



Water Quality in the Asan River, War in the Pacific National Historical Park

Summary Report 2007-2012

Natural Resource Data Series NPS/PACN/NRDS—2014/662



ON THE COVER

Asan River, War in the Pacific National Park, Guam.
Photograph by: David Raikow

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Abstract

This Natural Resource Data Series Report (NRDS) presents data collected from the Asan River, War in the Pacific National Historical Park, Guam. 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 limited description. The data presented in this report will be analyzed for the establishment of expected parameter value ranges and long-term trends in future reports published in the NPS Natural Resource Technical Report (NRTR) series. The purpose of collecting data on Vital Signs is to provide park managers information on current conditions and temporal trends in ecosystem health. Several parameters were found to be outside published water quality criteria values over the monitoring period. Slightly high pH, relative to water quality criteria (Guam 1997), may have been the result of autotrophic (plant) activity, i.e. macrophytes and/or algae. Supersaturation of oxygen was measured when high pH was measured, indicating the high autotrophic activity. Because autotrophs consume CO₂, they can alter the carbonic acid balance in the water column resulting in higher pH (Wetzel 2001). Elevated turbidity may have been the result of siltation caused by the construction of homes just outside the park border in the upper reaches of the Asan River.

Acknowledgments

We thank Mike Gawel, Justin Mills, Barbara Alberti, and other staff of WAPA 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
$\mu\text{gP} \cdot \text{L}^{-1}$	Micrograms of Phosphorus per Liter
$\text{mS} \cdot \text{cm}^{-1}$	Milli-Siemens per Centimeter
Chl	Chlorophyll
CO ₂	Carbon dioxide
HAVO	Hawai'i Volcanoes National Park
I&M	Inventory and Monitoring Program of the National Park Service
$\text{mg} \cdot \text{L}^{-1}$	Milligrams per Liter
$\text{mgN} \cdot \text{L}^{-1}$	Milligrams of Nitrogen per Liter
n	Number of measurements or samples
NO ₂	Nitrite
NO ₃	Nitrate
NPS	National Park Service
NRDS	Natural Resource Data Series Report
NRTR	Natural Resource Technical Report
NTU	Nephelometric Turbidity Units
O ₂	Oxygen
ODO	Optical Dissolved Oxygen
ODOsat	Optical Dissolved Oxygen in terms of saturation
PO ₄	Orthophosphate, or soluble reactive phosphorus
PACN	Pacific Island Inventory and Monitoring Network
ppt	Parts Per Thousand
SD	Standard Deviation
SE	Standard Error
SpC	Specific conductivity
TDN	Total Dissolved Nitrogen
TDP	Total Dissolved Phosphorus
Temp	Temperature
TN	Total Nitrogen
TP	Total Phosphorus
Turb	Turbidity
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) Pacific Island Network (PACN). This report presents data collected under the PACN water quality protocol (Jones et al. 2011) in Asan River, War in the Pacific National Historical Park, Guam, between 2007-2012.

Water quality criteria for streams in Guam are defined in Division II Water Control, Chapter 5, Water Quality Standards (Guam 1997), §22 GAR GEPA (Guam 1997, Table 1). The ASAN River appears to fall under category S-1 High, designated for “Surface waters...used for drinking water resources, conservation of wilderness areas, and propagation and preservation of aquatic life and aesthetic enjoyment.” Water quality criteria are defined for pH, PO₄, NO₃, O₂ saturation, turbidity, and other parameters including contaminants that are not addressed by the PACN Water Quality Protocol.

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 Technical Reports (NRTR).

The mission of the I&M Program 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 purpose of collecting data on Vital Signs is to provide park managers information on current conditions and temporal trends in ecosystem health. The primary purposes of the water monitoring protocol are to characterize the ecosystem and identify existing problems, and identify temporal trends especially with regard to emerging problems. Park managers can use this information to respond to resource conditions and evaluate management actions.

Table 1. Selected Guam-specific water criteria for S1- High waters (Guam 1997).

Parameter	Criterion ¹	Value	Unit
Orthophosphate (PO ₄ -P)	Shall not exceed	25	µg P · L ⁻¹
Nitrate (NO ₃ -N)	Shall not exceed	100	µgN · L ⁻¹
Oxygen saturation	Shall not be under	75	%
pH	Acceptable range	6.5 - 8.5	none
Turbidity	Shall not exceed	0.5	NTU

¹Except “when due to natural conditions”.

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

The Asan River is located in War in the Pacific National Historical Park on the island of Guam (Fig. 1). Site names used by I&M are formatted to designate fixed or temporary sites (“F” or “T” respectively), park (WAPA), a number (e.g. 01), and habitat type (“fw” for freshwater); e.g. “FWAPA01_fw” (Table 2). Names for temporary sites are based on the date of sampling. Sites were sampled during quarterly trips. A new set of temporary sites was chosen at random for each trip. Data were collected from May 2007 - April 2012 (Table 3).

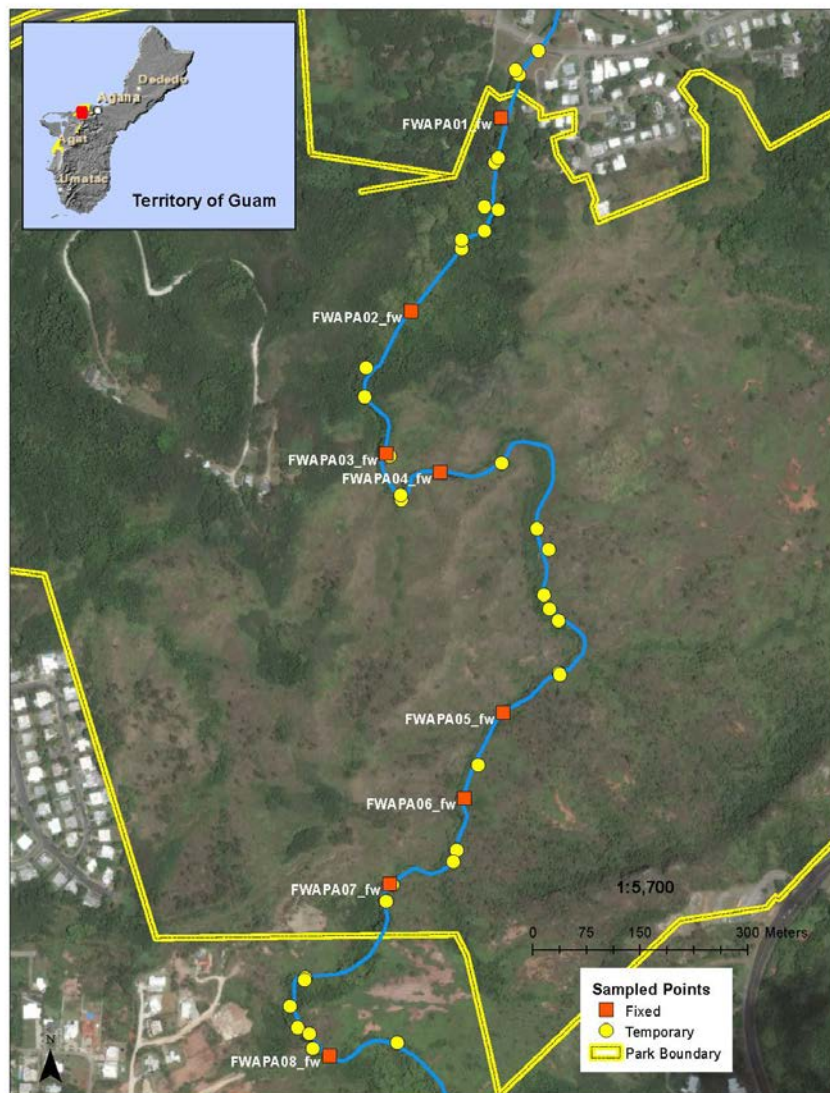


Figure 1. Sample sites in the Asan River, War in the Pacific National Historical Park.

