U.S. GEOLOGICAL SURVEY, CARIBBEAN WATER SCIENCE CENTER INTERNAL REPORT

Synoptic Water Quality Sampling at Puerto Mosquito Bay, Vieques, Puerto Rico, May 30, 2014

Introduction

The U. S. Geological Survey, Caribbean Water Science Center (CWSC) in cooperation with the Puerto Rico Department of Natural and Environmental Resources (PRDNER), the Puerto Rico Environmental Quality Board (PREQB) and the Vieques Conservation and Historical Trust (VCHT) conducted on May 30, 2014 a special water-quality sampling at Puerto Mosquito Bay in Vieques, Puerto Rico. The purpose of the sampling was to establish baseline water-quality data that would help to investigate the possible causes of a decrease of bioluminescence in the bay noticed since January 2014. Bioluminescence in the bay is produced by dinoflagellates. The CWSC collected field parameters at seven sites of the bay (fig. 1) including water temperature, salinity, specific conductance, dissolved oxygen, dissolved oxygen percent saturation, turbidity, pH, and water transparency. The PREQB collected samples for total nutrients and chlorophyll concentrations at four sites, and the VCHT collected samples for the concentration of dinoflagellates populations at those four sites.

Methods of Investigation

Water temperature, specific conductance, salinity, dissolved oxygen and percent saturation, pH, and turbidity were collected at six sites using a Yellow Springs Instruments (YSI) multi-parameter meter model 6920. Data for a seventh site (station 4) was collected at the continuous water quality monitor operating in Puerto Mosquito Bay since November 2011. The data at station 4 however do not include bottom values because the monitor is fixed at a depth of about 2 feet below the water surface. For this reason data from station 4 are not presented in the comparison in figure 2 but are included in table 2.

