



Water Quality in Anchialine Pools of Pu`uhonua o Hōnaunau National Historical Park

Summary Report 2007-2011

Natural Resource Data Series NPS/PACN/NRDS—2014/665



ON THE COVER

An anchialine pool at Pu'uhonua o Hōnaunau National Historical Park showing tilapia nests.

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Abstract

This Natural Resource Data Series Report (NRDS) presents data collected from anchialine pools associated with the Pu`uhonua o Hōnaunau National Historical Park (PUHO) on the west coast of the island of Hawai`i, Hawaii. 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. Five anchialine pools in Pu`uhonua o Hōnaunau NHP were sampled quarterly from the last quarter of 2007 through 2011. During this time no major ecological events were detected in pools. Relatively minor algal blooms may have occurred in February 2011 in FPUHO03_ap, FPUHO04_ap, and FPUHO05_ap, as indicated by elevated chlorophyll concentrations. Later, a tsunami hit Hawaii on March 11, 2011, which inundated anchialine pools with seawater along the Kona coast, including FPUHO03_ap, FPUHO04_ap, and FPUHO05_ap. Pools were sampled 16 days later, but there were no residual effects in pool chemistry.

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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
HAVO	Hawaii 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
NHP	National Historical Park
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
ODO	Optical Dissolved Oxygen
ODOsat	Optical Dissolved Oxygen in terms of saturation
PACN	Pacific Island Inventory and Monitoring Network
ppt	Parts Per Thousand
PUHO	Pu`uhonua o Hōnaunau National Historical Park
SD	Standard Deviation
SE	Standard Error
SpC	Specific conductivity
TDN	Total Dissolved Nitrogen
TDP	Total Dissolved Phosphorus
Temp	Temperature
Turb	Turbidity
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) Pacific Island Network (PACN). This report presents data collected under the PACN water quality protocol (Jones et al. 2011) on anchialine pools in Pu`uhonua O Hōnaunau National Historical Park on the island of Hawai`i, Hawaii, between 2007-2011.

Anchialine pools are spatially distinct waterbodies subject to tides fed both by freshwater and seawater groundwater inputs (Holthuis 1973). While anchialine pools have no regular overland input of water and no direct connection to the sea, exceptional events like tsunamis can introduce water to anchialine pools. Within this broad definition, the geomorphology of anchialine pools is quite variable, including pools in caves, pools in open pits, and pools at the surface. Size, substrate including lava, sand, or organic sediment, extent of macrophyte vegetation, periphyton, or other algae, presence of fish and/or native shrimp, exposure to sunlight, and alteration by humans, both historical and contemporary, vary greatly between pools. Many pools are of great cultural importance. Most of the world’s known anchialine pools occur along the Kona coast of the big island of Hawai`i, Hawaii, USA.

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.

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). There are no inland water quality criteria for anchialine pools under §11-54-5.1b of the State of Hawaii Department of Health Water Quality Standards (State of Hawaii 2012).

Sample Sites

Pu`uhonua o Hōnaunau National Historical Park is located on the Kona coast of the big island of Hawai`i (Fig. 1). Site names are formatted to designate fixed or temporary sites (“F” or “T” respectively), park designation (PUHO), a number (e.g. 01), and habitat type (“ap” for anchialine pool); e.g. “FPUHO01_ap” (Table 1). Data were collected from November 2007 to October 2011 (Table 2). Because anchialine pools are sensitive ecological and archeological sites, their precise locations are not published here. FPUHO01_ap is within a small cave with an open skylight. FPUHO02_ap is within a small pit and is generally kept covered to prevent leaves and organic matter from filling-in the pit. FPUHO03_ap, FPUHO04_ap, and FPUHO05_ap are located near the shore in vicinity of the Place of Refuge and Visitor’s Center. These pools are both of very high cultural significance, and are seen by the bulk of visitors to the park. All three of these pools are shallow, wide, and have an open canopy exposing them to direct sunlight.

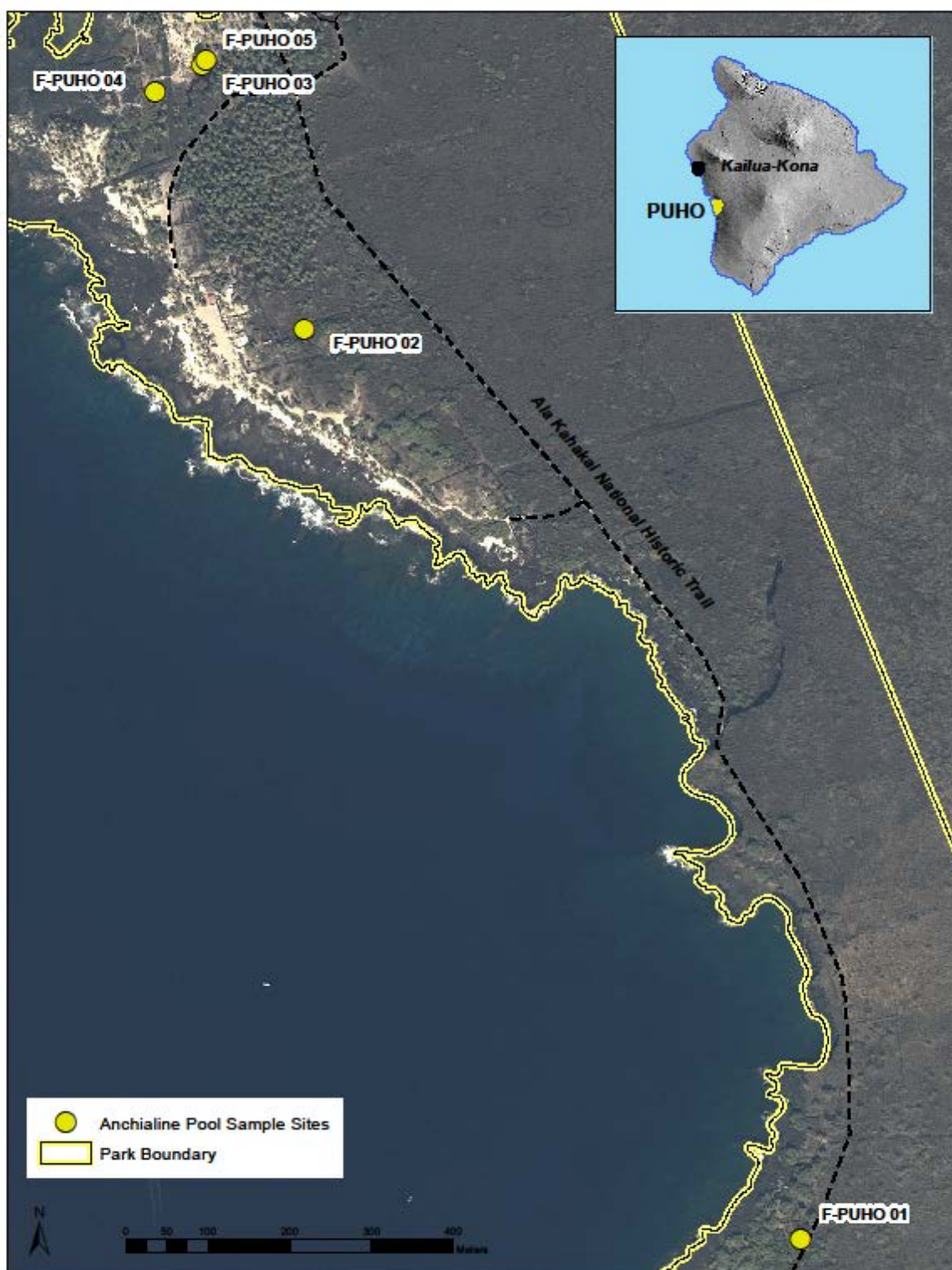


Figure 1. Sample sites in Pu'uuhonua o Hōnaunau National Historical Park on the island of Hawai'i.

Table 1. Pu`uhonua o Hōnaunau NHP sample site designations.

I&M Site Designation	Park Site Designation
FPUHO01_ap	Kiilae001
FPUHO02_ap	Keokea003
FPUHO03_ap	Honaun003
FPUHO04_ap	Honaun004
FPUHO05_ap	Honaun002

Table 2. Pu`uhonua o Hōnaunau NHP sampling events.

Park	Year	Date	Personnel
PUHO	2007	29-Nov-07	Danielle Gross, Lindsey Kramer, Tahzay Jones
PUHO	2008	30-Jan-08	Lindsey Kramer, Mariska Weijermen
PUHO	2008	21-May-08	Anne Farahi, Lindsey Kramer
PUHO	2008	19-Aug-08	Anne Farahi, Lindsey Kramer
PUHO	2008	13-Nov-08	Anne Farahi, Lindsey Kramer
PUHO	2009	10-Mar-09	Anne Farahi, Lindsey Kramer
PUHO	2009	18-Jun-09	Lindsey Kramer, Malia Hayes
PUHO	2009	24-Aug-09	Lindsey Kramer, Malia Hayes
PUHO	2009	17-Nov-09	Lindsey Kramer, Malia Hayes
PUHO	2010	24-Feb-10	Cory Johnson, Lindsey Kramer, Roger Gasper, Shane Johnson
PUHO	2010	12-May-10	Lily Souza, Lindsey Kramer
PUHO	2010	23-Aug-10	Lindsey Kramer, Roger Gasper
PUHO	2010	29-Nov-10	Anne Farahi, Lindsey Kramer, M. Jerolaman
PUHO	2011	04-Feb-11	Lindsey Kramer, M. Jerolaman
PUHO	2011	27-Apr-11	Anne Farahi, M. Jerolaman
PUHO	2011	10-Aug-11	Anne Farahi, Danielle Gross, Tonnie Casey
PUHO	2011	26-Oct-11	Danielle Gross, Malia Hayes

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 Hawai'i Volcanoes National Park (HAVO) on the day of collection and frozen, or deposited into a freezer on the day of collection and later transported while frozen to HAVO. Samples were delivered to the EPSCoR Analytical Laboratory at the University of Hawai'i at Hilo (UHH) Marine Science Department, 200 W. Kawili St., Hilo, Hawaii 96720 for chemical analysis. Samples were analyzed for total dissolved phosphorous (TDP), total dissolved nitrogen (TDN) and nitrate + nitrite (NO₃ + NO₂).

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 ($\text{mS} \cdot \text{cm}^{-1}$), 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 ($\text{NO}_3 + \text{NO}_2$).

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.

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 were entered into PACN databases. Data were downloaded from 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 Tazhay Jones or David Raikow. Data determined to be unreliable were flagged in databases, removed from further consideration. Data were explored visually by plotting time-series and boxplots. 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).

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 mean and the standard error are reported for individual sampling events, because the accuracy of the estimate of the mean is of interest (Tables 8-18). 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 3-7). 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. Standard deviation was not calculated for sets of data with $n \leq 2$. Data missing from tables were due to probe failure or the pool not being sampled on that date.

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. 2). 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.

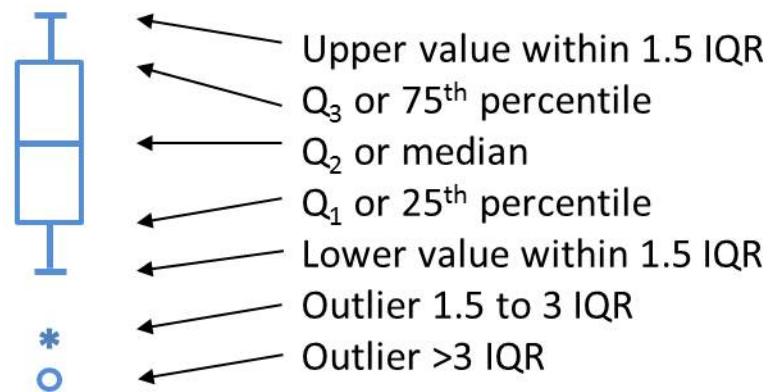


Figure 2. Box plot explanation.

Results

Sites in Pu`uhonua o Hōnaunau NHP were sampled up to 17 times from 2007 to 2011. Results are presented in summaries by year (Tables 3-7, Figs. 3-13) and parameter (Tables 8-18). Annual summaries present the minimum, maximum, median, and variance as standard deviation of all individual measurements at each site across an entire year. Parameter summaries present stable sonde readings and nutrient concentrations from each site and sampling event as mean and standard error of the mean. Box plots display data lumped from all three sample sites by year.

FPUHO01_ap

2007: No notable events were observed.
2008: No notable events were observed.
2009: No notable events were observed.
2010: No notable events were observed.
2011: No notable events were observed.

FPUHO02_ap

2007: No notable events were observed.
2008: No notable events were observed.
2009: No notable events were observed.
2010: No notable events were observed.
2011: No notable events were observed.

FPUHO03_ap

2007: No notable events were observed.
2008: No notable events were observed.
2009: No notable events were observed.
2010: No notable events were observed.
2011: An algal bloom may have occurred in February 2011 as indicated by chlorophyll.