Water Collection

Water was collected using a new or acid-washed 140 cc syringe just below the stream surface to avoid disturbance of sediment on the bottom or collection of floating material. This water was then discarded away from the collection location to rinse the syringe. Water was again collected using the rinsed syringe. An in-line filter holder and 0.7 μm filter were then placed on the syringe. Filtered water was used to rinse each sample bottle three times, for a total of 50ml per bottle, discarding water between each rinse. The filter assembly was removed, water again was drawn into the syringe, and a filter assembly was placed onto the syringe to input 140ml of filtered water into each sample bottle. Three 140ml samples were taken at each sample site. Sample bottles were placed on ice in the field inside an insulated backpack. Samples were transported to the facilities of War in the Pacific National Historical Park on the day of collection and then frozen. Samples were later transported to Hawai'i Volcanoes National Park (HAVO) while frozen. Samples were delivered to the EPSCoR Analytical Laboratory at the University of Hawaii at Hilo (UHH) Marine Science Department, 200 W. Kawili St., Hilo, Hawai'i 96720 for chemical analysis. Samples were analyzed for total dissolved phosphorous (TDP), total dissolved nitrogen (TDN) and nitrate + nitrite ($\text{NO}_3 + \text{NO}_2$).

Limnological Parameters and General Conditions

A YSI 6600 Multiparameter Sonde was calibrated a few days before commencing field sampling. The sonde was used to measure temperature ($^{\circ}\text{C}$), specific conductivity (SpC) in milli- Siemens per centimeter (mS cm^{-1}), pH, optical dissolved oxygen in milligrams per liter ($\text{mg} \cdot \text{L}^{-1}$, ODO), chlorophyll in micrograms per liter ($\mu\text{g} \cdot \text{L}^{-1}$), and turbidity in nephelometric turbidity units (NTU). The sonde also reported salinity in parts per thousand (ppt) calculated from SpC, dissolved oxygen in percent saturation (% ODOsat) calculated from ODO, and temperature. The sonde was placed under the surface of the water at a sample site for ten minutes with readings taken every 30 seconds. The mean and variance of stable values, excluding initial readings prior to reaching stability, over this time period is reported. Minimum analytical detection limits were $15.0 \mu\text{gP} \cdot \text{L}^{-1}$ for total dissolved phosphorus (TDP), $0.070 \text{ mgN} \cdot \text{L}^{-1}$ for total dissolved nitrogen (TDN), and $1.0 \mu\text{gN} \cdot \text{L}^{-1}$ for nitrate + nitrite ($\text{NO}_3 + \text{NO}_2$).

PO_4 is a form of dissolved phosphorus that along with dissolved organic phosphorus make up Total Dissolved Phosphorus (TDP). Concentrations of TDP below threshold values for PO_4 indicate non-impaired waters. Similarly $\text{NO}_2 + \text{NO}_3$ concentrations below thresholds for NO_3 indicate non-impaired waters. TDP and $\text{NO}_2 + \text{NO}_3$ concentrations that exceed criteria for PO_4 and NO_3 may indicate impairment, and such results are indicated in tables. Environmental conditions, canopy cover, and water depth were estimated. Average wind speed over three minutes and wind direction were measured using a Kestrel wind speed device. Global positioning system coordinates and site elevation were recorded. Photographs of sample sites were also taken.

Table 2. Asan River sample site locations.

I&M site designation	Decimal Degrees Latitude	Decimal Degrees Longitude
FWAPA01_fw	13.47012	144.71274
FWAPA02_fw	13.46767	144.71160
FWAPA03_fw	13.46587	144.71131
FWAPA04_fw	13.46564	144.71200
FWAPA05_fw	13.46261	144.71284
FWAPA06_fw	13.46153	144.71235
FWAPA07_fw	13.46044	144.71140
FWAPA08_fw	13.45826	144.71064
TWAPA0120090803	13.47067	144.71297
TWAPA0120091029	13.46087	144.71226
TWAPA0120100201	13.46468	144.71341
TWAPA0120100524	13.46896	144.71272
TWAPA0120100812	13.46392	144.71342
TWAPA0120110125	13.46331	144.71384
TWAPA0120120410	13.46072	144.71222
TWAPA0220090803	13.46311	144.71355
TWAPA0220091029	13.47097	144.71322
TWAPA0220100127	13.46956	144.71267
TWAPA0220100524	13.46378	144.71354
TWAPA0220100812	13.45861	144.71023
TWAPA0220110117	13.46331	144.71384
TWAPA0320070517	13.45835	144.71043
TWAPA0320090803	13.46043	144.71143
TWAPA0320091029	13.45924	144.71033
TWAPA0320100202	13.46529	144.71151
TWAPA0320100524	13.46310	144.71357
TWAPA0320100812	13.46869	144.71254
TWAPA0320110118	13.46666	144.71094
TWAPA0320120404	13.46857	144.71225
TWAPA0420070517	13.45843	144.71152
TWAPA0420090803	13.46410	144.71335
TWAPA0420091029	13.46534	144.71150
TWAPA0420100524	13.46846	144.71225
TWAPA0420100812	13.47073	144.71292
TWAPA0420110128	13.46109	144.71236
TWAPA0520070517	13.45922	144.71032
TWAPA0520090803	13.46899	144.71254
TWAPA0520091029	13.46961	144.71271
TWAPA0520100524	13.46658	144.71102
TWAPA0520100812	13.46695	144.71104
TWAPA0720070517	13.45853	144.71038
TWAPA0720110118	13.46791	144.71168
TWAPA0820070521	13.46583	144.71135
TWAPA0820110127	13.46275	144.71311
TWAPA0820120406	13.46576	144.71279
TWAPA0920100210	13.46195	144.71253

Table 2. Asan River sample site locations (continued).

I&M site designation	Decimal Degrees Latitude	Decimal Degrees Longitude
TWAPA0720070517	13.45853	144.71038
TWAPA0720110118	13.46791	144.71168
TWAPA0820070521	13.46583	144.71135
TWAPA0820110127	13.46275	144.71311
TWAPA0820120406	13.46576	144.71279
TWAPA0920100210	13.46195	144.71253
TWAPA0520110117	13.46899	144.71265
TWAPA0520120411	13.46022	144.71136
TWAPA0620070517	13.45888	144.71013
TWAPA0620100201	13.46494	144.71326
TWAPA0620110129	13.46085	144.71222

Table 3. Asan River sampling events.

Year	Date	Personnel
2007	16-May-07	Danielle McKay, Tahzay Jones
2009	12-Apr-09	Anne Farahi, Chris Rillahan, Tahzay Jones
2009	19-May-09	Chris Rillahan, Eric Brown, Kazuki Kageyama, Lindsey Kramer, Mark Capone, Paul Brown
2009	03-Aug-09	Chris Rillahan, Heather Moulton
2009	29-Oct-09	Chris Rillahan, Heather Moulton
2010	26-Jan-10	Anne Farahi, Chris Rillahan
2010	01-Feb-10	Anne Farahi, Chris Rillahan, Tahzay Jones
2010	17-May-10	Chris Rillahan, Kazuki Kageyama, Tahzay Jones
2010	12-Aug-10	Chris Rillahan
2011	15-Jan-11	Amanda deVillers, Anne Farahi, Kaity Mattos, Mike Gawel, Tahzay Jones
2011	02-Feb-11	Tahzay Jones
2011	20-Aug-11	Amanda deVillers, Bert Fuiava, Jim Nimz, Mike Gawel
2012	04-Apr-12	Adrianna Jimenez, Amanda deVillers, Anne Farahi, John Gering, Justin Mills, Karrie Coleman, Katie Conner

Data Analysis, Management, and Quality Control

Environmental parameters, habitat descriptions, and general observations were recorded on datasheets in the field. Datasheets were stored at park offices, scanned, and uploaded to PACN servers. All data including results of laboratory analyses and photographs were entered into PACN databases. Data were downloaded from the YSI 6600 through the YSI 650 control unit 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 Tahzay Jones or David Raikow. Data determined to be unreliable were flagged in databases and removed from further consideration. Data were explored visually by plotting time-series and boxplots. 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. Statistical analysis of water quality data followed recommendations by the USGS (Helsel and Hirsch 2002) as described in the protocol (Jones et al. 2011).

Non-normal distributions 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 4-8). 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. Standard deviation was not calculated for sets of data with $n \leq 2$. 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 extremely very low turbidity to 0.1 NTU is based on the assumption that natural stream water, while often visually indistinguishable from transparent deionized (distilled) water, can never be completely particulate-free.

Within boxplots, the upper edge of the box indicates the third quartile (Q3, upper quartile, or 75th percentile), and the lower edge indicates the first quartile (Q1, lower quartile, or 25th percentile, Fig. 6). Within the box, the line indicates the median (Q2, or 50th percentile). The whiskers extend up or down until the maximum or minimum value within 1.5 IQRs (inter-quartile range, or $Q3 - Q1$). Data outside 1.5 IQRs are displayed as dots, and considered outliers. If there are no outliers the box or whiskers display the entire range of data.