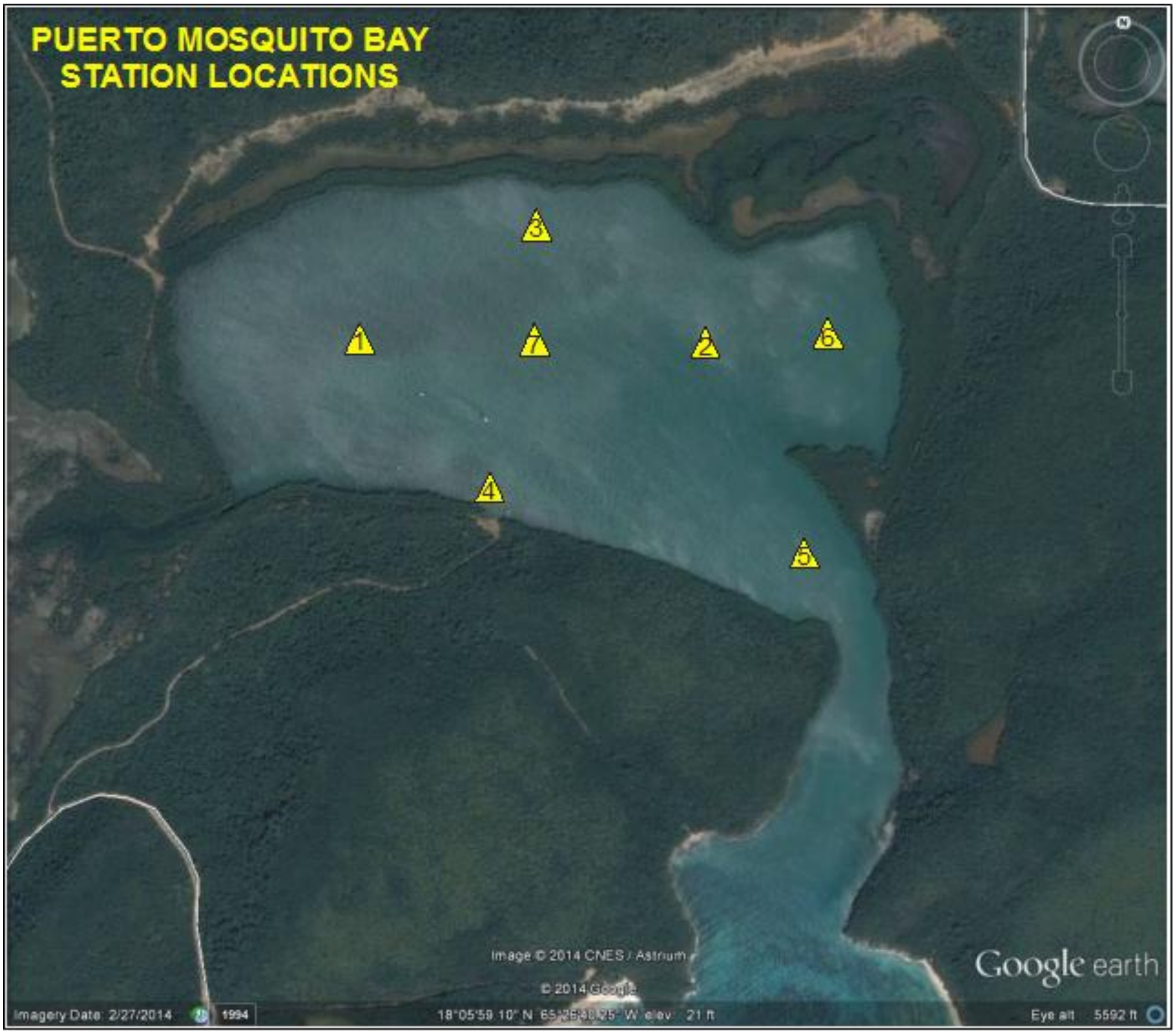


Figure 1. Location and identification number of water-quality stations at Puerto Mosquito Bay, Vieques, Puerto Rico, May 30, 2014.

Water transparency was measured at six sites (except station 4) using a Secchi disk. In addition, water column community productivity was determined using the light/dark bottles method at two sites (stations 1 and 2). At four of these sites, water samples were collected by the PREQB for analysis of total nutrients and chlorophyll concentration. Table 1 specifies the field determinations by station at Puerto Mosquito Bay. Station 4 is the existing water quality monitor deployed at Puerto Mosquito Bay and data for the day and time of the sampling are presented in table 2.

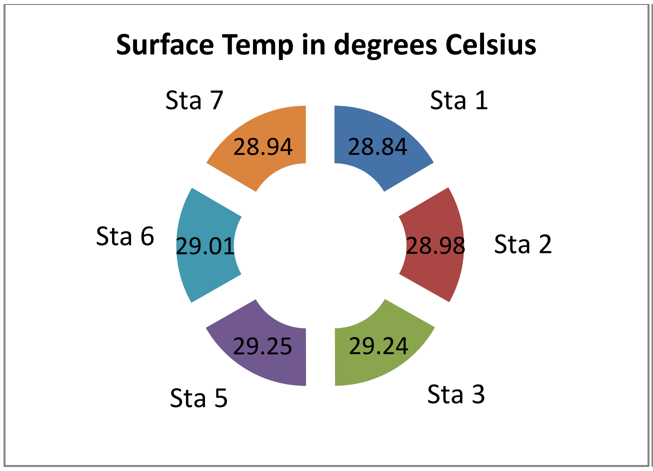
Table 1. Puerto Mosquito water quality sampling stations and applicable determinations conducted on May 30, 2014. [NAD 83, North American Datum of 1983; field determinations were water temperature in degrees Celsius, specific conductance in microsiemens per centimeter, salinity in parts per thousand, dissolved oxygen in milligrams per liter and percent saturation, pH in standard units, turbidity in formazin nephelometric units, and Secchi disk water transparency in inches].