FPUHO04_ap

2007: No notable events were observed.
2008: No notable events were observed.
2009: No notable events were observed.
2010: No notable events were observed.
2011: An algal bloom may have occurred in February 2011 as indicated by chlorophyll.

FPUHO05_ap

2007: No notable events were observed.
2008: No notable events were observed.
2009: No notable events were observed.
2010: No notable events were observed.
2011: An algal bloom may have occurred in February 2011 as indicated by chlorophyll.

Table 3. 2007 summary of water quality parameters in anchialine pools in Pu`uhonua o Hōnaunau NHP.

Parameter	Unit	Site	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	FPUHO02_ap	3	39.0	73.0	61.0	17.2
		FPUHO03_ap	3	56.0	97.0	65.0	21.5
		FPUHO04_ap	3	56.0	73.0	67.0	8.6
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	FPUHO02_ap	3	0.3	0.7	0.5	0.2
		FPUHO03_ap	3	0.2	0.3	0.2	0.1
		FPUHO04_ap	3	0.2	0.3	0.2	0.1
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	FPUHO02_ap	3	285.0	666.0	582.0	200.2
		FPUHO03_ap	3	83.0	220.0	103.0	74.0
		FPUHO04_ap	3	97.0	207.0	164.0	55.4
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	FPUHO02_ap	1	7.3			
		FPUHO03_ap	1	5.6			
		FPUHO04_ap	1	8.9			
Dissolved Oxygen Saturation	%	FPUHO02_ap	1	87.8			
		FPUHO03_ap	1	75.4			
		FPUHO04_ap	1	121.4			
pH	none	FPUHO02_ap	1	6.7			
		FPUHO03_ap	1	7.2			
		FPUHO04_ap	1	7.4			
Salinity	ppt	FPUHO02_ap	1	7.6			
		FPUHO03_ap	1	14.5			
		FPUHO04_ap	1	14.5			
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	FPUHO02_ap	1	13.2			
		FPUHO03_ap	1	24.0			
		FPUHO04_ap	1	24.0			
Temperature	$^{\circ}\text{C}$	FPUHO02_ap	1	22.3			
		FPUHO03_ap	1	26.0			
		FPUHO04_ap	1	26.9			

Table 4. 2008 summary of water quality parameters in anchialine pools in Pu`uhonua o Hōnaunau NHP.

Parameter	Unit	Site	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	FPUHO01_ap	12	65.0	116.0	92.5	20.2
		FPUHO02_ap	9	69.0	109.0	106.0	16.2
		FPUHO03_ap	12	61.0	123.0	88.5	21.5
		FPUHO04_ap	6	49.0	111.0	72.0	26.6
		FPUHO05_ap	3	77.0	101.0	92.0	12.1
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	FPUHO01_ap	12	0.2	0.6	0.4	0.1
		FPUHO02_ap	9	0.5	0.9	0.9	0.2
		FPUHO03_ap	12	0.2	0.4	0.3	0.1
		FPUHO04_ap	6	0.1	0.4	0.3	0.1
		FPUHO05_ap	3	0.3	0.5	0.5	0.1
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	FPUHO01_ap	12	270.0	573.0	412.5	117.2
		FPUHO02_ap	9	452.0	914.0	753.0	161.3
		FPUHO03_ap	12	48.0	191.0	63.5	49.8
		FPUHO04_ap	6	47.0	175.0	120.0	65.5
		FPUHO05_ap	3	213.0	320.0	316.0	60.7
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	FPUHO01_ap	3	0.0	0.3	0.0	0.2
		FPUHO02_ap	2	0.0	0.4	0.2	0.3
		FPUHO03_ap	3	2.2	5.6	4.9	1.8
		FPUHO04_ap	1	0.0			
		FPUHO05_ap	1	1.2			
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	FPUHO01_ap	4	8.0	8.2	8.1	0.1
		FPUHO02_ap	3	6.5	7.0	6.9	0.3
		FPUHO03_ap	4	5.2	7.1	6.2	0.9
		FPUHO04_ap	2	10.6	11.4	11.0	0.5
		FPUHO05_ap	2	9.7	11.7	10.7	1.4
Dissolved Oxygen Saturation	%	FPUHO01_ap	3	91.3	94.5	93.4	1.6
		FPUHO02_ap	3	78.6	84.2	83.5	3.1
		FPUHO03_ap	3	79.5	94.0	92.9	8.1
		FPUHO04_ap	1	159.4			
		FPUHO05_ap	1	164.2			
pH	none	FPUHO01_ap	4	7.4	7.7	7.6	0.1
		FPUHO02_ap	3	6.7	6.8	6.7	0.1
		FPUHO03_ap	4	7.1	7.3	7.2	0.1
		FPUHO04_ap	2	7.6	8.1	7.9	0.3
		FPUHO05_ap	2	7.7	7.9	7.8	0.2
Salinity	ppt	FPUHO01_ap	4	5.1	5.2	5.2	0.1
		FPUHO02_ap	3	7.4	7.7	7.4	0.1
		FPUHO03_ap	4	12.9	14.7	13.4	0.8
		FPUHO04_ap	2	12.9	17.5	15.2	3.2
		FPUHO05_ap	2	12.0	14.7	13.3	1.9
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	FPUHO01_ap	4	9.1	9.3	9.3	0.1
		FPUHO02_ap	3	12.9	13.3	12.9	0.2
		FPUHO03_ap	4	21.6	24.3	22.2	1.2
		FPUHO04_ap	2	21.6	28.5	25.1	4.9
		FPUHO05_ap	2	20.2	24.2	22.2	2.8

Table 4. 2008 summary of water quality parameters in anchialine pools in Pu`uhonua o Hōnaunau NHP (continued).

Parameter	Unit	Site	n	Minimum	Maximum	Median	SD
Temperature	°C	FPUHO01_ap	4	20.1	20.5	20.3	0.2
		FPUHO02_ap	3	22.1	22.8	22.5	0.4
		FPUHO03_ap	4	25.7	30.3	27.3	1.9
		FPUHO04_ap	2	29.1	29.6	29.3	0.4
		FPUHO05_ap	2	27.2	29.8	28.5	1.9
Turbidity	NTU	FPUHO01_ap	4	0.0	0.5	0.0	0.3
		FPUHO02_ap	2	0.0	0.0	0.0	0.0
		FPUHO03_ap	4	0.6	1.8	1.1	0.5
		FPUHO04_ap	2	1.1	1.5	1.3	0.3
		FPUHO05_ap	2	3.0	4.2	3.6	0.8

Table 5. 2009 summary of water quality parameters in anchialine pools in Pu`uhonua o Hōnaunau NHP.

Parameter	Unit	Site	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	FPUHO01_ap	12	50.5	127.5	89.0	24.0
		FPUHO02_ap	12	55.0	123.0	90.1	18.1
		FPUHO03_ap	12	29.8	100.7	71.8	21.3
		FPUHO04_ap	12	15.0	82.6	28.8	26.0
		FPUHO05_ap	12	19.2	103.0	52.0	31.8
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	FPUHO01_ap	12	0.3	0.6	0.5	0.1
		FPUHO02_ap	12	0.5	1.2	0.8	0.2
		FPUHO03_ap	12	0.1	0.3	0.2	0.1
		FPUHO04_ap	12	0.2	0.3	0.2	0.0
		FPUHO05_ap	12	0.1	0.4	0.2	0.1
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	FPUHO01_ap	12	305.8	607.2	471.6	104.9
		FPUHO02_ap	12	253.2	1019.4	701.1	232.8
		FPUHO03_ap	12	12.2	188.6	76.4	53.7
		FPUHO04_ap	12	1.0	175.0	31.3	65.3
		FPUHO05_ap	12	24.5	323.0	66.8	114.8
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	FPUHO01_ap	4	0.0	0.0	0.0	0.0
		FPUHO02_ap	3	0.3	0.5	0.5	0.1
		FPUHO03_ap	4	4.2	10.2	5.6	2.6
		FPUHO04_ap	3	0.0	5.1	3.8	2.6
		FPUHO05_ap	4	2.4	8.5	6.4	2.9
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	FPUHO01_ap	4	8.2	8.5	8.3	0.1
		FPUHO02_ap	4	6.4	7.2	6.7	0.3
		FPUHO03_ap	4	3.0	8.7	6.1	2.4
		FPUHO04_ap	4	9.5	13.1	11.3	1.8
		FPUHO05_ap	4	4.5	13.5	9.8	3.7
Dissolved Oxygen Saturation	%	FPUHO01_ap	4	94.0	97.6	95.0	1.6
		FPUHO02_ap	4	77.3	86.1	81.2	3.6
		FPUHO03_ap	4	40.9	132.9	80.3	38.6
		FPUHO04_ap	4	121.0	198.4	155.3	37.2
		FPUHO05_ap	3	59.2	138.2	122.4	41.8
pH	none	FPUHO01_ap	4	7.5	7.7	7.7	0.1
		FPUHO02_ap	4	6.7	7.0	6.8	0.1
		FPUHO03_ap	4	7.0	7.6	7.3	0.3
		FPUHO04_ap	4	7.2	8.5	8.3	0.6
		FPUHO05_ap	4	7.6	8.2	7.8	0.3
Salinity	ppt	FPUHO01_ap	4	5.4	5.5	5.4	0.0
		FPUHO02_ap	4	7.5	7.8	7.8	0.2
		FPUHO03_ap	4	10.4	15.4	12.8	2.2
		FPUHO04_ap	4	11.4	12.7	12.4	0.6
		FPUHO05_ap	4	10.9	13.5	12.3	1.0
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	FPUHO01_ap	4	9.5	9.7	9.6	0.1
		FPUHO02_ap	4	12.9	13.5	13.4	0.3
		FPUHO03_ap	4	17.7	25.6	21.4	3.5
		FPUHO04_ap	4	19.2	21.5	20.7	1.0
		FPUHO05_ap	4	18.7	22.5	20.6	1.6

Table 5. 2009 summary of water quality parameters in anchialine pools in Pu`uhonua o Hōnaunau NHP (continued).

Parameter	Unit	Site	n	Minimum	Maximum	Median	SD
Temperature	°C	FPUHO01_ap	4	20.2	20.4	20.3	0.1
		FPUHO02_ap	4	22.1	22.6	22.4	0.2
		FPUHO03_ap	4	24.1	33.5	27.9	3.9
		FPUHO04_ap	4	24.1	35.8	27.1	5.1
		FPUHO05_ap	4	24.1	32.1	27.1	3.4
Turbidity	NTU	FPUHO01_ap	3	0.0	0.0	0.0	0.0
		FPUHO02_ap	4	0.0	6.0	0.2	2.9
		FPUHO03_ap	4	1.1	2.1	1.8	0.4
		FPUHO04_ap	3	6.1	9.2	9.1	1.8
		FPUHO05_ap	4	2.1	8.0	4.5	2.4

Table 6. 2010 summary of water quality parameters in anchialine pools in Pu`uhonua o Hōnaunau NHP.

Parameter	Unit	Site	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	FPUHO01_ap	12	73.0	113.0	91.0	13.9
		FPUHO02_ap	12	63.0	93.0	72.5	9.6
		FPUHO03_ap	12	38.0	120.0	61.5	22.3
		FPUHO04_ap	12	34.0	175.0	65.5	38.5
		FPUHO05_ap	11	34.0	151.0	56.0	35.9
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	FPUHO01_ap	12	0.2	0.6	0.4	0.1
		FPUHO02_ap	12	0.5	1.0	0.7	0.2
		FPUHO03_ap	12	0.2	0.5	0.3	0.1
		FPUHO04_ap	12	0.1	0.5	0.3	0.1
		FPUHO05_ap	12	0.1	0.5	0.2	0.1
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	FPUHO01_ap	12	237.0	510.0	410.0	77.3
		FPUHO02_ap	12	440.0	849.0	618.5	171.0
		FPUHO03_ap	12	15.0	254.0	50.5	84.5
		FPUHO04_ap	12	9.0	257.0	64.5	97.1
		FPUHO05_ap	12	62.0	270.0	135.5	71.2
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	FPUHO01_ap	4	0.0	0.2	0.0	0.1
		FPUHO02_ap	4	0.0	2.2	0.2	1.0
		FPUHO03_ap	4	4.0	11.2	4.8	3.3
		FPUHO04_ap	4	2.2	7.5	4.6	2.3
		FPUHO05_ap	4	2.2	13.3	3.8	5.2
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	FPUHO01_ap	4	8.1	8.5	8.4	0.2
		FPUHO02_ap	4	6.5	7.1	6.9	0.2
		FPUHO03_ap	4	2.9	8.6	4.4	2.5
		FPUHO04_ap	4	5.8	10.4	7.8	2.0
		FPUHO05_ap	4	7.0	11.4	10.0	1.9
Dissolved Oxygen Saturation	%	FPUHO01_ap	4	92.3	96.5	96.1	2.0
		FPUHO02_ap	3	78.6	85.4	83.4	3.5
		FPUHO03_ap	4	38.8	119.4	57.2	35.4
		FPUHO04_ap	4	67.8	143.4	100.5	31.8
		FPUHO05_ap	3	86.8	136.3	130.1	26.9
pH	none	FPUHO01_ap	4	7.6	7.8	7.7	0.1
		FPUHO02_ap	4	6.8	7.1	6.9	0.1
		FPUHO03_ap	4	7.0	7.8	7.1	0.4
		FPUHO04_ap	4	7.3	8.2	7.9	0.4
		FPUHO05_ap	4	7.5	8.3	8.1	0.4
Salinity	ppt	FPUHO01_ap	4	5.1	5.3	5.2	0.1
		FPUHO02_ap	4	7.4	7.6	7.4	0.1
		FPUHO03_ap	4	12.1	14.3	12.7	1.0
		FPUHO04_ap	4	6.6	14.2	9.4	3.2
		FPUHO05_ap	4	12.2	12.9	12.3	0.3
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	FPUHO01_ap	4	9.0	9.4	9.3	0.2
		FPUHO02_ap	4	12.8	13.2	12.9	0.2
		FPUHO03_ap	4	20.3	23.8	21.2	1.6
		FPUHO04_ap	4	11.5	23.5	16.2	5.1
		FPUHO05_ap	4	20.5	21.5	20.7	0.5

Table 6. 2010 summary of water quality parameters in anchialine pools in Pu'uhonua o Hōnaunau NHP (continued).