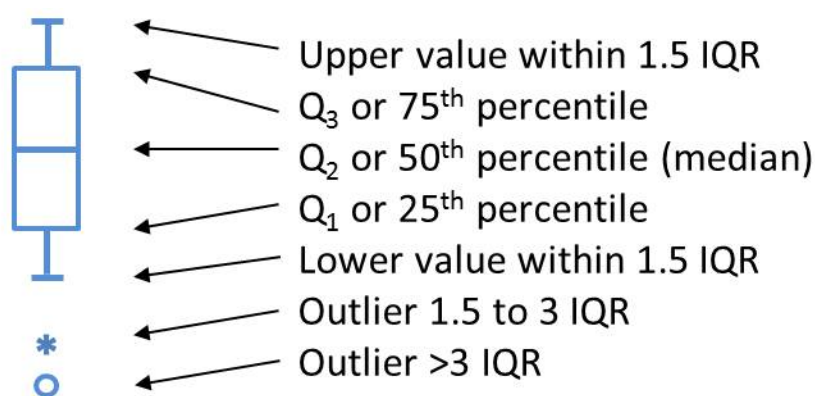


Figure 2. Box plot explanation.

Results

Thirteen sampling trips were conducted in the Asan River from 2007 to 2012. No data was collected in 2008. Results are presented in summaries by year (Tables 4-8, Figs. 3-13). Annual summaries present the minimum, maximum, median, and variance as standard deviation of all individual measurements taken in the stream across an entire year. Box plots display data grouped from all sites in the stream by year.

2007

One sampling trip was conducted in 2007. This was the start of the monitoring program and a partial set of data was collected. Maximum and median pH exceeded water quality criteria. Maximum, minimum and median turbidity exceeded water quality criteria.

Table 4. 2007 summary of water quality parameters in the Asan River.

Parameter	Unit	n	Minimum ¹	Maximum ¹	Median ¹	SD
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	6	0	0	0	0
Dissolved Oxygen Saturation	%	4	96.7	119.4	112.9	9.7
pH	none	6	8.33	8.97	8.74	0.253
Salinity	ppt	6	0.15	0.19	0.18	0.015
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	6	0.31	0.39	0.37	0.03
Temperature	°C	6	26.2	29.4	26.8	1.31
Turbidity	NTU	6	8.2	12.5	9.2	1.5

¹Values that exceed water quality criteria (Guam 1997) are shown in bold and italics.

2009

Three sampling trips were conducted in 2009. Maximum pH, maximum turbidity, and maximum TDP exceeded water quality criteria. Minimum oxygen saturation was below the water quality criterion.

Table 5. 2009 summary of water quality parameters in the Asan River.

Parameter	Unit	n	Minimum ¹	Maximum ¹	Median ¹	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	83	15.0	36.0	15.0	4.1
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	83	0.1	0.3	0.1	0.1
Nitrite +Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	81	1.0	88.0	17.0	19.8
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	28	0.0	6.3	2.1	1.6
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	28	5.5	9.0	8.4	0.8
Dissolved Oxygen Saturation	%	28	69.4	113.8	104.9	10.0
pH	none	28	7.7	8.7	8.2	0.2
Salinity	ppt	28	0.1	0.2	0.1	0.0
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	28	0.2	0.4	0.3	0.1
Temperature	°C	28	25.6	29.7	26.9	0.9
Turbidity	NTU	23	0.1	50.8	10.4	12.7

¹Values that exceed water quality criteria (Guam 1997) are shown in bold and italics.

2010

Four sampling trips were conducted in 2010. Maximum pH, maximum turbidity, and maximum TDP exceeded water quality criteria. Minimum oxygen saturation was below the water quality criterion.

Table 6. 2010 summary of water quality parameters in the Asan River.

Parameter	Unit	n	Minimum ¹	Maximum ¹	Median ¹	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	92	15.0	<i>40.0</i>	15.0	5.6
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	93	0.1	0.5	0.1	0.1
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	87	1.0	34.0	2.0	7.5
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	28	0.6	8.1	1.1	1.8
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	33	5.9	9.4	8.2	0.8
Dissolved Oxygen Saturation	%	31	<i>73.4</i>	121.7	103.1	10.1
pH	none	33	8.0	<i>8.9</i>	8.3	0.3
Salinity	ppt	33	0.1	0.2	0.2	0.0
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	33	0.3	0.4	0.3	0.0
Temperature	°C	33	23.7	29.3	26.8	1.6
Turbidity	NTU	20	0.1	<i>2.3</i>	0.4	0.7

¹Values that exceed water quality criteria (Guam 1997) are shown in bold and italics.

2011

Three sampling trips were conducted 2011. Maximum pH exceeded the water quality criterion. Turbidity exceeded the water quality criterion.

Table 7. 2011 summary of water quality parameters in the Asan River.

Parameter	Unit	n	Minimum ¹	Maximum ¹	Median ¹	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	24	15.0	15.0	15.0	0.0
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	24	0.1	0.2	0.1	0.0
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	23	1.0	98.0	6.0	32.1
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	16	0.8	1.8	1.2	0.3
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	16	7.3	8.8	8.1	0.4
Dissolved Oxygen Saturation	%	16	88.4	107.2	99.1	5.6
pH	none	16	8.1	8.6	8.4	0.2
Salinity	ppt	16	0.1	0.2	0.2	0.0
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	16	0.3	0.4	0.3	0.0
Temperature	°C	16	24.9	27.2	25.7	0.6
Turbidity	NTU	15	1.3	3.9	1.7	0.8

¹Values that exceed water quality criteria (Guam 1997) are shown in bold and italics.

2012

One sampling trip was conducted in 2012. Maximum TDP and maximum turbidity exceeded the water quality criteria.

Table 8. 2012 summary of water quality parameters in the Asan River.

Parameter	Unit	n	Minimum ¹	Maximum ¹	Median ¹	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	21	15.0	<i>34.0</i>	15.0	6.1
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	21	0.1	0.1	0.1	0.0
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	21	1.0	18.0	4.0	4.3
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	9	0.6	2.6	0.9	0.7
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	11	6.6	8.9	8.2	0.7
Dissolved Oxygen Saturation	%	10	80.5	114.6	99.2	9.6
pH	none	11	7.8	8.4	8.0	0.2
Salinity	ppt	11	0.2	0.2	0.2	0.0
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	11	0.3	0.5	0.3	0.0
Temperature	°C	11	24.1	29.2	26.7	1.6
Turbidity	NTU	11	0.1	<i>3.1</i>	0.2	0.9

¹Values that exceed water quality criteria (Guam 1997) are shown in bold and italics.

