



Water Quality in Streams of Haleakala National Park

Summary Report 2007-2011

Natural Resource Data Series NPS/PACN/NRDS—2016/1007



ON THE COVER

Piipiwai stream in Haleakala National Park, Maui, Hawaii, USA.

Photograph by: David Raikow

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February 2016

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Please cite this publication as:

Raikow, D. F., and A. Farahi. 2016. Water quality in streams of Haleakala National Park: Summary report 2007-2011. Natural Resource Data Series NPS/PACN/NRDS—2016/1007. National Park Service, Fort Collins, Colorado.

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Abstract

This Natural Resource Data Series Report (NRDS) presents data collected from Pipiwai Stream, Palikea Stream, and Alelele Stream in Haleakala National Park on the island of Maui, Hawaii, 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 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 Report (NRR) series. The purpose of collecting data on Vital Signs is to provide park managers information on current conditions and temporal trends in ecosystem health. Alelele Stream and Palikea Stream exceeded state water quality criteria for Nitrate + Nitrite in some years and seasons. Palikea Stream and Pipiwai Stream exceeded state water quality criteria for turbidity in 2007. Because dissolved nutrient concentrations do not include particulate nutrient concentrations, total nutrient concentrations, in which state criteria are written, will be higher in the stream. Thus, while dissolved nutrient levels in streams did not exceed the state total phosphorus (TP) and total nitrogen (TN) criteria, the stream may in fact exceed state criteria at all times due to additional phosphorus in particulate form. Similar values in water quality parameters were observed in all three streams, with possible exception of slightly dissolved nitrogen (total and nitrate + nitrite) concentrations in Alelele Stream.

Acknowledgments

We thank Matt Brown and the staff of HALE 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
HALE	Haleakala National Park
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
NRR	Natural Resource Report
NTU	Nephelometric Turbidity Units
ODO	Optical Dissolved Oxygen
ODOsat	Optical Dissolved Oxygen in terms of saturation
PACN	Pacific Island Inventory and Monitoring Network
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
Temp	Temperature
TN	Total Nitrogen
TP	Total Phosphorus
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) in Piiwai Stream, Palikea Stream, and Alelele Stream in Haleakala National Park on the island of Maui, Hawaii, USA, between 2007-2011.

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).

Water quality criteria for streams are defined in §11-54-5.1b of the State of Hawai'i Department of Health Water Quality Standards (Hawaii 2012, Table 1). Streams in Hawaiian national parks are classified as Class 1.a protected waters (Hawaii 2012). Criteria in the water column are defined for the wet season (November 1 - April 30) and the dry season (May 1 - October 31). Criteria are defined for total phosphorus, total nitrogen, nitrate + nitrite, total suspended solids, and turbidity in terms of a geometric mean not to be exceeded, and values not to be exceeded 10% and 2% of the time. The arithmetic mean, or average, of a set of values is defined as the sum of those values divided by the count, and the geometric mean is the n^{th} root of the product of n values.

Nutrients can be classified as particulate or dissolved. Total phosphorus (TP) is the sum of particulate phosphorus (PP) and total dissolved phosphorus (TDP), and total nitrogen is the sum of particulate nitrogen (PN) and total dissolved nitrogen (TDN). TDN or TDP values that exceed state criteria indicate impaired waters, but TDN or TDP values that do not exceed state criteria do not indicate non-impaired waters because of unknown PN and PP values.

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 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).

Table 1. State of Hawaii specific inland water criteria for streams (Hawaii 2012).

Parameter	Unit	Season	Geometric mean not to exceed the given value	Not to exceed the given value more than 10% of the time	Not to exceed the given value more than 2% of the time
Total Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Wet ¹	50.0	100.0	150.0
		Dry ²	30.0	60.0	80.0
Total Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Wet	0.250	0.520	0.800
		Dry	0.180	0.380	0.600
Nitrate + Nitrite	$\mu\text{gN} \cdot \text{L}^{-1}$	Wet	70.0	180.0	300.0
		Dry	30.0	90.0	170.0
Total Suspended Solids	$\text{mg} \cdot \text{L}^{-1}$	Wet	20.0	50.0	80.0
		Dry	10.0	30.0	55.0
Turbidity	NTU	Wet	5.0	15.0	25.0
		Dry	2.0	5.5	10.0

¹Wet season: November 1 - April 30.

²Dry season: May 1 - October 31.

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

Haleakala National Park is located on the island of Maui. Site names used by I&M were formatted to designate fixed or temporary sites (“F” or “T” respectively), park (HALE), a number (e.g. 01), and habitat type (“fw” for freshwater); e.g. “FHALE01_fw” (Table 2, Figs. 1-3). Names for temporary sites were based on the date of sampling. Sites were sampled during quarterly trips from November 2007 - November 2011 (Table 3). A new set of four temporary sites were chosen at random for each quarterly trip.

Table 2. Sample site locations at Haleakala National Park.

I&M site designation	Stream	Decimal Degrees Latitude	Decimal Degrees Longitude
FHALE01_fw	Piipiwai	20.66339	-156.04226
FHALE02_fw	Palikea	20.66827	-156.05212
FHALE03_fw	Piipiwai	20.67783	-156.05646
FHALE05_fw	Alelele	20.64824	-156.08487
FHALE06_fw	Alelele	20.65030	-156.08607
FHALE07_fw	Piipiwai	20.66925	-156.05767
FHALE08_fw	Piipiwai	20.67043	-156.05425
FHALE09_fw	Palikea	20.66415	-156.04560
FHALE10_fw	Alelele	20.65314	-156.08602
THALE0520120423	Alelele	20.64979	-156.08609
THALE0720091020	Alelele	20.65068	-156.08576
THALE07201111005	Alelele	20.65266	-156.08596
THALE0820100524	Alelele	20.64929	-156.08579
THALE0920100112	Alelele	20.64824	-156.08455
THALE0920100414	Alelele	20.64853	-156.08543
THALE0920101005	Alelele	20.64945	-156.08599
THALE09201110106	Alelele	20.65249	-156.08588
THALE09201110406	Alelele	20.65425	-156.08684

Table 2 (continued). Sample site locations at Haleakala National Park.

I&M site designation	Stream	Decimal Degrees Latitude	Decimal Degrees Longitude
THALE1420110706	Alelele	20.64810	-156.08456
THALE1520090607	Alelele	20.64855	-156.08539
THALE0120070404	Palikea	20.66397	-156.04442
THALE0120071024	Palikea	20.66802	-156.05172
THALE0120080911	Palikea	20.66413	-156.04415
THALE0120100113	Palikea	20.66941	-156.05695
THALE0120100413	Palikea	20.66956	-156.05691
THALE0120101005	Palikea	20.66764	-156.05160
THALE0120110405	Palikea	20.66899	-156.05751
THALE0120111004	Palikea	20.66545	-156.04984
THALE0220090306	Palikea	20.66386	-156.04376
THALE0220100113	Palikea	20.66371	-156.04294
THALE0220100413	Palikea	20.66543	-156.04960
THALE0220101006	Palikea	20.66966	-156.05553
THALE0220110105	Palikea	20.67018	-156.05794
THALE0220110406	Palikea	20.66556	-156.04992
THALE0320080604	Palikea	20.66402	-156.04424
THALE0320081210	Palikea	20.66410	-156.04584
THALE0320100113	Palikea	20.66688	-156.05089
THALE0320100413	Palikea	20.66345	-156.04300
THALE0320100520	Palikea	20.66979	-156.05462
THALE0320101006	Palikea	20.66983	-156.05684
THALE0320110105	Palikea	20.66580	-156.05038
THALE0320110710	Palikea	20.66386	-156.04477
THALE0420080911	Palikea	20.66806	-156.05183
THALE0420091020	Palikea	20.66544	-156.04910
THALE0420100113	Palikea	20.66694	-156.05089
THALE0420111004	Palikea	20.66386	-156.04386
THALE0520070624	Palikea	20.66888	-156.05243

Table 2 (continued). Sample site locations at Haleakala National Park.

I&M site designation	Stream	Decimal Degrees Latitude	Decimal Degrees Longitude
THALE0520080604	Palikea	20.66563	-156.04997
THALE0520090305	Palikea	20.66558	-156.05036
THALE0520091020	Palikea	20.66415	-156.04587
THALE0520100518	Palikea	20.66386	-156.04486
THALE0520110105	Palikea	20.67002	-156.05458
THALE0620070404	Palikea	20.66795	-156.05178
THALE0620070625	Palikea	20.66540	-156.04798
THALE0620080910	Palikea	20.66962	-156.05534
THALE0620081210	Palikea	20.66997	-156.05475
THALE0720070625	Palikea	20.66997	-156.05482
THALE0720080605	Palikea	20.66966	-156.05561
THALE0920091020	Palikea	20.66858	-156.05671
THALE0920110712	Palikea	20.66957	-156.05550
THALE1020070624	Palikea	20.66580	-156.05042
THALE1020071211	Palikea	20.66765	-156.05157
THALE1020080228	Palikea	20.66764	-156.05151
THALE1120070626	Palikea	20.66298	-156.04185
THALE1120110712	Palikea	20.66803	-156.05184
THALE1220070625	Palikea	20.66521	-156.04960
THALE1220070822	Palikea	20.66506	-156.04712
THALE1220071023	Palikea	20.66294	-156.04174
THALE1320080228	Palikea	20.66511	-156.04736
THALE1320100526	Palikea	20.66349	-156.04258
THALE1420070626	Palikea	20.66395	-156.04413
THALE1420071212	Palikea	20.67012	-156.05431
THALE1520071024	Palikea	20.66765	-156.05144
THALE1520100526	Palikea	20.66521	-156.04880
THALE1620070405	Palikea	20.67773	-156.05748
THALE1620071023	Palikea	20.66433	-156.04590

Table 2 (continued). Sample site locations at Haleakala National Park.

I&M site designation	Stream	Decimal Degrees Latitude	Decimal Degrees Longitude
THALE1920070404	Palikea	20.66398	-156.04400
THALE1920071024	Palikea	20.66985	-156.05561
THALE2020070822	Palikea	20.66547	-156.05029
THALE2220070403	Palikea	20.66580	-156.05048
THALE2320070822	Palikea	20.66988	-156.05543
THALE2620070404	Palikea	20.66930	-156.05605
THALE3620070821	Palikea	20.66297	-156.04174
THALE8a20070404	Palikea	20.66293	-156.04178
THALE8b20070404	Palikea	20.66292	-156.04182
THALE0220091020	Piipiwai	20.67210	-156.05595
THALE0220110709	Piipiwai	20.67730	-156.05678
THALE0220111004	Piipiwai	20.67272	-156.05593
THALE0320090305	Piipiwai	20.67857	-156.05662
THALE0420071024	Piipiwai	20.67085	-156.05450
THALE0420090302	Piipiwai	20.67597	-156.05670
THALE0420100519	Piipiwai	20.67134	-156.05474
THALE0420101006	Piipiwai	20.67162	-156.05504
THALE0420110105	Piipiwai	20.67098	-156.05432
THALE0420110405	Piipiwai	20.67361	-156.05622
THALE0420110709	Piipiwai	20.67289	-156.05601
THALE0420120718	Piipiwai	20.67664	-156.05626
THALE0520070405	Piipiwai	20.67137	-156.05467
THALE0520100413	Piipiwai	20.67180	-156.05520
THALE0520110405	Piipiwai	20.67249	-156.05593
THALE0520111004	Piipiwai	20.67084	-156.05427
THALE0720070405	Piipiwai	20.67177	-156.05545
THALE0720070822	Piipiwai	20.67088	-156.05447
THALE0720080910	Piipiwai	20.67421	-156.05631
THALE0720081210	Piipiwai	20.67421	-156.05631

Table 2 (continued). Sample site locations at Haleakala National Park.