Parameter	Unit	Site	n	Minimum	Maximum	Median	SD
Temperature	°C	FPUHO01_ap	4	20.2	20.3	20.3	0.0
		FPUHO02_ap	4	22.2	22.4	22.3	0.1
		FPUHO03_ap	4	23.7	27.9	26.4	1.9
		FPUHO04_ap	4	21.3	27.7	25.5	2.7
		FPUHO05_ap	4	22.8	26.9	26.1	1.8
Turbidity	NTU	FPUHO01_ap	4	0.0	0.2	0.1	0.1
		FPUHO02_ap	3	0.0	1.8	0.0	1.0
		FPUHO03_ap	3	0.0	0.4	0.2	0.2
		FPUHO04_ap	2	0.8	2.3	1.6	1.0
		FPUHO05_ap	4	1.1	2.3	2.0	0.5

Table 7. 2011 summary of water quality parameters in anchialine pools in Pu`uhonua o Hōnaunau NHP.

Parameter	Unit	Site	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	FPUHO01_ap	9	88.0	119.9	107.1	10.9
		FPUHO02_ap	12	79.3	109.8	99.7	10.0
		FPUHO03_ap	12	57.4	109.6	86.0	15.7
		FPUHO04_ap	12	40.7	141.5	90.9	27.3
		FPUHO05_ap	12	48.9	90.2	57.3	13.7
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	FPUHO01_ap	9	0.3	0.6	0.5	0.1
		FPUHO02_ap	12	0.4	1.4	1.0	0.3
		FPUHO03_ap	12	0.2	0.5	0.3	0.1
		FPUHO04_ap	12	0.3	0.4	0.4	0.0
		FPUHO05_ap	12	0.1	1.0	0.3	0.2
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	FPUHO01_ap	9	326.4	527.8	486.2	83.9
		FPUHO02_ap	12	326.7	1125.8	816.6	266.2
		FPUHO03_ap	12	37.0	143.2	85.9	42.5
		FPUHO04_ap	12	1.0	260.5	111.0	117.7
		FPUHO05_ap	11	83.0	240.2	205.4	62.9
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	FPUHO01_ap	3	0.0	0.0	0.0	0.0
		FPUHO02_ap	4	0.1	0.6	0.4	0.2
		FPUHO03_ap	4	2.1	20.5	4.3	8.6
		FPUHO04_ap	4	2.6	15.2	6.9	5.6
		FPUHO05_ap	4	3.0	39.4	9.2	16.4
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	FPUHO01_ap	3	7.9	8.5	8.0	0.3
		FPUHO02_ap	4	5.8	6.8	6.4	0.4
		FPUHO03_ap	4	3.0	8.2	4.4	2.3
		FPUHO04_ap	4	5.1	8.8	7.2	1.7
		FPUHO05_ap	4	5.5	8.9	8.1	1.4
Dissolved Oxygen Saturation	%	FPUHO01_ap	3	90.0	96.1	91.2	3.3
		FPUHO02_ap	4	69.9	82.0	76.9	5.0
		FPUHO03_ap	4	39.6	125.2	60.1	37.8
		FPUHO04_ap	3	64.0	113.0	93.1	24.7
		FPUHO05_ap	4	70.0	125.9	109.6	24.0
pH	none	FPUHO01_ap	3	7.6	7.7	7.6	0.0
		FPUHO02_ap	4	6.6	6.8	6.8	0.1
		FPUHO03_ap	4	7.0	7.7	7.6	0.3
		FPUHO04_ap	4	7.2	8.1	7.6	0.4
		FPUHO05_ap	4	7.2	7.9	7.7	0.3
Salinity	ppt	FPUHO01_ap	3	5.1	5.5	5.2	0.2
		FPUHO02_ap	4	7.7	8.0	7.8	0.1
		FPUHO03_ap	4	13.3	15.7	14.3	1.0
		FPUHO04_ap	4	13.2	16.5	14.5	1.4
		FPUHO05_ap	4	11.8	14.9	13.7	1.3
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	FPUHO01_ap	3	9.1	9.7	9.2	0.3
		FPUHO02_ap	4	13.3	13.8	13.5	0.2
		FPUHO03_ap	4	22.2	26.0	23.7	1.6
		FPUHO04_ap	4	22.1	27.1	24.1	2.2
		FPUHO05_ap	4	19.9	24.7	22.7	2.1

Table 7. 2011 summary of water quality parameters in anchialine pools in Pu`uhonua o Hōnaunau NHP (continued).

Parameter	Unit	Site	n	Minimum	Maximum	Median	SD
Temperature	°C	FPUHO01_ap	3	20.1	20.5	20.3	0.2
		FPUHO02_ap	4	22.1	22.5	22.3	0.2
		FPUHO03_ap	4	25.3	33.4	27.2	3.6
		FPUHO04_ap	4	22.6	30.9	29.9	3.9
		FPUHO05_ap	4	23.2	29.7	27.1	2.7
Turbidity	NTU	FPUHO01_ap	3	0.0	0.0	0.0	0.0
		FPUHO02_ap	4	0.0	0.2	0.1	0.1
		FPUHO03_ap	4	1.3	14.4	2.4	6.2
		FPUHO04_ap	3	2.4	4.0	3.5	0.9
		FPUHO05_ap	4	1.7	6.6	3.1	2.2

Summaries by parameter
Total Dissolved Phosphorus

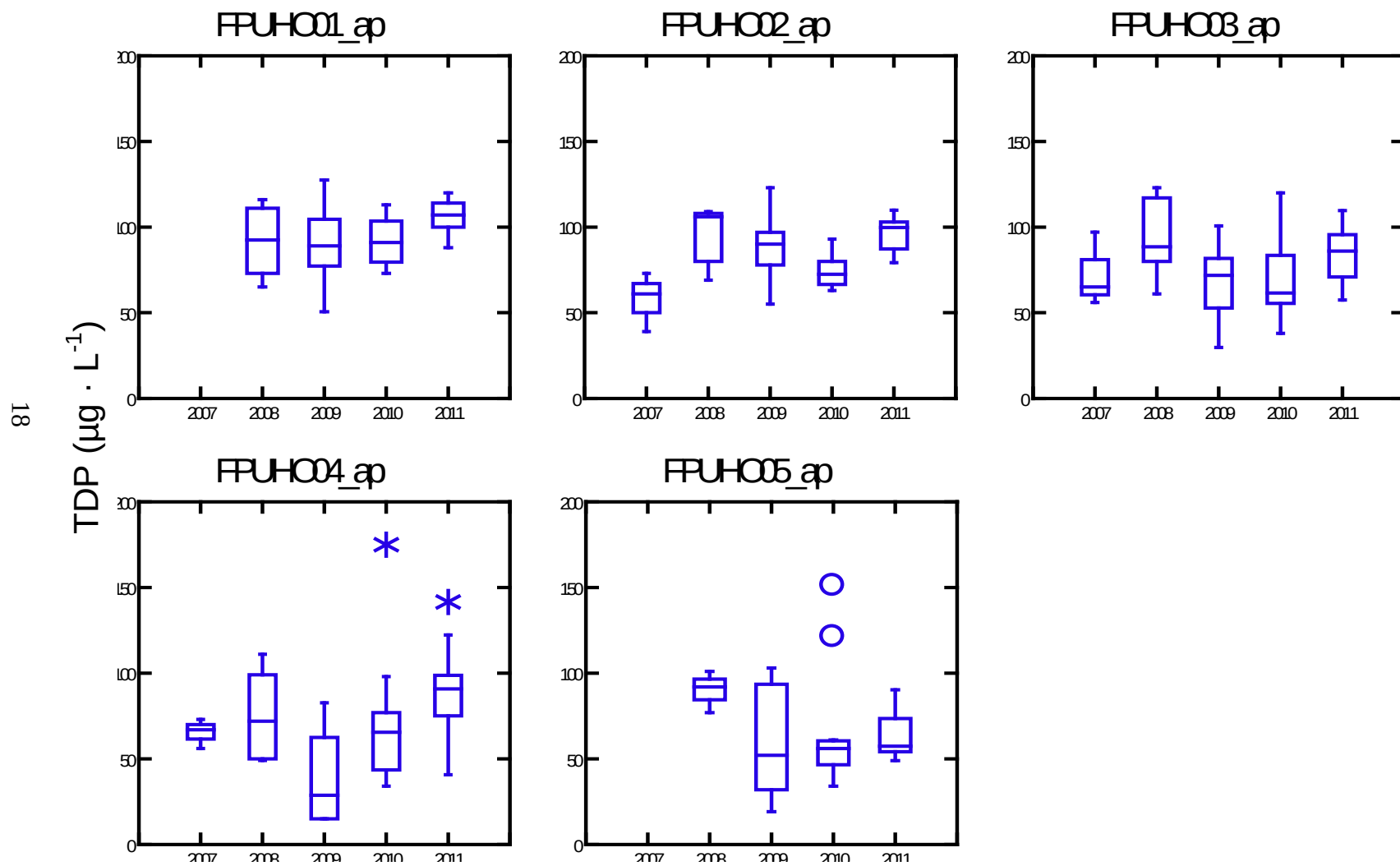


Figure 3. Box plots of Total Dissolved Phosphorus in Pu`uhonua o Hōnaunau NHP anchialine pools.

Table 8. Mean Total Dissolved Phosphorus (TDP, $\mu\text{gP} \cdot \text{L}^{-1}$) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	TDP	SE ¹	n	TDP	SE ¹	n	TDP	SE ¹	n	TDP	SE ¹	n	TDP	SE ¹	n
11/29/2007				57.7	10.0	3	72.7	12.4	3	65.3	5.0	3			
1/30/2008	74.0	5.9	3	75.7	3.4	3	88.0	1.5	3	52.7	3.2	3			
5/21/2008	81.7	9.5	3				67.7	4.1	3						
8/19/2008	114.3	1.2	3	108.7	0.3	3	97.7	10.7	3						
11/13/2008	97.7	11.8	3	106.0	0.6	3	120.0	2.5	3	98.3	7.5	3	90.0	7.0	3
3/10/2009	109.3	5.8	3	101.0	11.5	3	73.3	7.1	3	66.3	3.8	3	96.7	3.3	3
6/18/2009	86.3	2.9	3	93.8	3.7	3	69.2	3.4	3	17.3	1.3	3	40.3	2.2	3
8/24/2009	62.1	10.8	3	63.0	4.8	3	38.9	4.7	3	15.0	0.0	3	22.7	2.7	3
11/17/2009	102.0	15.6	3	93.2	2.5	3	91.4	6.2	3	55.4	13.8	3	76.6	11.5	3
2/24/2010	77.3	2.2	3	73.3	0.9	3	77.7	7.4	3	101.7	37.2	3	136.0	15.0	2
5/12/2010	98.7	8.7	3	79.7	5.4	3	91.3	14.7	3	75.3	1.5	3	57.0	2.1	3
8/23/2010	97.7	5.5	3	63.3	0.3	3	57.0	2.1	3	67.3	15.7	3	45.0	6.4	3
11/29/2010	91.0	9.9	3	79.3	7.1	3	47.0	6.2	3	36.7	2.2	3	51.0	4.5	3
2/4/2011	96.0	5.7	3	96.7	6.7	3	96.3	7.0	3	89.5	3.7	3	70.8	9.8	3
4/27/2011	116.6	1.7	3	104.0	1.8	3	66.4	4.5	3	54.0	7.5	3	54.8	0.9	3
8/10/2011	104.4	3.8	3	88.5	6.1	3	81.7	10.1	3	106.4	8.1	3	68.0	10.3	3
10/26/2011				94.9	6.2	3	92.3	3.4	3	106.5	17.6	3	60.7	7.9	3

