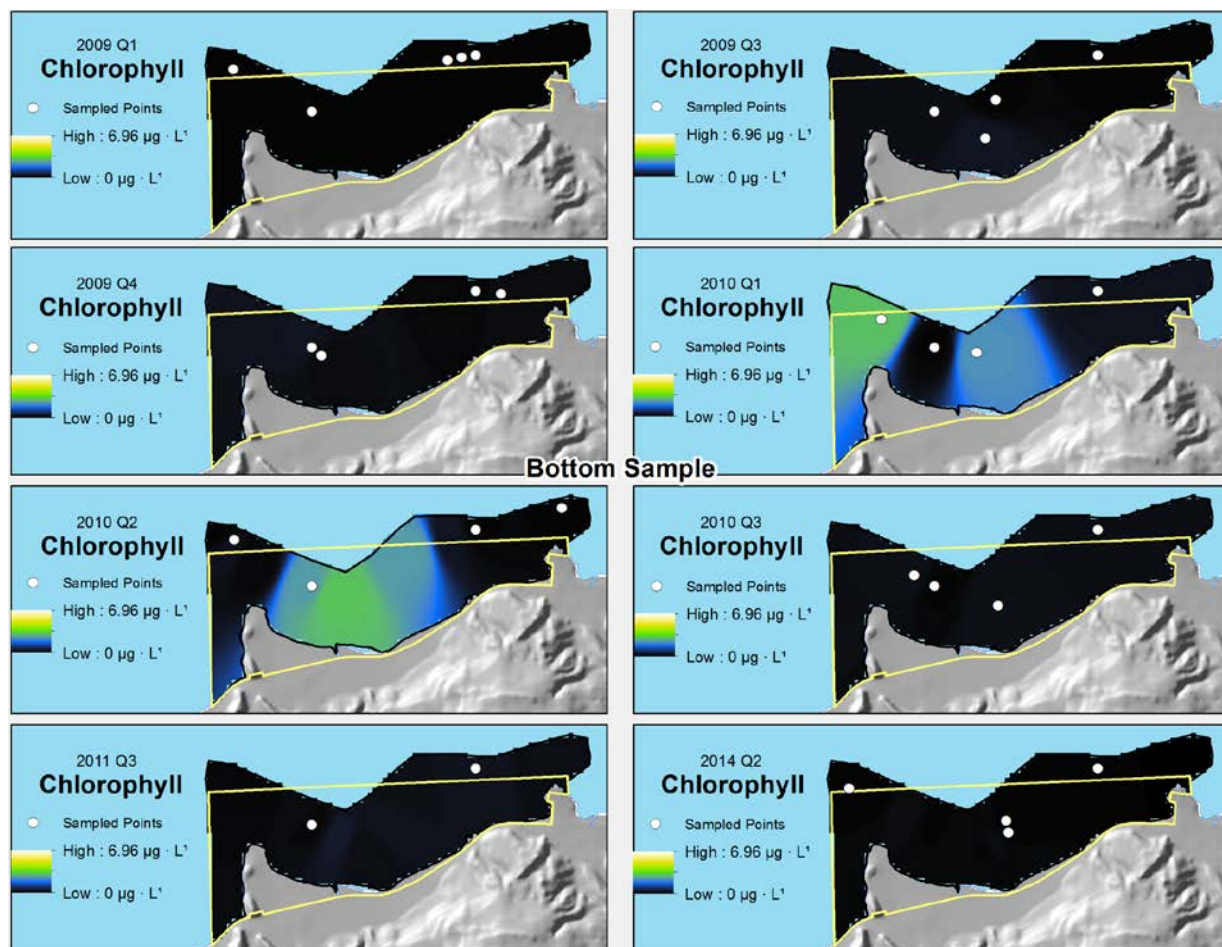


Figure 25. Spatial distribution of bottom chlorophyll in bottom marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

Dissolved Oxygen Concentration

Dissolved oxygen concentrations were generally consistent between years (Tables. 11-12, Figures 26-27). Spatial patterns were inconsistent in Agat, and the highest concentrations of dissolved oxygen in Asan were found in surface waters near the Asan stream input (Figures 28-31).

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

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	5.3	6.5	7.7	0.6
	2	Bottom	15	6.1	6.5	6.8	0.2
	3	Bottom	5	6.2	6.5	7.5	0.5
	4	Surface	4	5.4	6.3	6.3	0.5
	4	Bottom	4	4.8	6.1	6.1	0.6
2010	1	Surface	4	6.7	6.7	7.0	0.1
	1	Bottom	4	6.8	6.8	6.9	0.1
	2	Surface	10	5.2	6.4	7.1	0.5
	2	Bottom	10	5.8	6.4	6.8	0.3
	3	Surface	4	6.2	6.6	6.8	0.3
	3	Bottom	4	6.5	6.6	6.7	0.1
2011	3	Bottom	8	5.4	6.3	6.4	0.3
2014	2	Surface	9	5.4	6.5	6.7	0.4
	2	Bottom	9	5.8	6.3	6.4	0.2
	3	Surface	1	6.6	6.6	6.6	NA
	3	Bottom	1	6.6	6.6	6.6	NA

Table 12. Dissolved oxygen concentration ($\text{mg} \cdot \text{L}^{-1}$) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	6.4	6.5	7.7	0.4
	2	Bottom	15	6.1	6.5	6.7	0.2
	3	Bottom	4	6.3	6.5	6.6	0.1
	4	Surface	4	6.3	6.3	6.4	0.1
	4	Bottom	4	6.1	6.1	6.4	0.1
2010	1	Surface	4	6.6	6.7	7.1	0.2
	1	Bottom	4	6.5	6.8	6.8	0.1
	2	Surface	18	5.9	6.4	7.8	0.4
	2	Bottom	18	5.5	6.4	6.9	0.3
	3	Surface	4	6.5	6.6	8.1	0.8
	3	Bottom	4	6.5	6.6	6.6	0.1
2011	3	Bottom	9	6.3	6.3	6.6	0.1
2014	2	Surface	8	6.3	6.5	7.2	0.3
	2	Bottom	8	5.7	6.3	6.4	0.2

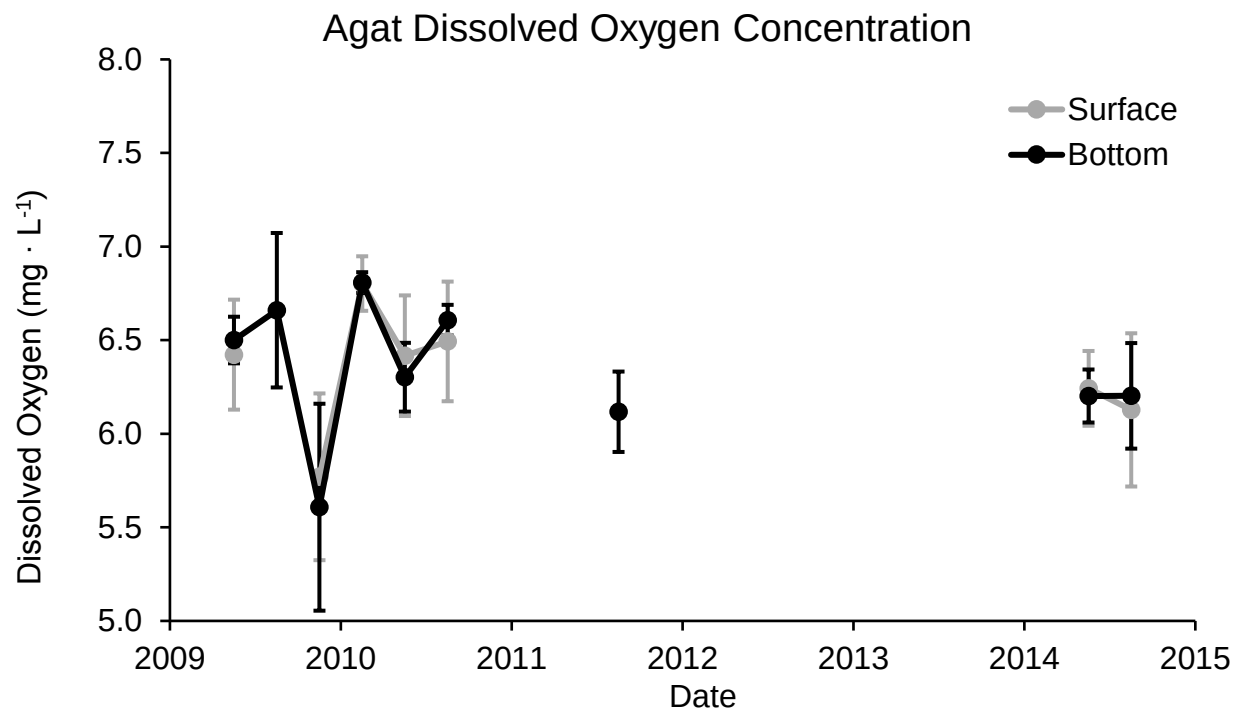


Figure 26. Dissolved oxygen concentration in marine waters of WAPA in Agat. Data are means and 95% confidence intervals.

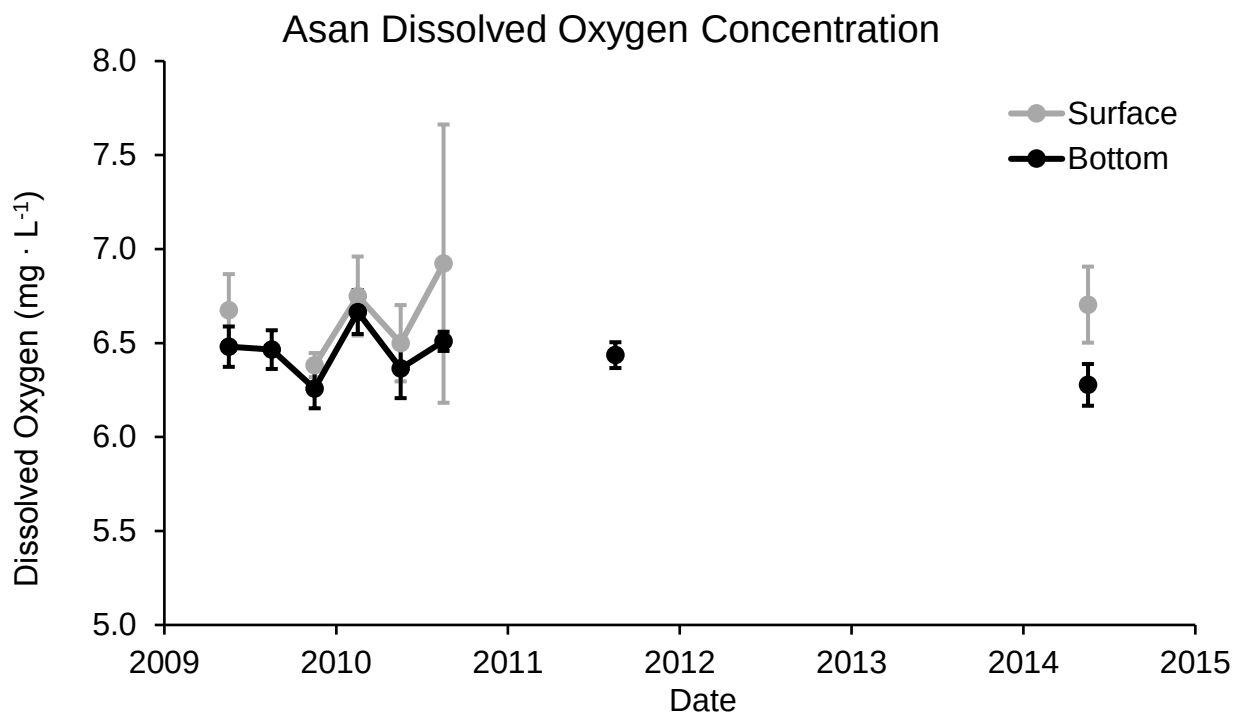


Figure 27. Dissolved oxygen concentration in marine waters of WAPA in Asan. Data are means and 95% confidence intervals.

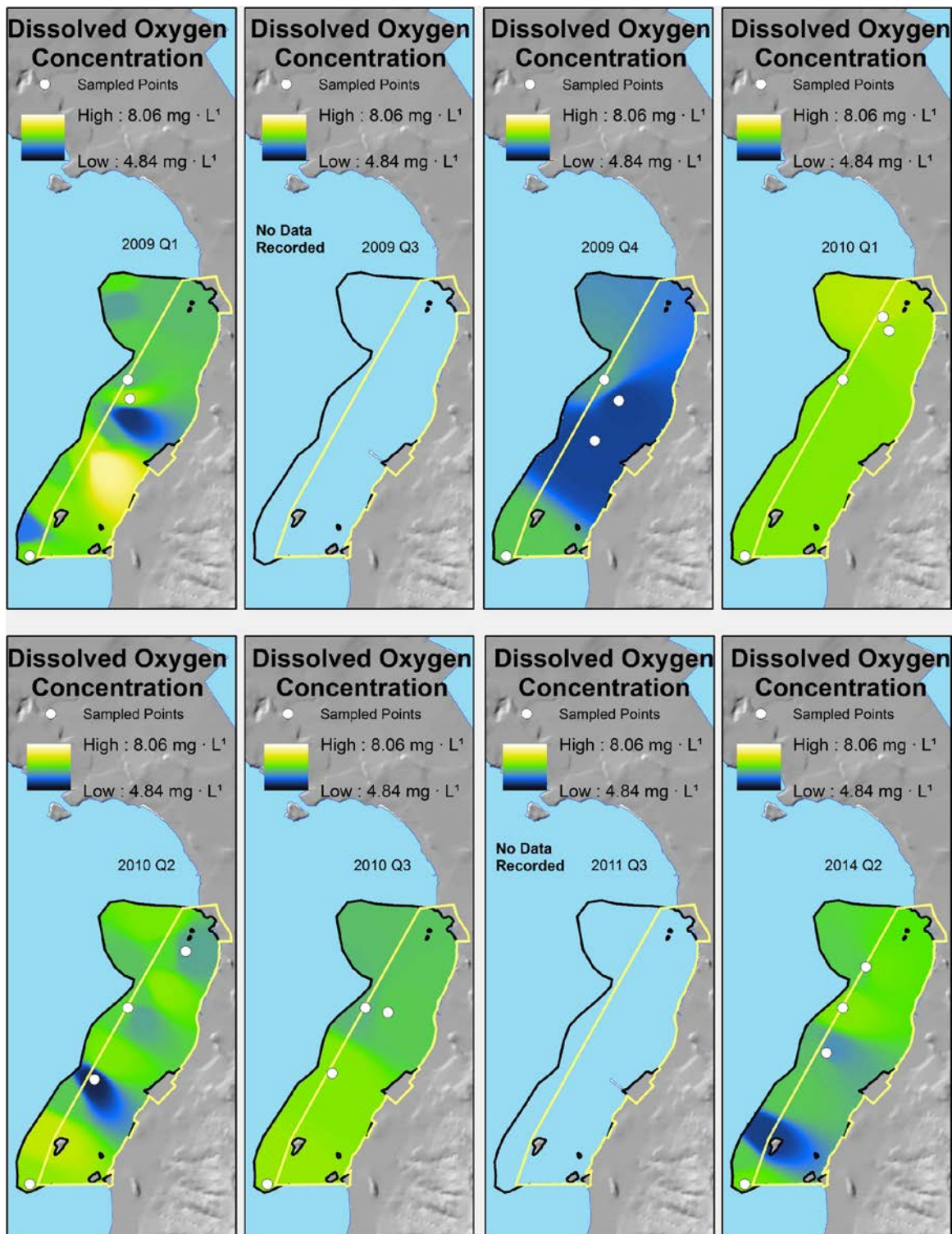


Figure 28. Spatial distribution of surface dissolved oxygen concentration in marine waters WAPA in Agat using the total range of results observed in both surface and bottom samples.

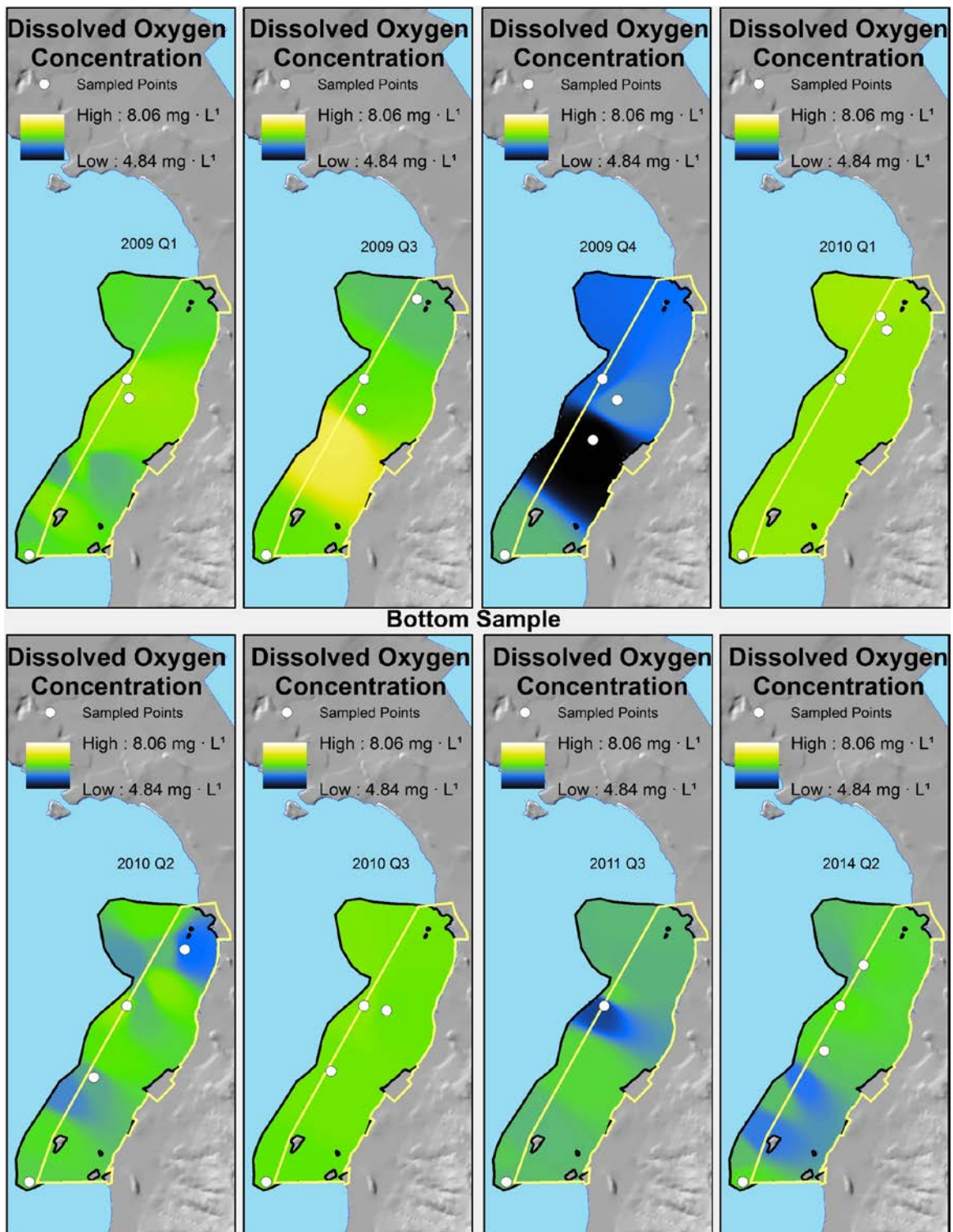


Figure 29. Spatial distribution of bottom dissolved oxygen concentration in marine waters of WAPA on Agat using the total range of results observed in both surface and bottom samples.