Summaries by parameter

Total Dissolved Phosphorus

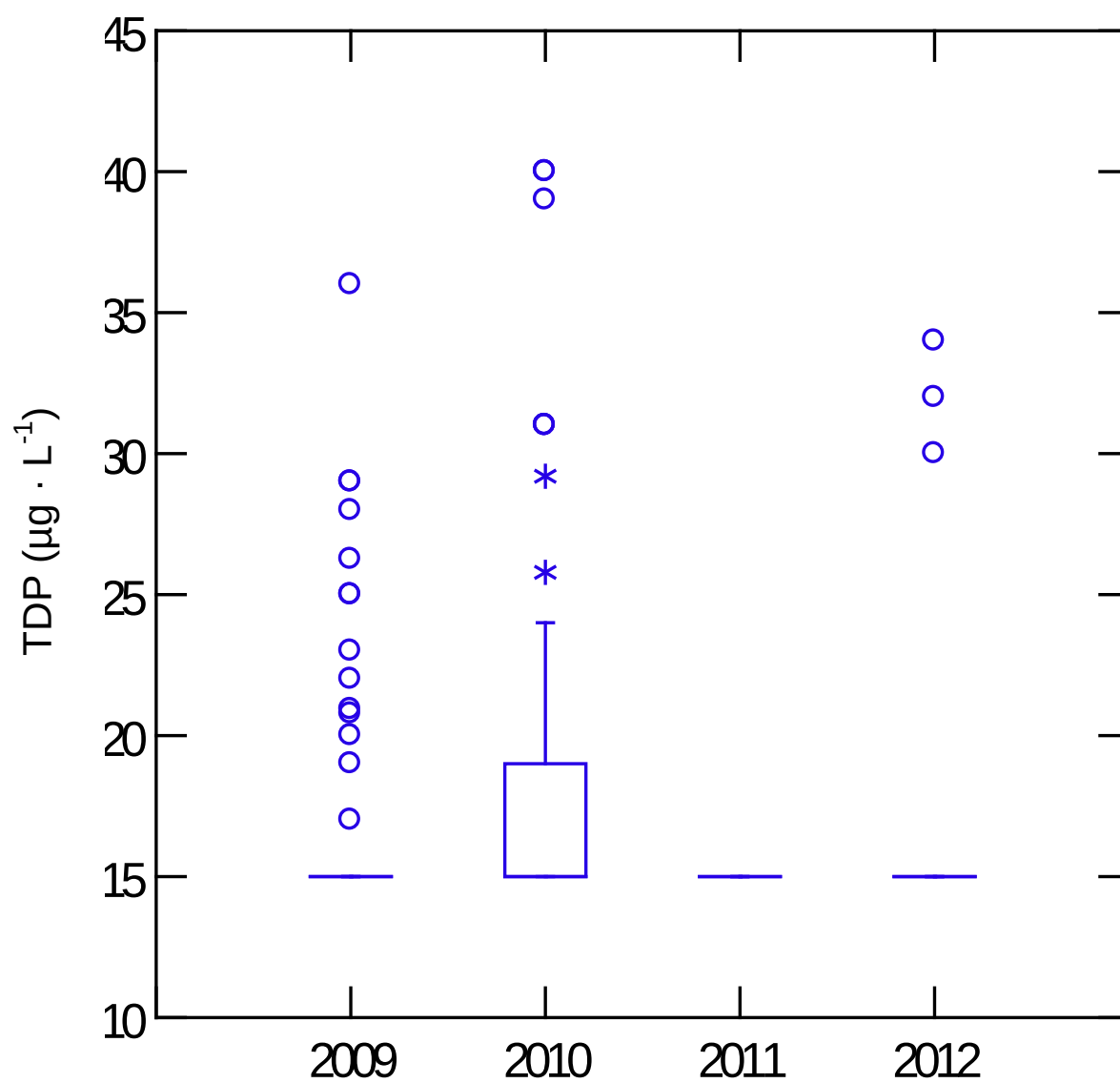


Figure 3. Box plots of total dissolved phosphorus in the Asan River.

Total Dissolved Nitrogen

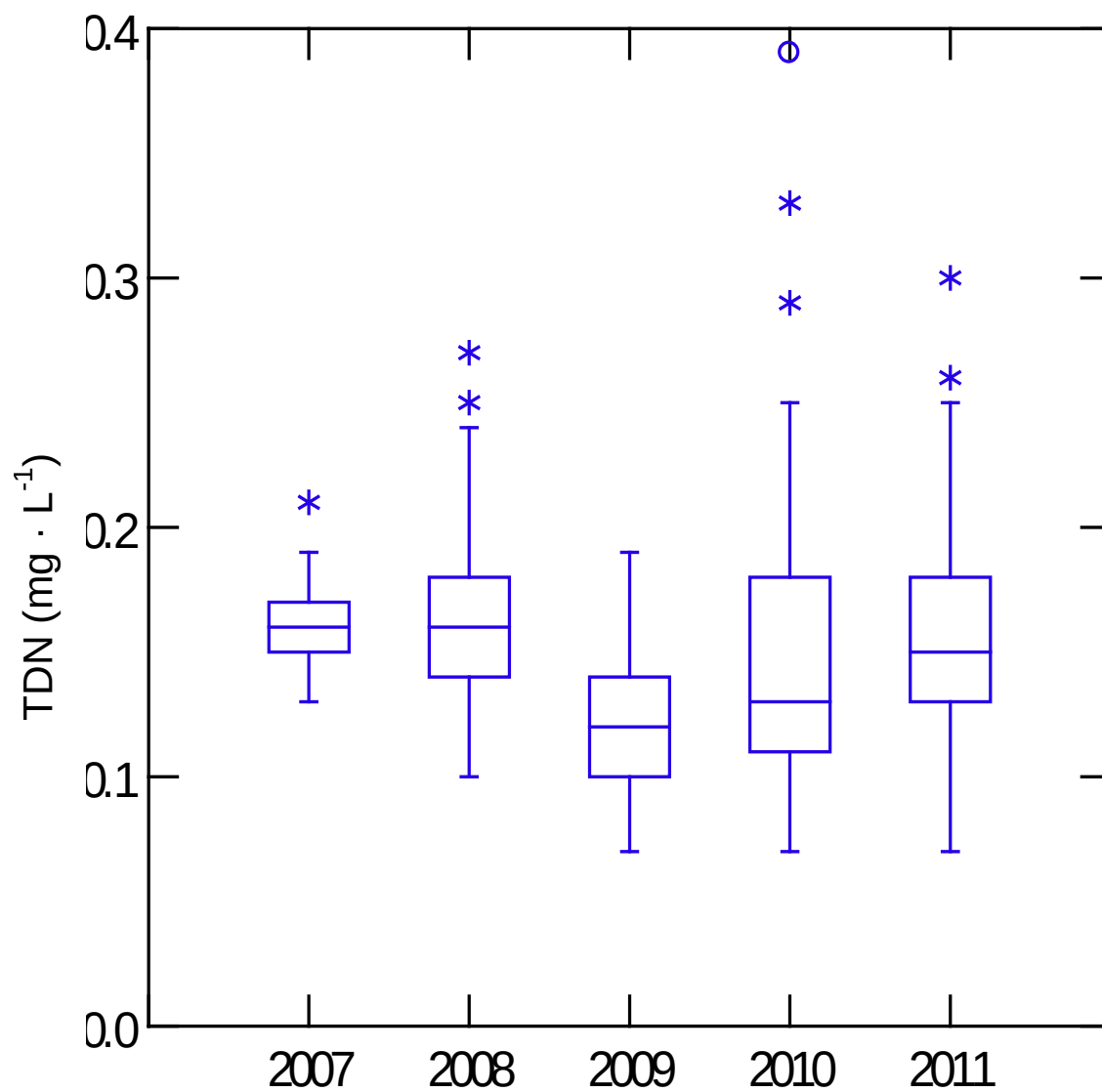


Figure 4. Box plots of total dissolved nitrogen in the Asan River.