¹SE = Standard Error

Total Dissolved Nitrogen

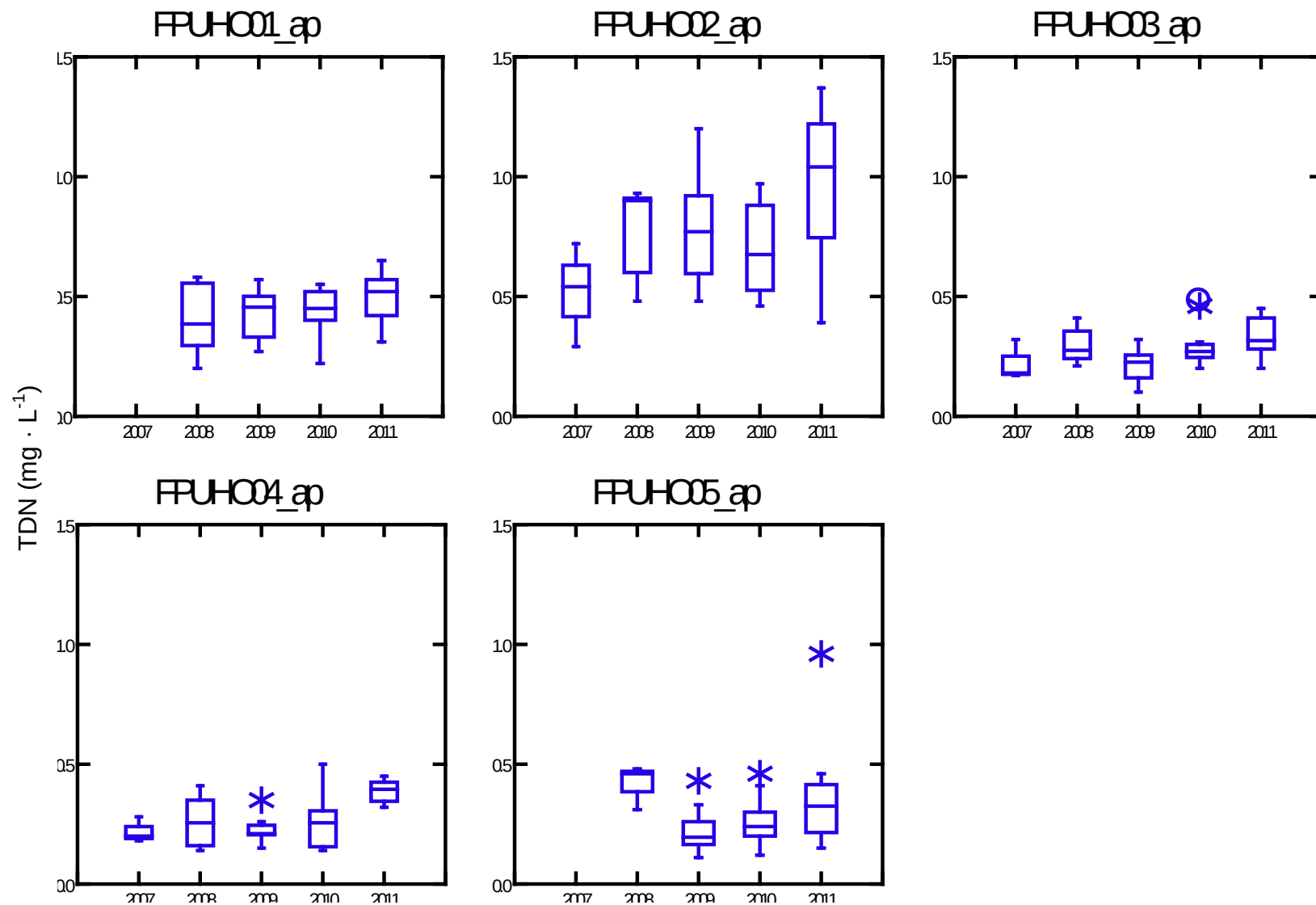


Figure 4. Box plots of Total Dissolved Nitrogen in Pu`uhonua o Hōnaunau NHP anchialine pools.

Table 9. Mean Total Dissolved Nitrogen (TDN, mgN · L⁻¹) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	TDN	SE ¹	n	TDN	SE ¹	n	TDN	SE ¹	n	TDN	SE ¹	n	TDN	SE ¹	n
11/29/2007				0.52	0.13	3	0.22	0.05	3	0.22	0.03	3			
1/30/2008	0.30	0.05	3	0.56	0.04	3	0.27	0.01	3	0.16	0.01	3			
5/21/2008	0.31	0.04	3				0.24	0.03	3						
8/19/2008	0.51	0.05	3	0.91	0.01	3	0.28	0.04	3						
11/13/2008	0.49	0.08	3	0.90	0.00	3	0.37	0.02	3	0.37	0.02	3	0.42	0.05	3
3/10/2009	0.48	0.05	3	0.73	0.11	3	0.21	0.02	3	0.23	0.01	3	0.35	0.04	3
6/18/2009	0.47	0.02	3	1.05	0.08	3	0.29	0.02	3	0.22	0.02	3	0.19	0.02	3
8/24/2009	0.41	0.08	3	0.79	0.09	3	0.20	0.03	3	0.19	0.02	3	0.14	0.02	3
11/17/2009	0.36	0.06	3	0.56	0.06	3	0.16	0.04	3	0.26	0.05	3	0.19	0.02	3
2/24/2010	0.48	0.05	3	0.91	0.03	3	0.40	0.07	3	0.43	0.05	3	0.37	0.06	3
5/12/2010	0.40	0.04	3	0.66	0.11	3	0.24	0.02	3	0.15	0.00	3	0.21	0.02	3
8/23/2010	0.47	0.03	3	0.52	0.02	3	0.27	0.01	3	0.18	0.04	3	0.17	0.03	3
11/29/2010	0.41	0.10	3	0.70	0.12	3	0.26	0.03	3	0.27	0.01	3	0.29	0.02	3
2/4/2011	0.41	0.06	3	0.71	0.18	3	0.35	0.02	3	0.42	0.01	3	0.54	0.22	3
4/27/2011	0.54	0.01	3	1.20	0.06	3	0.45	0.01	3	0.41	0.01	3	0.43	0.03	3
8/10/2011	0.55	0.07	3	0.83	0.12	3	0.26	0.03	3	0.33	0.00	3	0.23	0.05	3
10/26/2011				1.13	0.16	3	0.28	0.02	3	0.40	0.02	3	0.23	0.05	3

¹SE = Standard Error

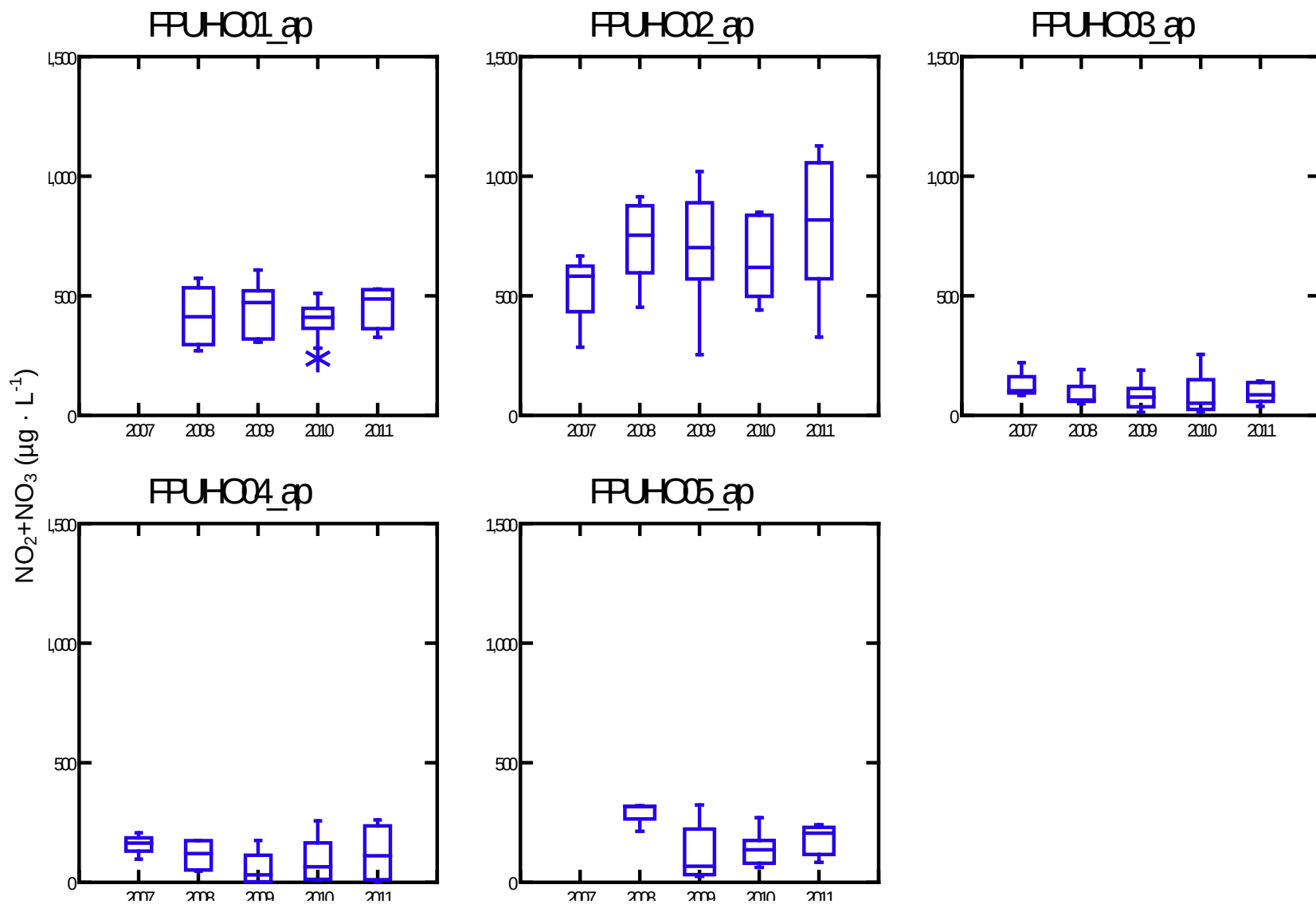
Nitrate + Nitrite

Figure 5. Box plots of nitrate + nitrite in Pu`uhonua o Hōnaunau NHP anchialine pools.

Table 10. Mean nitrate + nitrite ($\text{NO}_3 + \text{NO}_2$, $\mu\text{gN} \cdot \text{L}^{-1}$) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	$\text{NO}_3 + \text{NO}_2$	SE ¹	n	$\text{NO}_3 + \text{NO}_2$	SE ¹	n	$\text{NO}_3 + \text{NO}_2$	SE ¹	n	$\text{NO}_3 + \text{NO}_2$	SE ¹	n	$\text{NO}_3 + \text{NO}_2$	SE ¹	n
11/29/2007				511.0	115.6	3	135.3	42.7	3	156.0	32.0	3			
1/30/2008	330.7	50.1	3	541.7	45.2	3	59.3	3.7	3	55.0	6.1	3			
5/21/2008	354.7	48.2	3				72.0	11.1	3						
8/19/2008	487.3	46.4	3	900.3	12.2	3	64.3	11.7	3						
11/13/2008	480.0	90.0	3	753.0	3.5	3	169.3	12.7	3	174.0	0.6	3	283.0	35.0	3
3/10/2009	411.7	56.1	3	684.7	107.1	3	109.3	15.8	3	144.7	16.1	3	293.7	21.0	3
6/18/2009	521.4	43.0	3	925.2	37.2	3	58.1	4.9	3	1.9	0.9	3	29.1	2.3	3
8/24/2009	388.9	79.7	3	805.2	108.9	3	15.4	2.3	3	3.4	1.6	3	37.5	4.0	3
11/17/2009	443.3	61.8	3	446.6	109.5	3	134.1	28.2	3	88.7	16.4	3	126.6	32.7	3
2/24/2010	411.7	26.3	3	840.3	4.7	3	220.3	17.2	3	236.3	19.2	3	231.3	37.2	3
5/12/2010	367.0	44.1	3	664.3	117.8	3	84.3	9.8	3	11.3	1.2	3	110.0	16.6	3
8/23/2010	401.3	28.0	3	506.0	10.4	3	29.7	3.4	3	17.3	4.9	3	69.0	6.5	3
11/29/2010	401.0	83.5	3	581.3	93.2	3	21.3	3.3	3	119.7	9.0	3	163.7	14.1	3
2/4/2011	401.1	61.3	3	489.3	81.3	3	140.5	2.0	3	257.7	1.6	3	230.9	0.2	2
4/27/2011	526.7	0.6	3	1050.7	5.1	3	71.8	0.5	3	1.0	0.0	3	230.9	4.9	3
8/10/2011	434.6	37.3	3	729.4	104.0	3	41.7	2.4	3	22.1	0.9	3	105.3	11.2	3
10/26/2011				962.4	131.3	3	124.2	12.6	3	209.7	5.5	3	144.1	30.9	3