I&M site designation	Stream	Decimal Degrees Latitude	Decimal Degrees Longitude
THALE0720110713	Piipiwai	20.67442	-156.05606
THALE0820070625	Piipiwai	20.67538	-156.05600
THALE0820080605	Piipiwai	20.67377	-156.05606
THALE0820081210	Piipiwai	20.67553	-156.05635
THALE0820110708	Piipiwai	20.67115	-156.05431
THALE08201210	Piipiwai	20.67000	-156.05663
THALE0920070625	Piipiwai	20.67717	-156.05687
THALE0920100520	Piipiwai	20.67554	-156.05677
THALE1120071024	Piipiwai	20.67149	-156.05483
THALE1220100522	Piipiwai	20.67418	-156.05636
THALE1520071211	Piipiwai	20.67382	-156.05629
THALE1520080227	Piipiwai	20.67543	-156.05607
THALE2320070405	Piipiwai	20.67738	-156.05630

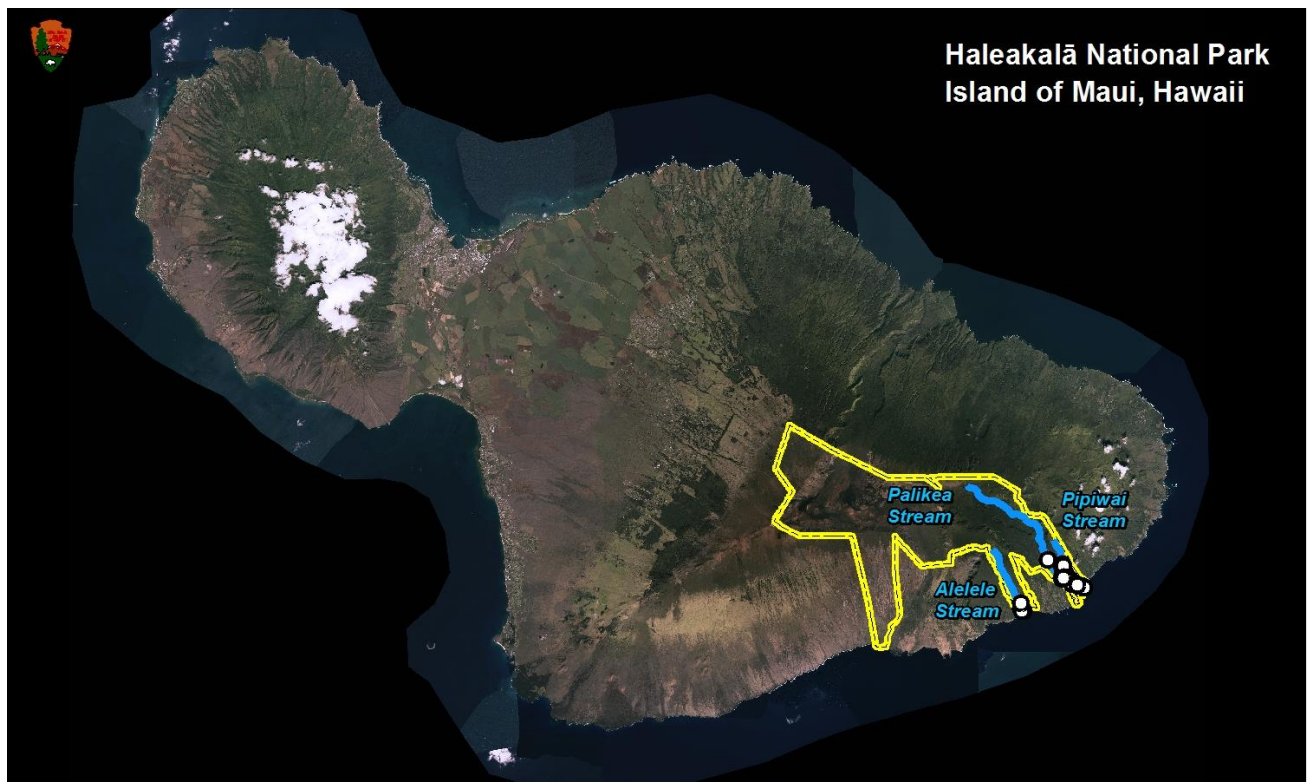


Figure 1. Sample Sites in Haleakala National Park.

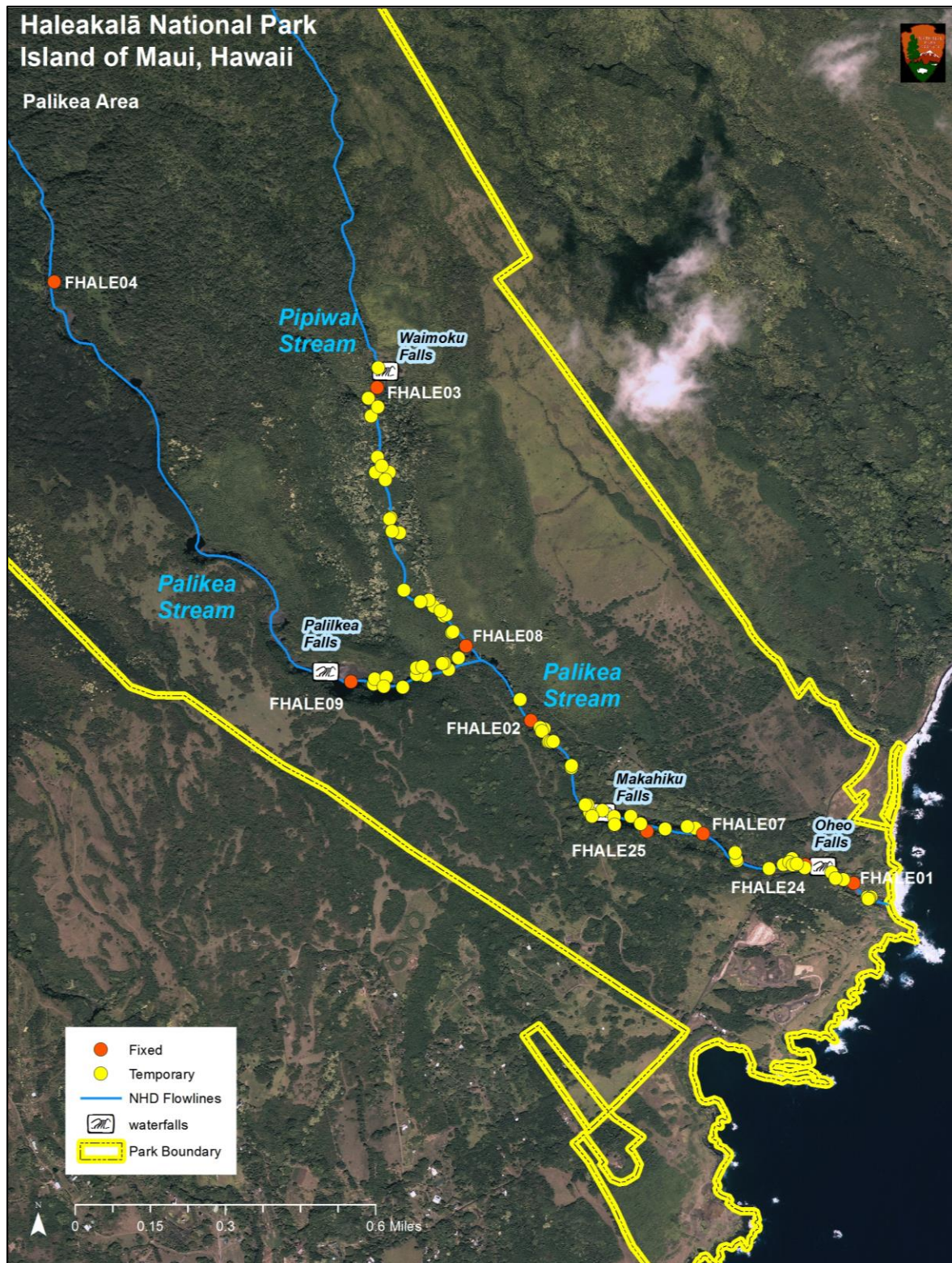


Figure 2. Sample Sites in Pipiwai Stream and Palikea Stream, Haleakala National Park.