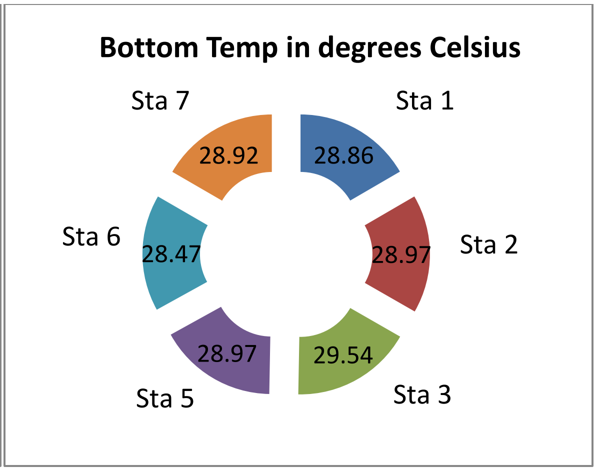
Station name	**Geographic Coordinates (NAD83)**	**Parameters sampled**
Puerto Mosquito no. 1	18°06’07.8” 65°26’56.3”	Field determinations, nutrients, productivity, and transparency
Puerto Mosquito no. 2	18°06’06.4” 65°26’34.9”	Field determinations, nutrients, productivity, and transparency
Puerto Mosquito no. 3	18°06’13.7” 65°26’41.8”	Field determinations and transparency
Puerto Mosquito no. 4	18°05’58.8” 65°26’45.9”	Field determinations
Puerto Mosquito no. 5	18°05’56.8” 65°26’27.4”	Field determinations and transparency
Puerto Mosquito no. 6	18°06’09.1” 65°26’28.0”	Field determinations, nutrients, productivity, and transparency
Puerto Mosquito no. 7	18°06’07.9” 65°26’42.1”	Field determinations, nutrients, productivity, and transparency

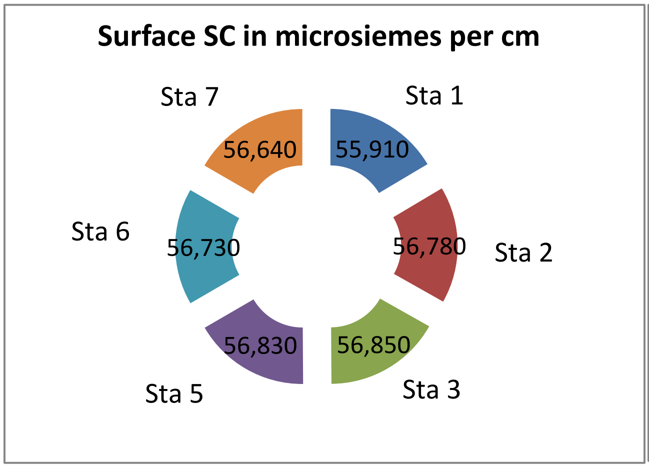
Results and discussion

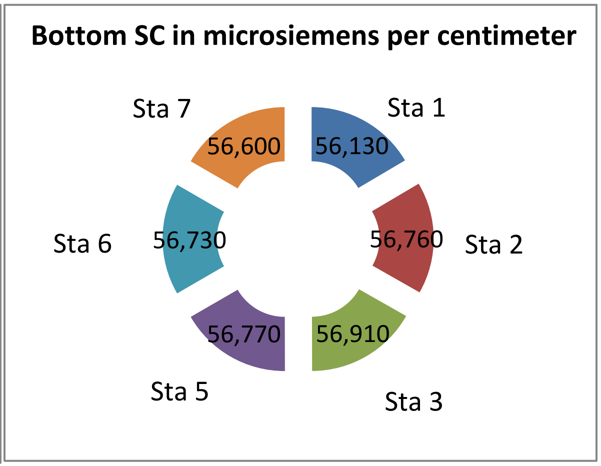
The water temperature, specific conductance, salinity, dissolved oxygen, percent saturation, pH, and turbidity values were within normal standards range and exhibited a homogeneous spatial distribution. Vertical stratification of the measured parameters was not observed with the exception of turbidity in which bottom values were slightly higher (figure 2). This finding suggests effective water mixing probably by the winds and tides effect, which is discussed below in this report.