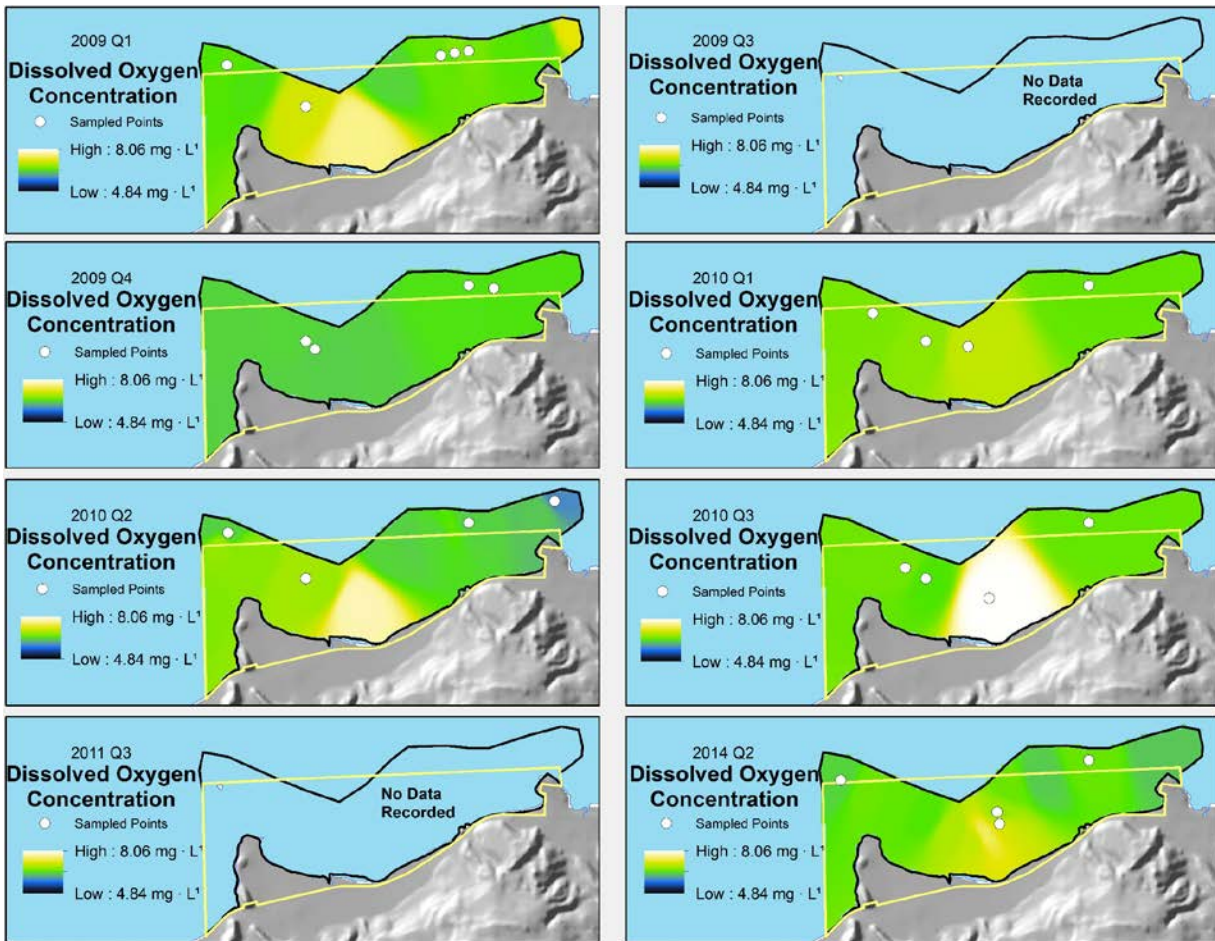


Figure 30. Spatial distribution of surface dissolved oxygen concentration in marine waters of WAPA on Asan using the total range of results observed in both surface and bottom samples.

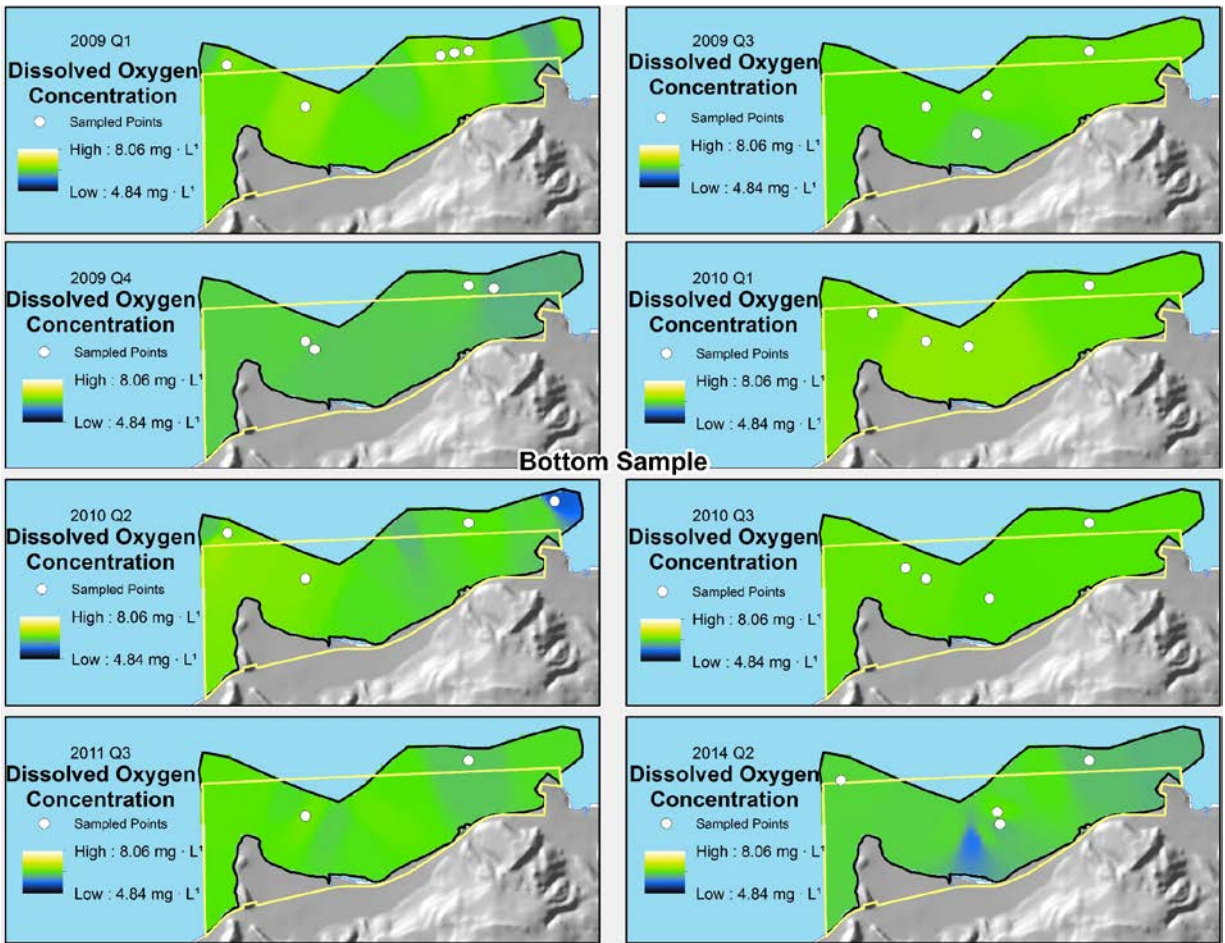


Figure 31. Spatial distribution of bottom dissolved oxygen concentration in marine waters of WAPA on Asan using the total range of results observed in both surface and bottom samples.

Dissolved Oxygen Saturation

Dissolved oxygen concentrations were generally consistent between years (Tables 12-13, Figures 32-37).

Table 13. Dissolved Oxygen Saturation (%) in marine waters of WAPA in Agat.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	11	100.8	102.6	100.0	6.0
	2	Bottom	15	100.3	103.0	99.0	3.9
	3	Bottom	5	103.6	103.7	99.5	2.2
	4	Surface	3	85.0	100.0	99.4	7.4
	4	Bottom	4	77.0	97.4	97.7	9.0
2010	1	Surface	4	103.6	103.9	108.7	2.4
	1	Bottom	4	104.7	104.8	106.7	0.9
	2	Surface	10	100.2	99.9	99.5	8.3
	2	Bottom	7	100.6	99.8	99.6	2.9
	3	Surface	4	100.1	103.9	98.1	5.2
	3	Bottom	4	103.7	104.2	107.0	1.4
2011	3	Bottom	8	100.8	100.8	99.6	4.9
2014	2	Surface	9	100.1	101.7	99.8	6.6
	2	Bottom	9	100.1	100.1	99.3	3.4
	3	Surface	1	106.3	106.3	106.3	NA
	3	Bottom	1	104.3	104.3	104.3	NA

Table 14. Dissolved Oxygen Saturation (%) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	100.5	102.6	121.9	6.4
	2	Bottom	15	100.4	103.0	98.5	3.5
	3	Bottom	4	101.0	103.7	104.5	1.5
	4	Surface	4	101.0	100.0	100.0	1.0
	4	Bottom	4	100.4	97.4	99.4	1.7
2010	1	Surface	4	101.3	103.9	109.1	3.4
	1	Bottom	4	100.9	104.8	104.9	1.9
	2	Surface	14	101.0	99.9	99.3	4.7
	2	Bottom	14	100.2	99.8	99.8	4.4
	3	Surface	4	102.8	103.9	129.2	12.9
	3	Bottom	4	102.6	104.2	104.3	0.9
2011	3	Bottom	9	100.4	100.8	99.0	1.7
2014	2	Surface	8	100.5	101.7	99.0	5.3
	2	Bottom	8	100.3	100.1	98.0	3.6

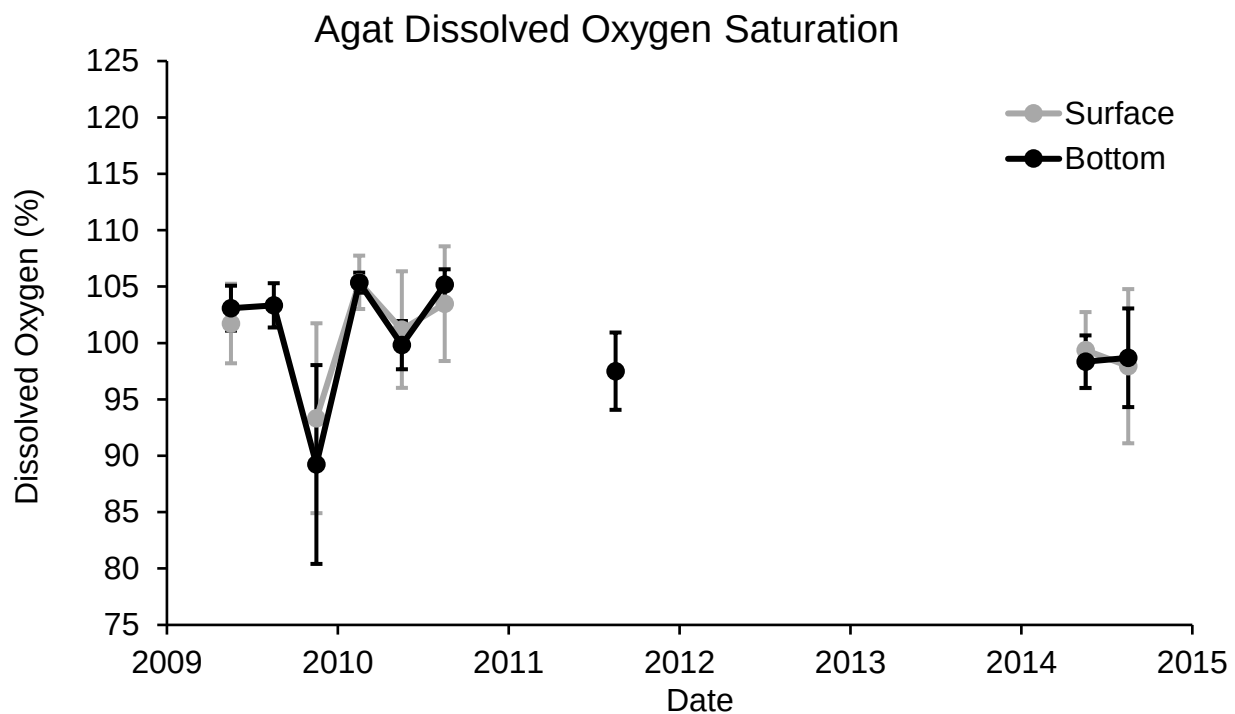


Figure 32. Dissolved oxygen saturation in marine waters of WAPA in Agat. Data are means and 95% confidence intervals.

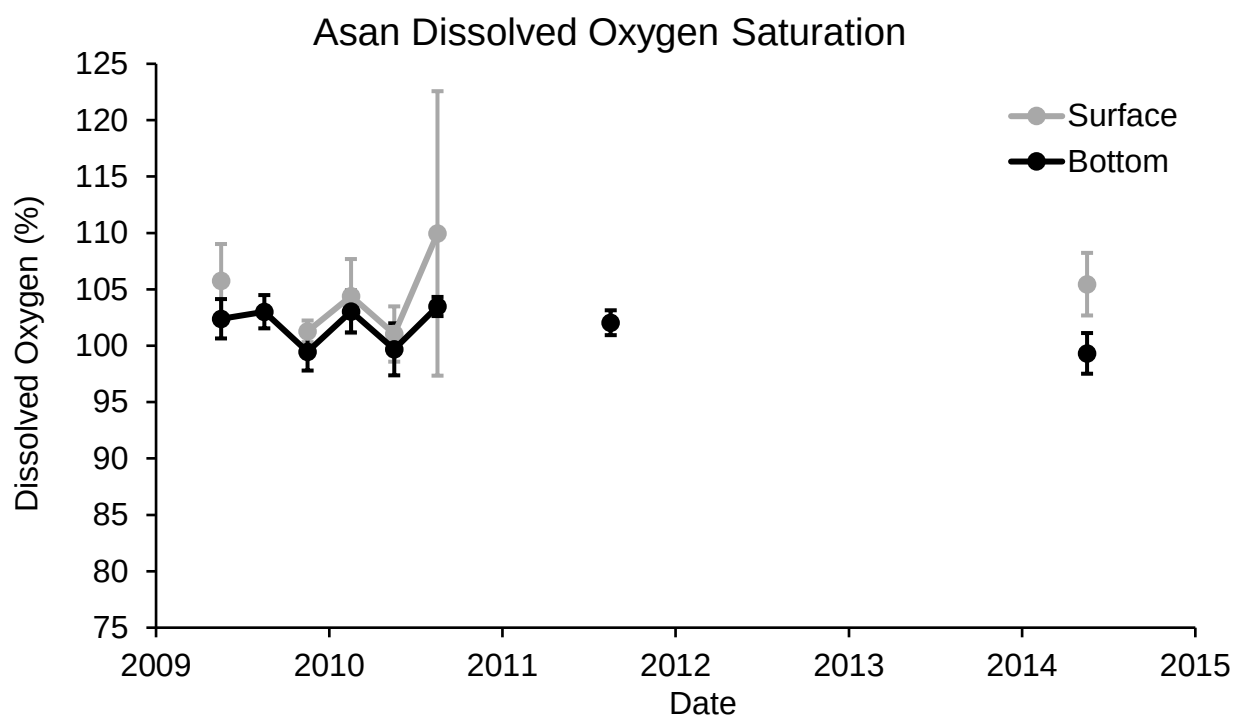


Figure 33. Dissolved oxygen saturation in marine waters of WAPA in Agat. Data are means and 95% confidence intervals.

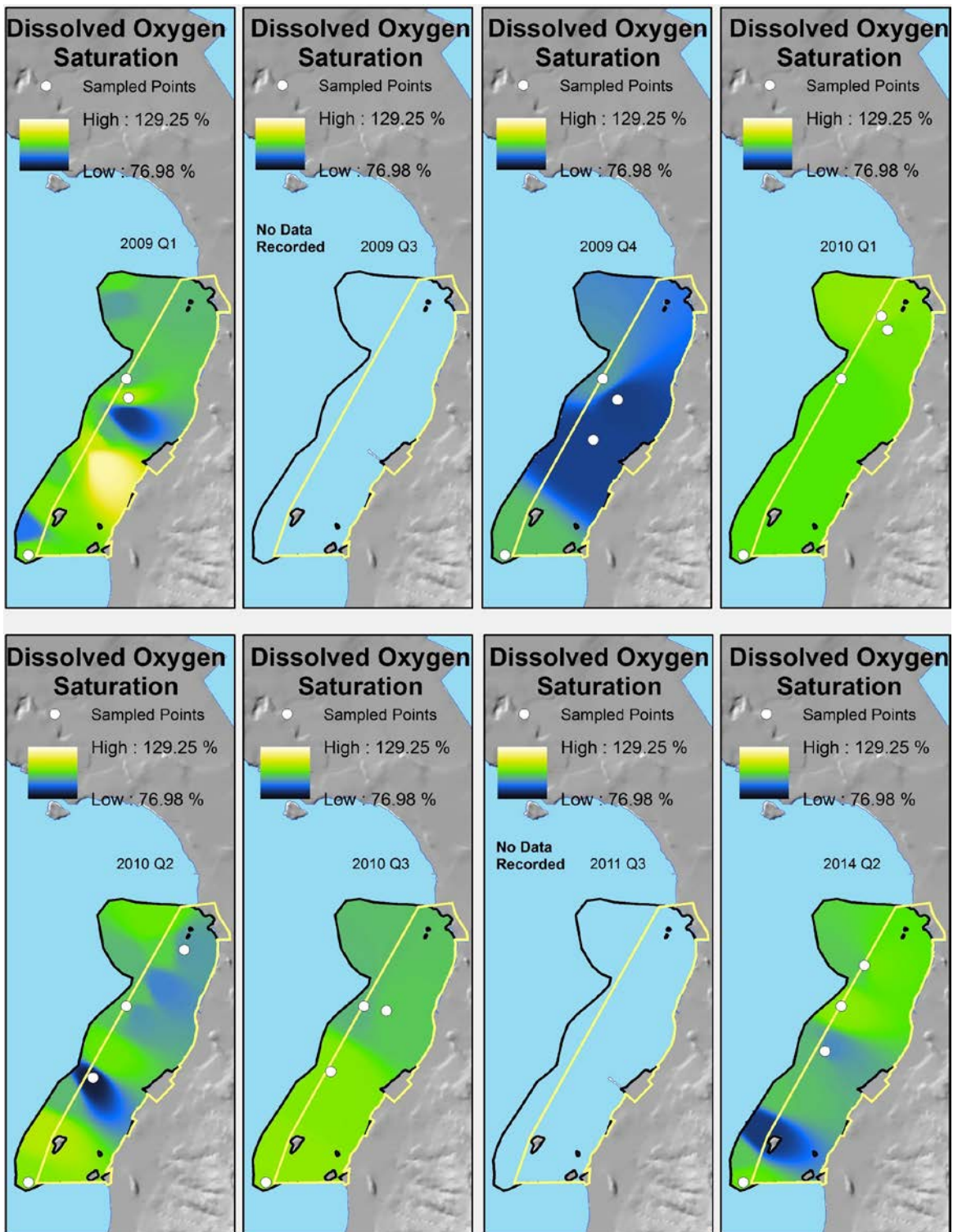


Figure 34. Spatial distribution of surface dissolved oxygen saturation in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

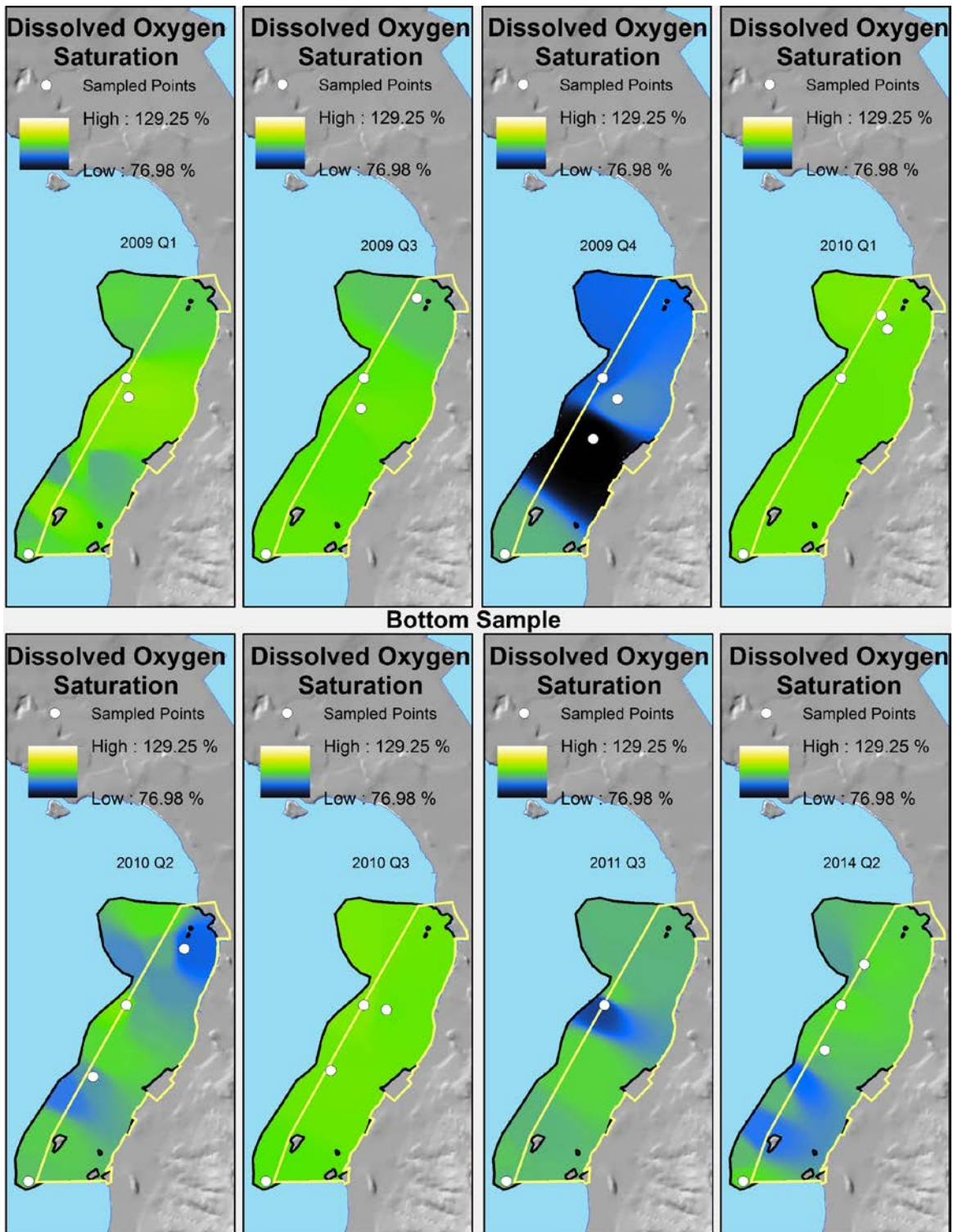


Figure 35. Spatial distribution of bottom dissolved oxygen saturation in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