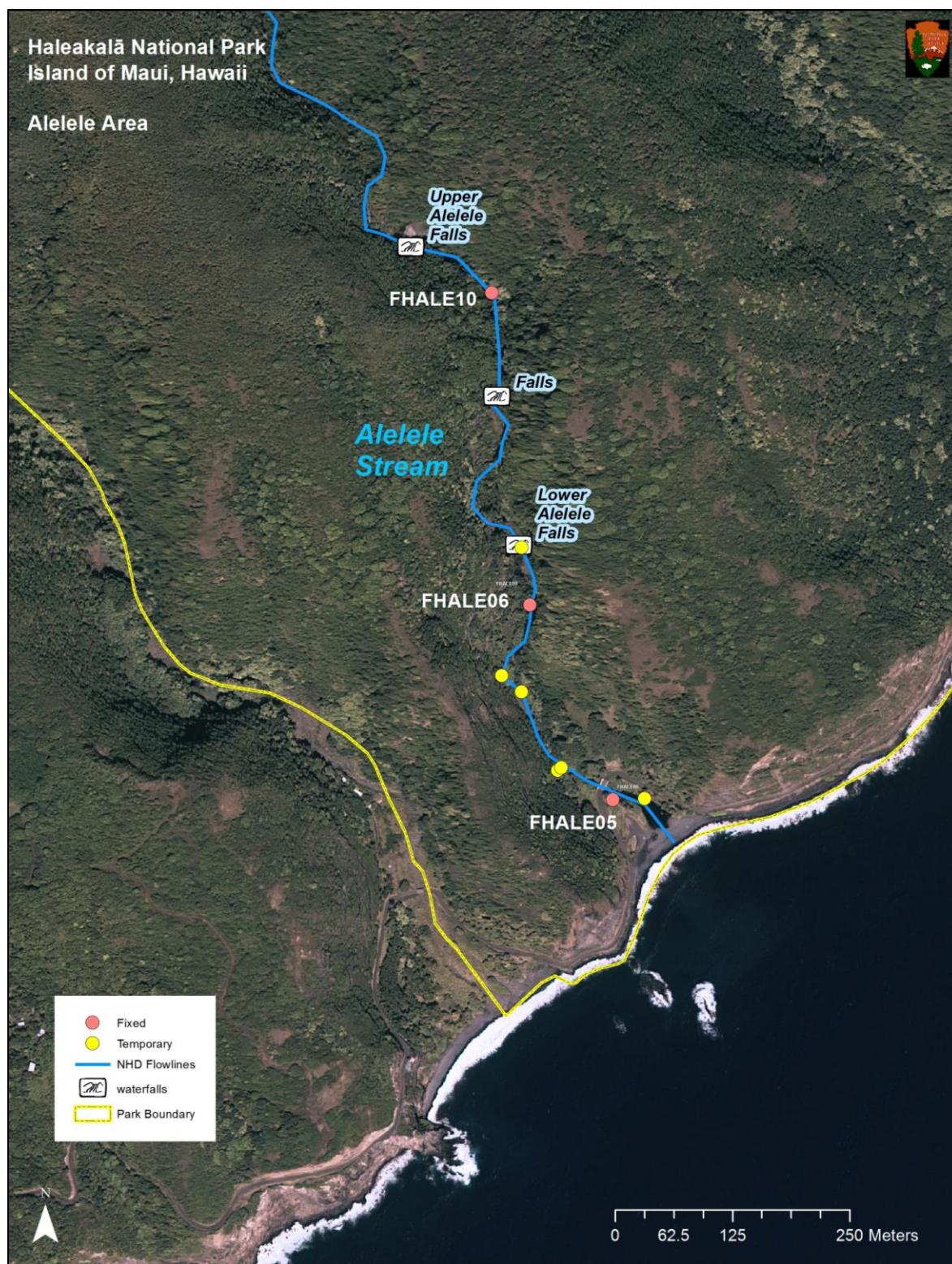


Figure 3. Sample Sites in Alelele Stream, Haleakala National Park.

Table 3. Sampling events at Haleakala National Park.

Year	Date	Personnel
2007	03-Apr-07	Danielle McKay, Jeff Hjelt, Tahzay Jones
2007	24-Jun-07	Danielle McKay, Tahzay Jones
2007	21-Aug-07	Danielle McKay, Lindsey Kramer
2007	23-Oct-07	Danielle McKay, Lindsey Kramer
2007	11-Dec-07	Danielle McKay, Lindsey Kramer
2008	27-Feb-08	Anne Farahi, Kelly Kozar, Lindsey Kramer
2008	04-Jun-08	Anne Farahi, Lindsey Kramer
2008	10-Sep-08	Anne Farahi, Lindsey Kramer
2008	10-Dec-08	Anne Farahi, M. Jerolaman
2009	02-Mar-09	Anne Farahi, Lindsey Kramer
2009	07-Jun-09	Anne Farahi, Jeannine Rossa, Tahzay Jones
2009	20-Oct-09	Alyra Halyn, Anne Farahi
2010	12-Jan-10	Anne Farahi, M. Jerolaman
2010	13-Apr-10	Anne Farahi, Kimberley Tice
2010	18-May-10	Anne Farahi, Katie Woollven, Kimberley Tice
2010	05-Oct-10	Anne Farahi, Kimberley Tice, Tahzay Jones
2011	04-Jan-11	Anne Farahi, Kimberley Tice
2011	04-Apr-11	Anne Farahi, Perry Bednorz
2011	06-Jul-11	Anne Farahi, Jackie Frost, Jake Duros, Jeannine Rossa, John Souva, K. Tice
2011	03-Oct-11	Brian Wardlow, Kimberley Tice

Water Collection

Water was collected using a new or acid-washed 140cc syringe just below the surface to avoid disturbance of sediment 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 then used to rinse each sample bottle three times, for a total of 50ml per bottle, discarding water between each rinse. The filter assembly was then removed, water again was drawn into the syringe, and a filter assembly was again placed onto the syringe. 140ml of water was then filtered 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 transferred to a freezer on the day of collection. 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 ($\text{mS} \cdot \text{cm}^{-1}$), 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, and 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, during which readings were taken every 30 seconds. The mean and variance of stable values, excluding initial readings, 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. 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).

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 (Tables 7-17). 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 3-6). 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 very low turbidity values 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. 4). 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.

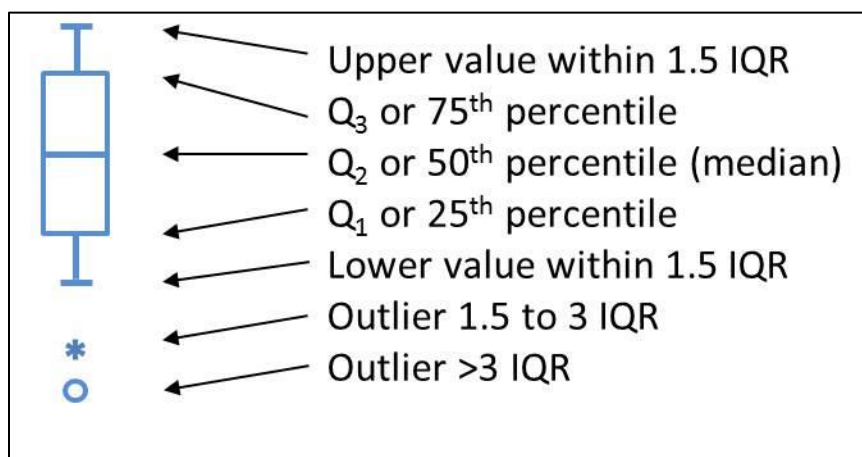


Figure 4. Box plot explanation.

Results

Fixed sites in Haleakala National Park were sampled 20 times from 2007 to 2011. Results are presented as summaries by year (Tables 4-8), geometric means of parameters matching or similar to state water quality criteria (Table 9-11) and parameter (Figs. 5-15). Annual summaries present the minimum, maximum, median, and variance as standard deviation of all individual measurements at each stream across an entire year. Box plots display individual replicate data lumped from all sampling events within a stream across a year.

2007

Five sampling trips were conducted in 2007. This was the start of the monitoring program at Haleakala National Park (Table 4).

Table 4. 2007 summary of water quality parameters in Haleakala National Park streams.

Parameter	Unit	Site	n	Minimum ¹	Maximum ¹	Median ¹	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Palikea	32	1.00	104.00	3.70	25.91
		Piipiwai	22	1.00	103.00	5.00	27.76
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Palikea	32	0.06	0.17	0.08	0.02
		Piipiwai	23	0.04	0.14	0.08	0.03
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	Palikea	32	5.00	94.00	27.65	17.16
		Piipiwai	22	6.00	78.00	28.50	20.28
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	Palikea	37	0.00	1.25	0.00	0.35
		Piipiwai	26	0.00	2.51	0.00	0.59
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	Palikea	17	8.22	9.76	8.93	0.41
		Piipiwai	14	8.10	9.25	8.75	0.33
pH	none	Palikea	35	7.06	8.91	8.01	0.39
		Piipiwai	23	7.04	8.93	8.04	0.51
Salinity	ppt	Palikea	35	0.01	0.05	0.03	0.01
		Piipiwai	25	0.01	0.04	0.03	0.01
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	Palikea	34	0.02	0.10	0.05	0.02
		Piipiwai	22	0.01	0.09	0.06	0.02
Temperature	$^{\circ}\text{C}$	Palikea	37	16.26	25.40	21.76	1.62
		Piipiwai	26	16.48	23.47	21.11	1.99
Turbidity	NTU	Palikea	36	0.88	16.06	8.27	3.32
		Piipiwai	26	0.10	12.82	7.83	3.22

2008

Three sampling trips were conducted in 2008 (Table 5).

Table 5. 2008 summary of water quality parameters in Haleakala National Park streams.

Parameter	Unit	Site	n	Minimum ¹	Maximum ¹	Median ¹	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Palikea	39	2.66	23.00	15.00	4.18
		Piipiwai	33	3.90	15.00	15.00	3.70
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Palikea	39	0.04	0.28	0.11	0.05
		Piipiwai	33	0.02	0.15	0.10	0.03
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	Palikea	39	2.00	120.00	19.00	36.19
		Piipiwai	33	5.00	42.00	13.00	11.51
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	Palikea	15	0.00	4.16	1.35	1.07
		Piipiwai	13	0.09	2.79	1.37	0.98
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	Palikea	15	7.68	9.64	8.90	0.57
		Piipiwai	13	7.79	8.88	8.70	0.37
Dissolved Oxygen Saturation	%	Palikea	14	88.04	114.83	100.07	6.98
		Piipiwai	13	91.82	100.83	95.76	2.39
pH	none	Palikea	15	6.87	9.11	7.54	0.59
		Piipiwai	13	6.76	9.01	7.61	0.56
Salinity	ppt	Palikea	14	0.02	0.04	0.03	0.01
		Piipiwai	13	0.02	0.04	0.03	0.01
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	Palikea	12	0.03	0.09	0.06	0.02
		Piipiwai	11	0.05	8.89	0.07	2.66
Temperature	$^{\circ}\text{C}$	Palikea	15	19.21	27.69	21.36	2.40
		Piipiwai	13	18.73	24.77	20.74	1.82
Turbidity	NTU	Palikea	14	0.10	9.09	0.88	3.20
		Piipiwai	12	0.10	3.56	0.74	0.99

2009

Three sampling trips were conducted in 2009 (Table 6).

Table 6. 2009 summary of water quality parameters in Haleakala National Park streams.

Parameter	Unit	Site	n	Minimum ¹	Maximum ¹	Median ¹	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Alelele	18	15.00	30.77	18.21	6.35
		Palikea	27	15.00	18.33	15.00	0.68
		Piipiwai	30	15.00	28.85	15.00	2.53
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Alelele	18	0.08	0.25	0.17	0.05
		Palikea	27	0.07	0.22	0.12	0.05
		Piipiwai	30	0.07	0.26	0.10	0.06
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	Alelele	18	7.65	167.96	101.45	47.04
		Palikea	27	1.00	102.55	46.00	23.94
		Piipiwai	29	4.00	85.93	25.92	24.25
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	Alelele	5	0.45	3.23	2.91	1.40
		Palikea	8	0.55	5.10	1.61	1.43
		Piipiwai	10	0.12	6.36	1.53	1.99
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	Alelele	5	7.32	9.17	8.52	0.67
		Palikea	9	8.59	10.35	9.26	0.65
		Piipiwai	10	7.37	9.58	8.51	0.74
Dissolved Oxygen Saturation	%	Alelele	5	88.77	107.02	100.50	6.61
		Palikea	9	99.59	127.20	103.19	8.30
		Piipiwai	10	88.30	112.88	98.46	6.92
pH	none	Alelele	3	7.06	7.10	7.08	0.02
		Palikea	7	6.72	7.53	6.85	0.32
		Piipiwai	6	7.01	8.22	7.32	0.45
Salinity	ppt	Alelele	5	0.01	0.05	0.01	0.02
		Palikea	8	0.01	0.04	0.01	0.01
		Piipiwai	10	0.01	0.04	0.04	0.01
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	Alelele	4	0.03	0.11	0.07	0.04
		Palikea	7	0.02	0.09	0.02	0.03
		Piipiwai	8	0.02	0.10	0.08	0.03

Table 6 (continued). 2009 summary of water quality parameters in Haleakala National Park streams.