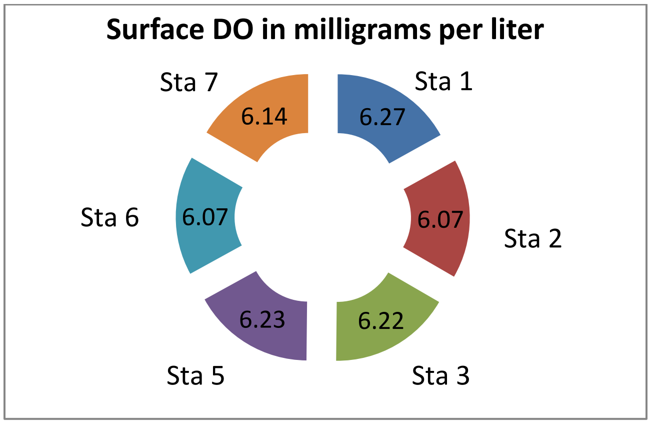
Data collected during the May 30, 2014 sampling were compared to data collected by the USGS at stations 1 and 2 of Puerto Mosquito Bay during four sampling events between November 2011 and August 2012 for another project in cooperation with the PREQB. These previous data showed an almost similar homogeneous trend with the exception of dissolved oxygen concentrations in which bottom values were consistently lower than top values. Values for temperature, specific conductance, and pH for samples collected on May 2014 were in the same range of values as samples collected during May 2012. However, dissolved oxygen concentrations measured during May 2014 at stations 1 and 2 were in the range of approximately 46 to 78 percent higher than concentrations measured during May 2012.

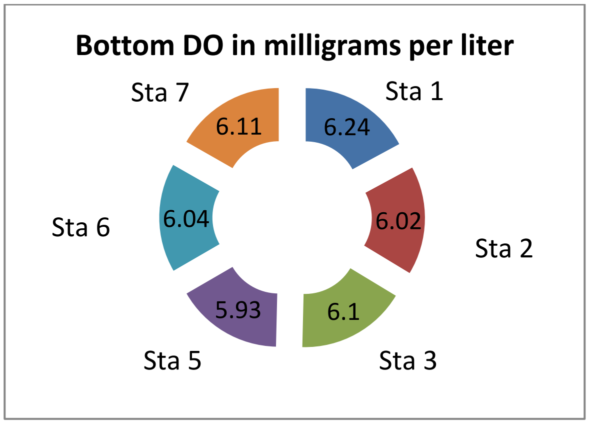

Surface Temp in degrees Celsius
Sta 7
Sta 1
28.94
28.84
Sta 6
29.01
28.98
Sta 2
29.25
29.24
Sta 5
Sta 3


Bottom Temp in degrees Celsius
Sta 7
Sta 1
28.92
28.86
Sta 6
28.47
28.97
Sta 2
28.97
29.54
Sta 5
Sta 3


Surface SC in microsiemes per cm
Sta 7
Sta 1
56,640
55,910
Sta 6
56,730
56,780
Sta 2
56,830
56,850
Sta 5
Sta 3


Bottom SC in microsiemens per centimeter
Sta 7
Sta 1
56,600
56,130
Sta 6
56,730
56,760
Sta 2
56,770
56,910
Sta 5
Sta 3


Surface DO in milligrams per liter
Sta 7
Sta 1
6.14
6.27
Sta 6
6.07
6.07
Sta 2
6.23
6.22
Sta 5
Sta 3


Bottom DO in milligrams per liter
Sta 7
Sta 1
6.11
6.24
Sta 6
6.04
6.02
Sta 2
5.93
6.1
Sta 5
Sta 3