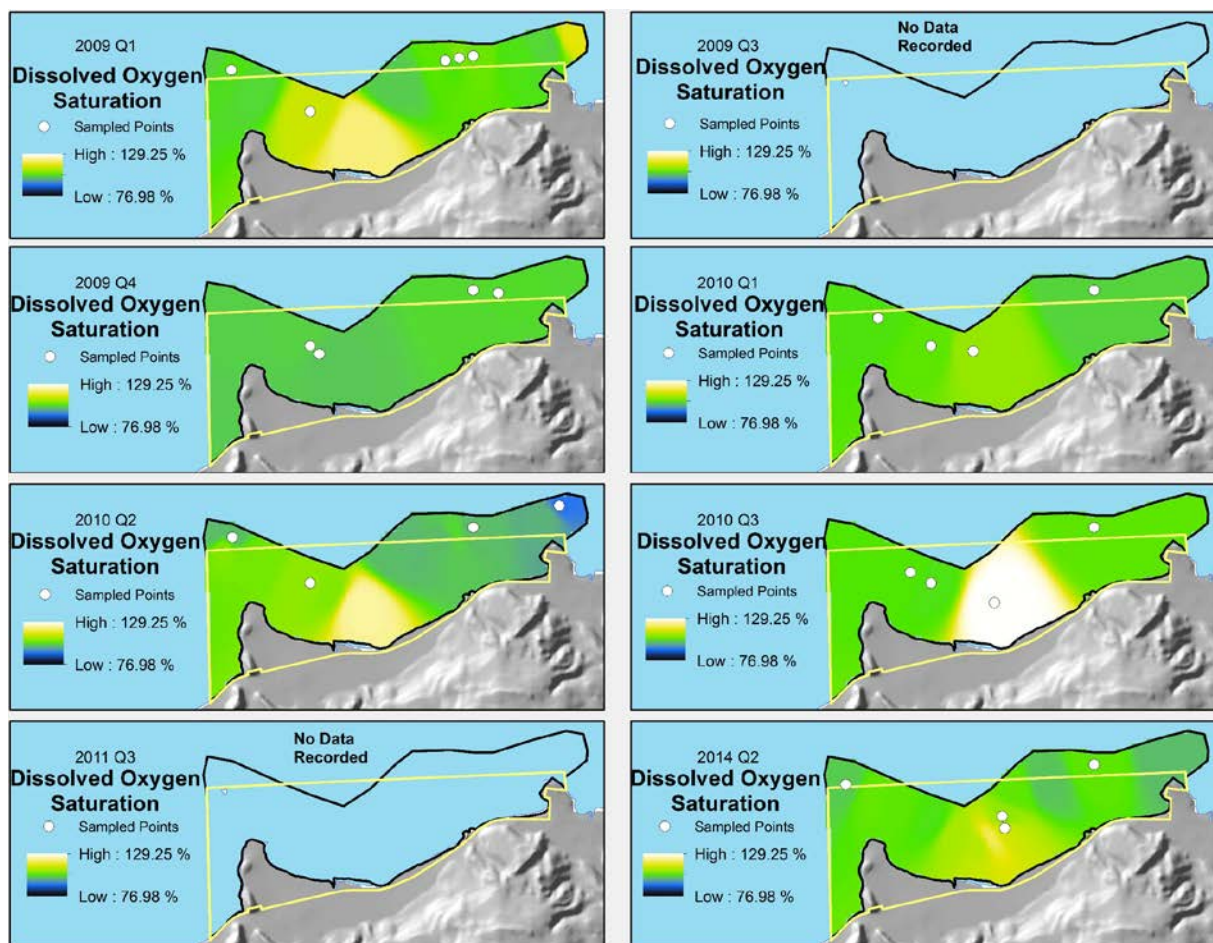


Figure 36. Spatial distribution of surface dissolved oxygen saturation in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

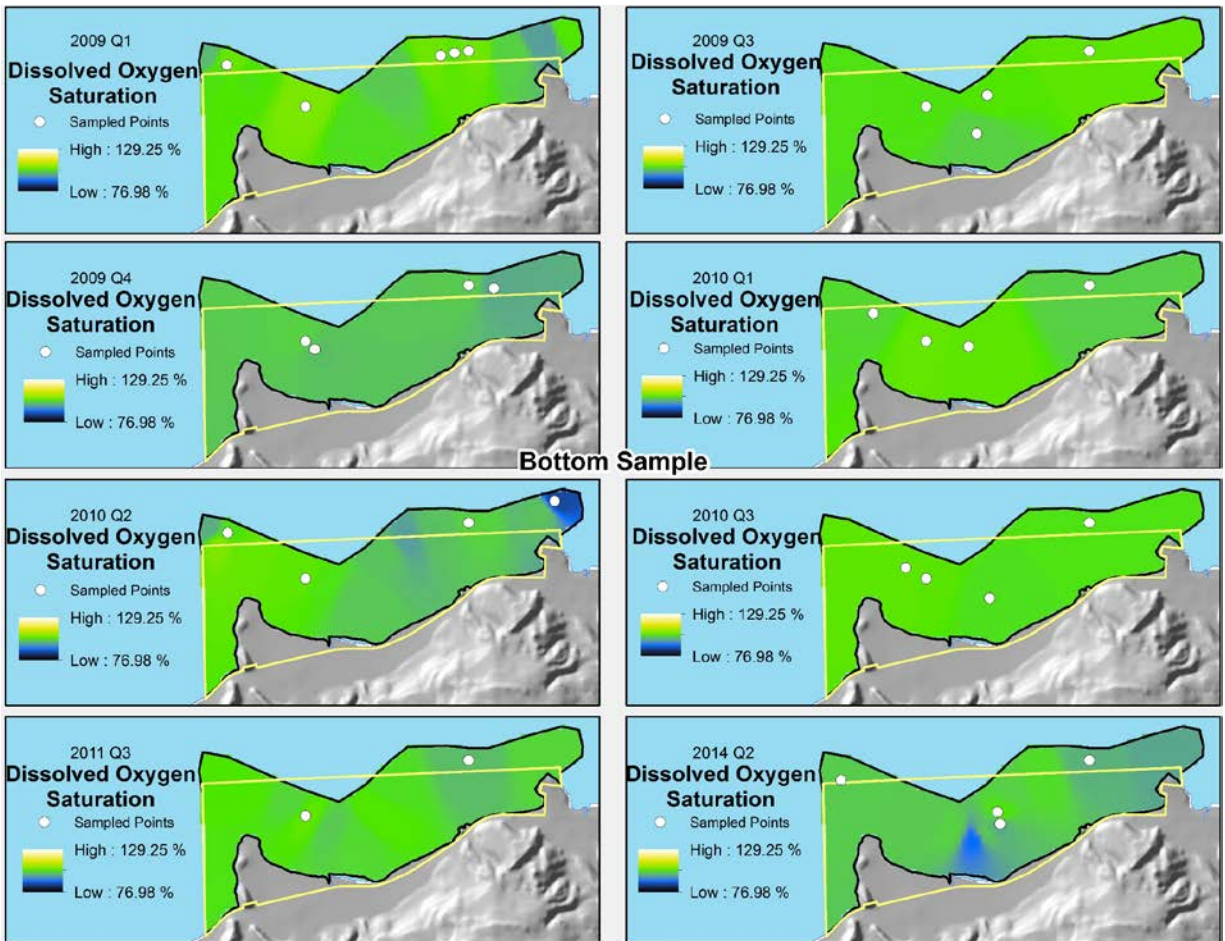


Figure 37. Spatial distribution of bottom dissolved oxygen saturation in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

pH

Surface and bottom waters displayed essentially identical measurements in bottom and surface waters, and pH was higher near the Asan stream input (Tables 14-15, Figures 38-43).

Table 15. pH in marine waters of WAPA in Agat.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	8.1	8.1	8.2	0.0
	2	Bottom	15	8.1	8.2	8.2	0.0
	3	Bottom	5	8.0	8.1	8.2	0.1
	4	Surface	4	8.2	8.3	8.3	0.0
	4	Bottom	4	8.2	8.3	8.3	0.0
2010	1	Surface	4	8.1	8.1	8.1	0.0
	1	Bottom	4	8.1	8.1	8.1	0.0
	2	Surface	10	8.1	8.1	8.2	0.0
	2	Bottom	10	8.1	8.1	8.2	0.0
	3	Surface	4	8.0	8.0	8.0	0.0
	3	Bottom	4	8.0	8.0	8.0	0.0
2011	3	Bottom	8	8.0	8.1	8.1	0.0
2014	2	Surface	9	7.9	8.0	8.0	0.0
	2	Bottom	9	8.0	8.0	8.0	0.0
	3	Surface	1	8.0	8.0	8.0	NA
	3	Bottom	1	7.9	7.9	7.9	NA

Table 16. pH in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	8.1	8.1	8.2	0.0
	2	Bottom	15	8.1	8.2	8.2	0.0
	3	Bottom	4	8.1	8.1	8.2	0.0
	4	Surface	4	8.3	8.3	8.3	0.0
	4	Bottom	4	8.3	8.3	8.3	0.0
2010	1	Surface	4	8.1	8.1	8.2	0.0
	1	Bottom	4	8.1	8.1	8.1	0.0
	2	Surface	18	8.1	8.1	8.3	0.1
	2	Bottom	18	8.0	8.1	8.3	0.1
	3	Surface	4	8.0	8.0	8.1	0.0
	3	Bottom	4	8.0	8.0	8.0	0.0
2011	3	Bottom	9	8.1	8.1	8.2	0.0
2014	2	Surface	8	7.9	8.0	8.1	0.0
	2	Bottom	8	7.9	8.0	8.0	0.0

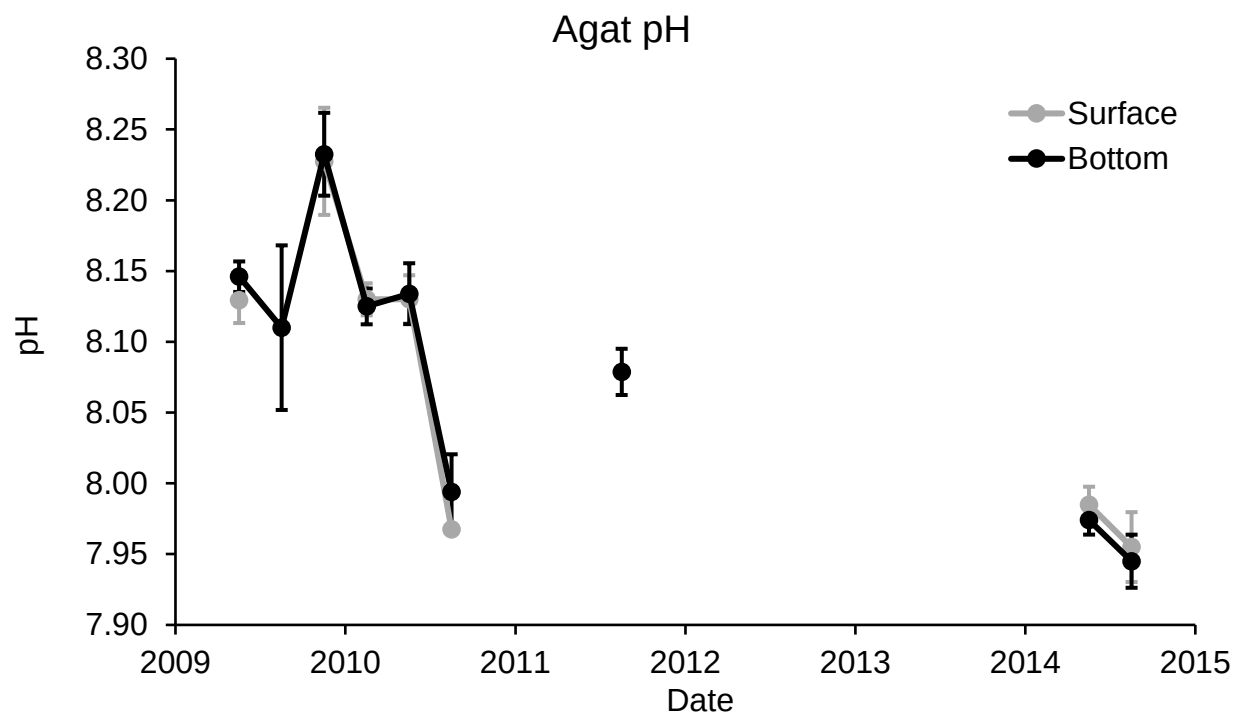


Figure 38. pH in marine waters of WAPA in Agat. Data are means and 95% confidence intervals.

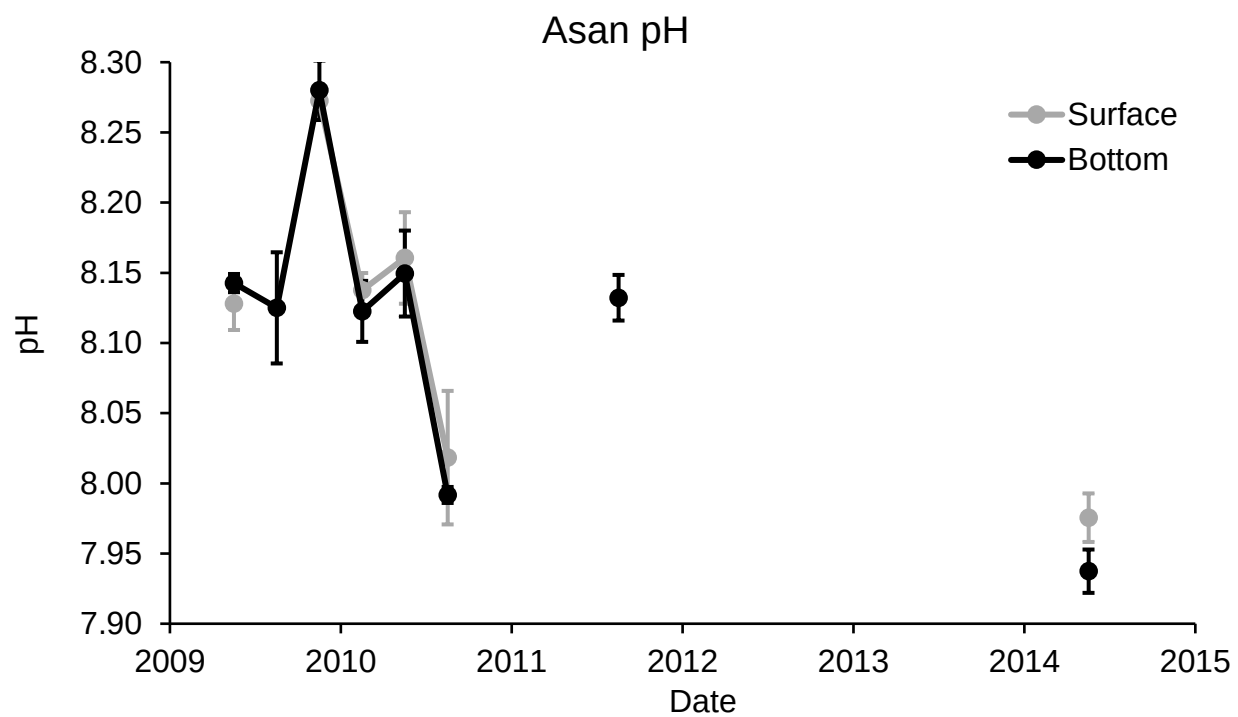


Figure 39. pH in marine waters of WAPA in Asan. Data are means and 95% confidence intervals.

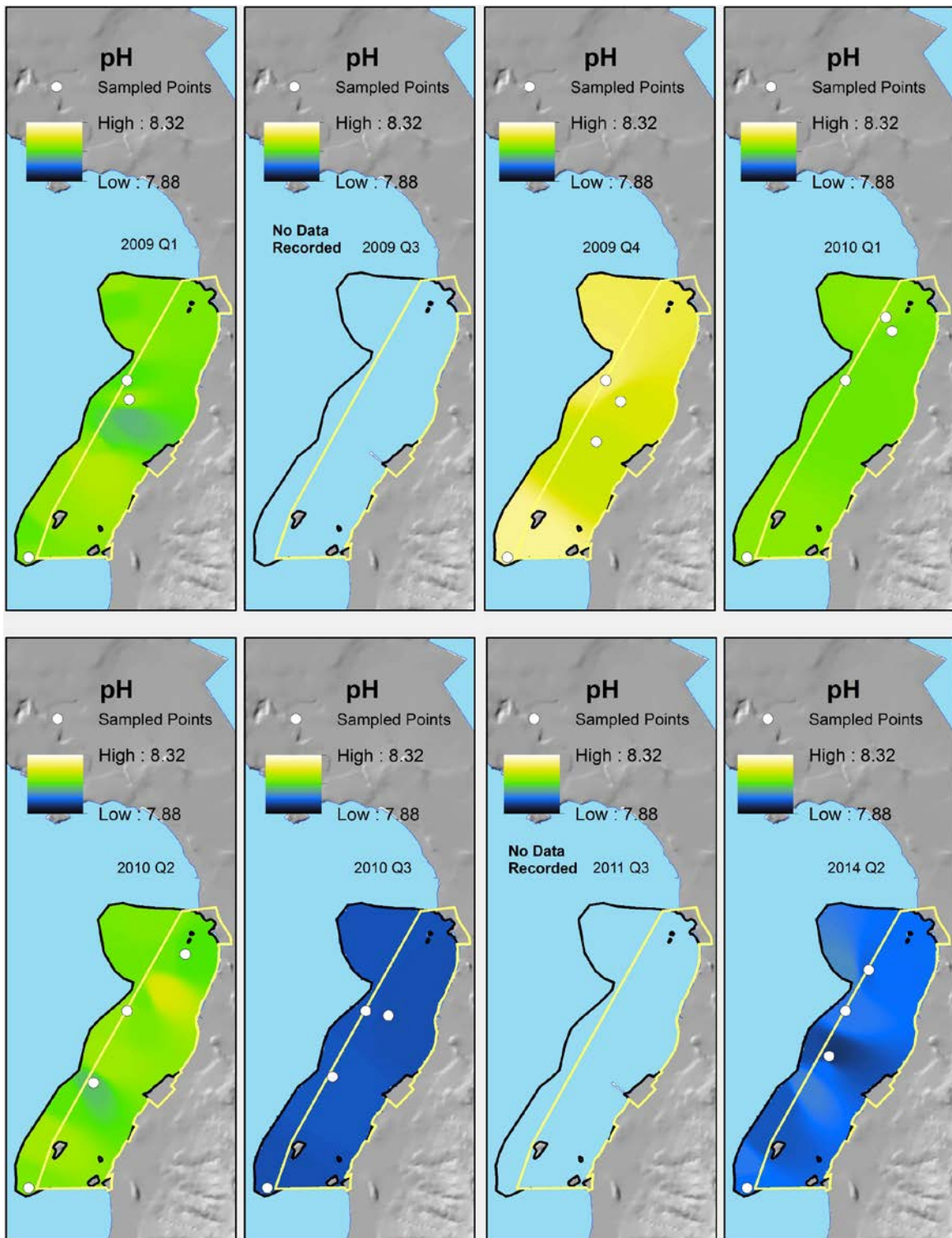


Figure 40. Spatial distribution of surface pH in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