Nitrate + Nitrite

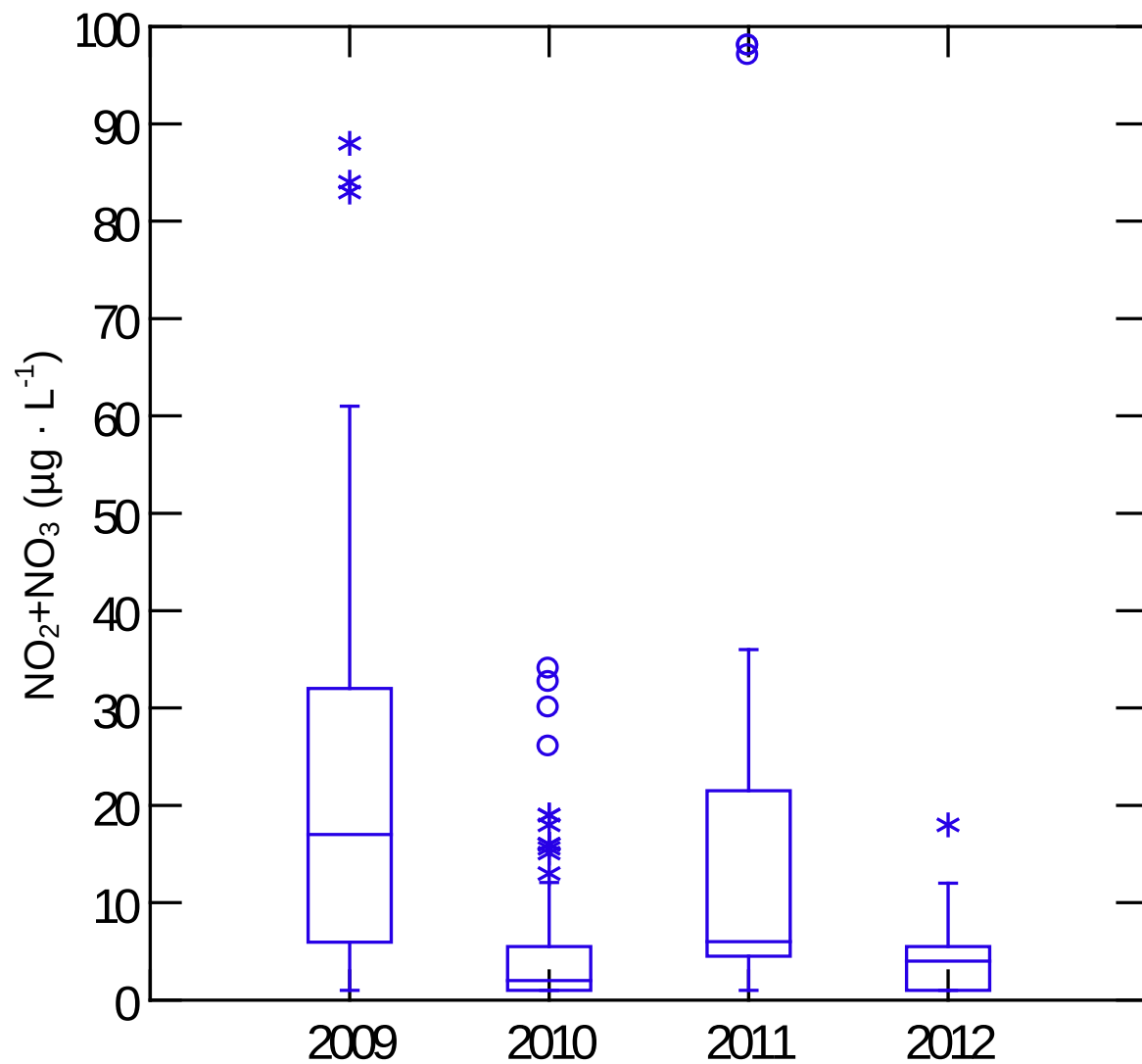


Figure 5. Box plots of nitrate + nitrite in the Asan River.

Chlorophyll

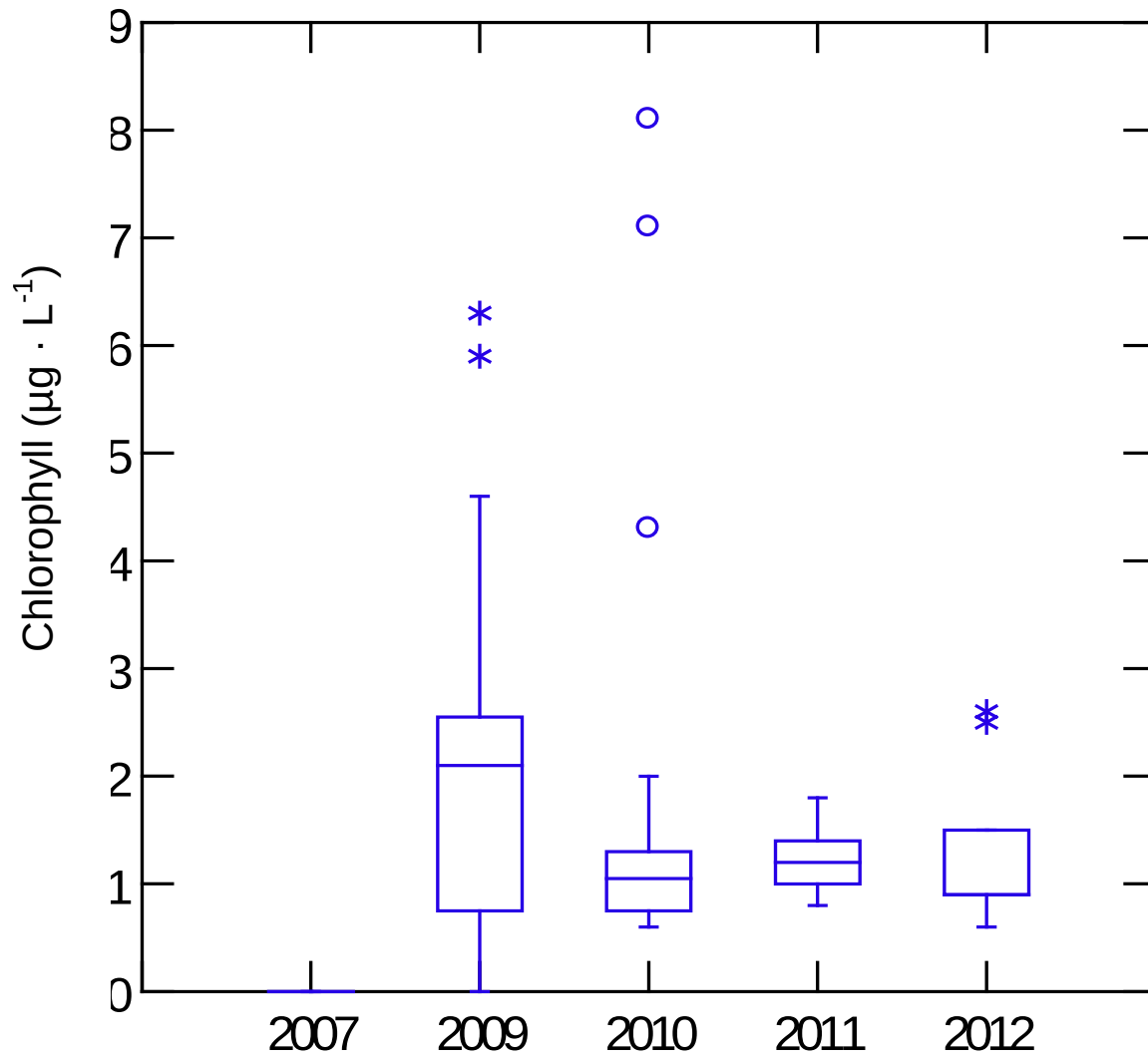


Figure 6. Box plots of chlorophyll in the Asan River.

Oxygen Concentration

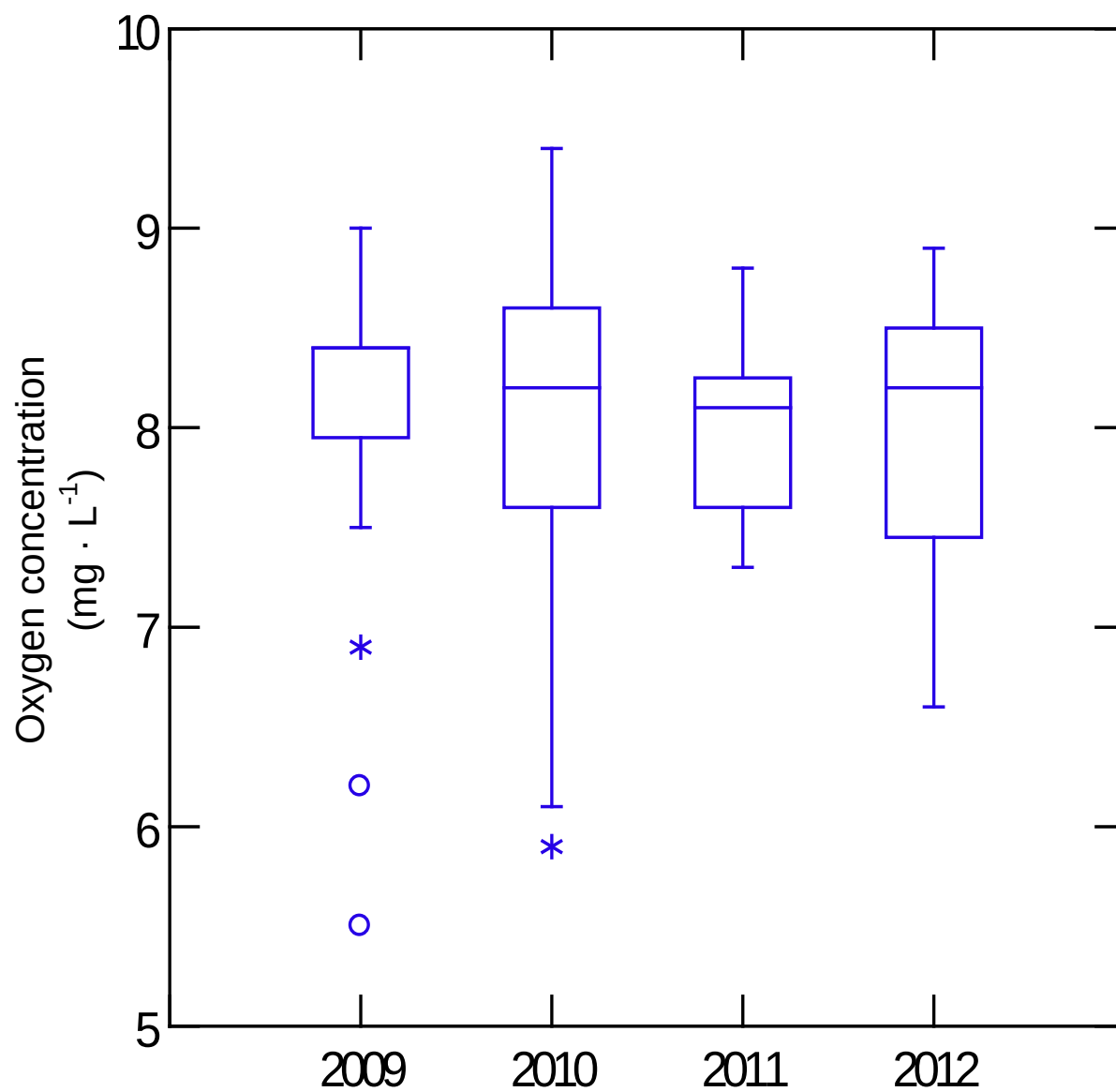


Figure 7. Box plots of oxygen concentration in the Asan River.