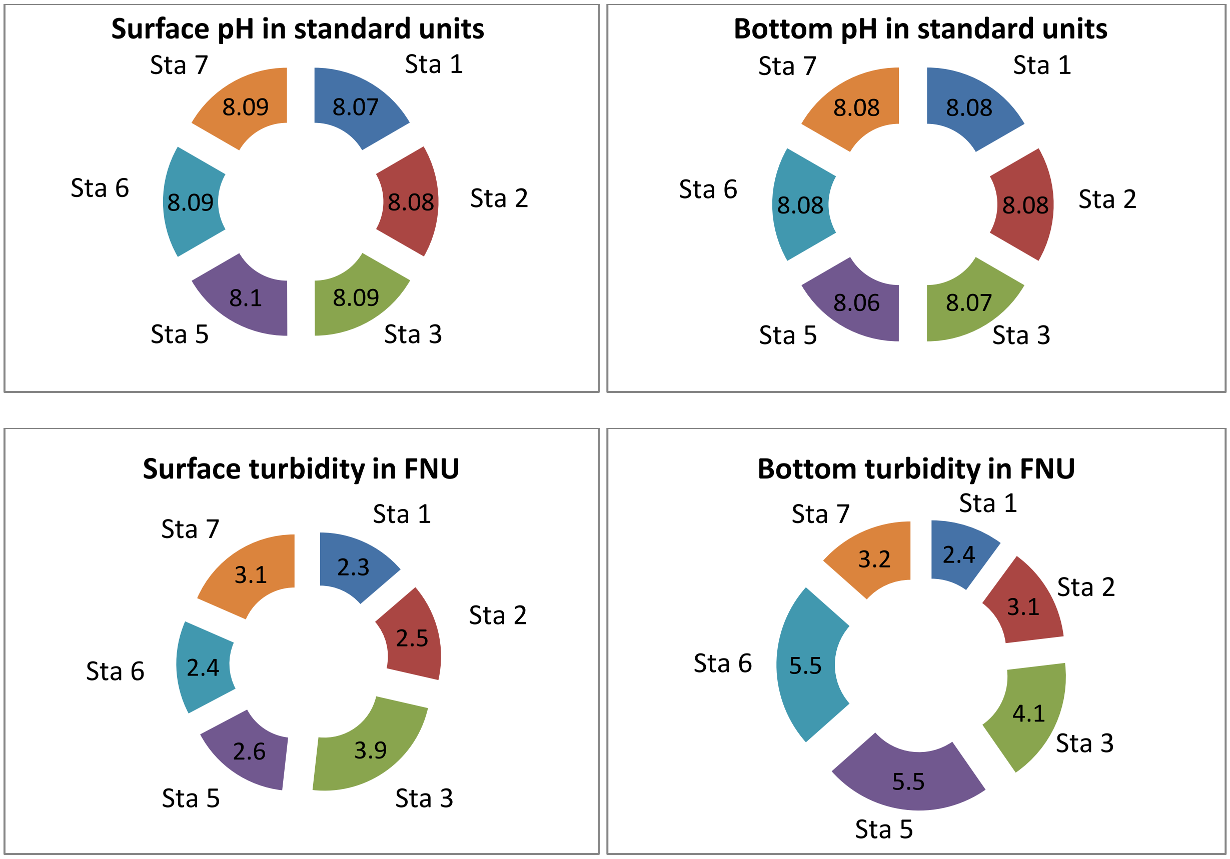


Figure 2. Selected water–quality field determinations collected at Puerto Mosquito Bay, Vieques, Puerto Rico, May 30, 2014. [Sta, station; temp, water temperature in degrees Celsius; SC, specific conductance in microsiemens per centimeter, DO, dissolved oxygen in milligrams per liter; pH in standard units; turbidity in formazin nephelometric units].

Water transparency of Puerto Mosquito Bay was measured using a Secchi disk, which provides a mean for determining the limit of visibility based on contrast between four quadrants with alternate black and white areas on the disk. Water transparency is at least twice the Secchi disk depth of dissappearance because light must travel twice through a water column before it is reflected by the disk and seen by the user. Biologists consider the depth of the euphotic zone to be roughly three times the measured transparency; the eupthotic zone is defined as the upper layer of a water body into which enough light penetrates to allow the growth of green plants and algae.

Water transparency was measured at six of the selected stations (not measured at station 4) in Puerto Mosquito Bay and values ranged from 36 to 48 inches (in), averaging 42 in (table 2). With a maximum water depth of about 12 feet and a mean depth of about 6 feet (Mitchell, 2004), light should penetrate the water column all the way down to the bottom in the vast majority of Puerto Mosquito Bay allowing aquatic vegetation and algal growth.

Table 2. Selected field parameters collected at Puerto Mosquito Bay, Vieques, Puerto Rico, May 30, 2014. [Temp, temperature in degrees Celsius; SC, specific conductance in microsiemens per centimeter; Sal, salinity in parts per thousands; DO, dissolved oxygen in milligrams per liter; DOsat, dissolved oxygen saturation in percent; turb, turbidity in formazin nephelometric units; surf, surface; m, meter; n/a, not applicable].