Parameter	Unit	Site	n	Minimum ¹	Maximum ¹	Median ¹	SD
Temperature	°C	Alelele	6	22.54	24.29	23.52	0.60
		Palikea	9	16.25	27.73	22.31	3.78
		Piipiwai	10	17.12	25.84	22.24	3.13
Turbidity	NTU	Alelele	5	0.10	4.07	0.36	1.71
		Palikea	8	0.10	5.66	1.24	2.21
		Piipiwai	10	0.10	3.42	0.25	1.30

2010

Four sampling trips were conducted in 2010 (Table 7).

Table 7. 2010 summary of water quality parameters in Haleakala National Park streams.

Parameter	Unit	Site	n	Minimum ¹	Maximum ¹	Median ¹	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Alelele	33	15.00	23.00	15.00	1.41
		Palikea	43	15.00	15.00	15.00	0.00
		Piipiwai	36	15.00	21.83	15.00	1.14
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Alelele	33	0.07	0.28	0.12	0.06
		Palikea	44	0.07	0.19	0.08	0.04
		Piipiwai	36	0.07	0.14	0.09	0.02
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	Alelele	33	25.90	177.00	81.43	52.45
		Palikea	44	1.00	133.00	19.50	35.55
		Piipiwai	36	1.00	83.05	19.50	24.73
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	Alelele	7	0.00	4.13	0.96	1.33
		Palikea	14	0.00	5.34	0.82	1.39
		Piipiwai	9	0.30	2.70	1.36	0.92
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	Alelele	11	6.60	9.53	8.95	0.84
		Palikea	19	8.10	9.62	9.07	0.43
		Piipiwai	15	7.82	9.63	8.97	0.46
Dissolved Oxygen Saturation	%	Alelele	11	72.85	110.76	100.98	9.80
		Palikea	18	89.65	105.20	101.15	3.52
		Piipiwai	15	87.52	110.01	97.54	5.12

Table 7 (continued). 2010 summary of water quality parameters in Haleakala National Park streams.

Parameter	Unit	Site	n	Minimum ¹	Maximum ¹	Median ¹	SD
pH	none	Alelele	12	6.46	7.88	6.91	0.43
		Palikea	19	6.49	7.64	7.05	0.28
		Piipiwai	15	6.70	7.59	7.01	0.27
Salinity	ppt	Alelele	12	0.01	0.05	0.03	0.01
		Palikea	19	0.01	0.04	0.02	0.01
		Piipiwai	15	0.01	0.04	0.02	0.01
Specific conductance	mS · cm ⁻¹	Alelele	11	0.03	0.10	0.04	0.03
		Palikea	19	0.03	0.08	0.03	0.02
		Piipiwai	15	0.03	0.08	0.05	0.02
Temperature	°C	Alelele	12	18.76	23.07	21.21	1.22
		Palikea	19	18.64	25.29	20.62	1.57
		Piipiwai	15	18.91	21.92	20.47	0.85
Turbidity	NTU	Alelele	6	0.10	0.10	0.10	0.00
		Palikea	9	0.10	0.79	0.10	0.23
		Piipiwai	10	0.10	2.59	0.10	0.82

2011

Four sampling trips were conducted in 2011 (Table 8).

Table 8. 2011 summary of water quality parameters in Haleakala National Park streams.

Parameter	Unit	Site	n	Minimum ¹	Maximum ¹	Median ¹	SD
Total Dissolved Phosphorus	µgP · L ⁻¹	Alelele	48	15.00	37.83	15.00	4.25
		Palikea	39	15.00	15.88	15.00	0.14
		Piipiwai	48	15.00	15.00	15.00	0.00
Total Dissolved Nitrogen	mgN · L ⁻¹	Alelele	48	0.07	0.30	0.17	0.06
		Palikea	39	0.07	0.23	0.13	0.04
		Piipiwai	48	0.07	0.21	0.11	0.04
Nitrite + Nitrate	µgN · L ⁻¹	Alelele	48	16.20	180.21	86.27	47.01
		Palikea	39	9.33	135.54	40.39	39.92
		Piipiwai	48	1.00	50.41	21.64	15.52

Table 8 (continued). 2011 summary of water quality parameters in Haleakala National Park streams.

Parameter	Unit	Site	n	Minimum ¹	Maximum ¹	Median ¹	SD
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	Alelele	16	0.00	1.79	0.45	0.51
		Palikea	14	0.00	2.79	0.74	1.01
		Piipiwai	18	0.00	4.08	1.40	1.05
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	Alelele	13	7.87	9.27	8.92	0.36
		Palikea	15	7.22	9.58	8.97	0.53
		Piipiwai	18	8.02	9.18	8.72	0.27
Dissolved Oxygen Saturation	%	Alelele	15	65.70	103.23	99.67	12.22
		Palikea	15	80.38	109.94	100.85	6.69
		Piipiwai	18	93.98	99.99	96.90	1.75
pH	none	Alelele	16	6.88	8.22	7.63	0.38
		Palikea	15	6.75	8.04	7.43	0.35
		Piipiwai	18	7.41	8.11	7.54	0.18
Salinity	ppt	Alelele	16	0.03	0.05	0.03	0.01
		Palikea	15	0.01	0.03	0.02	0.01
		Piipiwai	19	0.01	0.04	0.03	0.01
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	Alelele	16	0.05	0.10	0.06	0.02
		Palikea	15	0.02	0.06	0.04	0.01
		Piipiwai	19	0.04	0.08	0.06	0.01
Temperature	°C	Alelele	16	19.21	25.05	20.79	1.82
		Palikea	15	19.18	25.30	21.67	1.80
		Piipiwai	18	18.44	23.92	20.47	1.33
Turbidity	NTU	Alelele	16	0.10	1.36	0.10	0.34
		Palikea	15	0.10	5.23	0.28	1.31
		Piipiwai	19	0.10	2.02	0.40	0.68

Comparison to State Water Quality Criteria

Although the state criteria are defined in terms of geometric means, there is no specified time period or other methodology over which the geometric mean is to be calculated (State of Hawaii, personal communication). Here, geometric means have been applied to the data by year (Tables 9-11). The only values that consistently exceeded state water criteria were nitrate + nitrite concentrations in Alelele Stream and Palikea stream. However, there was substantial within and between season variability in the nitrate + nitrite measures, and state water criteria were not always exceeded during

the wet and dry season (Tables 4-11). TDP and TDN did not exceed state criteria, and turbidity only occasionally did, likely a result of stream conditions at time of sampling (e.g., higher turbidity can occur during times of greater runoff) (Tables 9-11). Bolded numbers indicate values that exceeded state criteria, none of which exceed the upper limits of state water criteria (i.e., values that should not be exceeded more than 2% or 10% of time).

Table 9. Geometric means of water quality parameters by season in Alelele Stream.

Parameter	Unit	Season	Year	Geometric mean
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Wet	2010	15.2
			2011	15.8
		Dry	2009	19.8
			2010	15.4
			2011	18.3
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Wet	2010	0.095
			2011	0.153
		Dry	2009	0.165
			2010	0.178
			2011	0.149
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	Wet	2010	54.3
			2011	107.5
		Dry	2009	59.6
			2010	123.8
			2011	71.7
Turbidity	NTU	Wet	2010	0.100
			2011	0.114
		Dry	2009	0.409
			2010	0.100
			2011	0.210

Table 10. Geometric means of water quality parameters by season in Palikea Stream.

Parameter	Unit	Season	Year	Geometric mean
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Wet	2007	28.3
			2008	14.4
			2009	15.0
			2010	15.0
			2011	15.0
		Dry	2007	2.9
			2008	11.6
			2009	15.2
			2010	15.0
			2011	15.0
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Wet	2007	0.082
			2008	0.142
			2009	0.088
			2010	0.074
			2011	0.106
		Dry	2007	0.080
			2008	0.077
			2009	0.137
			2010	0.123
			2011	0.148
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	Wet	2007	23.9
			2008	50.8
			2009	43.7
			2010	9.4
			2011	43.2
		Dry	2007	26.3
			2008	12.3
			2009	36.4
			2010	60.4
			2011	35.5

Table 10 (continued). Geometric means of water quality parameters by season in Palikea Stream.

Parameter	Unit	Season	Year	Geometric mean
Turbidity	NTU	Wet	2007	8.5
			2008	1.9
			2009	0.9
			2010	0.2
			2011	0.2
		Dry	2007	4.9
			2008	0.5
			2009	0.7
			2010	0.1
			2011	0.5

Table 11. Geometric means of water quality parameters by season in Pipiwai Stream.

Parameter	Unit	Season	Year	Geometric mean
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Wet	2007	36.0
			2008	13.9
			2009	15.0
			2010	15.4
			2011	15.0
		Dry	2007	4.2
			2008	11.3
			2009	15.5
			2010	15.0
			2011	15.0
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Wet	2007	0.073
			2008	0.098
			2009	0.073
			2010	0.090
			2011	0.085

Table 11 (continued). Geometric means of water quality parameters by season in Pipiwai Stream.

Parameter	Unit	Season	Year	Geometric mean
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	Dry	2007	0.084
			2008	0.078
			2009	0.133
			2010	0.096
			2011	0.135
		Wet	2007	20.2
			2008	16.5
			2009	19.5
			2010	7.3
			2011	11.6
Turbidity	NTU	Dry	2007	28.0
			2008	13.3
			2009	27.8
			2010	26.0
			2011	25.3
		Wet	2007	7.7
			2008	0.6
			2009	0.3
			2010	0.3
			2011	0.3
		Dry	2007	4.3
			2008	0.5
			2009	0.4
			2010	0.3
			2011	0.4

Summaries by parameter

The summary values for each parameter are shown in Figs. 6-15 below.