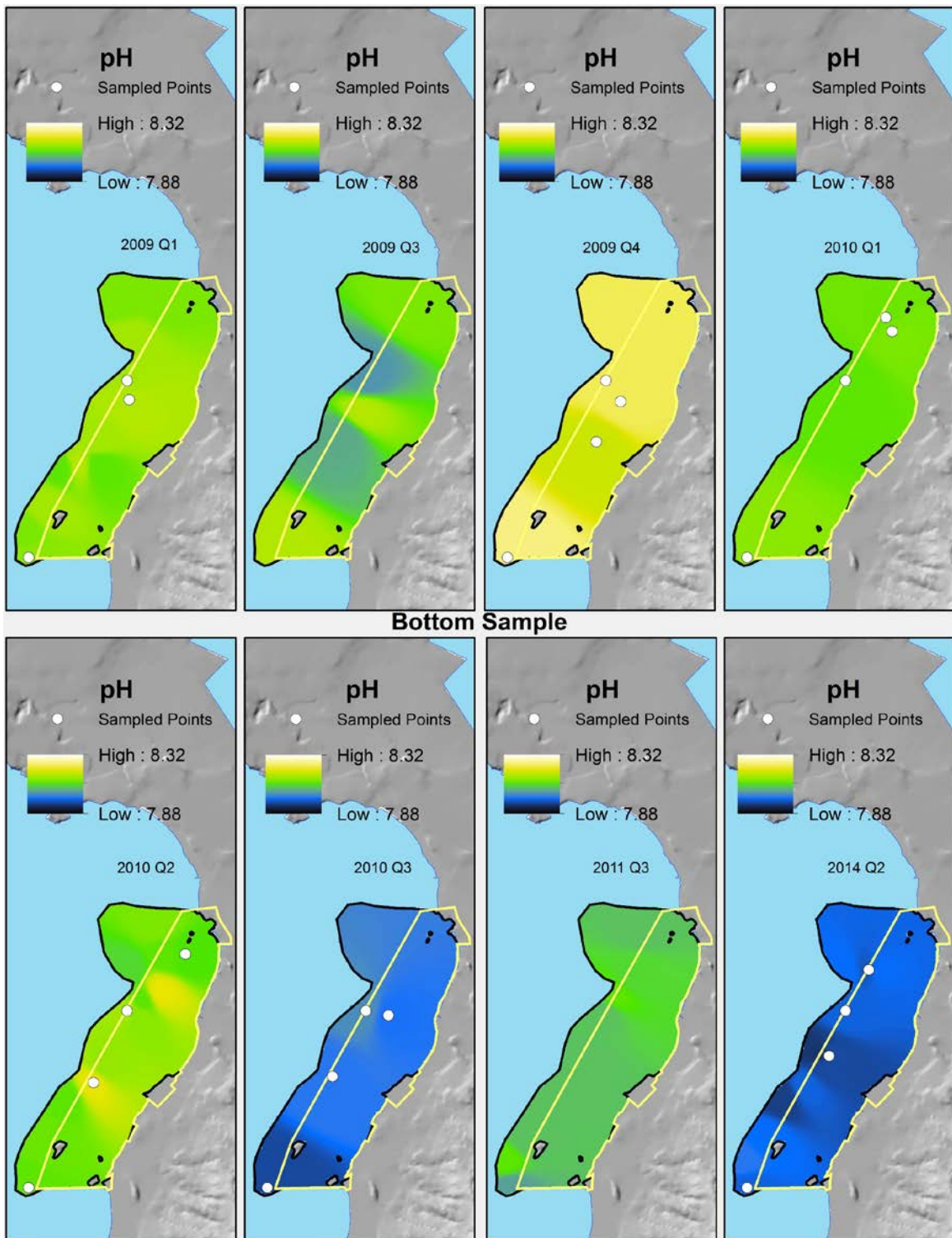


Figure 41. Spatial distribution of bottom pH in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

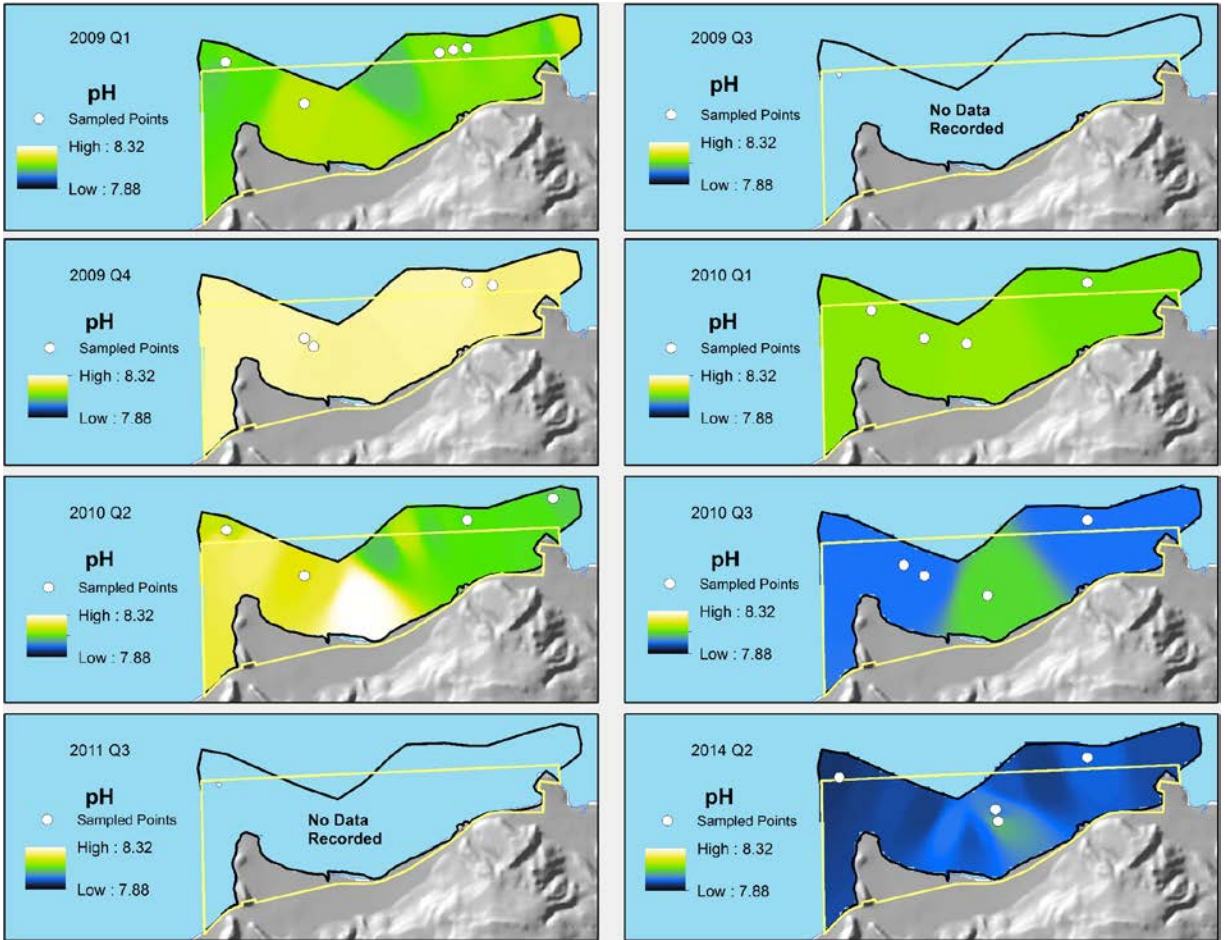


Figure 42. Spatial distribution of surface pH in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

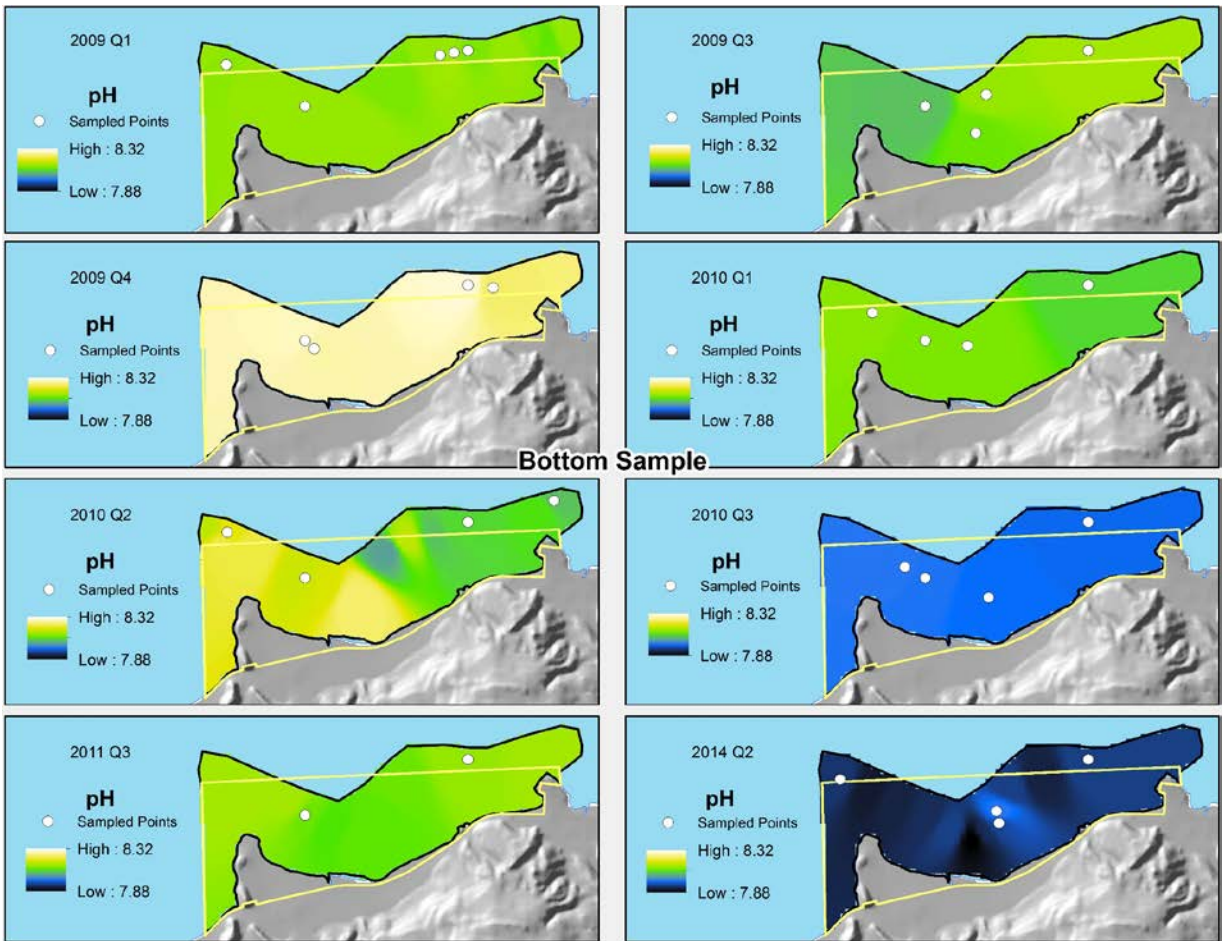


Figure 43. Spatial distribution of bottom pH in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples

Salinity

Salinity was relatively consistent between years and showed little spatial variation (Tables 17-18, Figures 44-49).

Table 17. Salinity (ppt) in marine waters of WAPA in Agat.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	35.6	35.7	35.7	0.0
	2	Bottom	15	35.7	35.7	35.7	0.0
	3	Bottom	5	35.6	35.6	35.7	0.0
	4	Surface	4	35.0	35.6	35.6	0.2
	4	Bottom	4	35.8	35.9	35.9	0.0
2010	1	Surface	4	36.3	36.3	36.4	0.0
	1	Bottom	4	36.3	36.4	36.4	0.0
	2	Surface	10	34.6	34.7	34.8	0.1
	2	Bottom	10	34.6	34.8	34.8	0.1
	3	Surface	4	34.1	34.2	34.3	0.1
	3	Bottom	4	34.3	34.3	34.4	0.0
2011	3	Bottom	8	35.1	35.1	35.2	0.0
2014	2	Surface	9	32.5	33.0	33.1	0.2
	2	Bottom	9	32.9	33.0	33.2	0.1
	3	Surface	1	32.9	32.9	32.9	NA
	3	Bottom	1	33.1	33.1	33.1	NA

Table 18. Salinity (ppt) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	34.8	35.7	35.7	0.2
		Bottom	15	35.5	35.7	35.7	0.1
	3	Bottom	4	35.6	35.6	35.7	0.0
	4	Surface	4	35.7	35.6	35.8	0.0
		Bottom	4	35.9	35.9	35.9	0.0
2010	1	Surface	4	36.3	36.3	36.4	0.0
		Bottom	4	36.3	36.4	36.4	0.0
	2	Surface	18	2.0	34.7	35.0	7.7
		Bottom	18	2.1	34.8	35.0	7.7
	3	Surface	4	31.5	34.2	34.3	1.3
		Bottom	4	34.2	34.3	34.2	0.0
2011	3	Bottom	9	34.9	35.1	35.2	0.1
2014	2	Surface	8	32.7	33.0	33.0	0.1
		Bottom	8	32.9	33.0	33.1	0.1

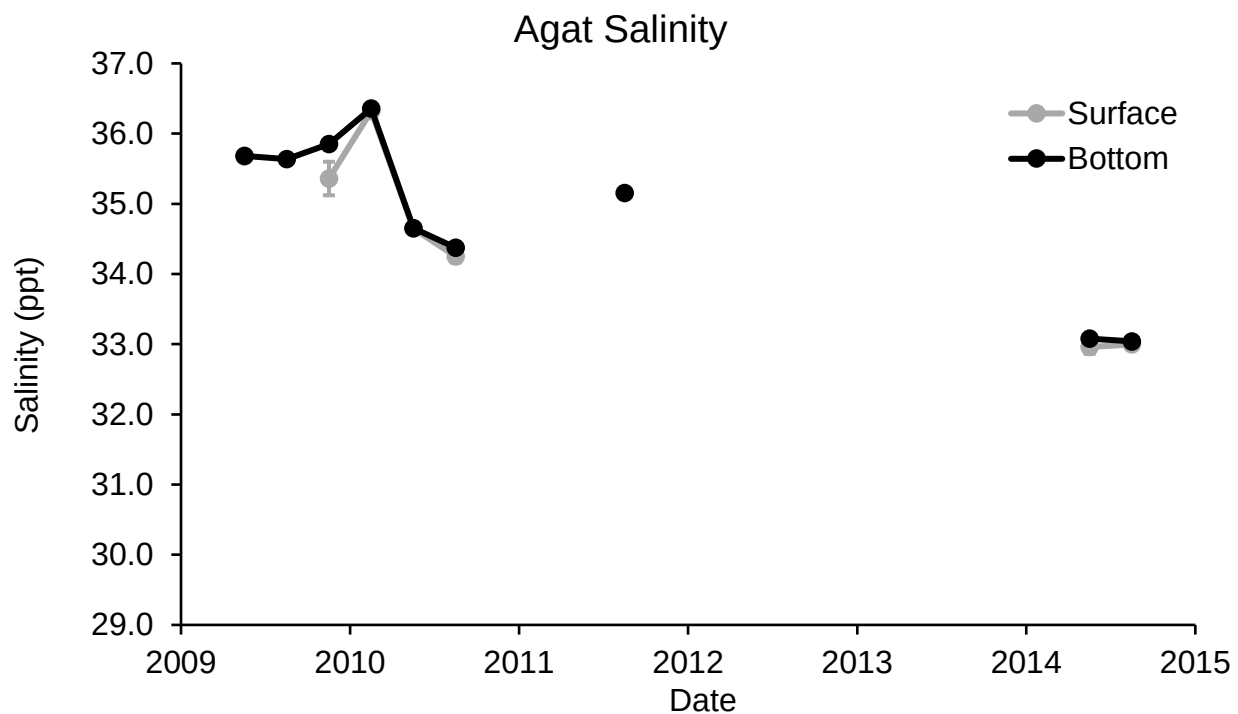


Figure 44. Salinity in marine waters of WAPA in Agat. Data are means and 95% confidence intervals.

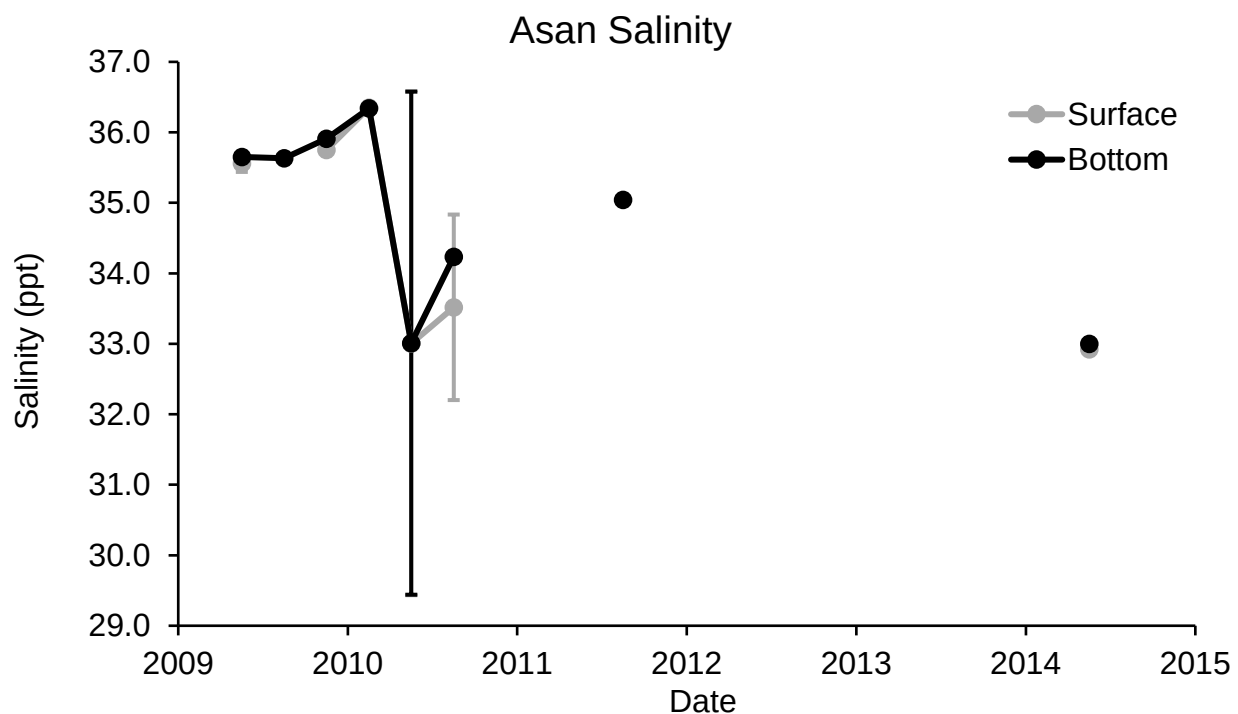


Figure 45. Salinity in marine waters of WAPA in Asan. Data are means and 95% confidence intervals.