¹SE = Standard Error

Chlorophyll

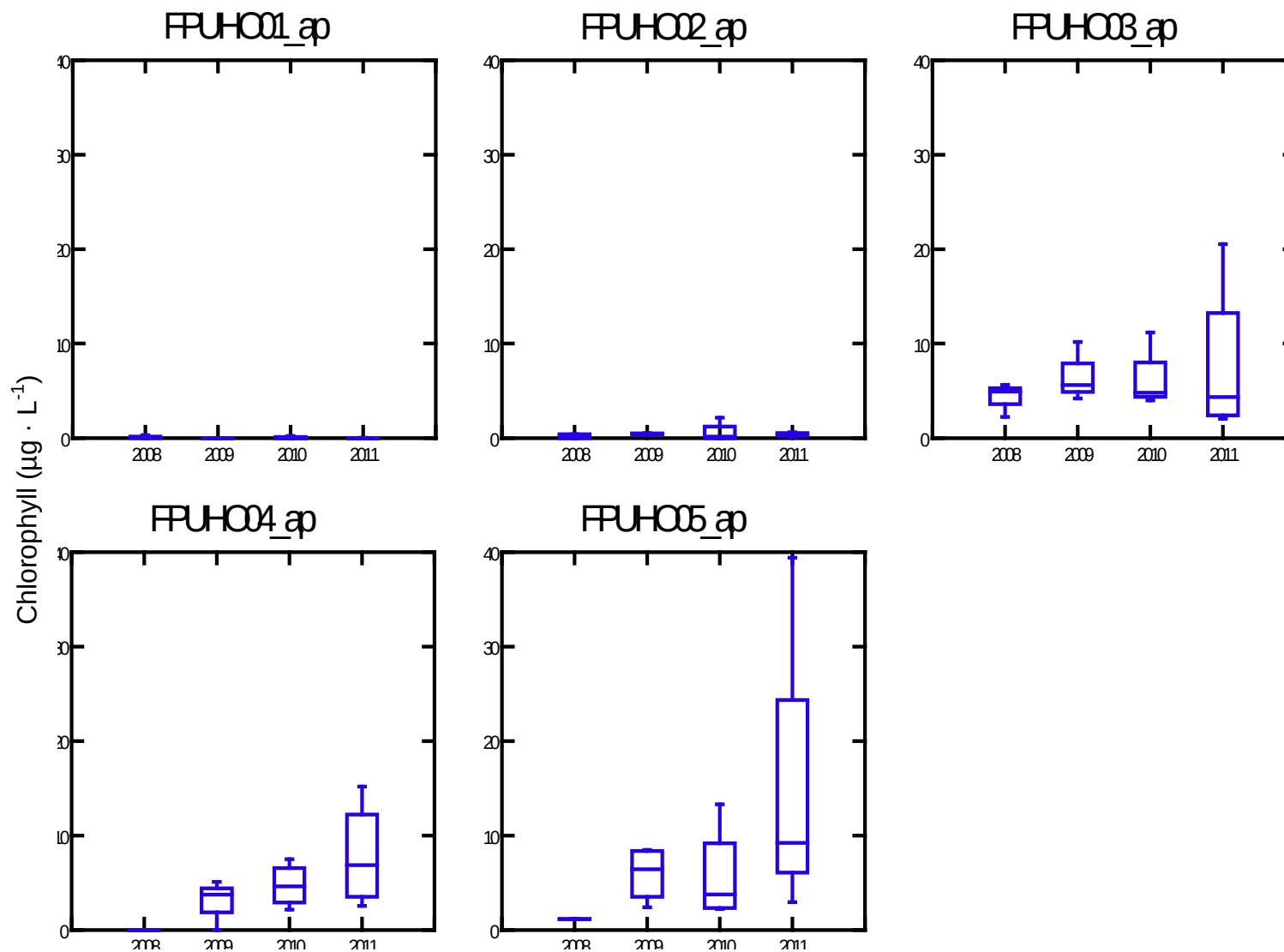


Figure 6. Box plots of chlorophyll in Pu`uhonua o Hōnaunau NHP anchialine pools.

Table 11. Mean chlorophyll (Chl-a, $\mu\text{g} \cdot \text{L}^{-1}$) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	Chl-a	SE ¹	n	Chl-a	SE ¹	n	Chl-a	SE ¹	n	Chl-a	SE ¹	n	Chl-a	SE ¹	n
5/21/2008	0.30	0.09	12				4.93	0.17	6						
8/19/2008	0.02	0.08	20	0.40	0.13	6	5.64	0.34	20				1.17	0.12	8
11/13/2008	0.00	0.00	10	0.00	0.00	10	2.24	0.33	14	0.00	0.00	15			
3/10/2009	0.00	0.00	16	0.46	0.32	15	5.62	0.27	14	3.75	0.33	9	2.41	0.32	12
6/18/2009	0.00	0.00	18				5.59	0.10	20	0.00	0.00	12	8.26	0.17	12
8/24/2009	0.00	0.00	12	0.31	0.06	16	10.18	0.13	19				8.47	0.22	19
11/17/2009	0.00	0.00	13	0.54	0.08	31	4.20	0.13	16	5.09	0.14	18	4.62	0.30	17
2/24/2010	0.21	0.17	18	0.30	0.16	18	3.99	0.32	10	2.16	0.27	16	2.22	0.09	19
5/12/2010	0.00	0.00	15	0.00	0.00	17	4.75	0.35	24	3.65	0.25	17	5.06	0.11	22
8/23/2010	0.00	0.00	20	0.00	0.00	14	4.86	0.15	18	5.60	1.96	16	2.45	0.16	11
11/29/2010	0.00	0.00	12	2.15	0.12	14	11.18	0.11	16	7.51	0.09	19	13.31	0.11	14
2/4/2011	0.02	0.10	14	0.61	0.09	14	20.54	0.53	17	15.18	0.57	19	39.42	0.93	17
4/27/2011	0.00	0.00	17	0.09	0.11	15	2.75	0.07	16	2.56	0.16	21	9.26	0.09	17
8/10/2011	0.00	0.00	15	0.39	0.10	11	2.05	0.40	11	4.49	0.09	15	9.19	0.11	13
10/26/2011				0.44	0.07	16	5.95	0.09	15	9.26	0.89	14	2.96	0.25	13

¹SE = Standard Error

Oxygen Concentration

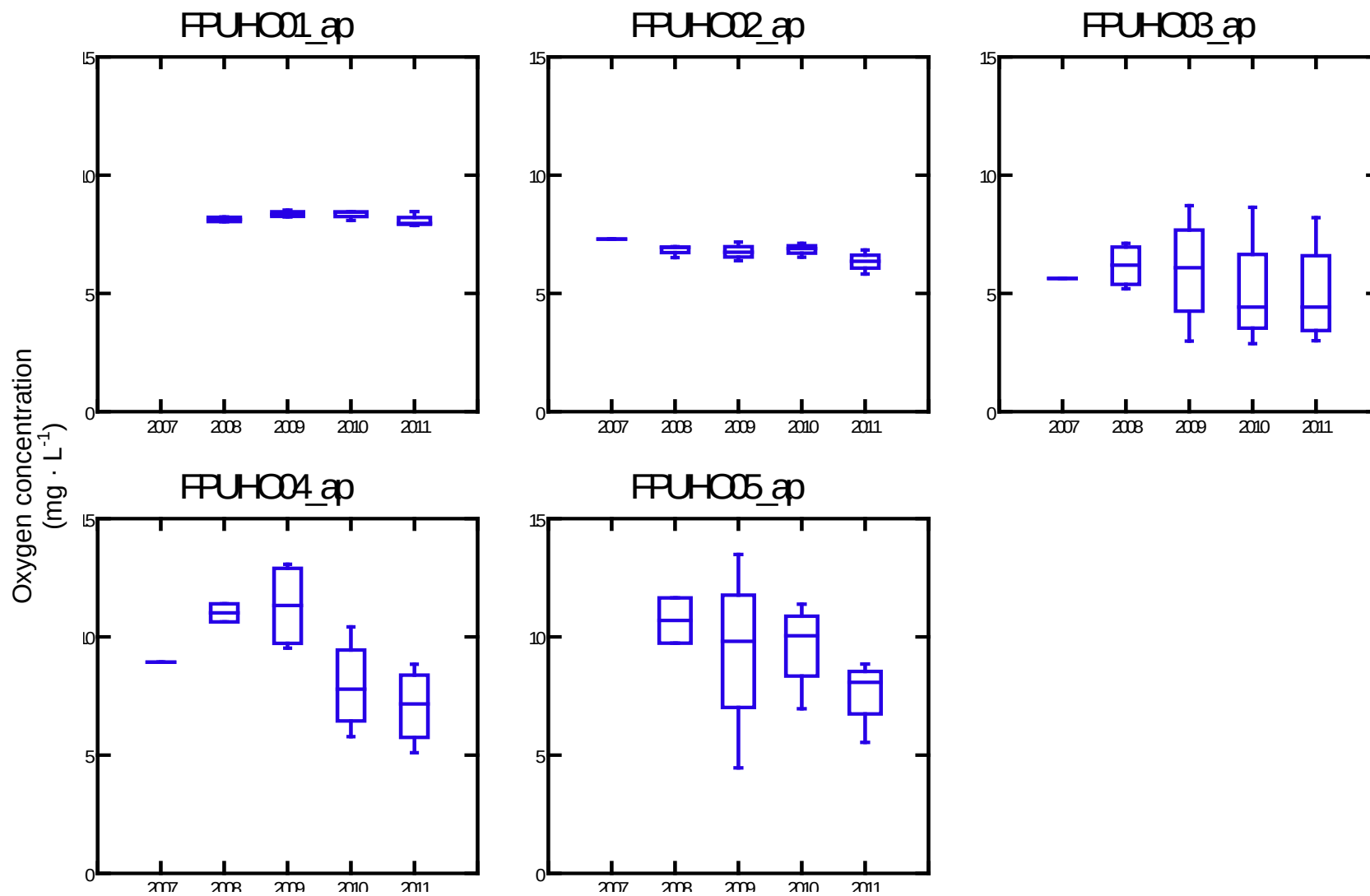


Figure 7. Box plots of oxygen concentration in Pu`uhonua o Hōnaunau NHP anchialine pools.

Table 12. Mean oxygen concentration (ODO, mg · L⁻¹) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	ODO	SE ¹	n	ODO	SE ¹	n	ODO	SE ¹	n	ODO	SE ¹	n	ODO	SE ¹	n
11/29/2007				7.29	0.02	16	5.63	0.02	10	8.93	0.04	13			
1/30/2008	8.03	0.01	17	6.97	0.02	19	7.11	0.03	20	11.40	0.06	16			
5/21/2008	8.20	0.00	12				6.81	0.01	6						
8/19/2008	8.23	0.01	20	6.94	0.01	6	5.57	0.01	20				11.65	0.04	8
11/13/2008	8.04	0.10	10	6.51	0.01	10	5.19	0.09	14	10.63	0.07	15	9.73	0.09	9
3/10/2009	8.23	0.01	16	7.17	0.01	15	5.52	0.02	14	9.52	0.04	9	9.57	0.03	12
6/18/2009	8.38	0.00	18	6.78	0.01	18	2.98	0.03	20	9.93	0.06	12	4.46	0.00	12
8/24/2009	8.52	0.02	12	6.38	0.01	16	8.71	0.01	19	12.73	0.05	16	13.48	0.09	19
11/17/2009	8.28	0.03	13	6.69	0.02	31	6.64	0.00	16	13.07	0.02	18	10.05	0.03	17
2/24/2010	8.08	0.02	18	6.87	0.07	18	4.18	0.01	10	5.78	0.02	16	6.96	0.03	19
5/12/2010	8.44	0.01	15	7.11	0.02	17	4.65	0.01	24	8.47	0.02	17	10.36	0.05	22
8/23/2010	8.45	0.01	20	6.92	0.03	14	2.87	0.03	18	7.11	0.03	16	9.73	0.05	11
11/29/2010	8.42	0.00	12	6.53	0.01	14	8.64	0.02	16	10.42	0.01	19	11.38	0.08	14
2/4/2011	8.46	0.01	14	6.83	0.01	14	3.00	0.02	17	5.10	0.03	19	5.54	0.02	17
4/27/2011	7.87	0.01	17	5.82	0.04	15	3.85	0.01	16	8.84	0.05	21	7.94	0.06	17
8/10/2011	7.96	0.02	15	6.39	0.03	11	8.20	0.02	11	6.40	0.03	15	8.85	0.02	13
10/26/2011				6.32	0.00	16	4.98	0.03	15	7.92	0.02	14	8.22	0.03	13