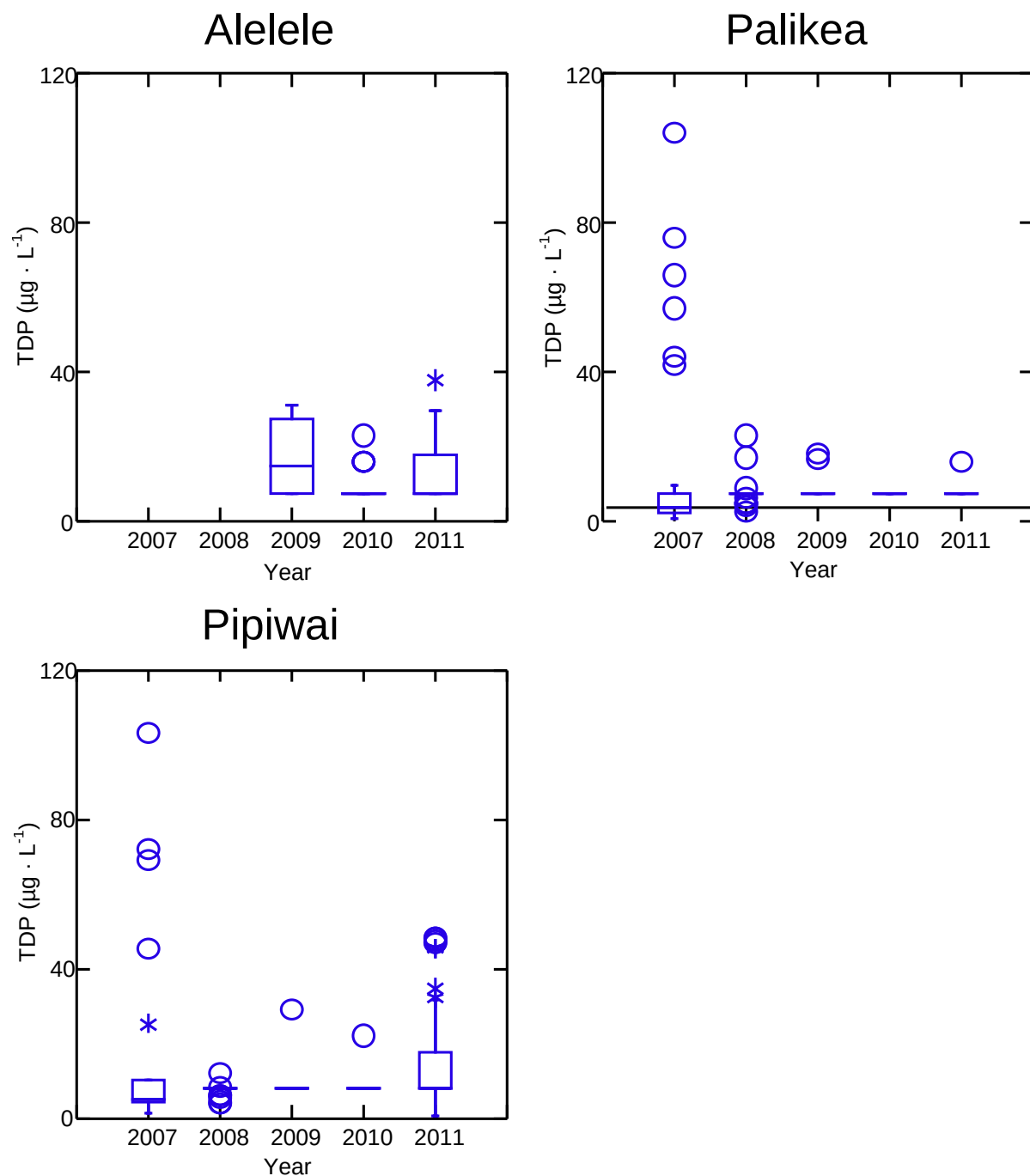


Figure 5. Box plots of total dissolved phosphorus in streams of Haleakala National Park.

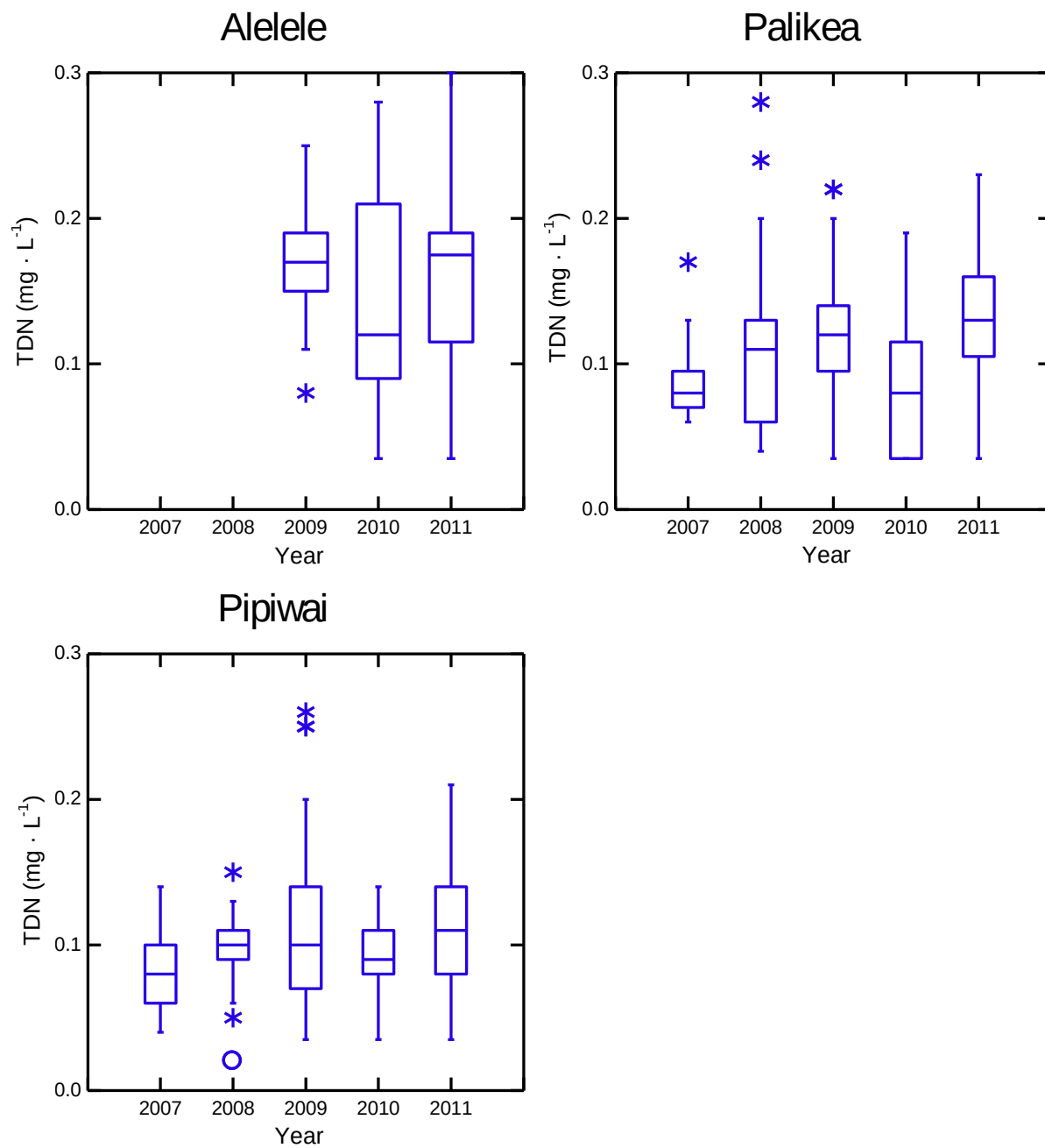


Figure 6. Box plots of total dissolved nitrogen in streams of Haleakala National Park.

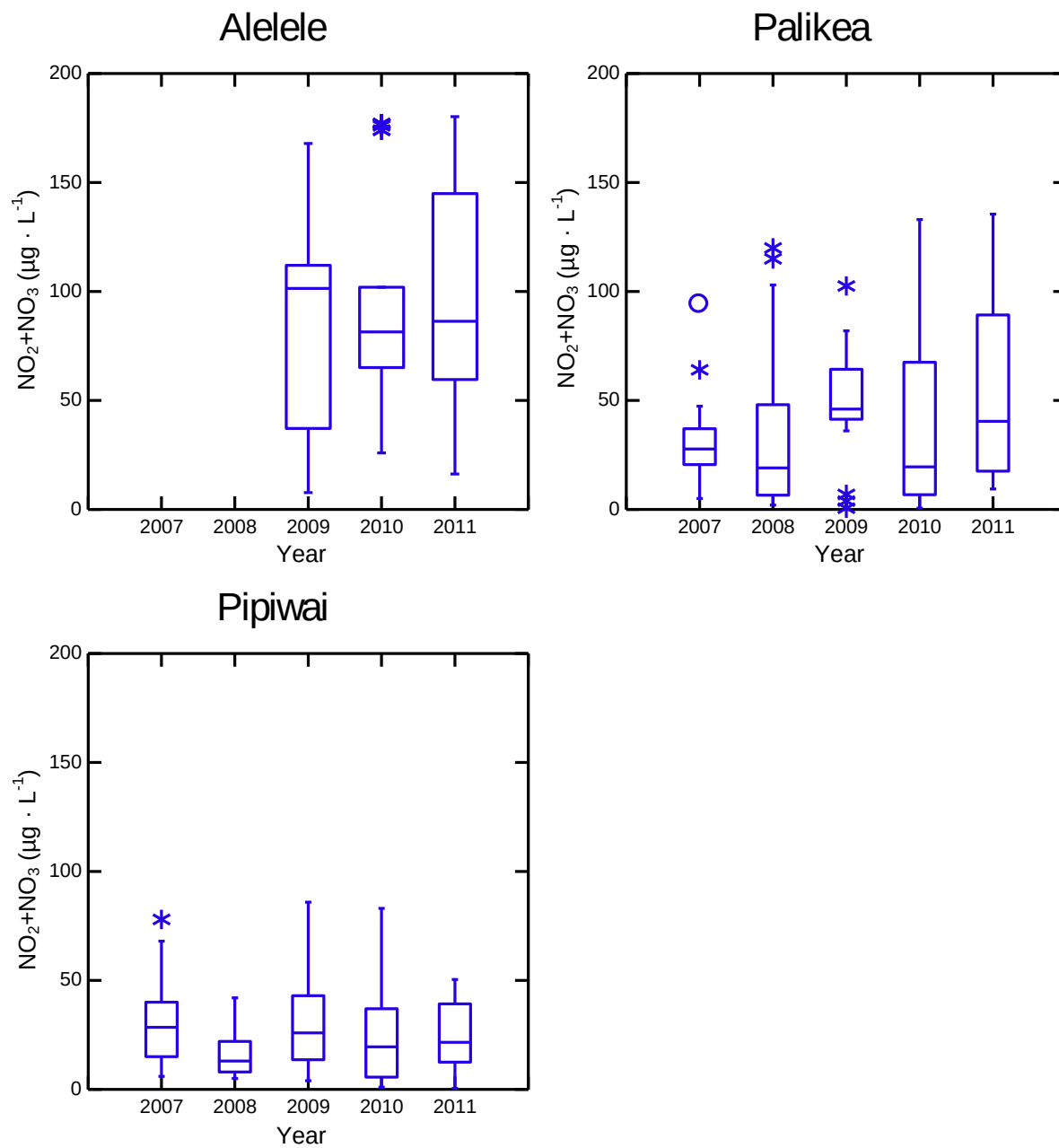


Figure 7. Box plots of Nitrate + Nitrite in streams of Haleakala National Park.