Oxygen Saturation

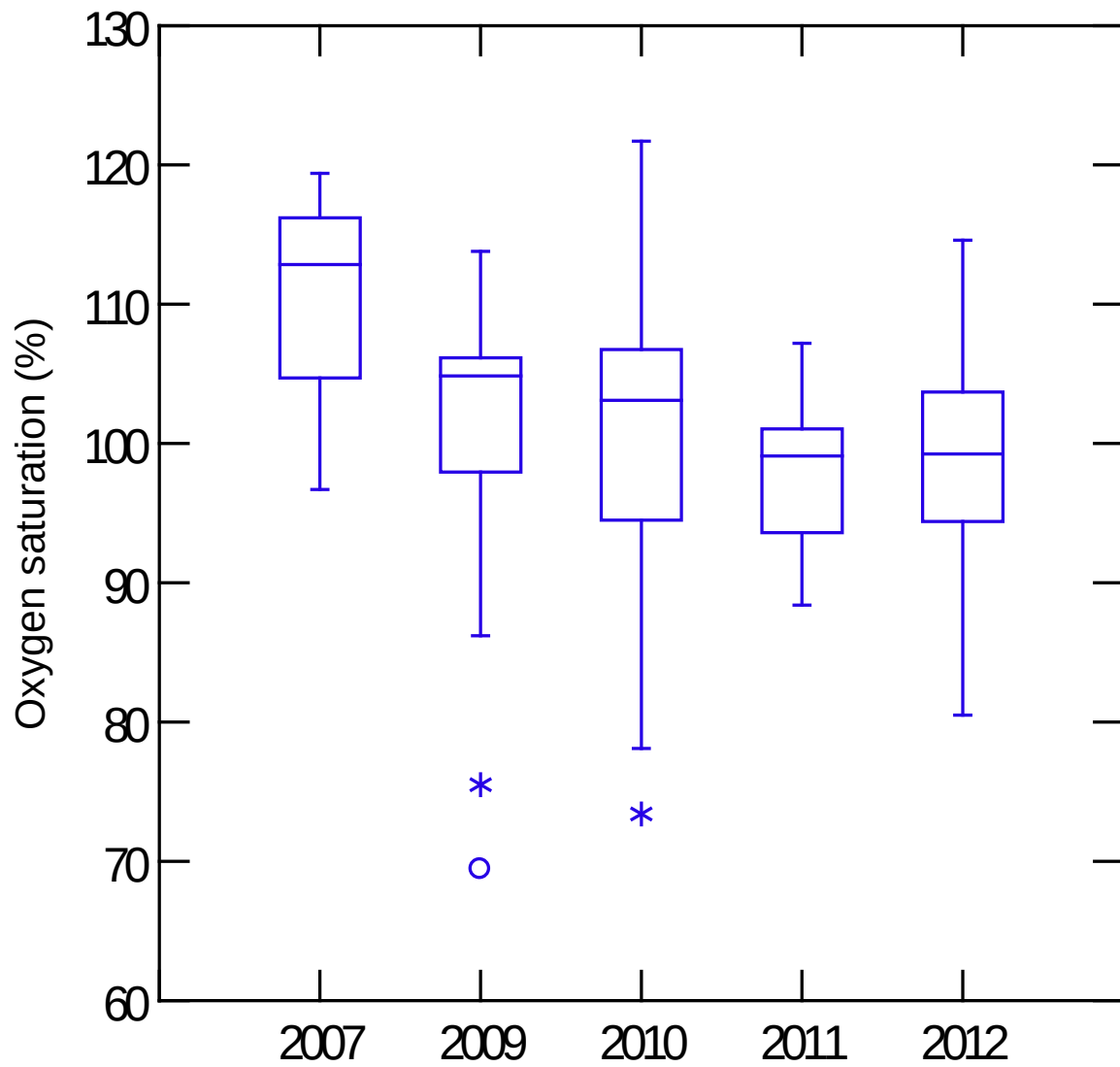


Figure 8. Box plots of oxygen saturation in the Asan River.

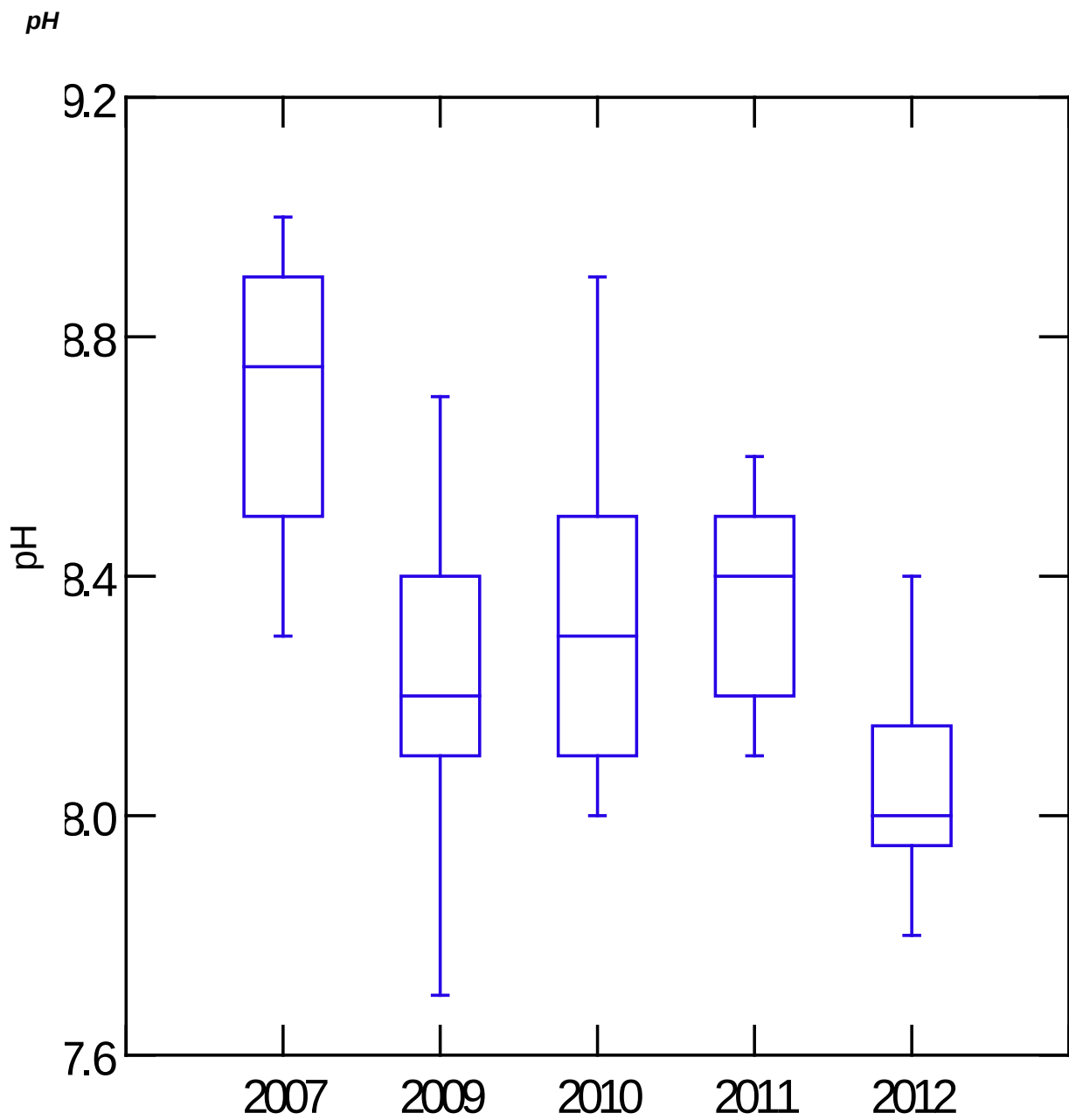


Figure 9. Box plots of pH in the Asan River.