¹SE = Standard Error

Oxygen Saturation

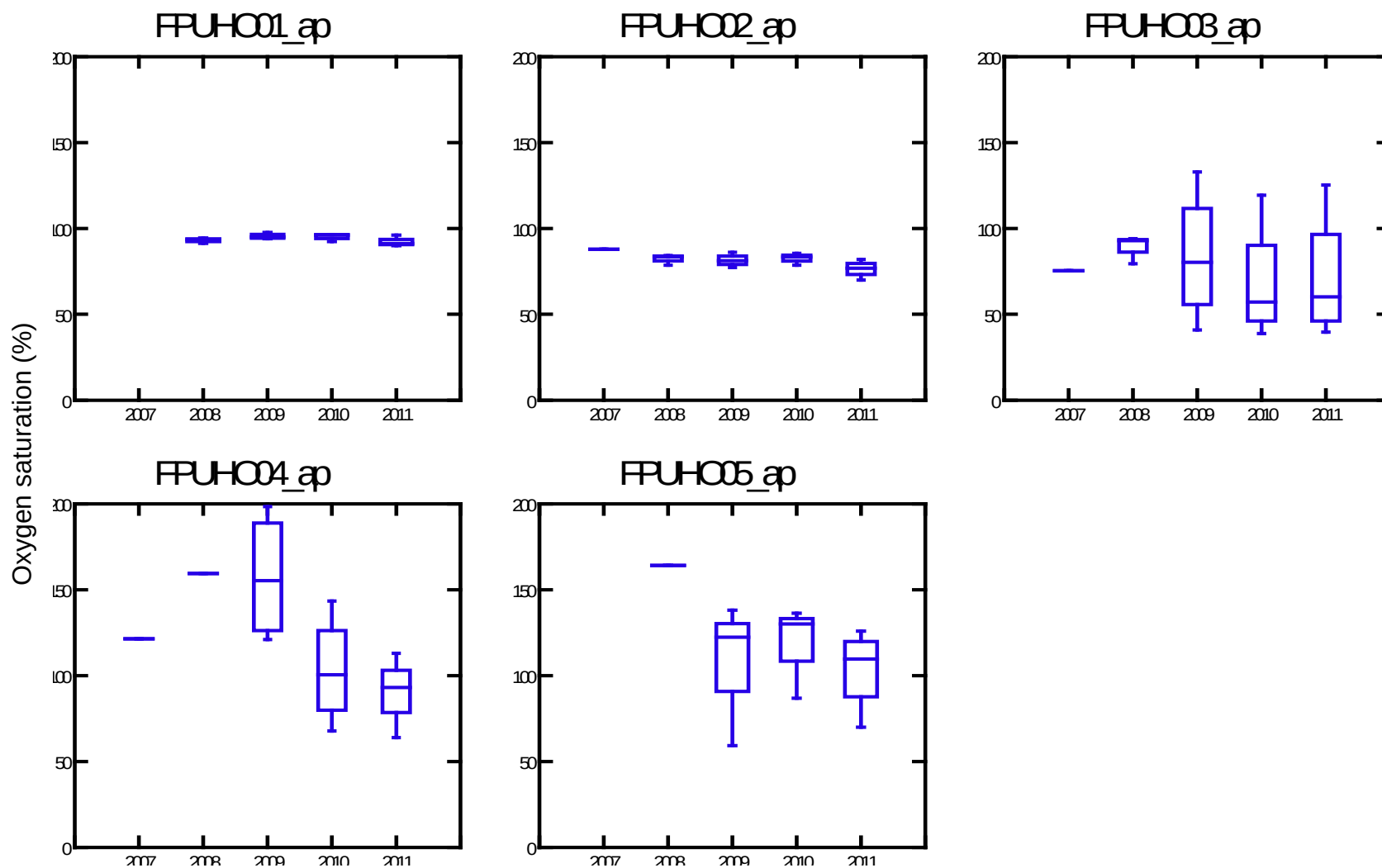


Figure 8. Box plots of oxygen saturation in Pu`uhonua o Hōnaunau NHP anchialine pools.

Table 13. Mean oxygen saturation (%) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	%	SE ¹	n	%	SE ¹	n	%	SE ¹	n	%	SE ¹	n	%	SE ¹	n
11/29/2007				87.8	0.2	16	75.4	0.3	10	121.4	0.4	13			
1/30/2008	91.3	0.1	17	83.5	0.3	19	94.0	0.3	20	159.4	0.7	16			
5/21/2008	93.4	0.1	12				92.9	0.1	6						
8/19/2008	94.5	0.1	20	84.2	0.1	6	79.5	0.2	20				164.2	0.5	8
11/13/2008				78.6	0.1	10									
3/10/2009	94.0	0.1	16	86.1	0.2	15	70.3	0.3	14	121.0	0.6	9	122.4	0.4	12
6/18/2009	95.4	0.0	18	81.7	0.1	18	40.9	0.5	20	131.5	0.8	12	59.2	0.1	12
8/24/2009	97.6	0.3	12	77.3	0.2	16	132.9	0.1	19	198.4	0.8	16			
11/17/2009	94.7	0.3	13	80.7	0.2	31	90.3	0.1	16	179.2	0.3	18	138.2	0.5	17
2/24/2010	92.3	0.2	18				53.3	0.1	10	67.8	0.3	16	86.8	0.4	19
5/12/2010	96.3	0.1	15	85.4	0.3	17	61.0	0.1	24	109.0	0.3	17	136.3	0.6	22
8/23/2010	96.5	0.1	20	83.4	0.4	14	38.8	0.4	18	91.9	0.5	16	130.1	0.7	11
11/29/2010	95.9	0.1	12	78.6	0.1	14	119.4	0.2	16	143.4	0.1	19			
2/4/2011	96.1	0.1	14	82.0	0.1	14	39.6	0.3	17	64.0	0.3	19	70.0	0.2	17
4/27/2011	90.0	0.1	17	69.9	0.5	15	52.5	0.1	16				105.3	0.8	17
8/10/2011	91.2	0.2	15	77.2	0.4	11	125.2	0.4	11	93.1	0.5	15	125.9	0.2	13
10/26/2011				76.5	0.1	16	67.7	0.4	15	113.0	0.3	14	113.9	0.4	13

¹SE = Standard Error

30

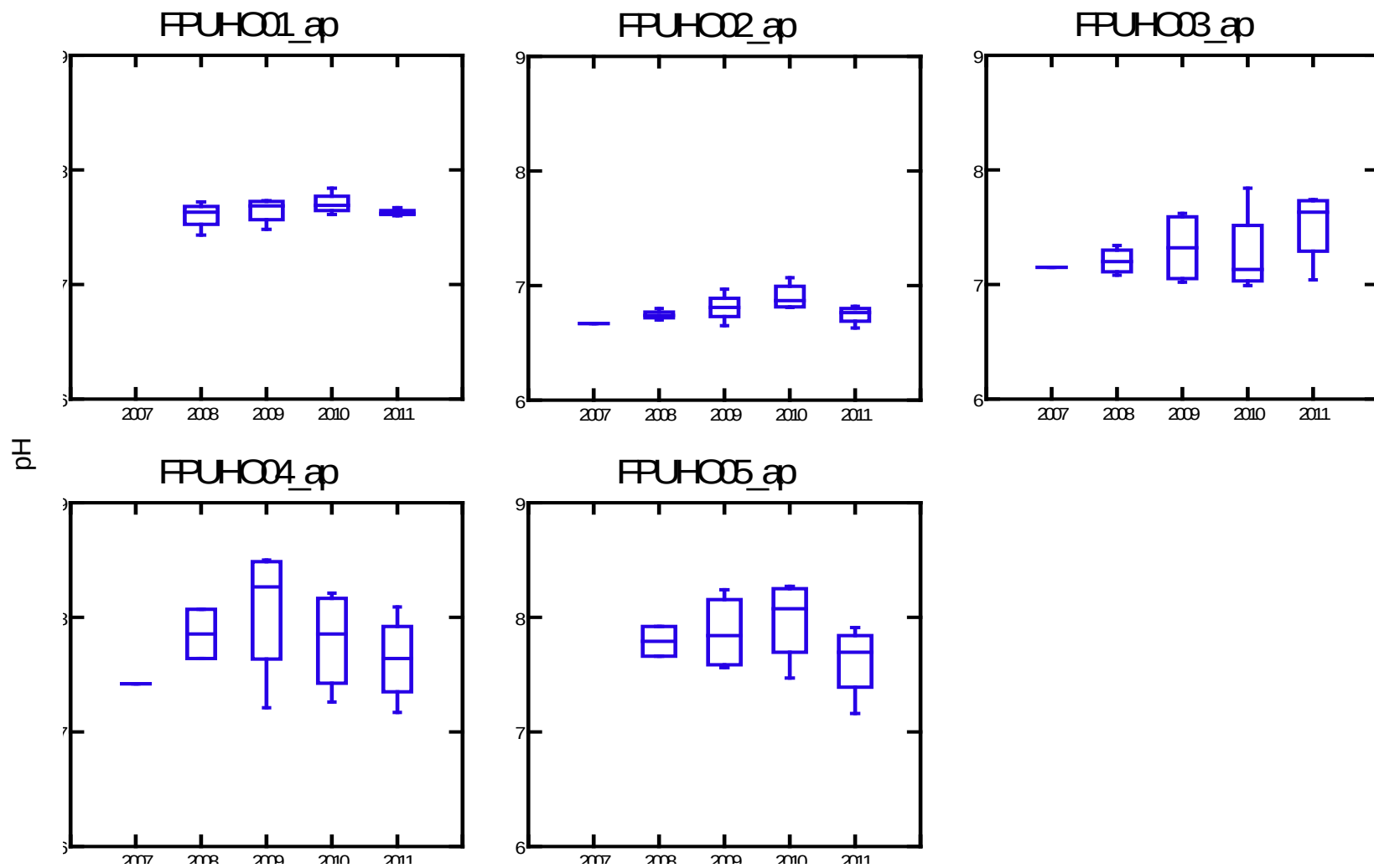


Figure 9. Box plots of pH in Pu`uhonua o Hōnaunau NHP anchialine pools.

Table 14. Mean pH in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	pH	SE ¹	n	pH	SE ¹	n	pH	SE ¹	n	pH	SE ¹	n	pH	SE ¹	n
11/29/2007				6.67	0.00	16	7.15	0.00	10	7.42	0.00	13			
1/30/2008	7.43	0.01	17	6.74	0.02	19	7.08	0.01	20	8.07	0.01	16			
5/21/2008	7.64	0.00	12				7.34	0.00	6						
8/19/2008	7.62	0.00	20	6.80	0.02	6	7.26	0.00	20				7.92	0.00	8
11/13/2008	7.72	0.01	10	6.70	0.01	10	7.14	0.00	14	7.64	0.00	15	7.66	0.01	9
3/10/2009	7.48	0.01	16	6.81	0.00	15	7.02	0.01	14	7.21	0.03	9	7.61	0.00	12
6/18/2009	7.73	0.00	18	6.81	0.01	18	7.08	0.00	20	8.06	0.00	12	7.56	0.00	12
8/24/2009	7.65	0.00	12	6.65	0.01	16	7.62	0.00	19	8.50	0.00	16	8.24	0.00	19
11/17/2009	7.72	0.01	13	6.97	0.00	31	7.56	0.01	16	8.47	0.00	18	8.07	0.01	17
2/24/2010	7.68	0.01	18	7.07	0.02	18	7.07	0.00	10	7.26	0.01	16	7.47	0.01	19
5/12/2010	7.84	0.01	15	6.92	0.00	17	7.19	0.00	24	8.12	0.00	17	8.27	0.00	22
8/23/2010	7.70	0.01	20	6.81	0.01	14	6.99	0.00	18	7.59	0.01	16	7.92	0.00	11
11/29/2010	7.61	0.01	12	6.82	0.01	14	7.84	0.00	16	8.21	0.01	19	8.23	0.01	14
2/4/2011	7.60	0.00	14	6.78	0.01	14	7.04	0.00	17	7.17	0.00	19	7.16	0.00	17
4/27/2011	7.62	0.00	17	6.82	0.00	15	7.72	0.00	16	8.09	0.00	21	7.77	0.00	17
8/10/2011	7.67	0.00	15	6.75	0.00	11	7.74	0.00	11	7.75	0.00	15	7.91	0.00	13
10/26/2011				6.63	0.00	16	7.54	0.00	15	7.53	0.00	14	7.62	0.01	13