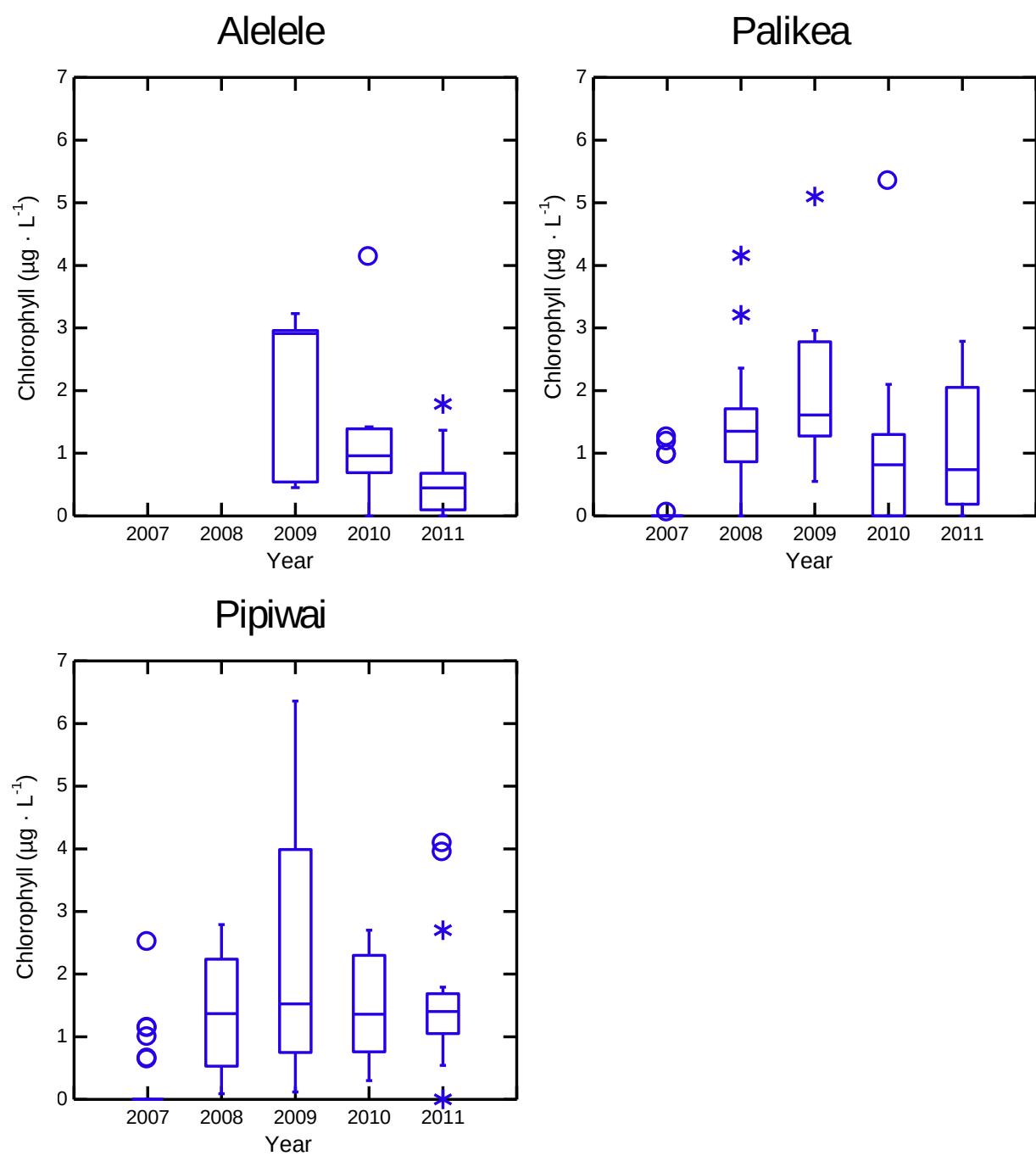


Figure 8. Box plots of chlorophyll in streams of Haleakala National Park.

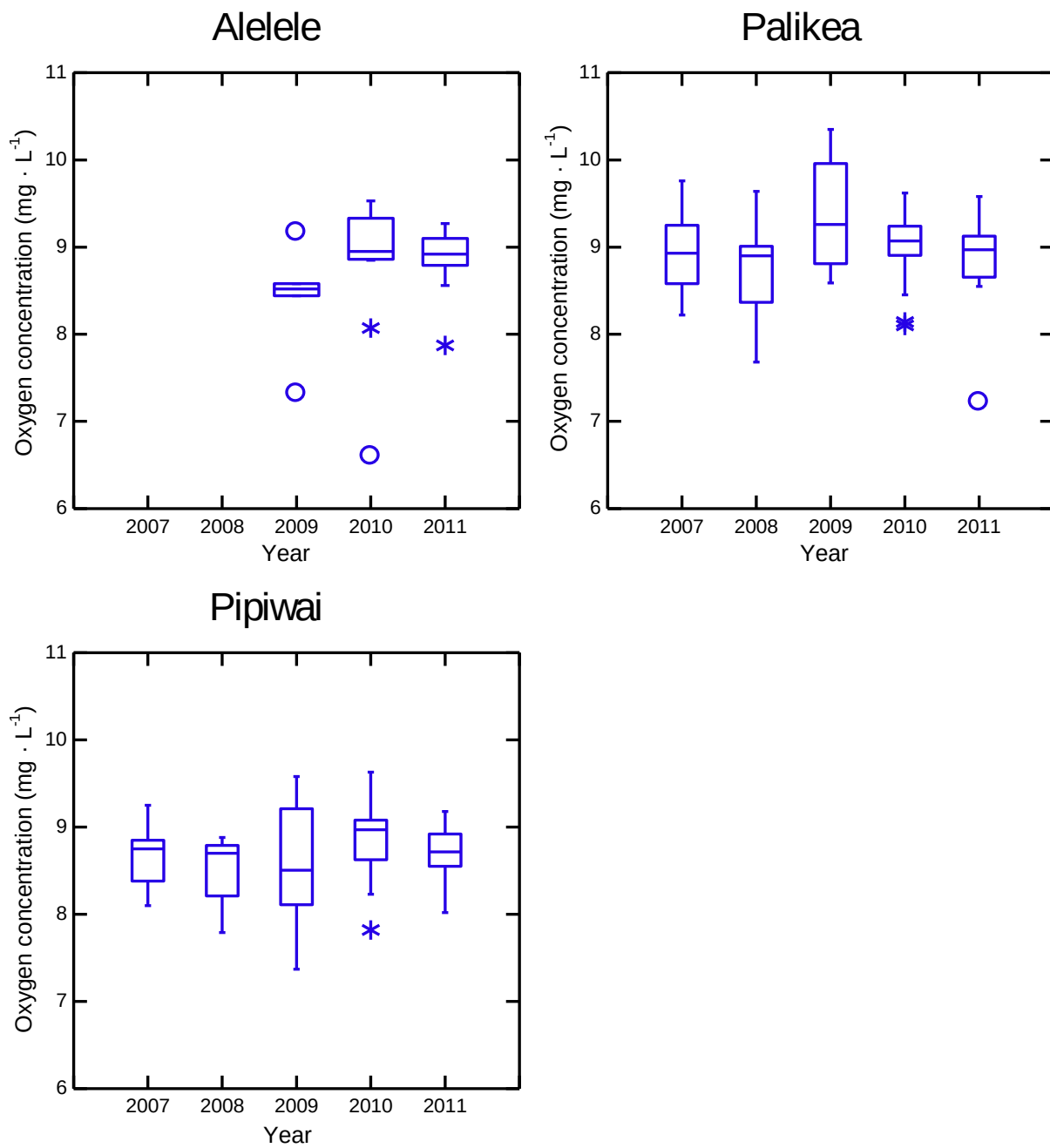


Figure 9. Box plots of oxygen concentration in streams of Haleakala National Park.

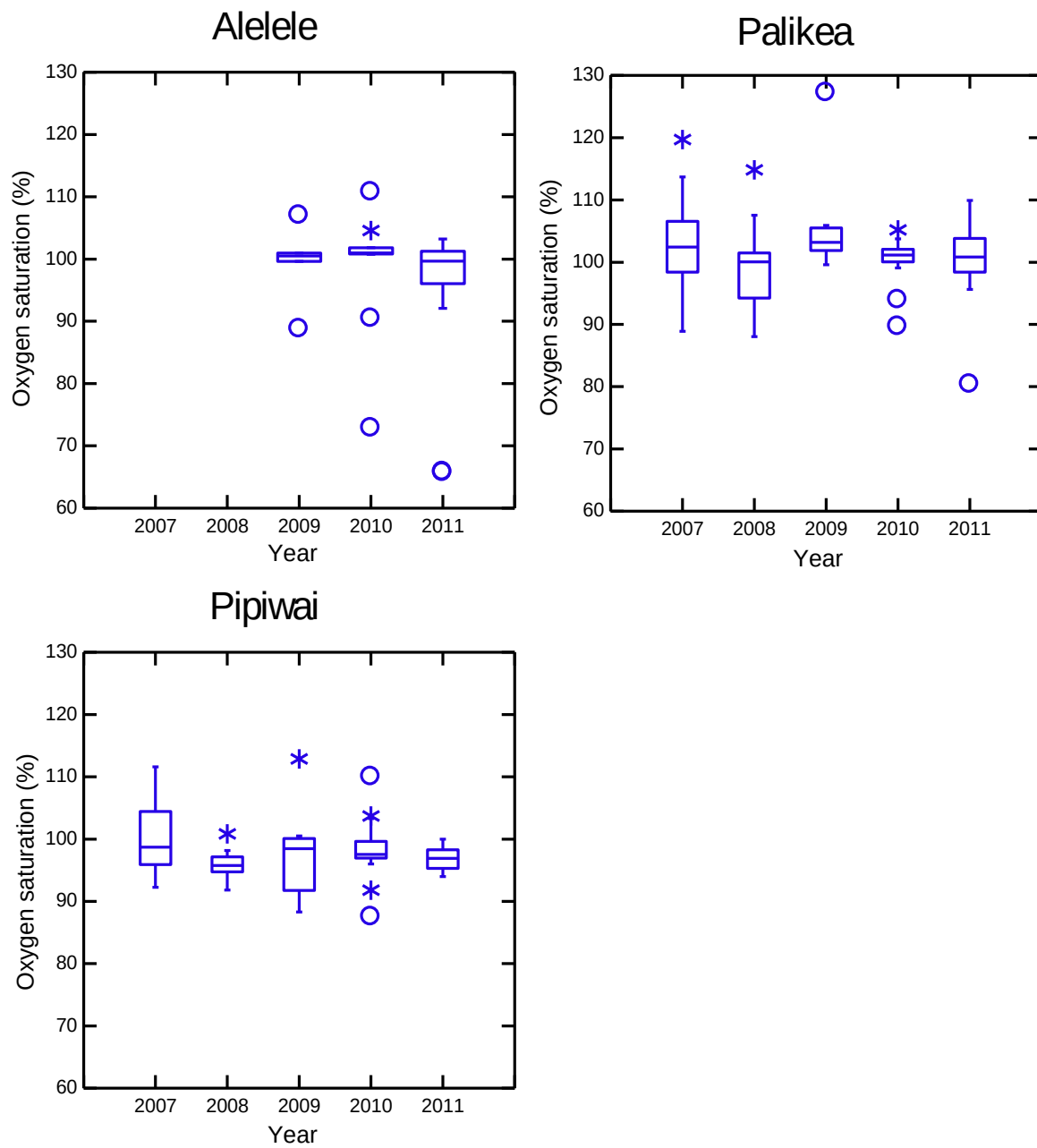


Figure 10. Box plots of oxygen saturation in streams of Haleakala National Park.