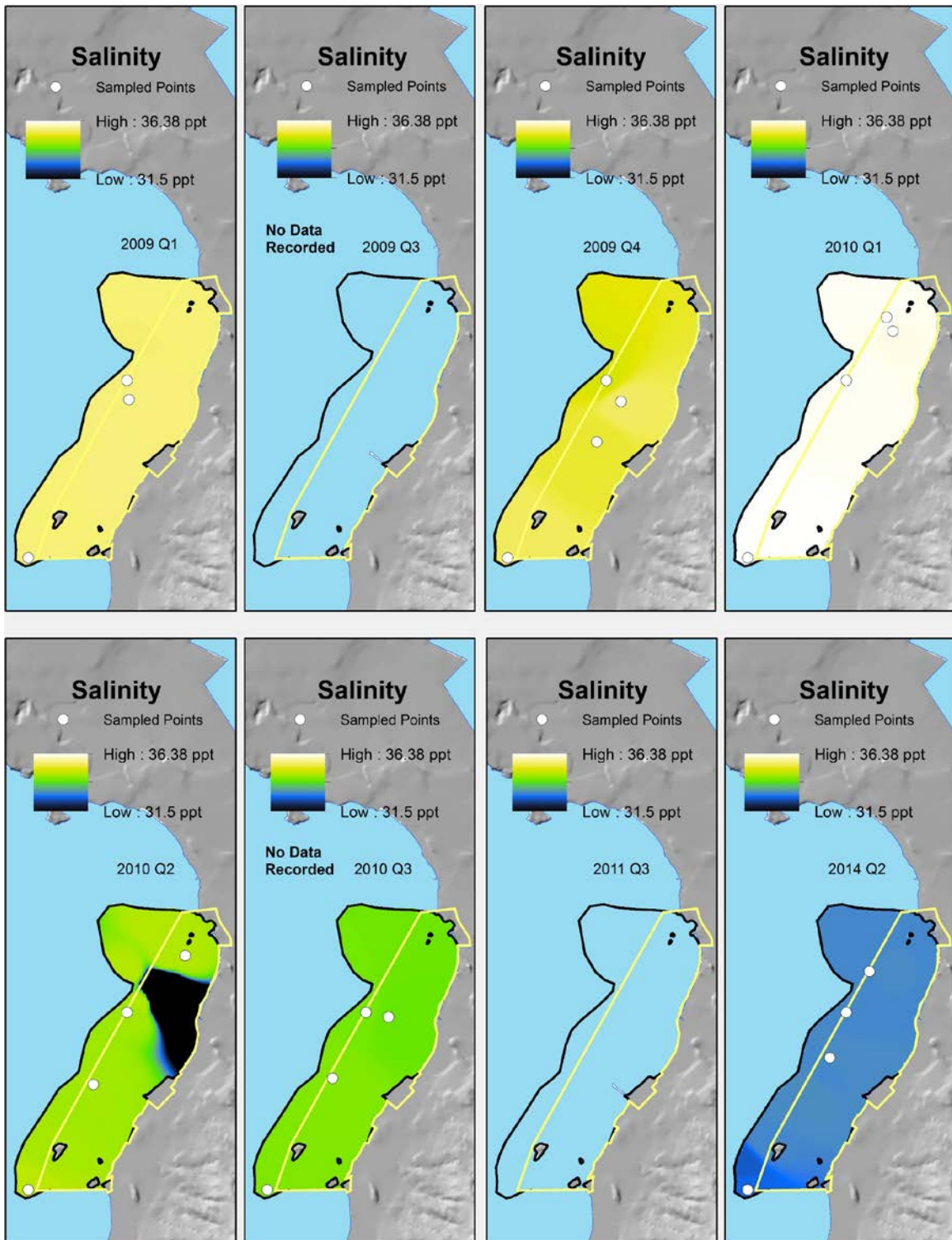


Figure 46. Spatial distribution of surface salinity in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

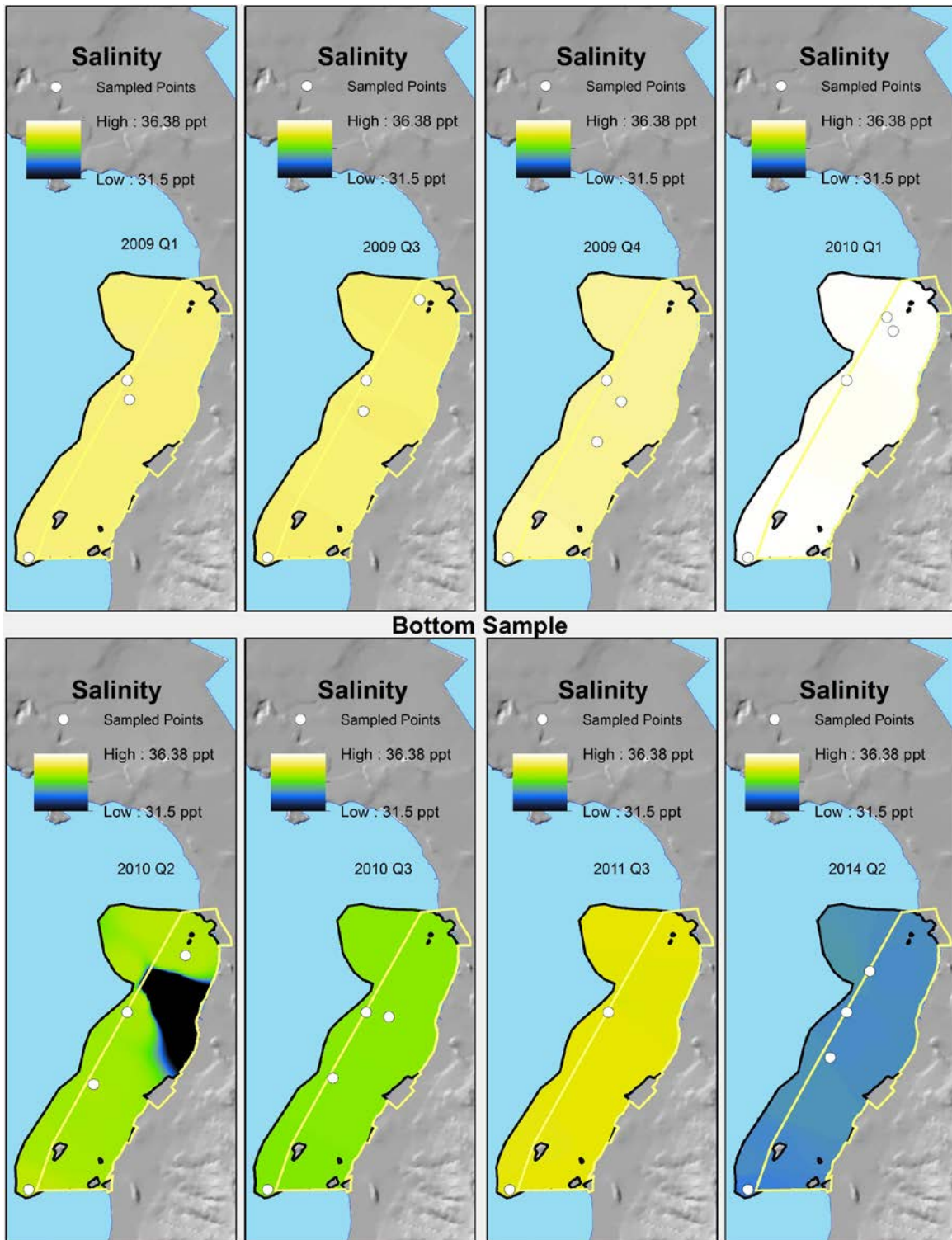


Figure 47. Spatial distribution of bottom salinity in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

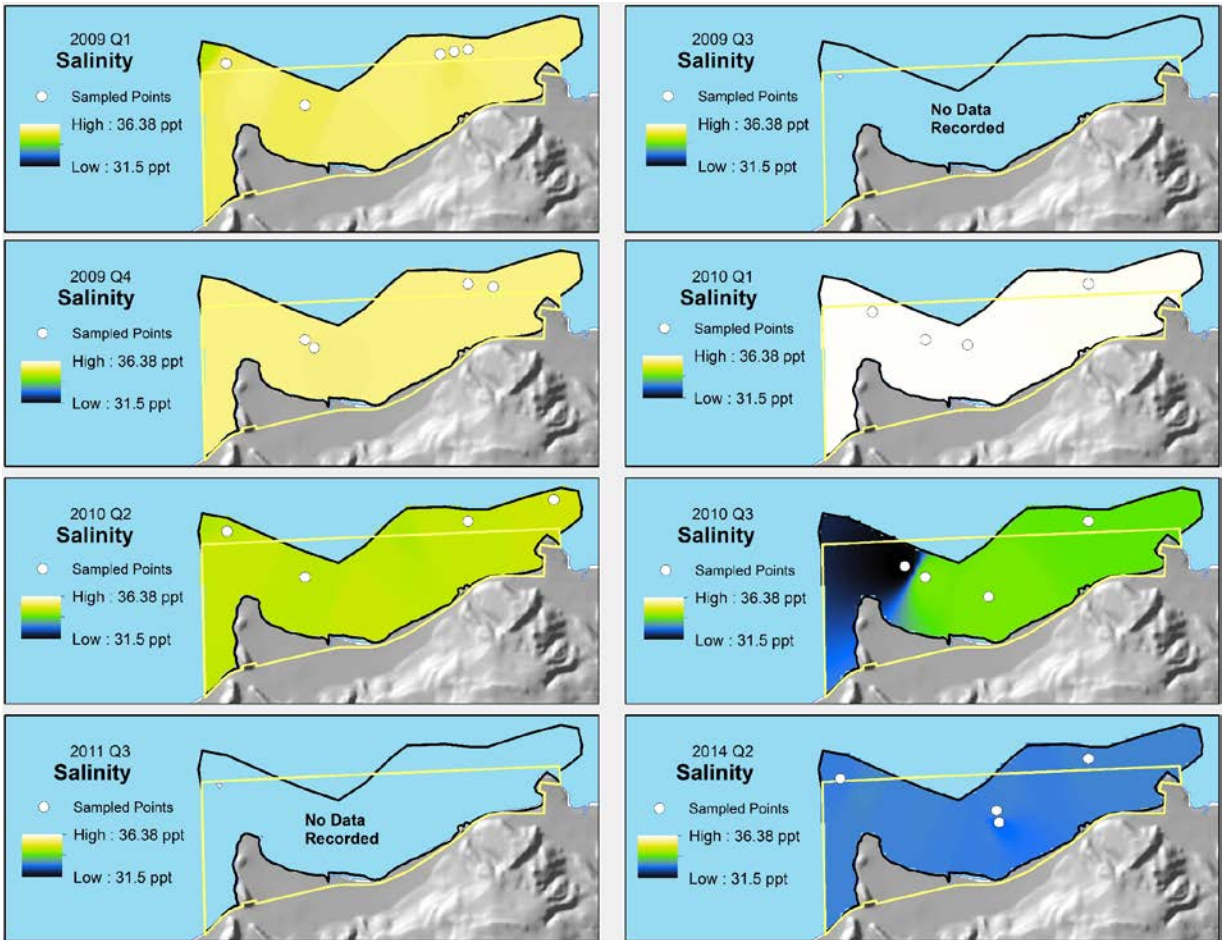


Figure 48. Spatial distribution of surface salinity in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

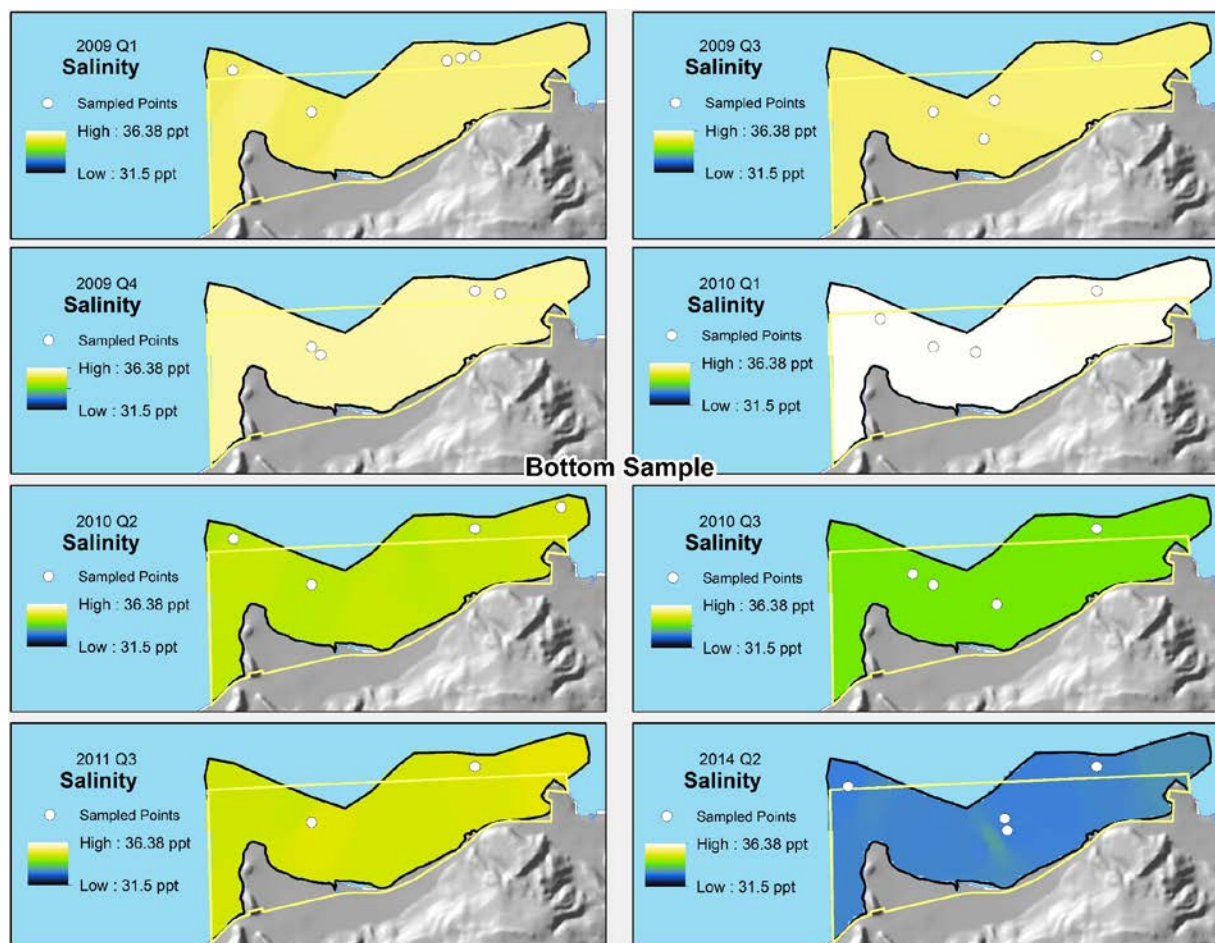


Figure 49. Spatial distribution of bottom salinity in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

Specific Conductance

Specific Conductance was relatively consistent between years and showed little spatial variation (Tables 19-20, Figures 50-55).

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

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	54.1	54.1	54.2	0.0
	2	Bottom	15	54.1	54.1	54.2	0.0
	3	Bottom	5	54.1	54.1	54.1	0.0
	4	Surface	4	53.3	54.1	54.0	0.3
	4	Bottom	4	54.3	54.4	54.4	0.0
2010	1	Surface	4	54.9	54.9	55.0	0.1
	1	Bottom	4	54.9	55.0	55.0	0.0
	2	Surface	10	52.6	52.9	52.9	0.1
	2	Bottom	10	52.6	52.9	52.9	0.1
	3	Surface	4	52.1	52.2	52.3	0.1
	3	Bottom	4	52.4	52.3	52.4	0.0
2011	3	Bottom	8	53.4	53.4	53.5	0.0
2014	2	Surface	9	49.9	50.5	50.6	0.3
	2	Bottom	9	50.5	50.6	50.8	0.1
	3	Surface	1	50.5	50.5	50.5	NA
	3	Bottom	1	50.7	50.7	50.7	NA

Table 20. Specific conductance ($\text{mS} \cdot \text{cm}^{-1}$) marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	52.9	54.1	54.2	0.3
	2	Bottom	15	53.9	54.1	54.2	0.1
	3	Bottom	4	54.0	54.1	54.2	0.1
	4	Surface	4	54.2	54.1	54.3	0.0
	4	Bottom	4	54.4	54.4	54.5	0.0
2010	1	Surface	4	54.9	54.9	55.0	0.0
	1	Bottom	4	54.9	55.0	55.0	0.0
	2	Surface	18	3.9	52.9	53.2	11.6
	2	Bottom	18	3.9	52.9	53.2	11.6
	3	Surface	4	48.2	52.2	52.3	2.0
	3	Bottom	4	52.2	52.3	52.2	0.0
2011	3	Bottom	9	53.1	53.4	53.4	0.1
2014	2	Surface	8	50.1	50.5	50.6	0.1
	2	Bottom	8	50.4	50.6	50.7	0.1

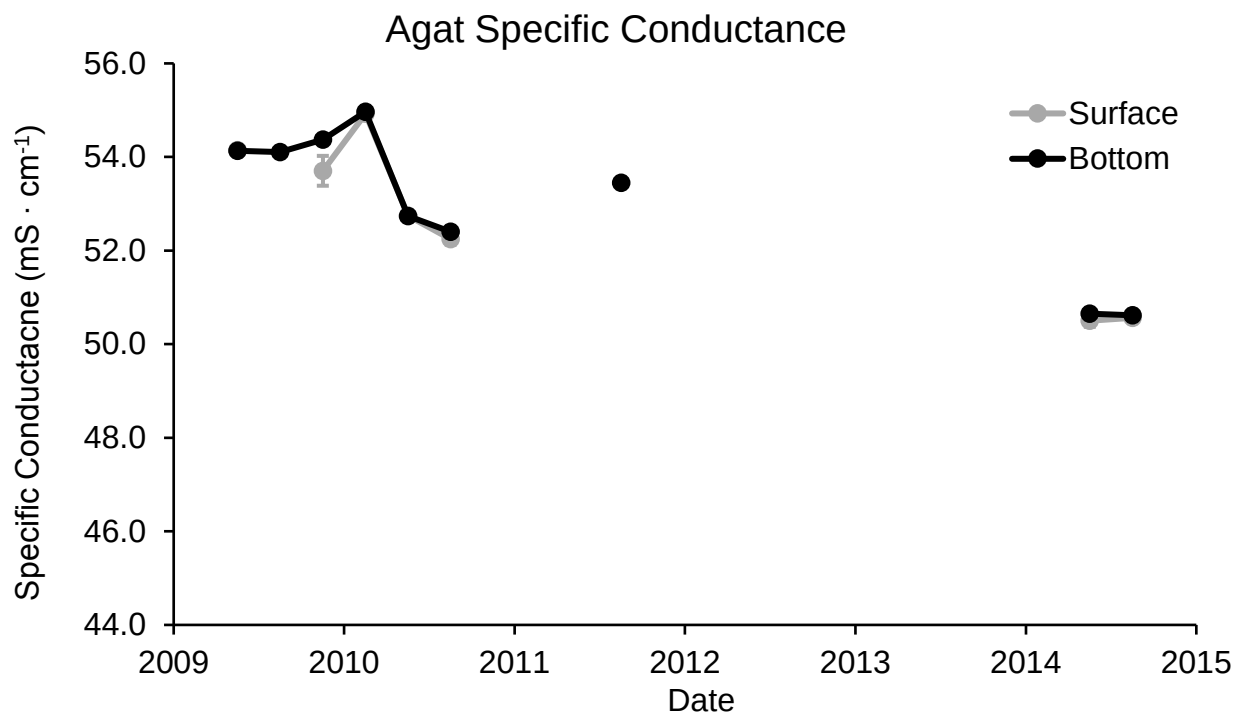


Figure 50. Specific conductance in marine waters of WAPA in Agat. Data are means and 95% confidence intervals.

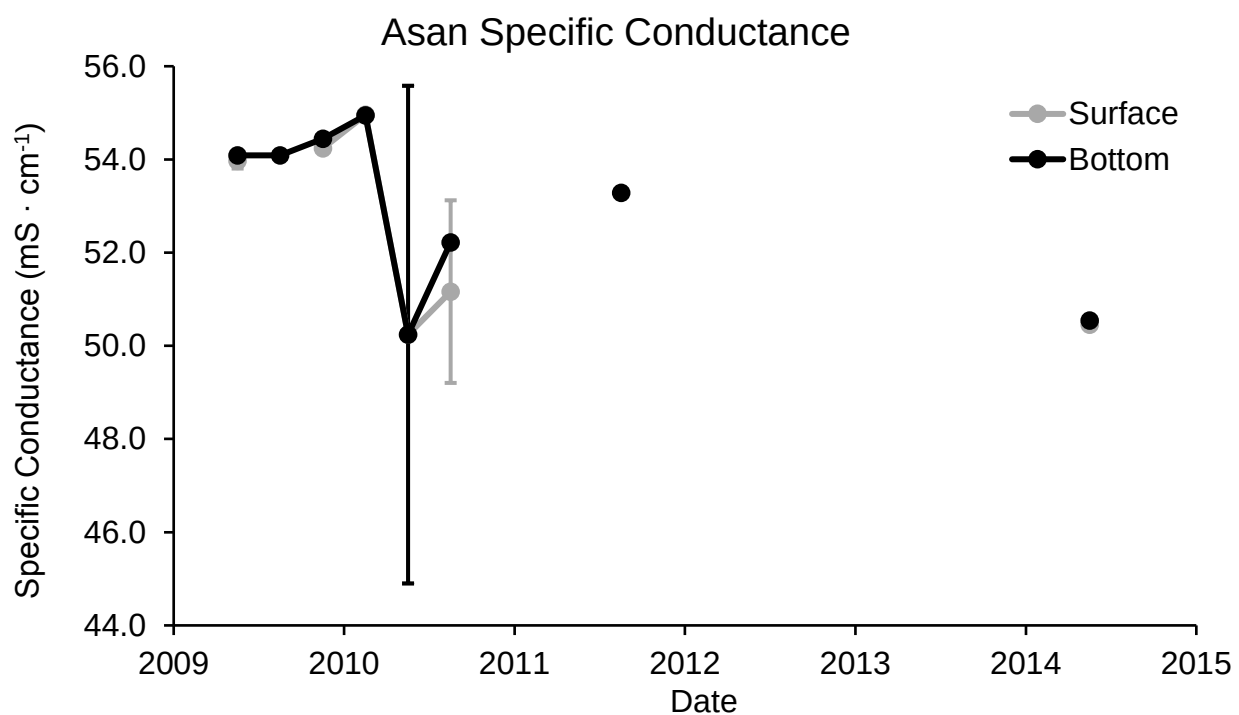


Figure 51. Specific conductance in marine waters of WAPA in Asan. Data are means and 95% confidence intervals.