Salinity

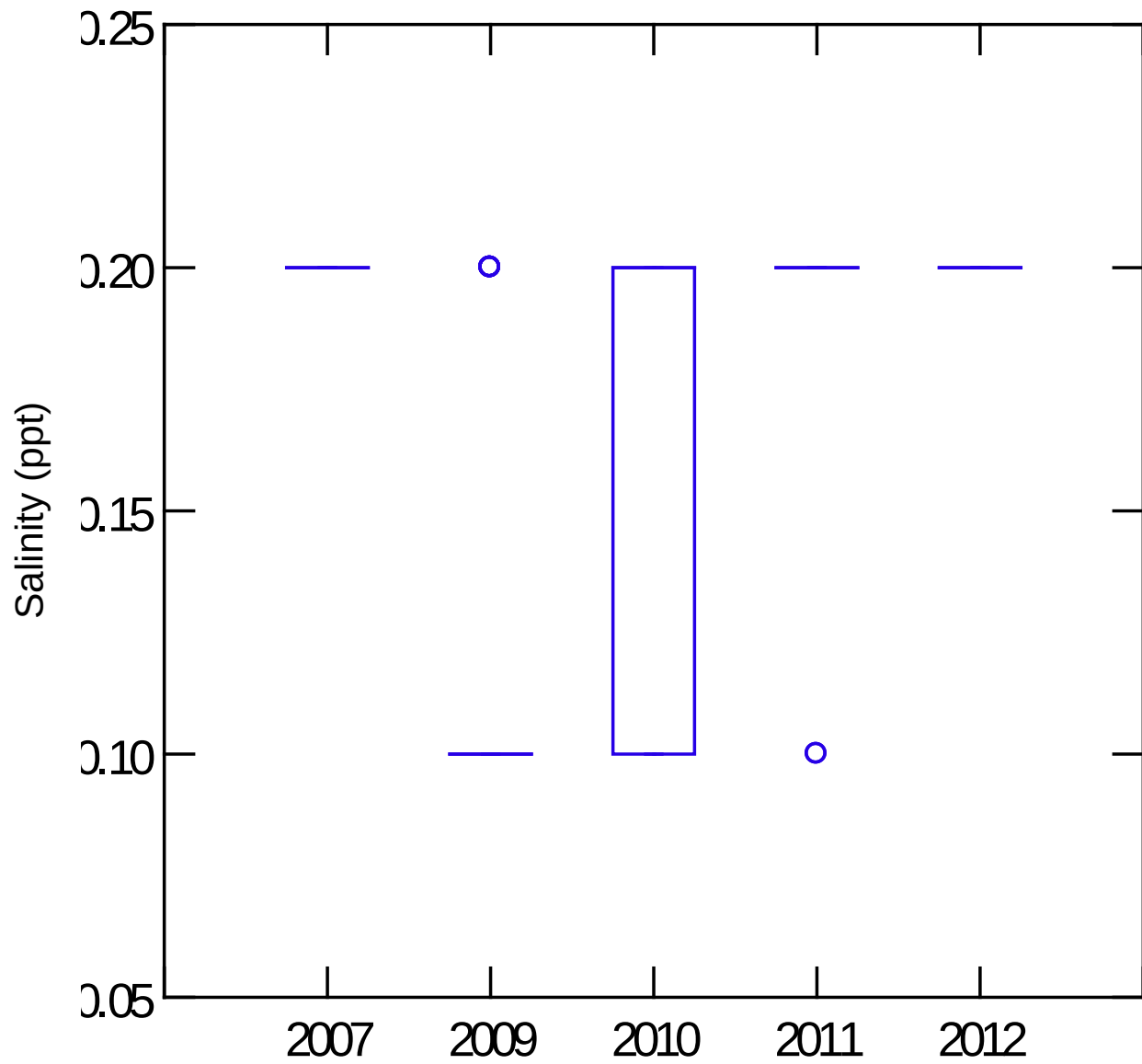


Figure 10. Box plots of salinity in the Asan River.

Specific Conductance

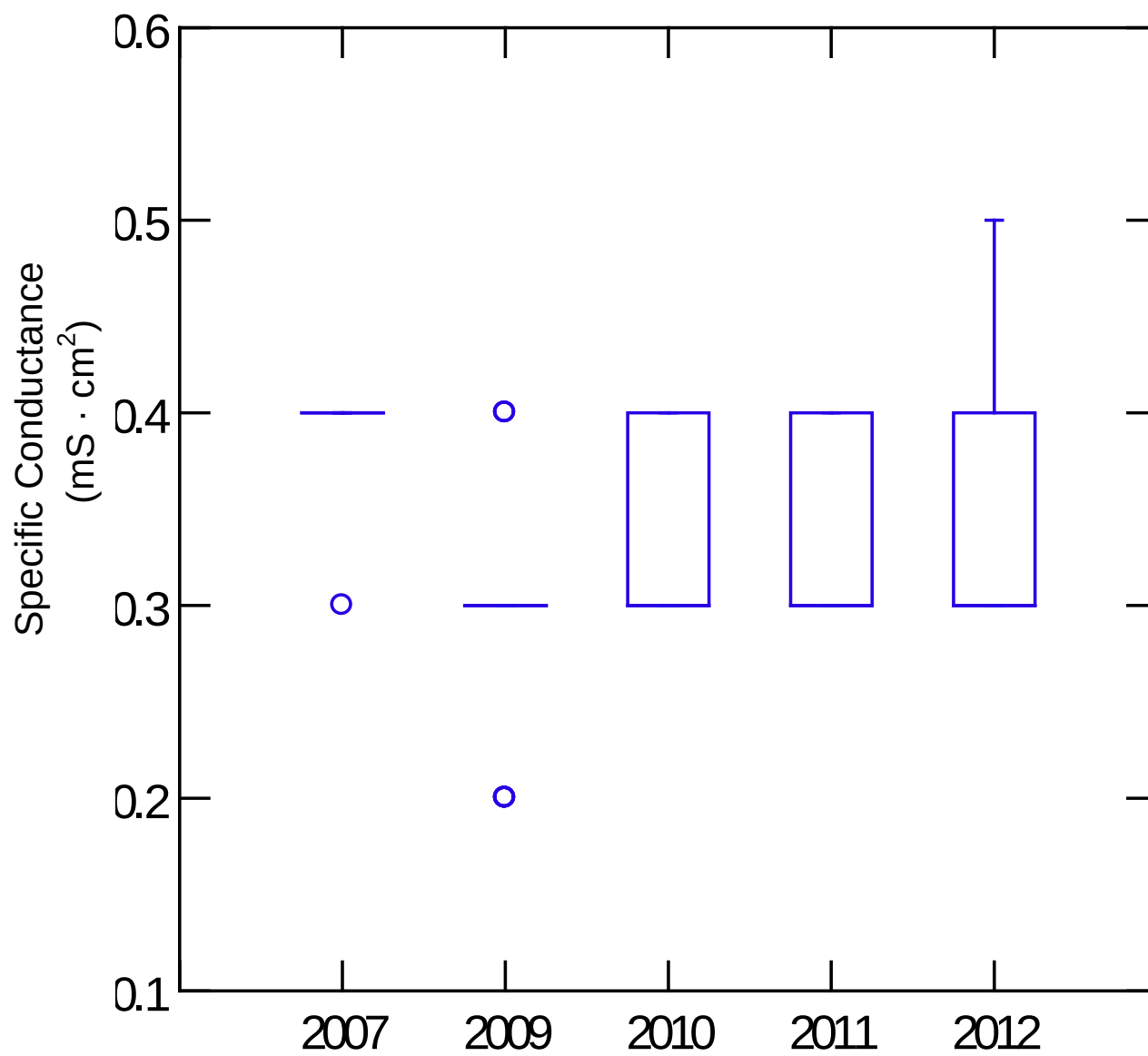


Figure 11. Box plots of specific conductance in the Asan River.