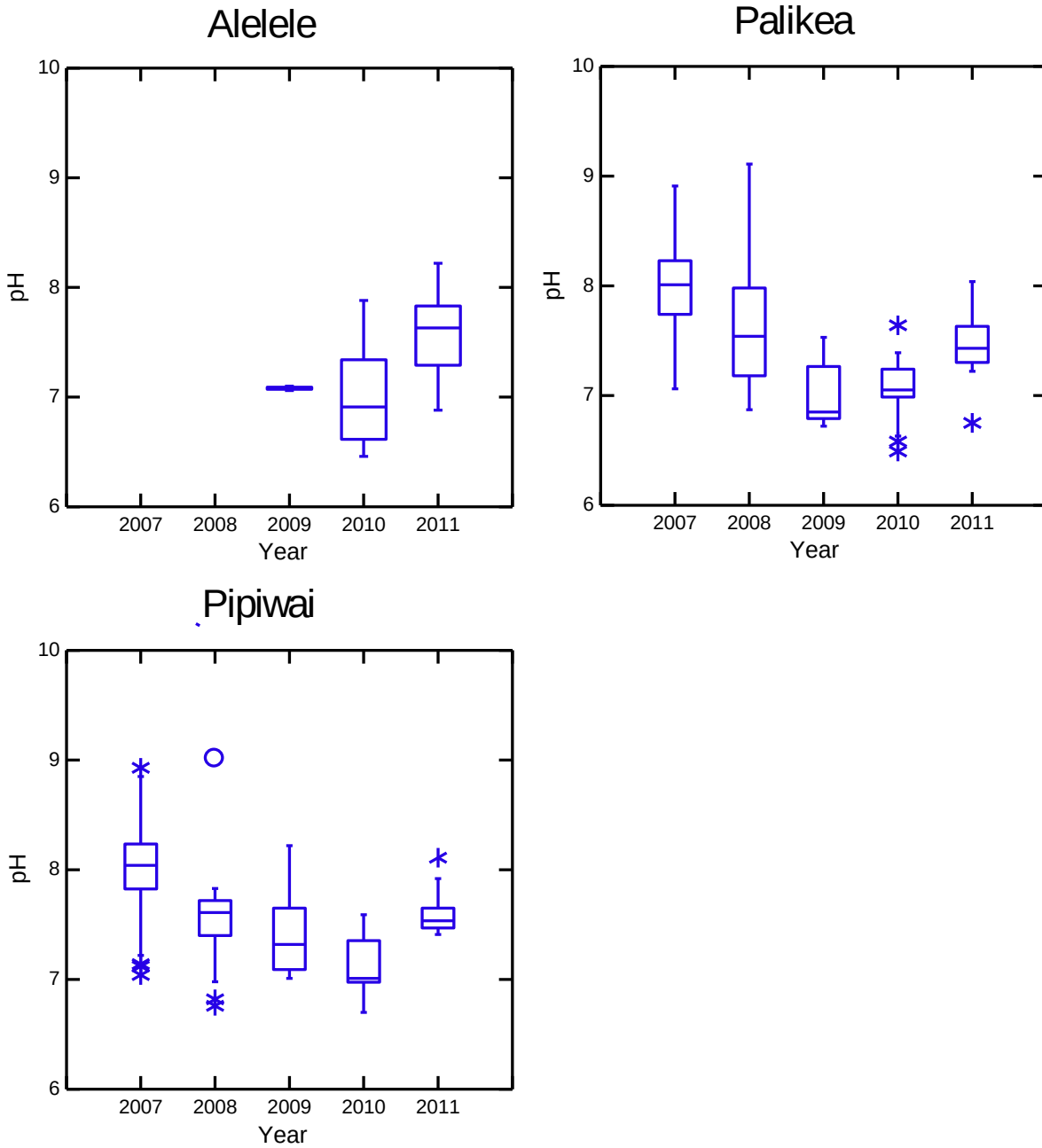


Figure 11. Box plots of pH in streams of Haleakala National Park.

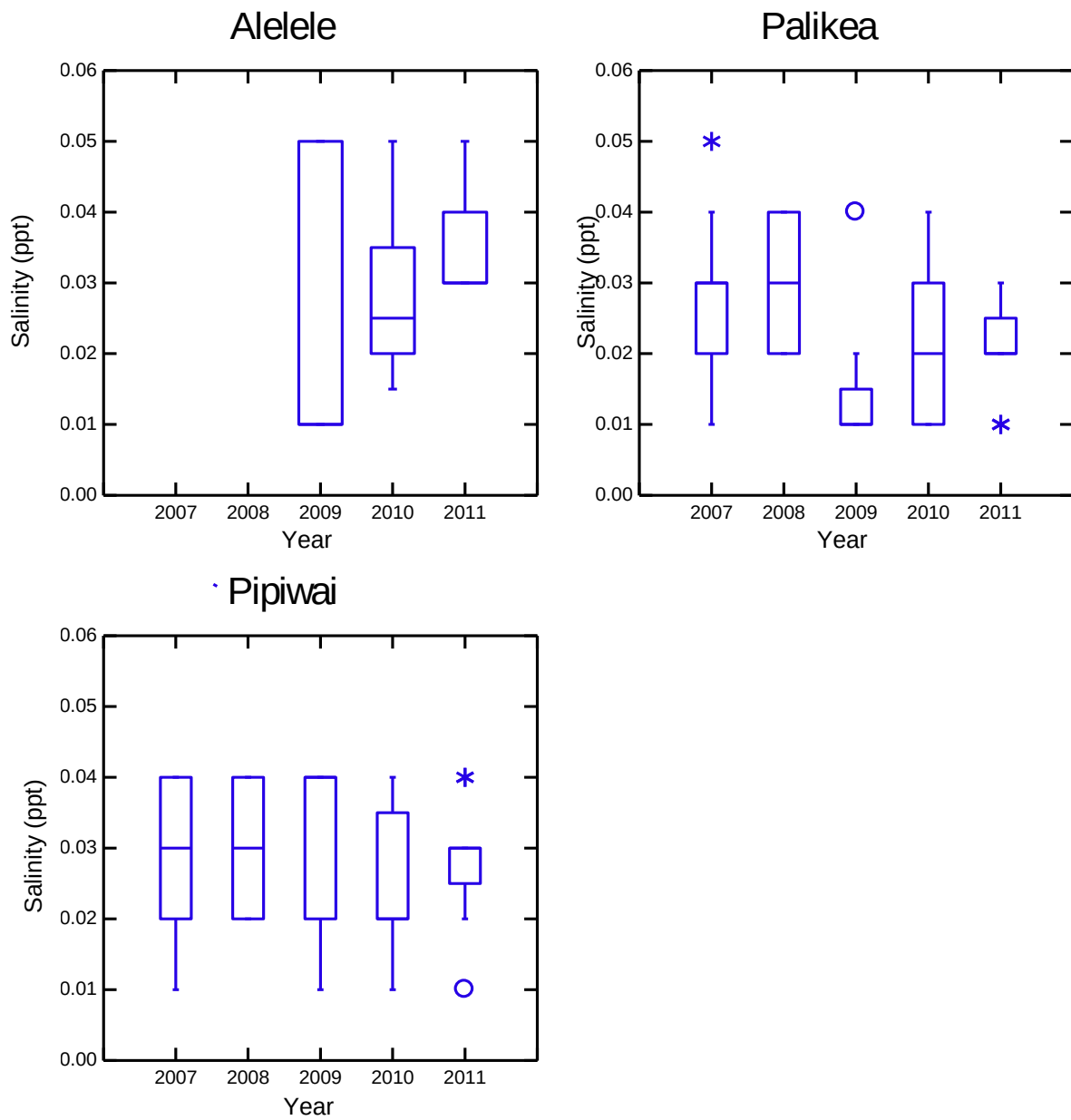


Figure 12. Box plots of salinity in streams of Haleakala National Park.