¹SE = Standard Error

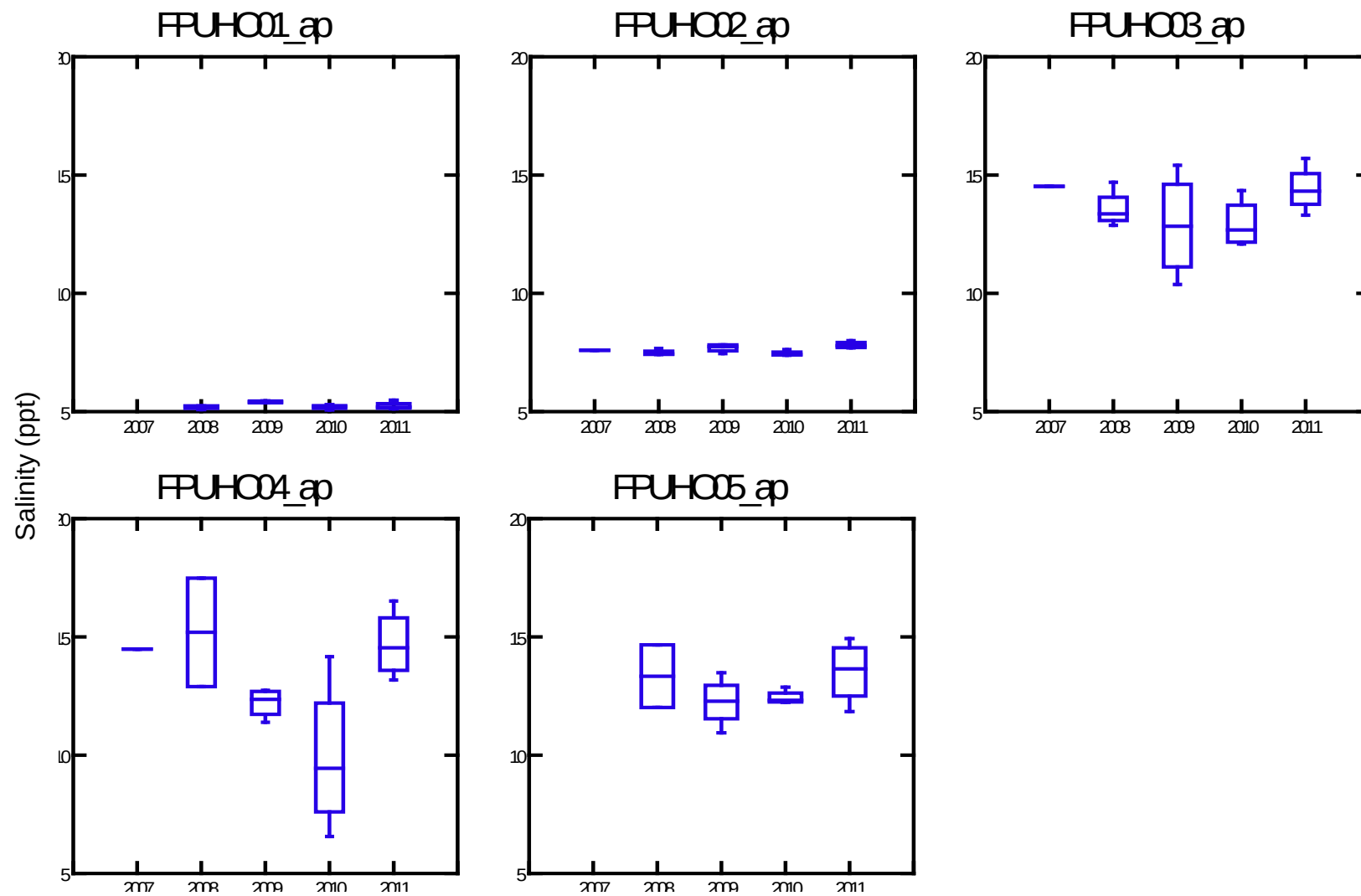
Salinity

Figure 10. Box plots of salinity in Pu`uhonua o Hōnaunau NHP anachialine pools.

Table 15. Mean salinity (ppt) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	ppt	SE ¹	n	ppt	SE ¹	n	ppt	SE ¹	n	ppt	SE ¹	n	ppt	SE ¹	n
11/29/2007				7.59	0.00	16	14.52	0.01	10	14.48	0.01	13			
1/30/2008	5.24	0.00	17	7.43	0.02	19	13.43	0.01	20	12.90	0.01	16			
5/21/2008	5.20	0.00	12				13.28	0.00	6						
8/19/2008	5.24	0.00	20	7.41	0.01	6	12.87	0.00	20				12.01	0.00	8
11/13/2008	5.08	0.00	10	7.67	0.00	10	14.69	0.01	14	17.48	0.01	15	14.66	0.01	9
3/10/2009	5.45	0.00	16	7.82	0.00	15	11.86	0.01	14	11.39	0.00	9	12.42	0.00	12
6/18/2009	5.37	0.00	18	7.45	0.00	18	13.80	0.01	20	12.65	0.01	12	12.14	0.00	12
8/24/2009	5.37	0.00	12	7.82	0.00	16	15.41	0.00	19	12.74	0.00	16	10.94	0.01	19
11/17/2009	5.44	0.00	13	7.68	0.00	31	10.37	0.00	16	12.06	0.00	18	13.48	0.00	17
2/24/2010	5.20	0.00	18	7.41	0.00	18	13.11	0.00	10	6.56	0.01	16	12.23	0.00	19
5/12/2010	5.21	0.00	15	7.38	0.00	17	12.08	0.00	24	10.25	0.00	17	12.27	0.00	22
8/23/2010	5.29	0.00	20	7.62	0.00	14	12.24	0.00	18	8.64	0.03	16	12.87	0.00	11
11/29/2010	5.07	0.00	12	7.41	0.00	14	14.34	0.00	16	14.16	0.00	19	12.37	0.00	14
2/4/2011	5.11	0.00	14	7.83	0.00	14	14.23	0.00	17	13.99	0.00	19	13.15	0.00	17
4/27/2011	5.48	0.00	17	7.69	0.00	15	13.30	0.00	16	13.18	0.00	21	11.84	0.00	17
8/10/2011	5.18	0.00	15	7.72	0.00	11	15.70	0.00	11	15.09	0.00	15	14.15	0.00	13
10/26/2011				8.00	0.00	16	14.41	0.00	15	16.51	0.00	14	14.93	0.00	13

¹SE = Standard Error

Specific Conductance

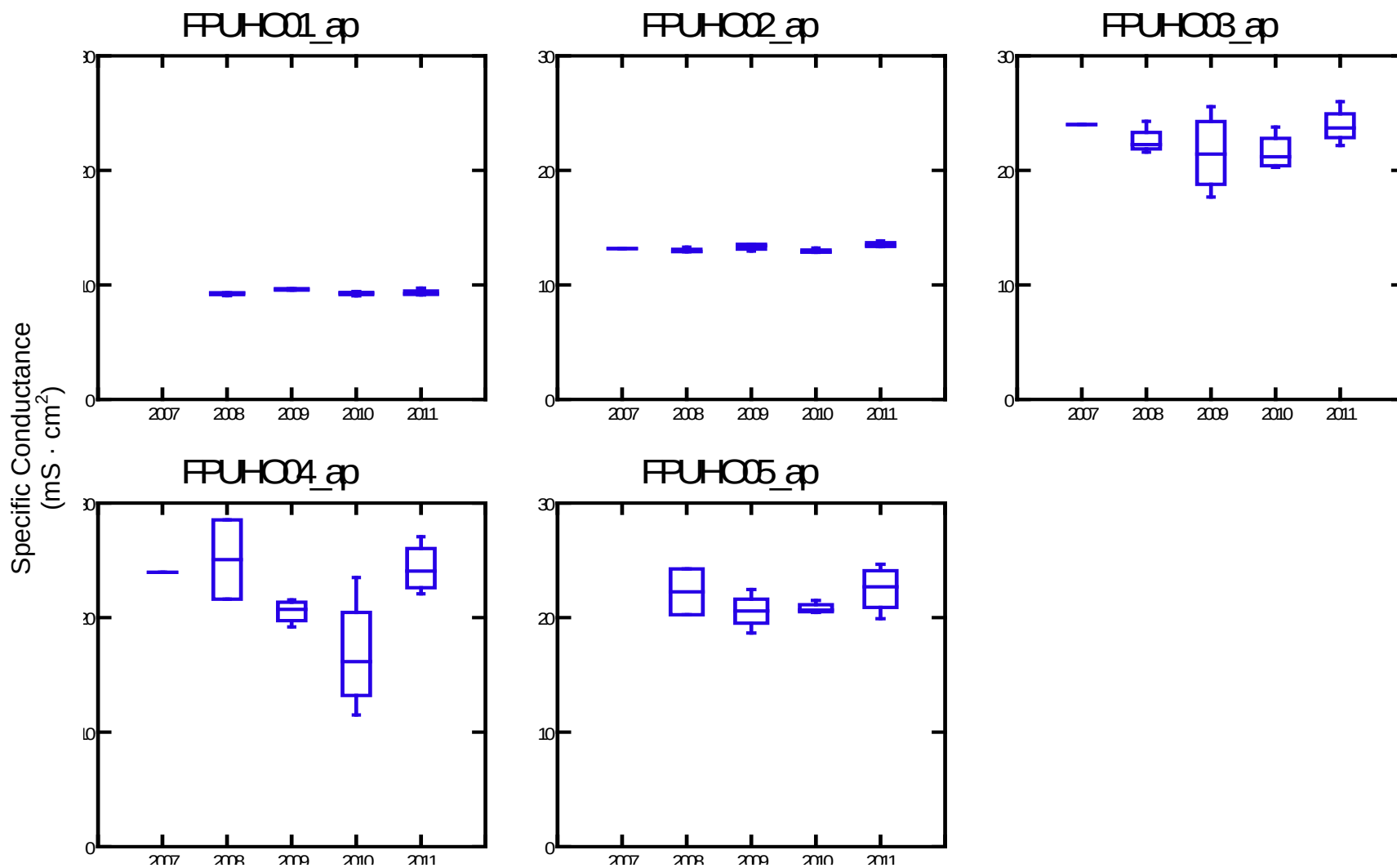


Figure 11. Box plots of specific conductance in Pu`uhonua o Hōnaunau NHP anchialine pools.

Table 16. Mean Specific Conductance SpC ($\text{mS} \cdot \text{cm}^{-1}$) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	SpC	SE ¹	n	SpC	SE ¹	n	SpC	SE ¹	n	SpC	SE ¹	n	SpC	SE ¹	n
11/29/2007				13.17	0.00	16	24.00	0.01	10	23.95	0.01	13			
1/30/2008	9.31	0.00	17	12.91	0.03	19	22.34	0.02	20	21.60	0.01	16			
5/21/2008	9.25	0.00	12				22.15	0.00	6						
8/19/2008	9.31	0.00	20	12.88	0.01	6	21.59	0.01	20				20.24	0.01	8
11/13/2008	9.06	0.01	10	13.29	0.00	10	24.28	0.01	14	28.52	0.01	15	24.24	0.02	9
3/10/2009	9.67	0.00	16	13.53	0.00	15	19.89	0.01	14	19.18	0.00	9	20.77	0.00	12
6/18/2009	9.54	0.00	18	12.94	0.01	18	22.95	0.01	20	21.15	0.02	12	20.37	0.00	12
8/24/2009	9.54	0.01	12	13.54	0.00	16	25.56	0.00	19	21.54	0.00	16	18.65	0.01	19
11/17/2009	9.65	0.00	13	13.31	0.00	31	17.66	0.01	16	20.29	0.00	18	22.45	0.00	17
2/24/2010	9.25	0.00	18	12.88	0.00	18	21.81	0.01	10	11.50	0.01	16	20.45	0.00	19
5/12/2010	9.26	0.00	15	12.83	0.00	17	20.26	0.00	24	17.42	0.01	17	20.56	0.00	22
8/23/2010	9.41	0.00	20	13.21	0.01	14	20.54	0.00	18	14.89	0.04	16	21.50	0.00	11
11/29/2010	9.04	0.00	12	12.88	0.00	14	23.77	0.00	16	23.49	0.00	19	20.74	0.00	14
2/4/2011	9.11	0.01	14	13.54	0.00	14	23.54	0.00	17	23.13	0.00	19	21.86	0.00	17
4/27/2011	9.71	0.00	17	13.33	0.00	15	22.17	0.00	16	22.07	0.00	21	19.91	0.00	17
8/10/2011	9.22	0.00	15	13.37	0.00	11	25.99	0.01	11	24.98	0.00	15	23.52	0.01	13
10/26/2011				13.83	0.00	16	23.86	0.01	15	27.06	0.01	14	24.66	0.00	13