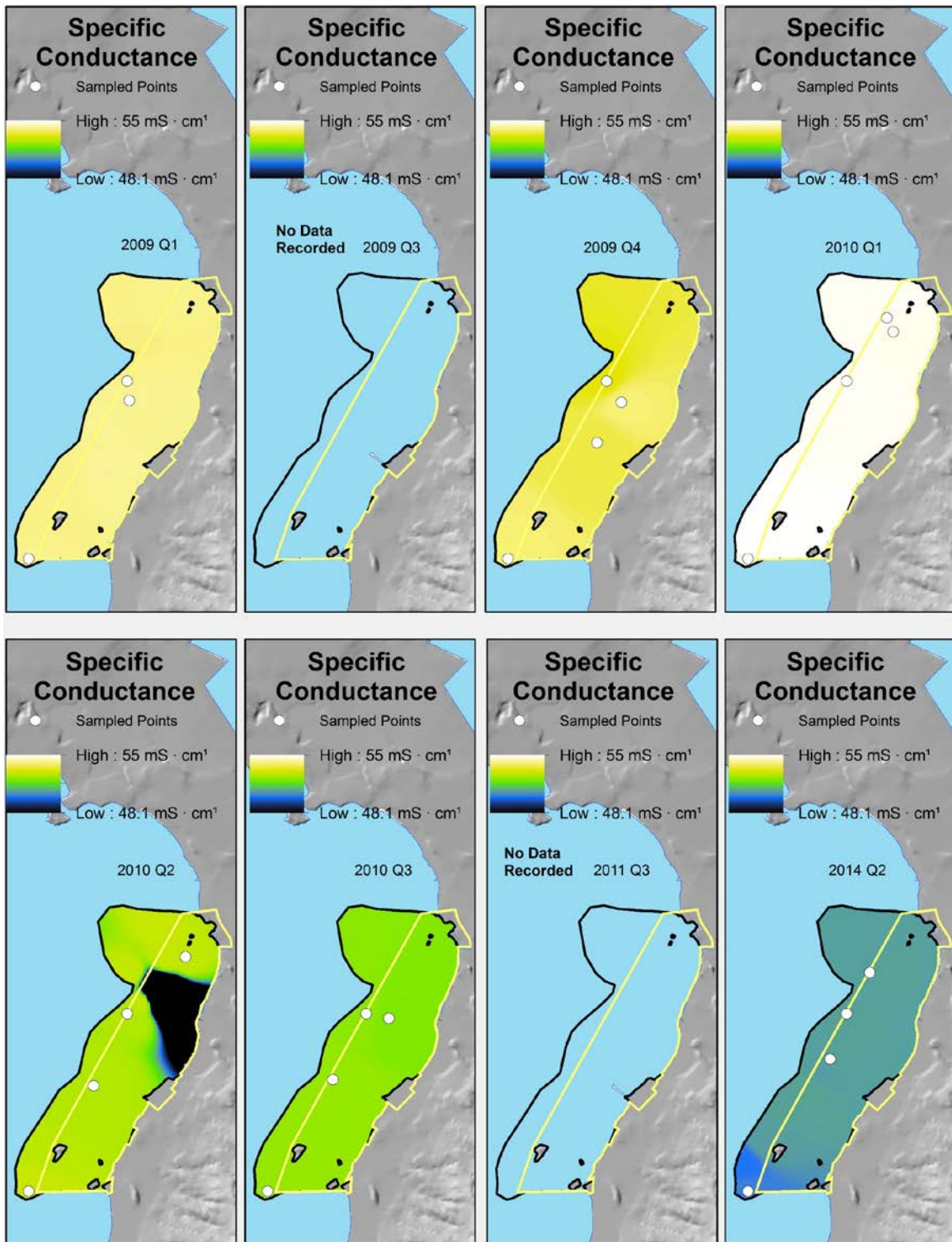


Figure 52. Spatial distribution of surface specific conductance in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

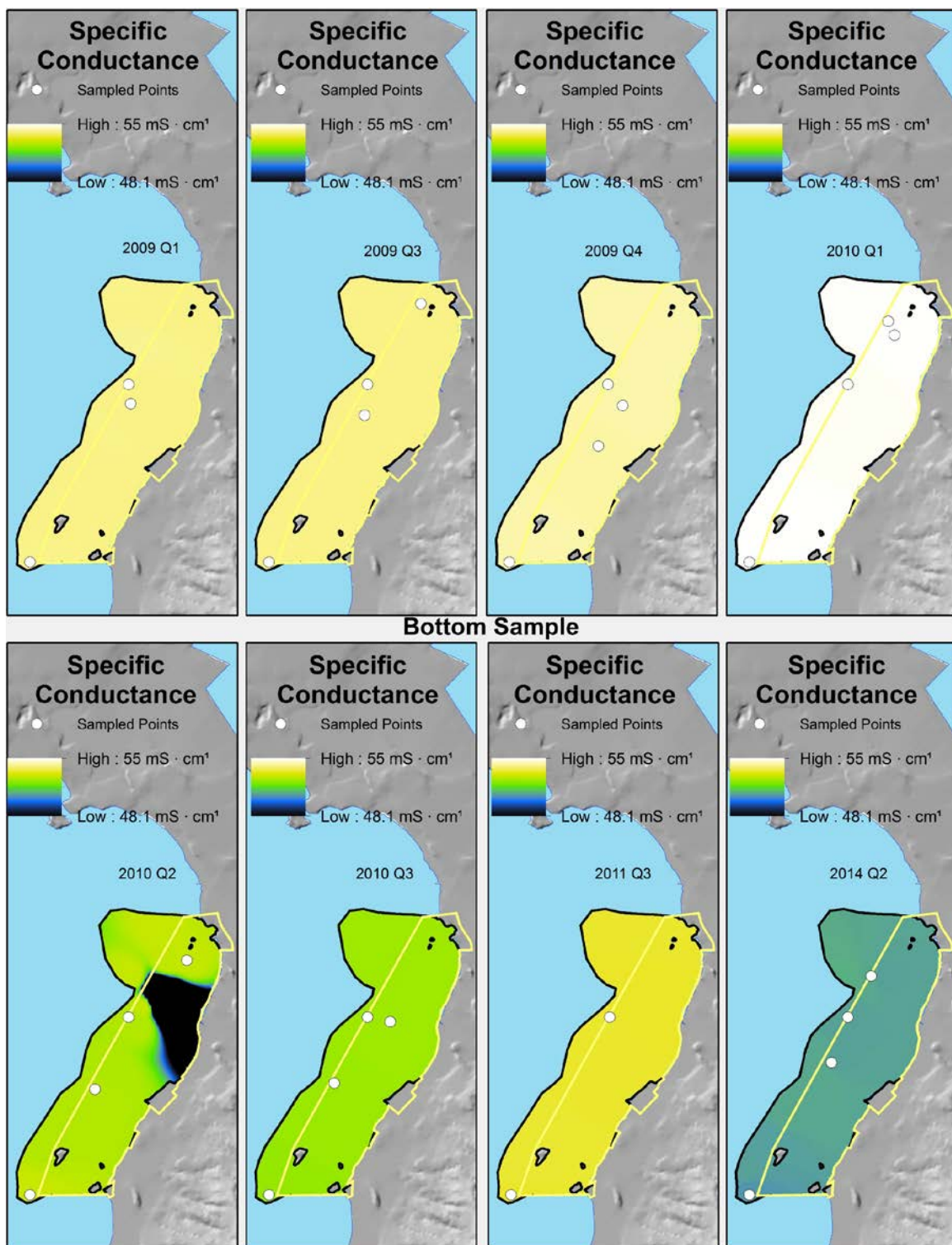


Figure 53. Spatial distribution of bottom specific conductance in marine waters of Agat using the total range of results observed in both surface and bottom samples.

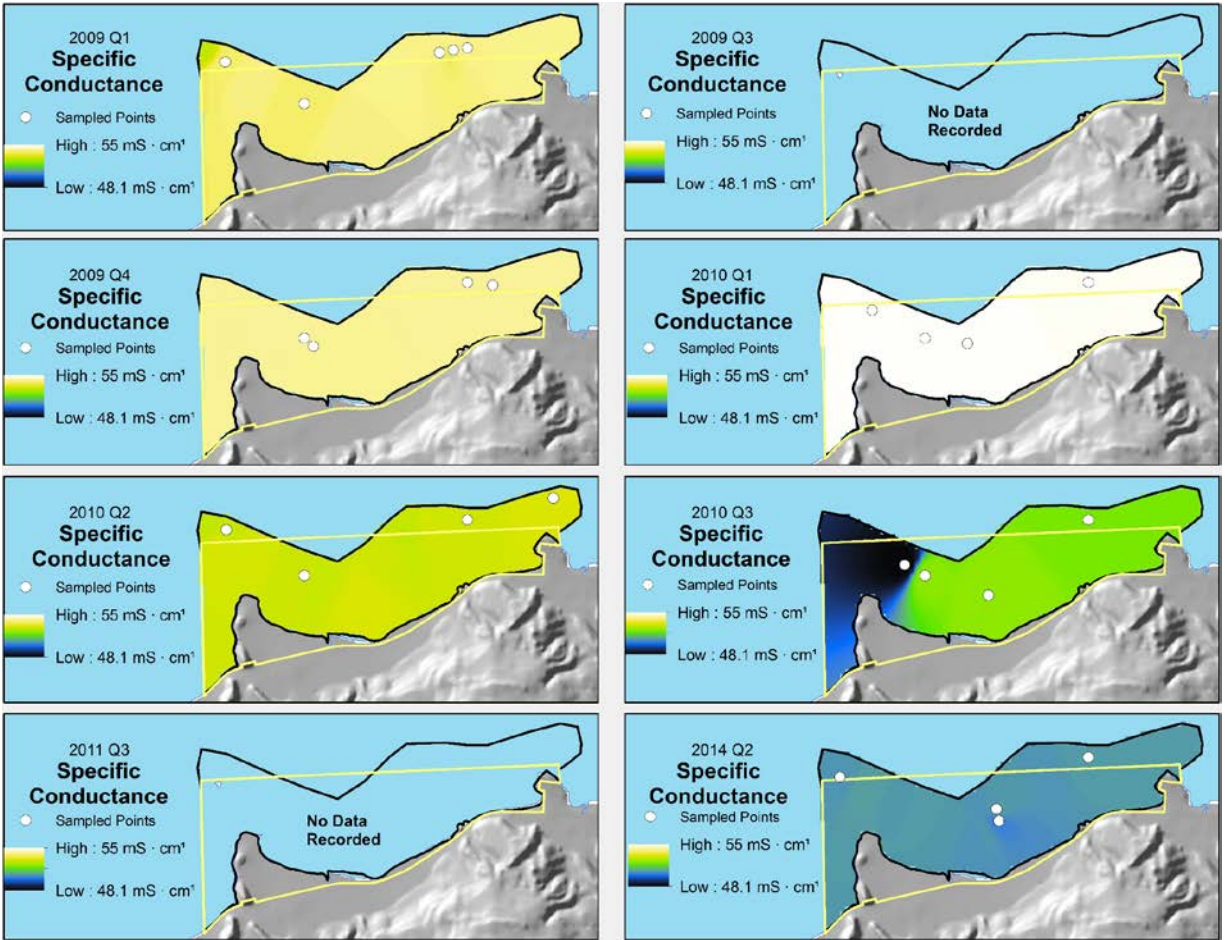


Figure 54. Spatial distribution of surface specific conductance in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

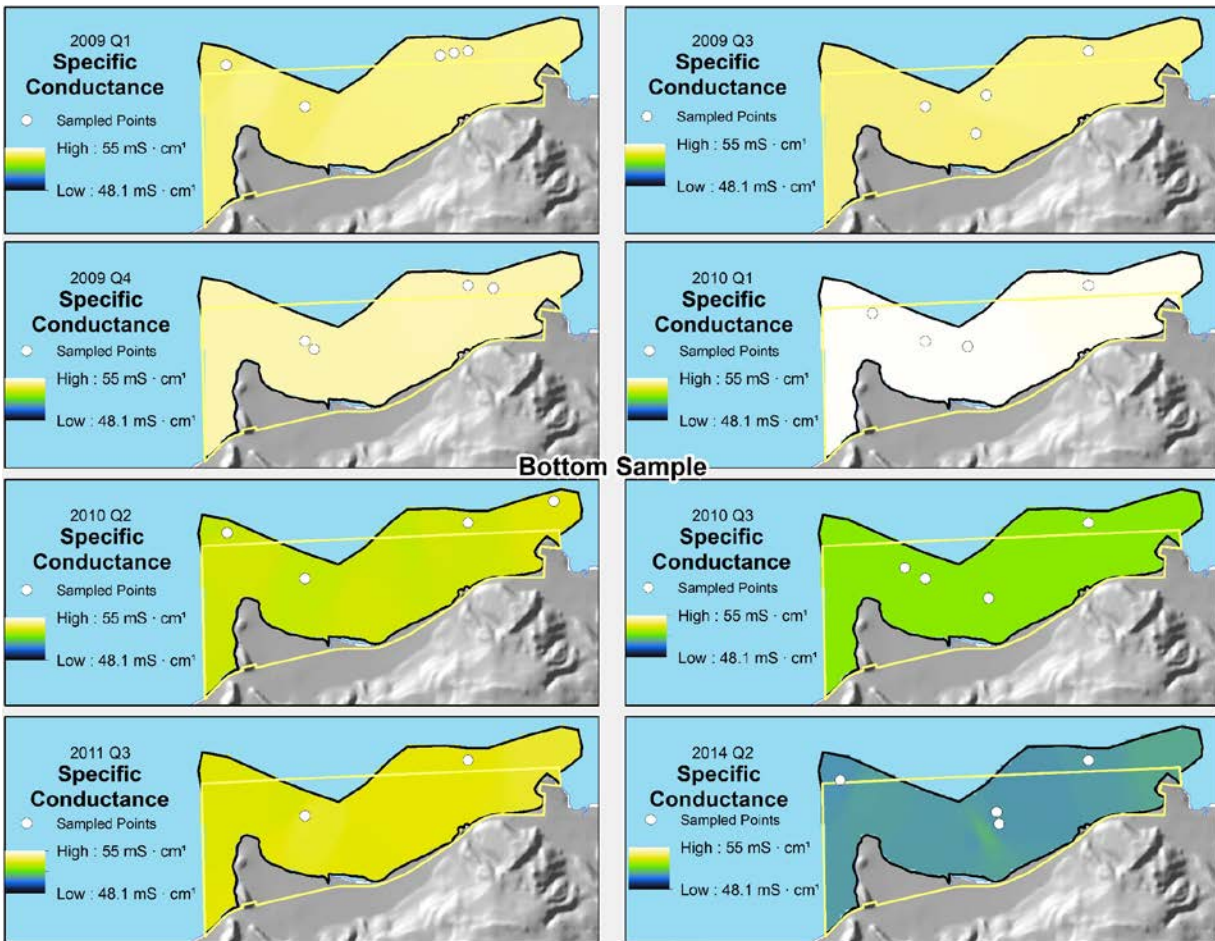


Figure 55. Spatial distribution of bottom specific conductance in marine waters of Asan using the total range of results observed in both surface and bottom samples.

Temperature

Surface and bottom waters had nearly identical temperatures, which varied during sample trips between years (Tables 21-22, Figures 56-57). Lower measurements of temperature were observed in the central parts of Asan and Agat (Figures 58-61).

Table 21. Temperature (°C) in marine waters of WAPA in Agat.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	29.2	29.3	30.3	0.4
	2	Bottom	15	28.6	28.9	29.3	0.2
	3	Bottom	5	29.4	29.4	29.7	0.1
	4	Surface	4	29.0	29.0	29.1	0.0
	4	Bottom	4	29.1	29.1	29.2	0.0
2010	1	Surface	4	27.3	27.3	27.5	0.1
	1	Bottom	4	27.3	27.3	27.3	0.0
	2	Surface	10	28.8	28.9	29.3	0.1
	2	Bottom	10	28.7	28.6	28.9	0.1
	3	Surface	4	29.8	29.9	29.9	0.1
	3	Bottom	4	29.7	29.8	29.8	0.0
2011	3	Bottom	8	29.5	29.4	29.6	0.0
2014	2	Surface	9	29.8	30.1	30.7	0.3
	2	Bottom	9	29.6	29.9	30.3	0.2
	3	Surface	1	30.8	30.8	30.8	NA
	3	Bottom	1	30.1	30.1	30.1	NA

Table 22. Temperature (°C) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	28.7	29.3	29.8	0.3
	2	Bottom	15	28.7	28.9	28.9	0.1
	3	Bottom	4	29.2	29.4	29.5	0.1
	4	Surface	4	29.0	29.0	29.1	0.0
	4	Bottom	4	29.1	29.1	29.1	0.0
2010	1	Surface	4	27.2	27.3	27.3	0.0
	1	Bottom	4	27.2	27.3	27.3	0.0
	2	Surface	18	28.2	28.9	31.9	0.8
	2	Bottom	18	28.1	28.6	33.3	1.2
	3	Surface	4	29.7	29.9	30.3	0.3
	3	Bottom	4	29.7	29.8	29.8	0.0
2011	3	Bottom	9	29.2	29.4	29.4	0.1
2014	2	Surface	8	29.8	30.1	30.2	0.1
		Bottom	8	29.5	29.9	29.9	0.1

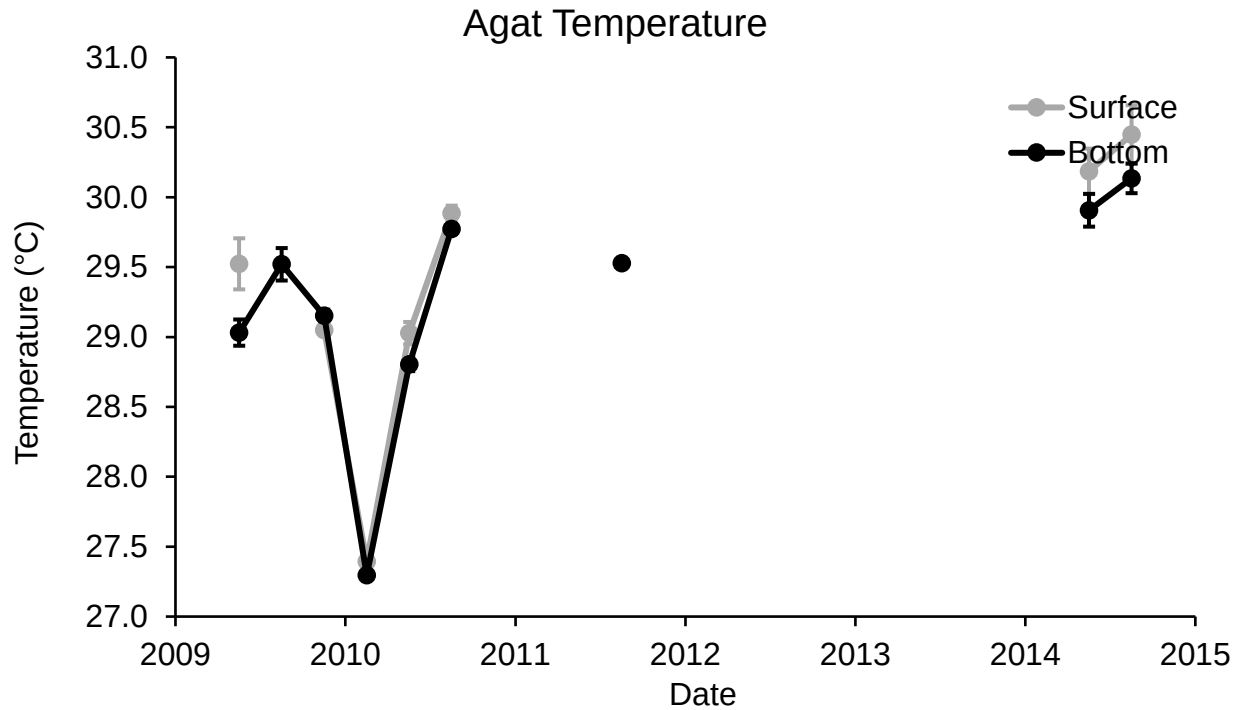


Figure 56. Temperature in marine waters of WAPA in Agat. Data are means and 95% confidence intervals.