Mosquito Bay no. 1
Time: 0935

Depth	Temp	SC	Sal	DO	DOsat	pH	turb	Secchi
Surf	28.84	55,910	37.07	6.27	100	8.07	2.3	
1m	28.86	56,130	37.17	6.24	99.4	8.08	2.3	
2m	28.86	56,130	37.17	6.24	99.4	8.08	2.4	42"

Mosquito Bay no. 2
Time: 1000

Depth	Temp	SC	Sal	DO	DOsat	pH	turb	Secchi
Surf	28.98	56,780	37.64	6.07	97.1	8.08	2.5	
1m	28.98	56,760	37.63	6.05	96.7	8.08	2.6	
2m	28.97	56,760	37.64	6.02	96.2	8.08	3.1	48"

Mosquito Bay no. 3
Time: 1130

Depth	Temp	SC	Sal	DO	DOsat	pH	turb	Secchi
Surf	29.24	56,850	37.72	6.22	100.1	8.09	3.9	
1m	29.38	56,900	37.73	6.18	99.6	8.08	4.1	
2m	29.54	56,910	37.74	6.1	98.6	8.07	4.1	36"

Mosquito Bay no. 4
Time: 1200

Depth	Temp	SC	Sal	DO	DOsat	pH	turb	Secchi
Surf	29.81	55,278	36.51	8.06	130	8.19	5.7	
1m	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
2m	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Mosquito Bay no. 5
Time: 1100

Depth	Temp	SC	Sal	DO	DOsat	pH	turb	Secchi
Surf	29.25	56,830	37.69	6.23	100.2	8.1	2.6	
1m	29.18	56,830	37.68	6.12	98.2	8.09	2.7	
2m	28.97	56,770	37.64	5.93	94.8	8.06	5.5	42"

Mosquito Bay no. 6
Time: 1045

Depth	Temp	SC	Sal	DO	DOsat	pH	turb	Secchi
Surf	29.01	56,730	37.63	6.07	97.2	8.09	2.4	
1m	28.98	56,730	37.63	6.04	96.7	8.08	2.7	
2m	28.47	56,730	37.62	6.04	96.6	8.08	5.5	42"

Mosquito Bay no. 7
Time: 1115

Depth	Temp	SC	Sal	DO	DOsat	pH	turb	Secchi
Surf	28.94	56,640	37.55	6.14	98.2	8.09	3.1	
1m	28.93	56,610	37.53	6.11	97.7	8.08	3.1	
2m	28.92	56,600	37.52	6.11	97.7	8.08	3.2	42"

Water column productivity of Puerto Mosquito Bay was determined at stations 1 and 2 using the light/dark bottles method which is the most straightforward and inexpensive method for estimating primary productivity in water bodies. The light (translucent) and dark (non-translucent) bottle method can be used to determine net changes in the concentration of dissolved oxygen for a given volume of water within a given time interval (Clesceri and others, 1998). This technique was used for the analysis of net primary productivity by phytoplankton, total respiration by plankton, and gross productivity by plankton in the water column. Incubation started before 6:00 a.m. and ended at about 10:30 a.m. The early initial time was selected to avoid high oxygen saturation levels at the time of sample collection so that an increase in dissolved oxygen concentration could be observed at the end of the incubation period. The initial concentration of dissolved oxygen prior to incubation was determined using the Winkler titration method (Clesceri and others, 1998). At both sites, an aluminum rack (fig. 3) was deployed that contained two contiguous light bottles and two contiguous dark bottles (Clesceri and others, 1998). The water samples were incubated at the depths from which they were collected for at least 4 hours.