¹SE = Standard Error

Temperature

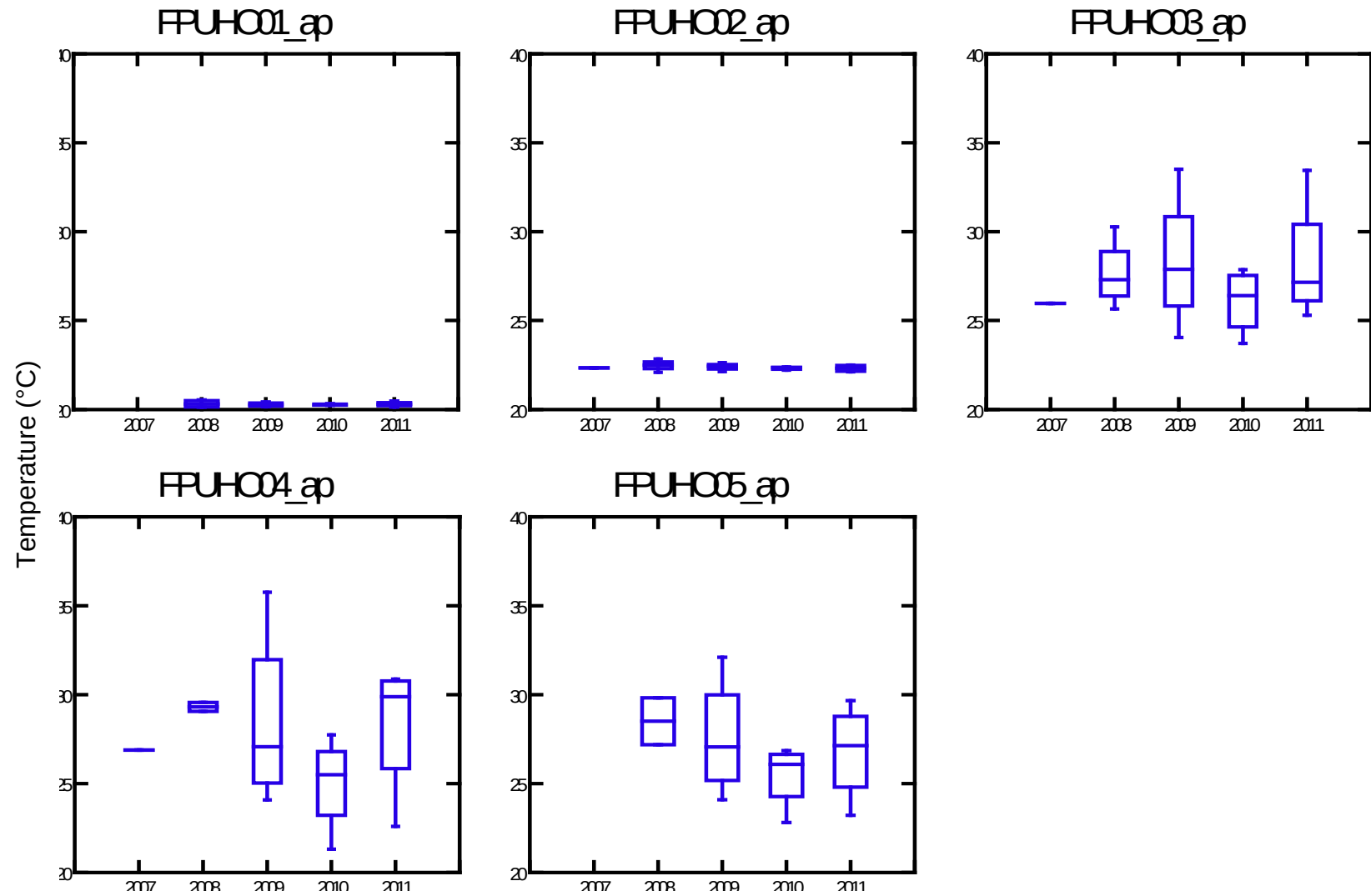


Figure 12. Box plots of temperature in Pu`uhonua o Hōnaunau NHP anachialine pools.

Table 17. Mean temperature (°C) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	Temp	SE ¹	n	Temp	SE ¹	n	Temp	SE ¹	n	Temp	SE ¹	n	Temp	SE ¹	n
11/29/2007				22.34	0.00	16	25.96	0.01	10	26.88	0.05	13			
1/30/2008	20.13	0.00	17	22.09	0.00	19	25.65	0.02	20	29.06	0.07	16			
5/21/2008	20.16	0.00	12				27.49	0.01	6						
8/19/2008	20.54	0.01	20	22.84	0.04	6	30.27	0.02	20				29.82	0.02	8
11/13/2008	20.45	0.01	10	22.50	0.01	10	27.11	0.02	14	29.56	0.03	15	27.19	0.04	9
3/10/2009	20.24	0.01	16	22.13	0.01	15	24.05	0.01	14	24.08	0.01	9	24.09	0.01	12
6/18/2009	20.15	0.01	18	22.43	0.01	18	27.58	0.00	20	25.97	0.00	12	26.26	0.00	12
8/24/2009	20.42	0.04	12	22.63	0.01	16	33.50	0.01	19	35.76	0.01	16	32.10	0.01	19
11/17/2009	20.29	0.00	13	22.43	0.00	31	28.18	0.00	16	28.17	0.01	18	27.87	0.01	17
2/24/2010	20.33	0.01	18	22.21	0.01	18	23.71	0.01	10	21.31	0.02	16	22.81	0.01	19
5/12/2010	20.27	0.00	15	22.33	0.02	17	25.58	0.01	24	25.13	0.02	17	25.73	0.00	22
8/23/2010	20.25	0.00	20	22.36	0.01	14	27.22	0.01	18	25.86	0.05	16	26.43	0.01	11
11/29/2010	20.23	0.00	12	22.39	0.01	14	27.86	0.01	16	27.74	0.01	19	26.85	0.00	14
2/4/2011	20.13	0.01	14	22.12	0.00	14	25.30	0.01	17	22.59	0.01	19	23.22	0.00	17
4/27/2011	20.30	0.00	17	22.18	0.00	15	27.39	0.02	16	30.87	0.04	21	26.38	0.01	17
8/10/2011	20.47	0.00	15	22.49	0.00	11	33.44	0.03	11	30.67	0.01	15	29.66	0.02	13
10/26/2011				22.46	0.00	16	26.92	0.02	15	29.10	0.01	14	27.89	0.01	13

¹SE = Standard Error

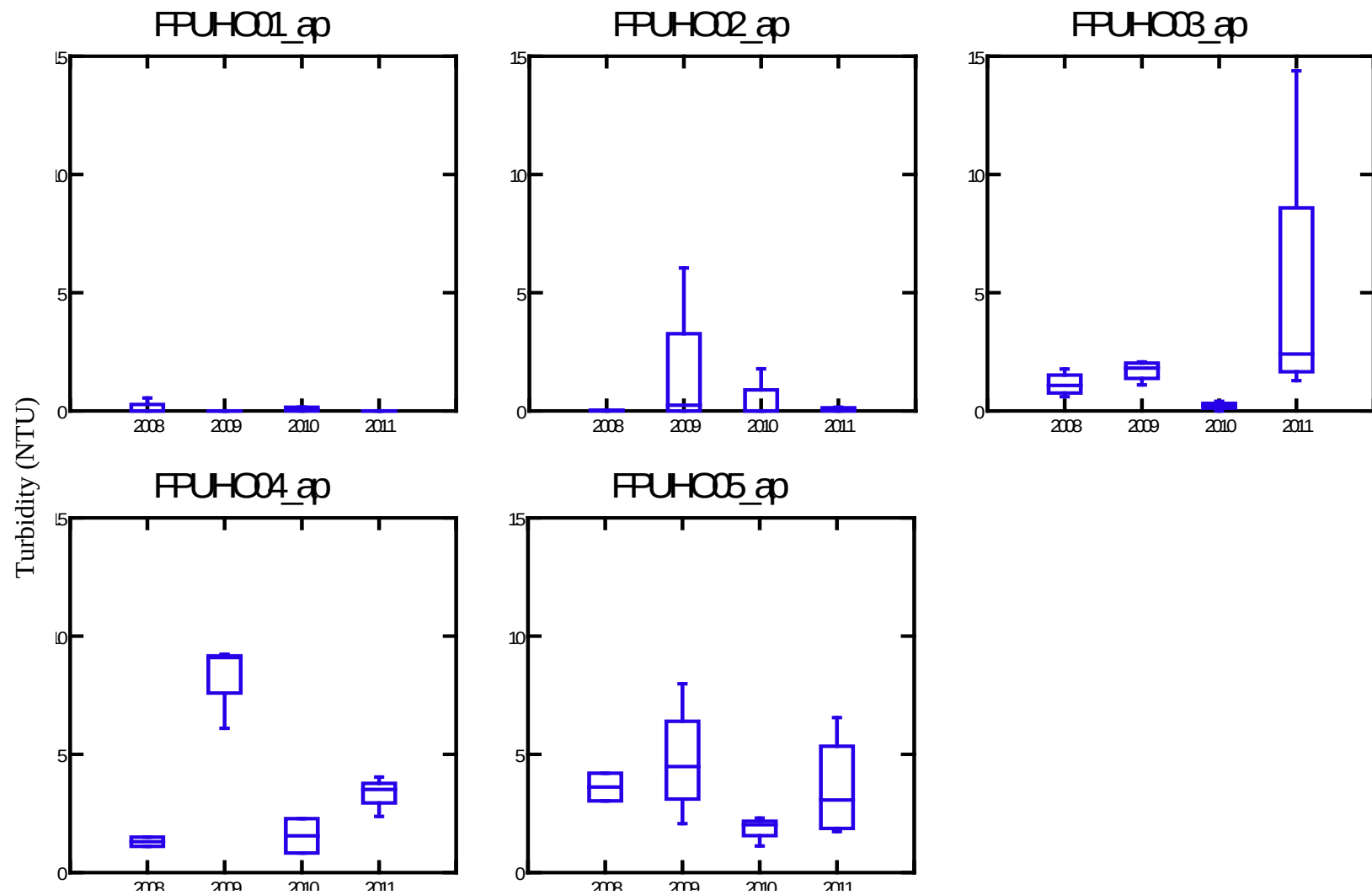
Turbidity

Figure 13. Box plots of turbidity in Pu`uhonua o Hōnaunau NHP anchialine pools.

Table 18. Mean turbidity (NTU) in Pu`uhonua o Hōnaunau NHP anchialine pools.

	FPUHO01_ap			FPUHO02_ap			FPUHO03_ap			FPUHO04_ap			FPUHO05_ap		
Date	NTU	SE ¹	n	NTU	SE ¹	n	NTU	SE ¹	n	NTU	SE ¹	n	NTU	SE ¹	n
1/30/2008	0.00	0.00	17				0.90	0.05	20	1.11	0.19	16			
5/21/2008	0.00	0.00	12				1.25	0.12	6						
8/19/2008	0.54	0.37	20	0.00	0.00	6	1.77	0.07	20				3.03	0.10	8
11/13/2008	0.00	0.00	10	0.03	0.10	10	0.60	0.03	14	1.50	0.08	15	4.20	0.21	9
3/10/2009	0.00	0.00	16	0.48	0.21	15	1.64	0.14	14				4.82	0.29	12
6/18/2009				0.00	0.00	18	1.10	0.41	20	9.09	0.39	12	2.07	0.09	12
8/24/2009	0.00	0.00	12	0.00	0.00	16	1.97	0.12	19	9.23	0.30	16	4.14	0.20	19
11/17/2009	0.00	0.00	13	6.04	0.36	31	2.07	0.11	16	6.10	0.18	18	7.98	0.70	17
2/24/2010	0.16	0.06	18	1.78	0.49	18	0.40	0.52	10				2.04	0.05	19
5/12/2010	0.14	0.08	15	0.00	0.00	17				2.28	0.20	17	2.30	0.08	22
8/23/2010	0.00	0.00	20				0.23	0.08	18				2.00	0.16	11
11/29/2010	0.00	0.00	12	0.00	0.00	14	0.00	0.00	16	0.83	0.07	19	1.12	0.08	14
2/4/2011	0.00	0.00	14	0.11	0.03	14	2.02	0.17	17	4.04	0.19	19	2.00	0.06	17
4/27/2011	0.00	0.00	17	0.00	0.00	15	14.38	0.40	16				6.55	0.10	17
8/10/2011	0.00	0.00	15	0.00	0.00	11	2.79	0.05	11	2.37	0.17	15	1.73	0.05	13
10/26/2011				0.15	0.02	16	1.28	0.03	15	3.51	0.42	14	4.14	0.34	13

¹SE = Standard Error

Discussion

Five anchialine pools in Pu`uhonua o Hōnaunau NHP were sampled quarterly from the last quarter of 2007 through 2011. During this time no major ecological events were detected in pools. Relatively minor algal blooms may have occurred in February 2011 in FPUHO03_ap, FPUHO04_ap, and FPUHO05_ap, as indicated by chlorophyll. Later, a tsunami hit Hawaii on March 11, 2011, which inundated anchialine pools with seawater along the Kona coast, including FPUHO03_ap, FPUHO04_ap, and FPUHO05_ap. Pools were sampled 16 days later, but there were no residual effects observed in pool chemistry.

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