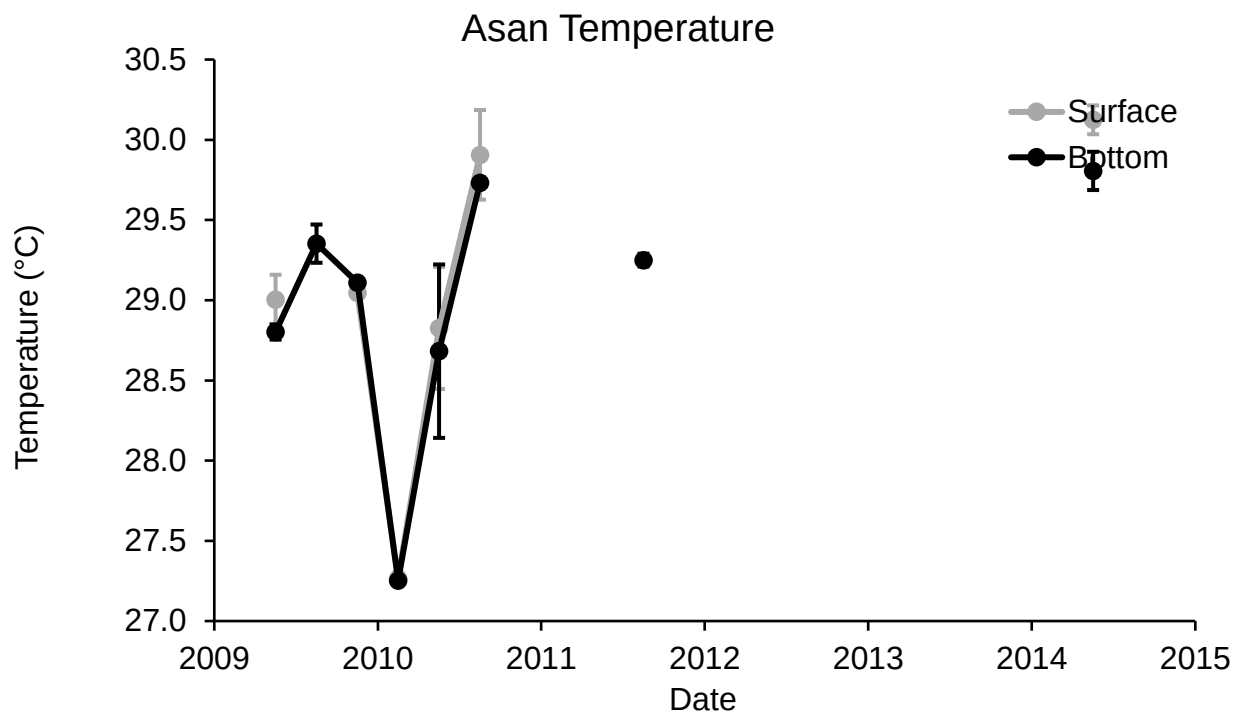


Figure 57. Temperature in marine waters of WAPA in Asan. Data are means and 95% confidence intervals.

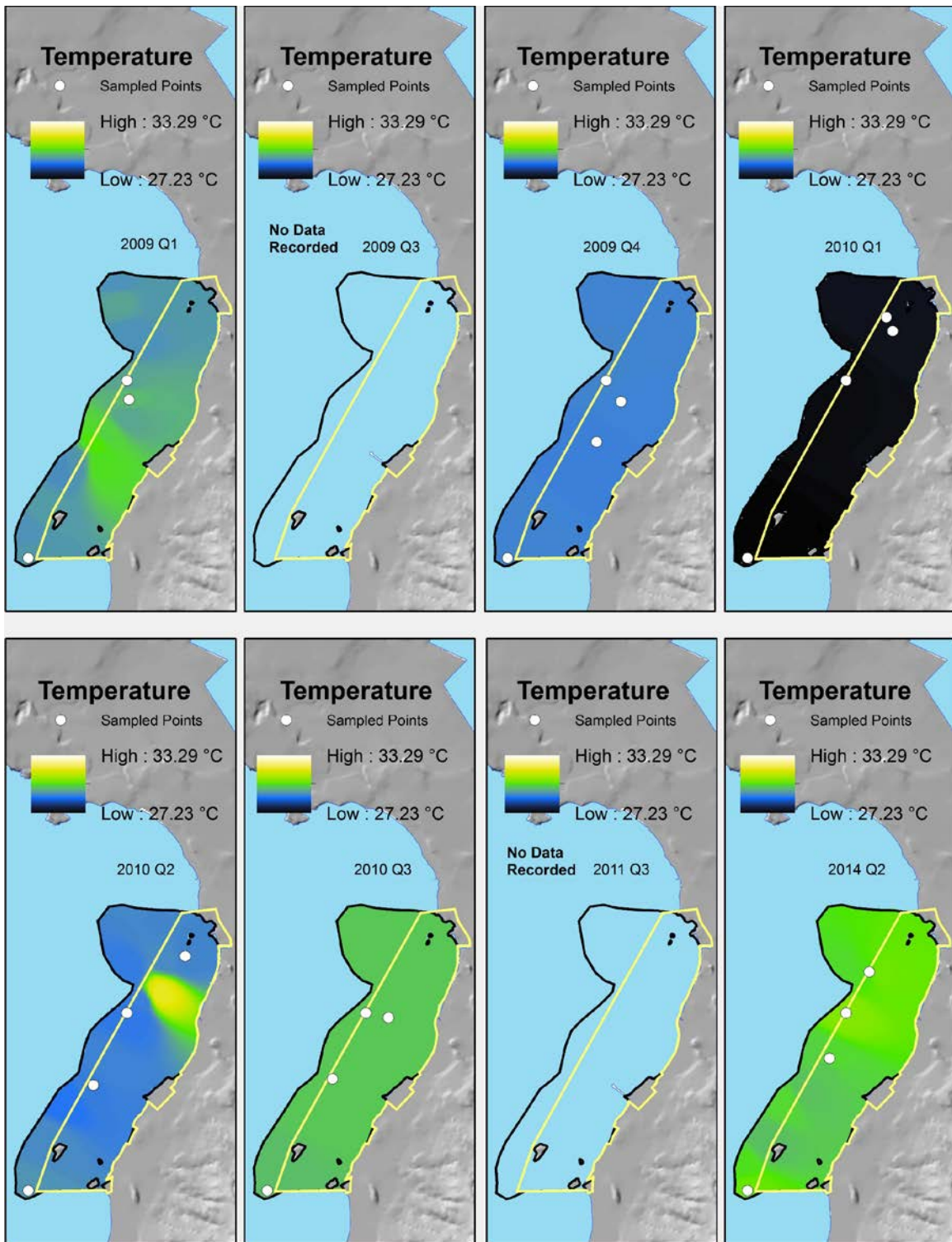


Figure 58. Spatial distribution of surface temperature in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

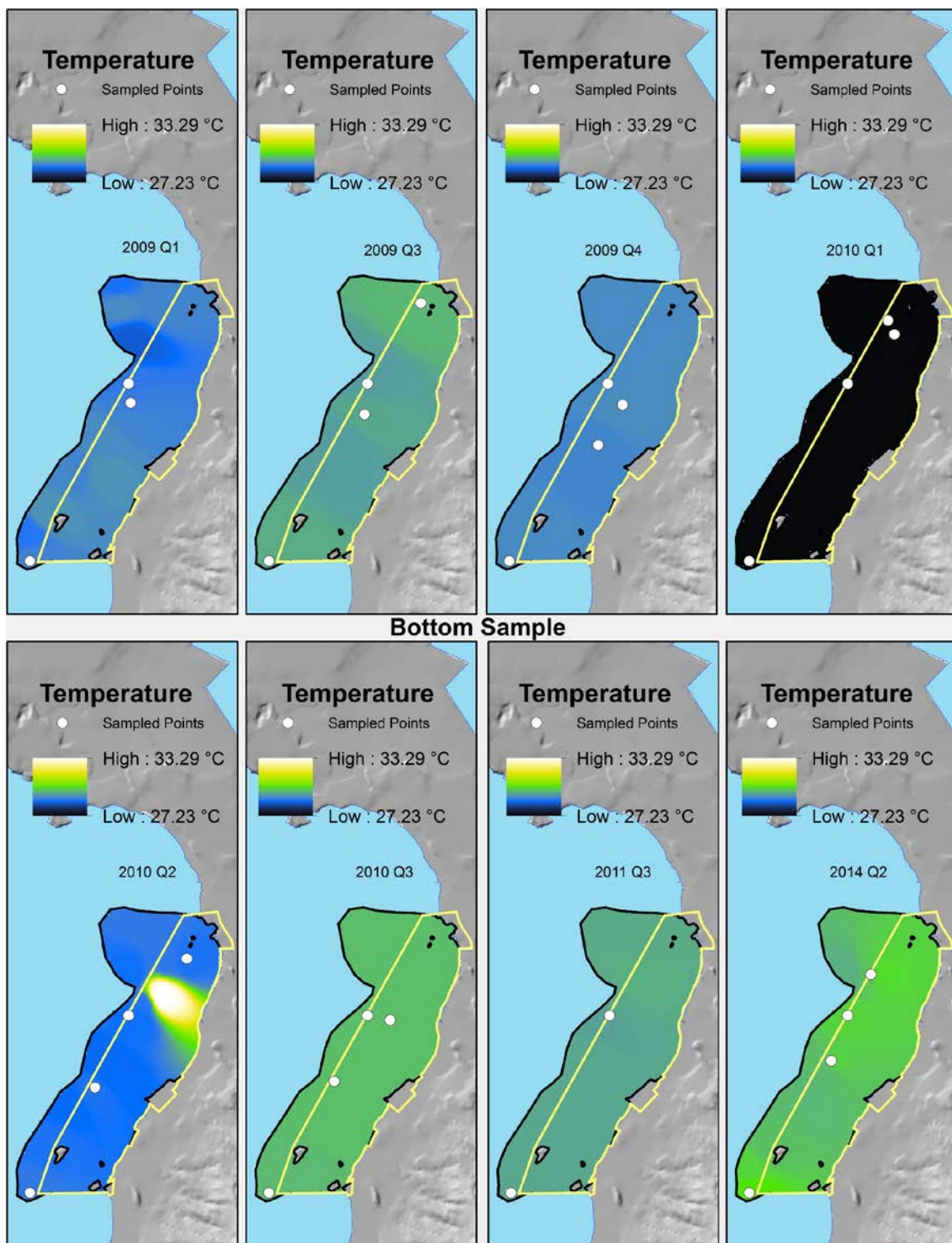


Figure 59. Spatial distribution of bottom temperature in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

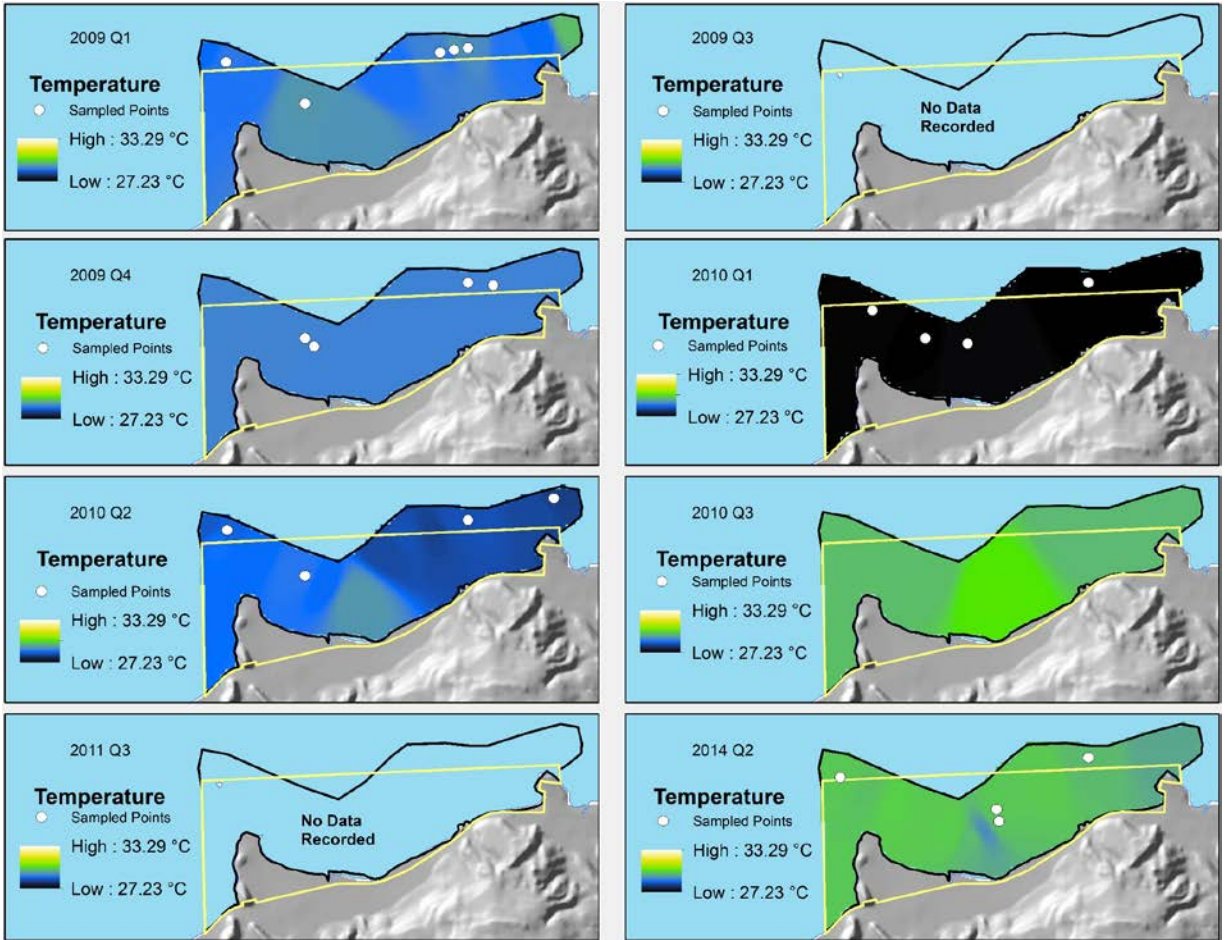


Figure 60. Spatial distribution of surface temperature in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

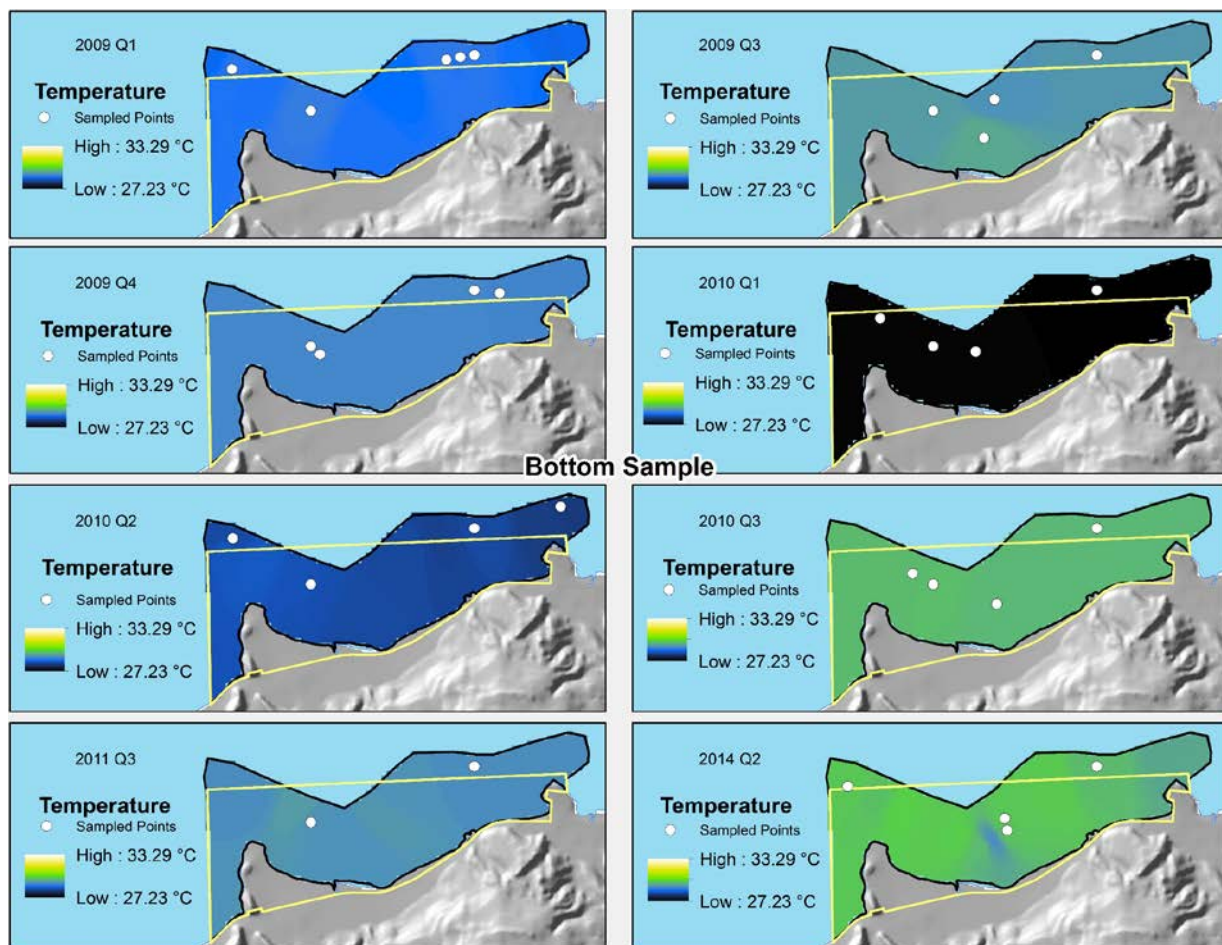


Figure 61. Spatial distribution of bottom temperature in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

Turbidity

Surface and bottom waters displayed very low turbidity, with the exception of some isolated spikes (Tables 23-24, Figures 62-67).

Table 23. Turbidity (NTU) in marine waters of WAPA in Agat.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	13	0.1	0.1	2.5	0.7
	2	Bottom	15	0.1	0.1	0.1	0.0
	3	Bottom	5	0.1	0.1	0.1	0.0
	4	Surface	4	0.1	0.1	0.9	0.4
	4	Bottom	4	0.1	0.1	0.4	0.2
2010	1	Surface	4	0.1	0.1	0.1	0.0
	1	Bottom	4	0.1	0.1	0.1	0.0
	3	Surface	4	0.1	0.1	0.1	0.0
	3	Bottom	4	0.1	0.1	0.1	0.0
2011	3	Bottom	8	0.1	0.1	0.1	0.0
2014	2	Surface	9	0.1	0.1	0.1	0.0
	2	Bottom	9	0.1	0.1	0.1	0.0
	3	Surface	1	0.1	0.1	0.1	NA
	3	Bottom	1	0.1	0.1	0.1	NA

Table 24. Turbidity (NTU) in marine waters of WAPA in Asan.