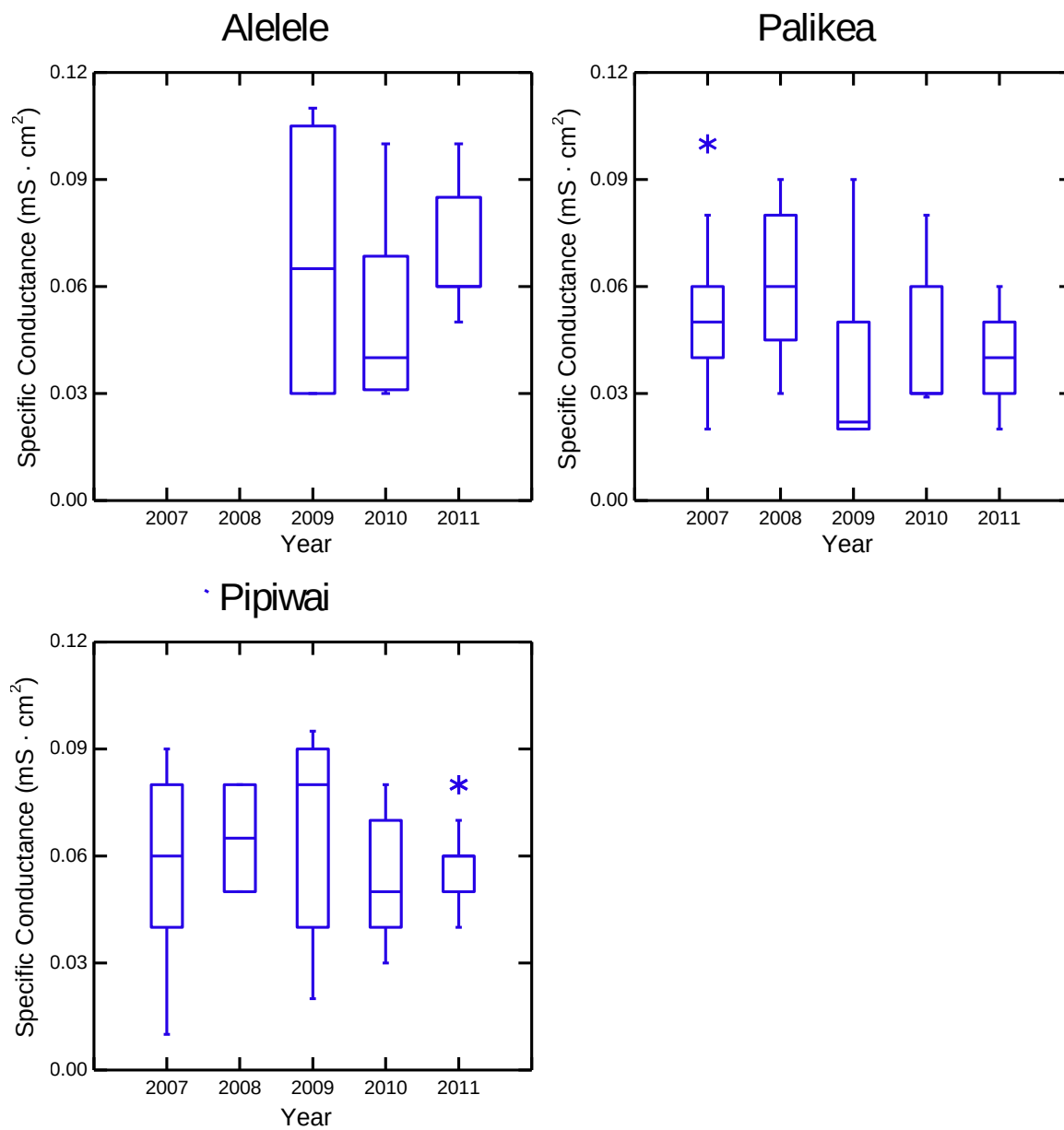


Figure 13. Box plots of specific conductance in streams of Haleakala National Park.

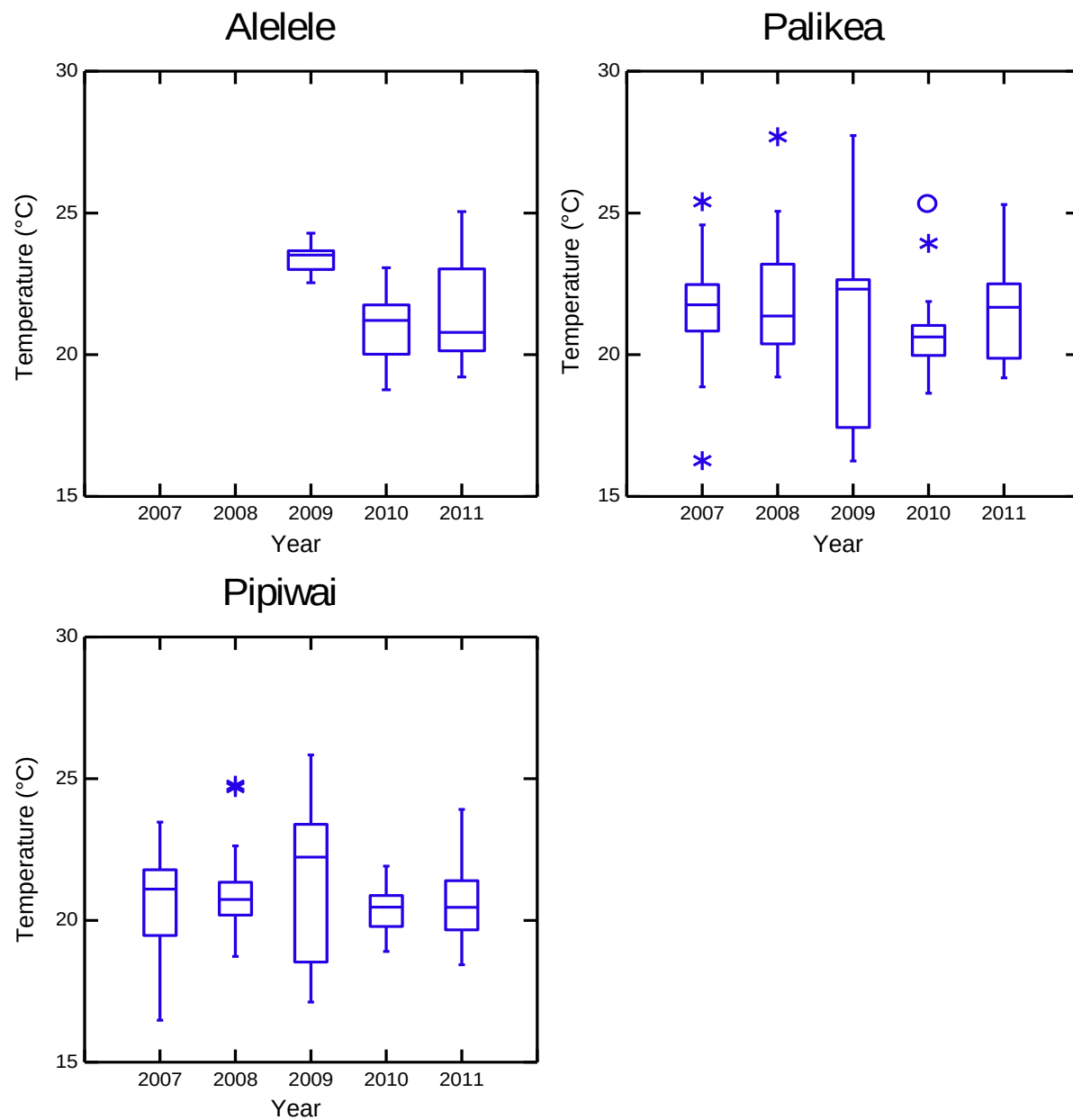


Figure 14. Box plots of temperature in streams of Haleakala National Park.

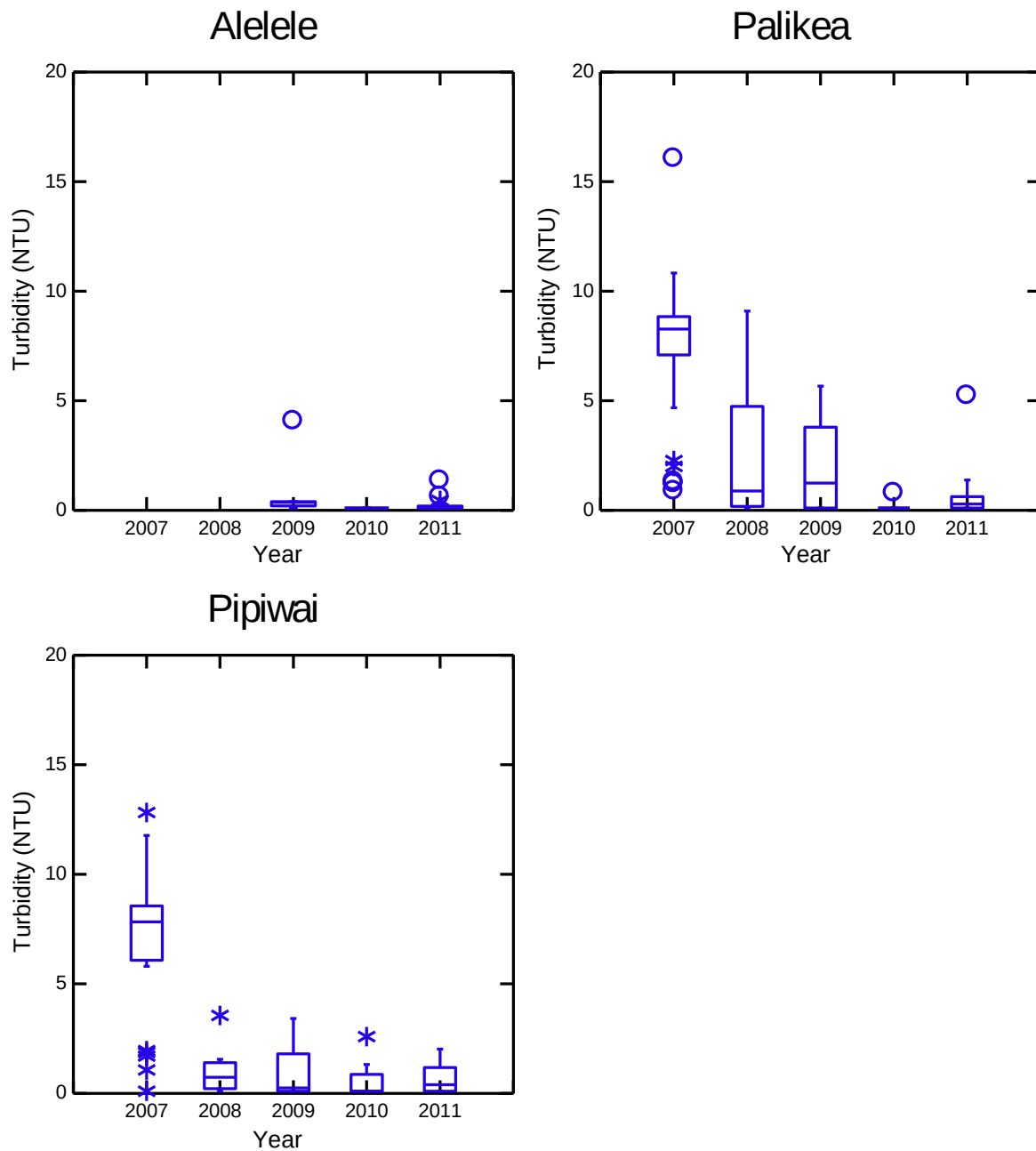


Figure 15. Box plots of turbidity in streams of Haleakala National Park.

Discussion

Total nutrient concentrations may be higher than dissolved nutrient concentrations during high flow events with large particulate loads. Current methods target periods of low flow when particulate loads are low.

Literature Cited

Hawaii, 2012, Title 11, Chapter 54, Water Quality Standards, Hawaii Administrative Rules, Department of Health.

Helsel, D. R. and R. M. Hirsch. 2002. Statistical Methods in Water Resources. US Geological Survey Techniques of Water Resources Investigations, Book 4, Chapter A3.

Jones, T., K. DeVerse, G. Dicus, D. McKay, A. Farahi, K. Kozar, and E. Brown. 2011. Water quality vital signs monitoring protocol for the Pacific Island Network: Volume 1; Version 1.0. Natural Resource Report NPS/PACN/NRR—2011/418. National Park Service, Fort Collins, CO.

https://irma.nps.gov/Reference.mvc/DownloadDigitalFile?code=430113&file=2011_PACN_water_quality_protocol_narrative.pdf

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

NPS 131/131597, February 2016

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