Temperature

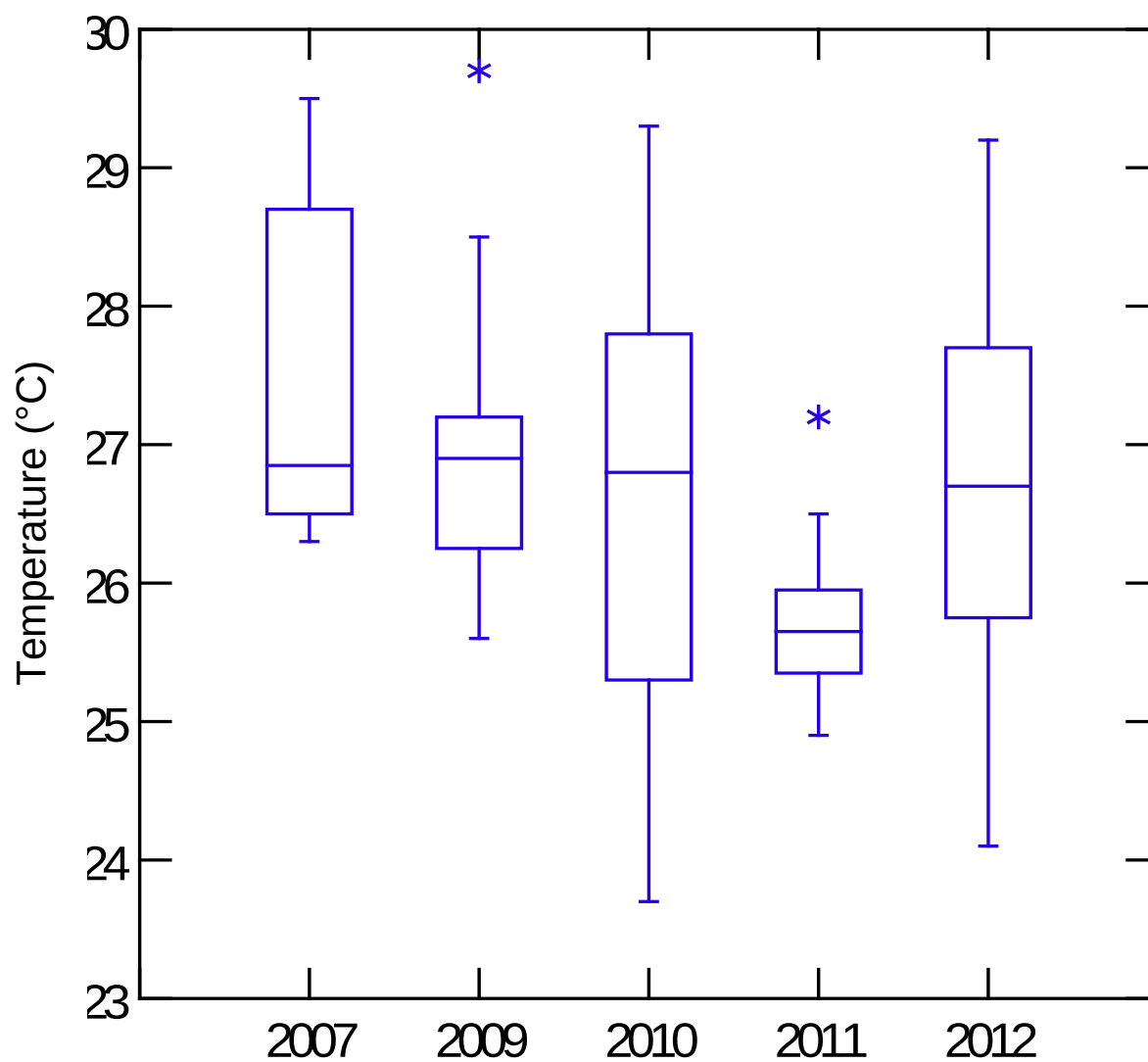


Figure 12. Box plots of temperature in the Asan River.

Turbidity

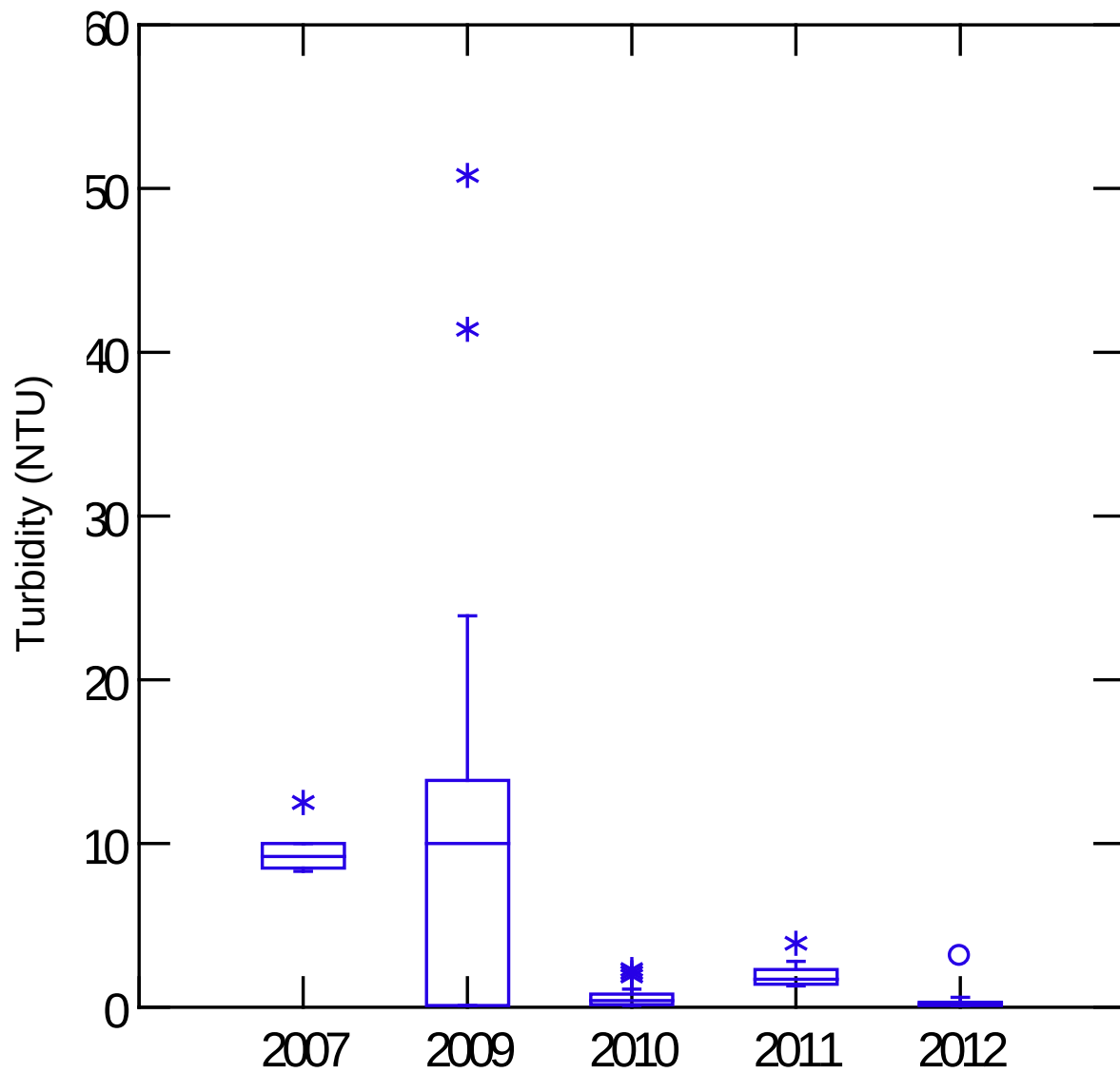


Figure 13. Box plots of turbidity in the Asan River.

Discussion

Several parameters were found to be outside published water quality criteria values over the monitoring period. Slightly high pH, relative to water quality criteria (Guam 1997), may have been the result of autotrophic (plant) activity, i.e. macrophytes and/or algae. Supersaturation of oxygen was measured when high pH was measured, indicating the high autotrophic activity. Because autotrophs consume CO₂, they can alter the carbonic acid balance in the water column resulting in higher pH (Wetzel 2001). Elevated turbidity may have been the result of siltation caused by the construction of homes just outside the park border in the upper reaches of the Asan River.

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