Year	Quarter	Depth	n	Minimum	Median	Maximum	SD
2009	2	Surface	15	0.1	0.1	0.6	0.1
	2	Bottom	14	0.1	0.1	0.1	0.0
	3	Bottom	4	0.1	0.1	0.4	0.2
	4	Surface	3	0.1	0.1	0.9	0.5
	4	Bottom	4	0.1	0.1	0.1	0.0
2010	1	Surface	4	0.1	0.1	0.1	0.0
	1	Bottom	4	0.1	0.1	0.1	0.0
	3	Surface	4	0.1	0.1	1.1	0.5
	3	Bottom	4	0.1	0.1	0.1	0.0
2011	3	Bottom	9	0.1	0.1	0.3	0.1
2014	2	Surface	8	0.1	0.1	0.1	0.0
	2	Bottom	8	0.1	0.1	0.1	0.0

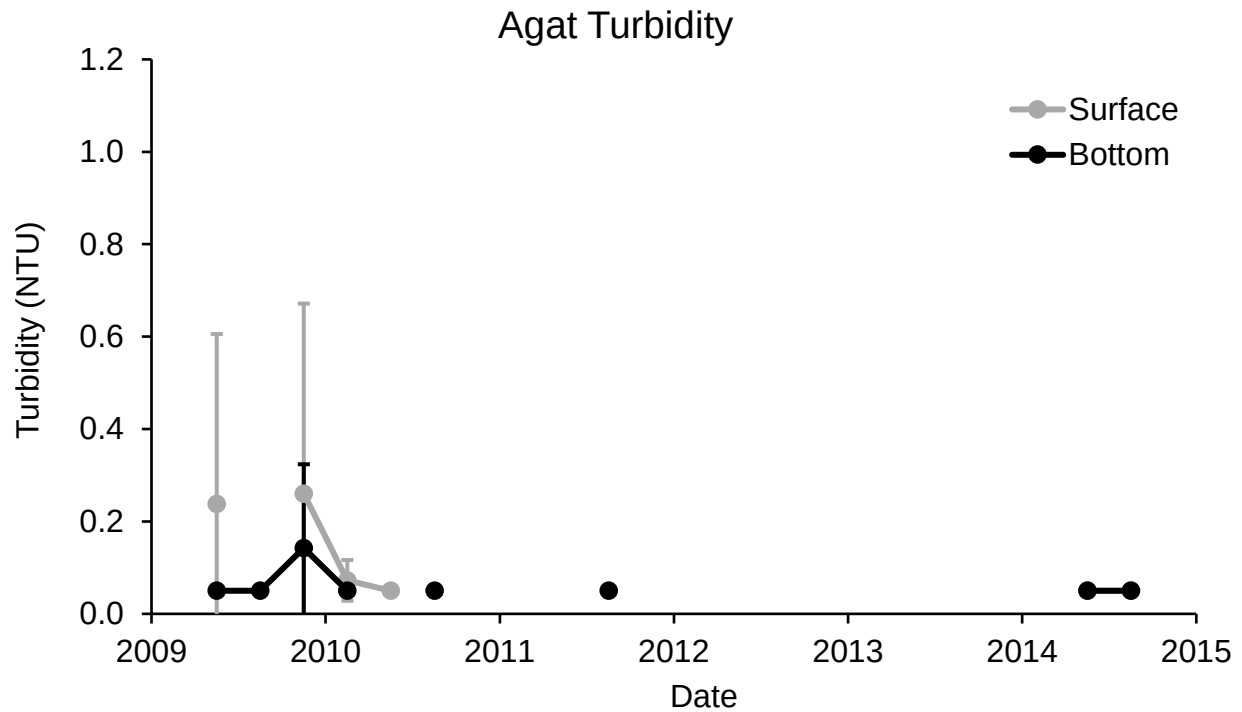


Figure 62. Turbidity in marine waters of WAPA in Agat. Data are means and 95% confidence intervals.

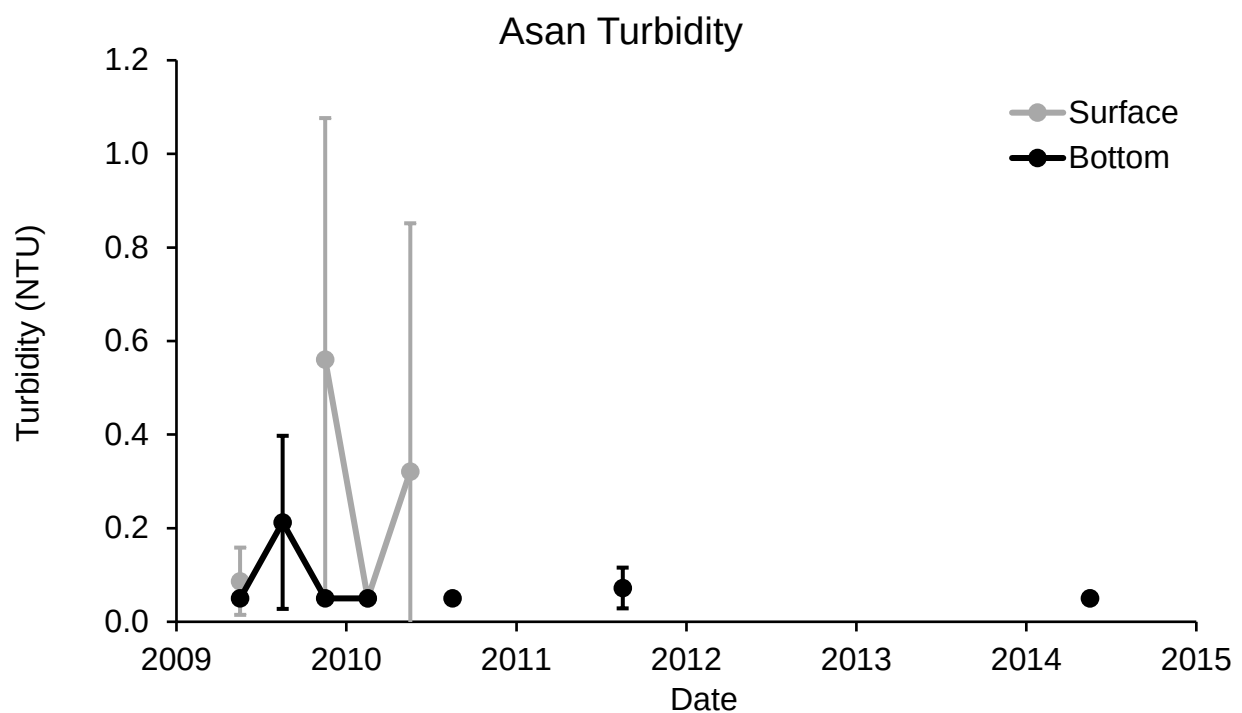


Figure 63. Turbidity in marine waters of WAPA in Asan. Data are means and 95% confidence intervals.

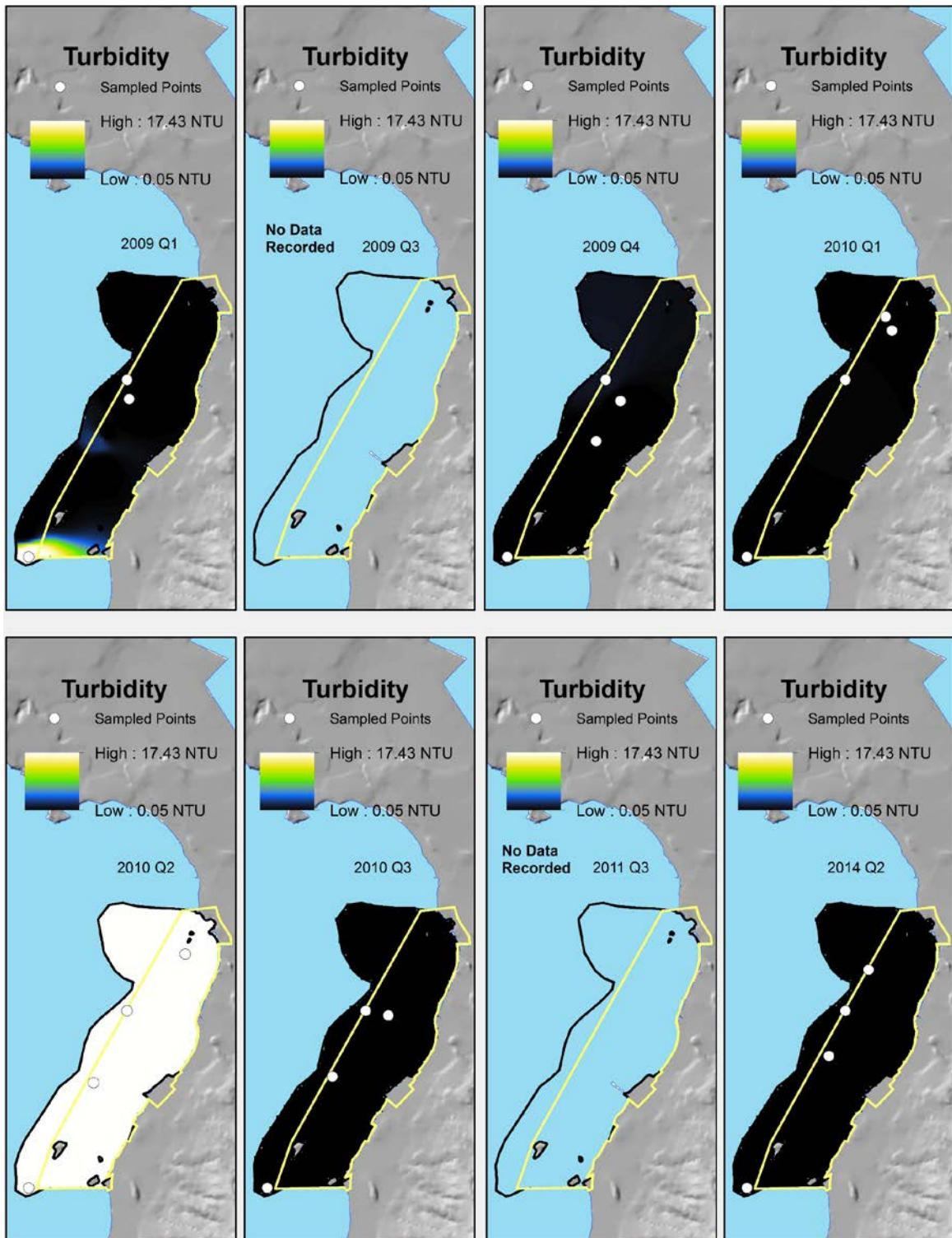


Figure 64. Spatial distribution of surface turbidity in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

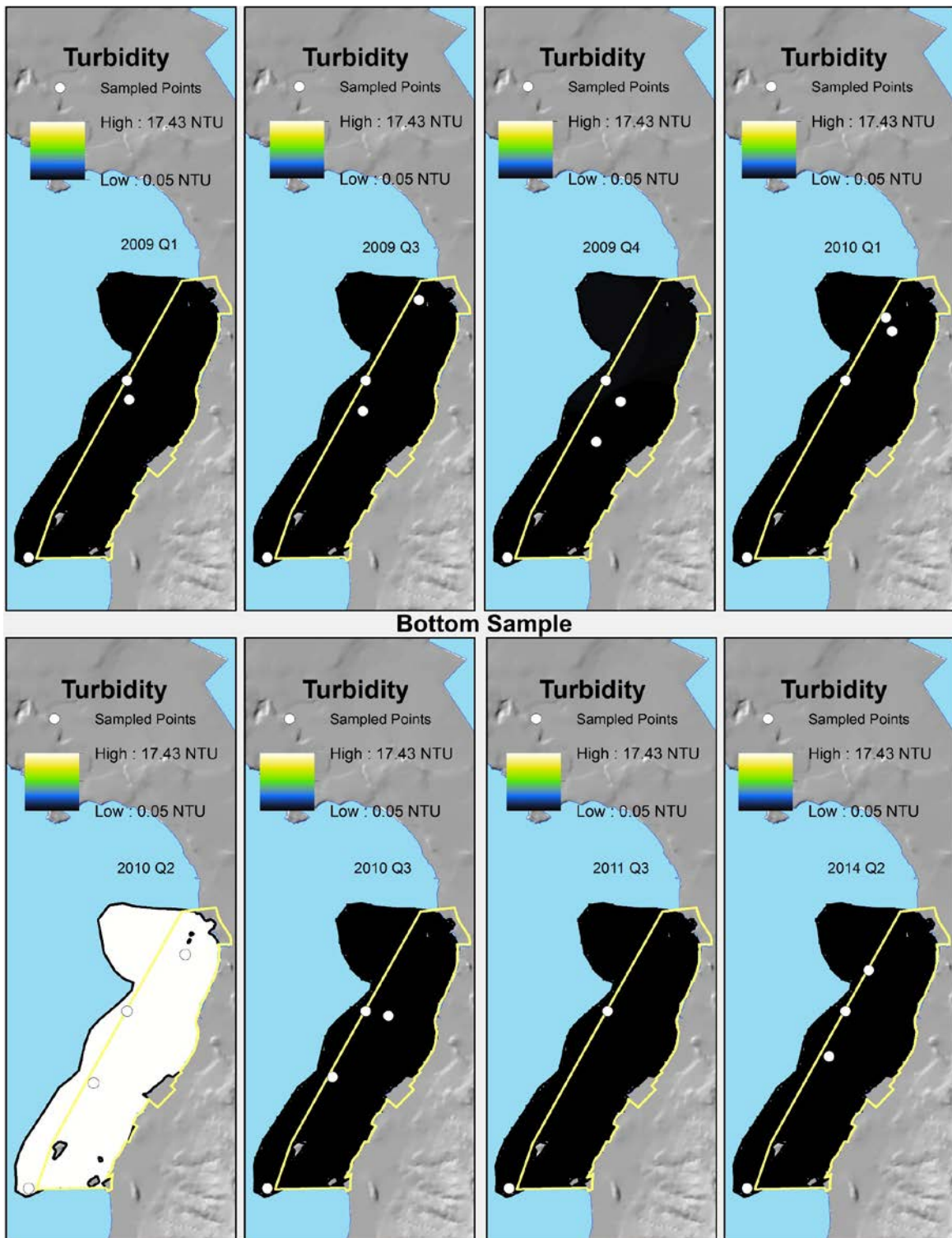


Figure 65. Spatial distribution of bottom turbidity in marine waters of WAPA in Agat using the total range of results observed in both surface and bottom samples.

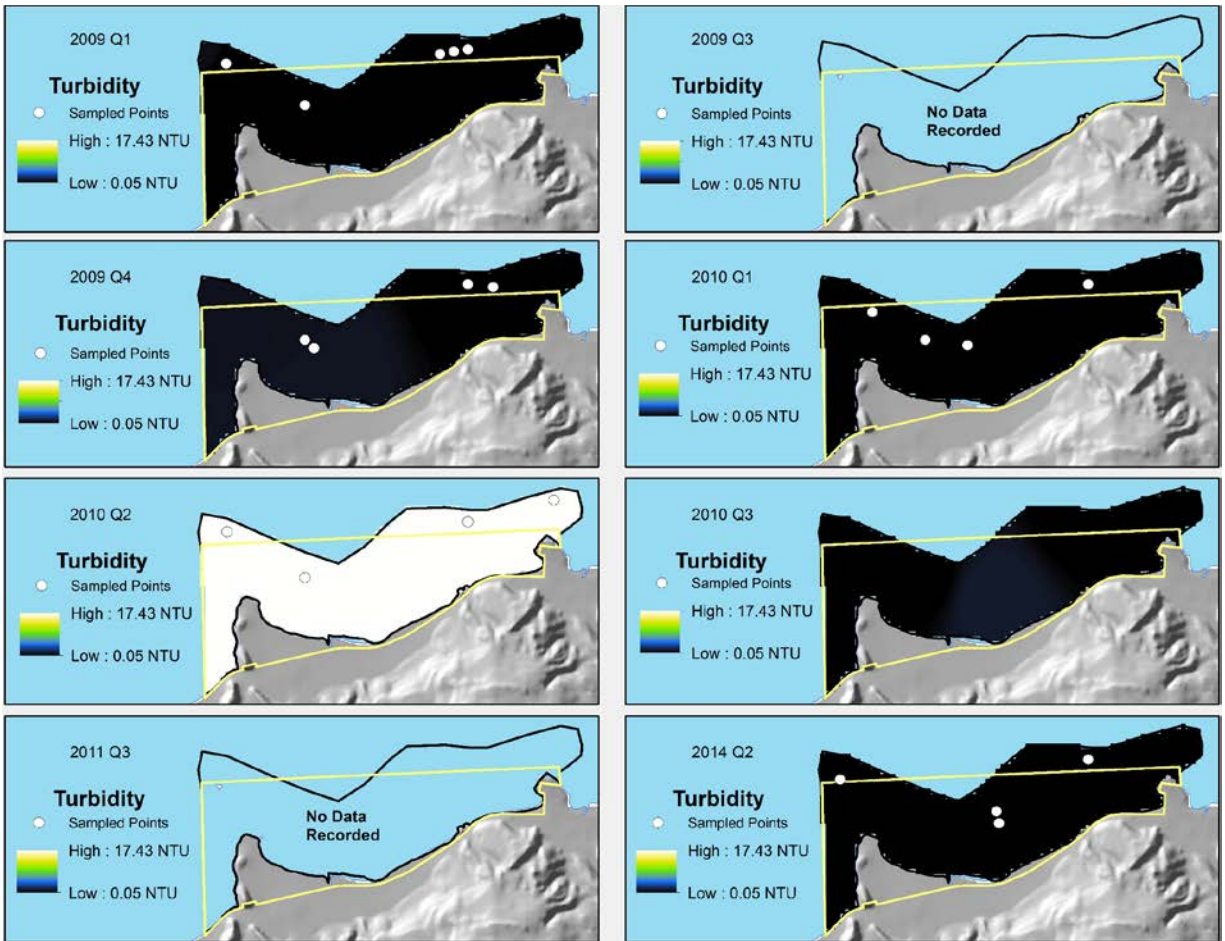


Figure 66. Spatial distribution of surface turbidity in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

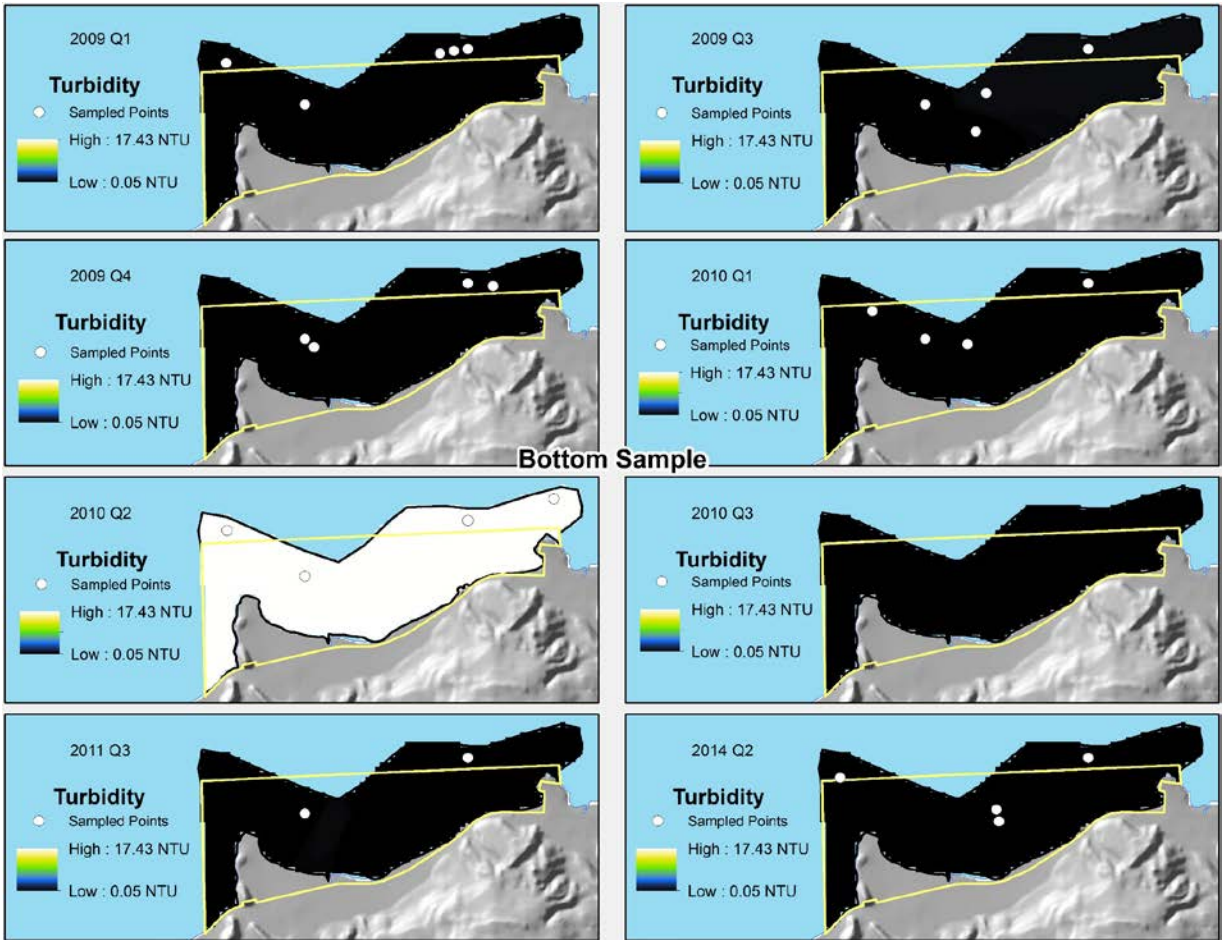


Figure 67. Spatial distribution of bottom turbidity in marine waters of WAPA in Asan using the total range of results observed in both surface and bottom samples.

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