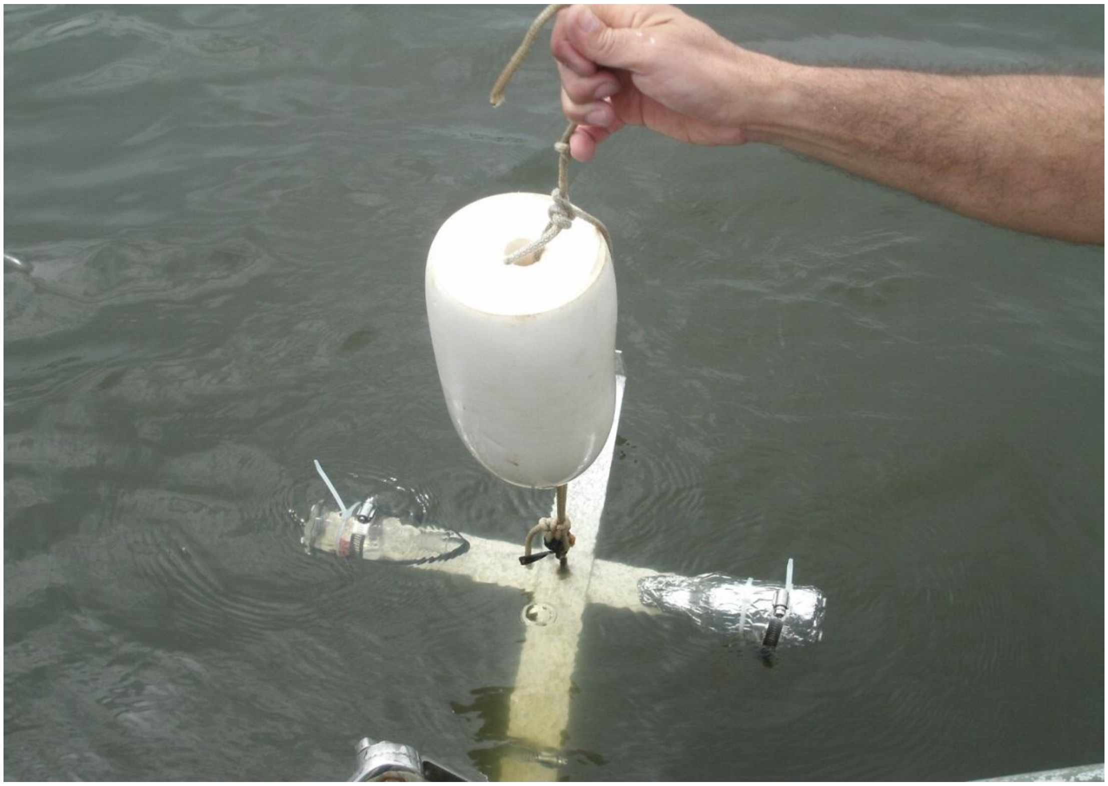


Figure 3. Typical deployment of the light/dark bottles method for water column productivity determinations.

After incubation, the dissolved oxygen concentration of the samples was determined by titration. The initial dissolved oxygen concentration was expected to decrease in the dark bottle by respiration, and was expected to increase in the light bottle by photosynthesis. The oxygen production and respiration results, therefore, can be expressed as:

Gross productivity (Pg) = OL - OD;

Net productivity (Pn) = OL - OI; and

Respiration (R) = OI – OD,

where,

OL is the dissolved oxygen concentration at the end of the incubation period in the light bottle;

OD is the dissolved oxygen concentration at the end of the incubation period in the dark bottle; and

OI is the initial dissolved oxygen concentration prior to incubation.

Based on the dissolved oxygen concentration results, the predominant plankton community at the time of incubation can be determined. If oxygen production is greater than respiration, phytoplankton community (autotrophic organisms) is predominant. On the other hand, if respiration is greater than oxygen production, plankton community (heterotrophic organisms) is predominant. Table 3 presents the productivity values determined using the light and dark bottles method.

Table 3. Productivity determinations using the light and dark bottles method at Puerto Mosquito Bay, Vieques, Puerto Rico, May 30, 2014. [OI, initial oxygen; OL, light bottle oxygen; OD, dark bottle oxygen; GP, gross productivity; NP, net productivity; R, respiration; IT, incubation time; GP rate, gross productivity rate; NP rate, net productivity rate; R rate, respiration rate; all oxygen concentrations are in milligrams per liter; time in hours].

Date	OI	OL	OD	GP	NP	R	IT	GP rate	NP rate	R rate
Station 1 – started incubation at 0515 – ended at 0930										
May 30, 2014	6.70	7.00	6.40	0.60	0.30	0.30	4.25 hrs	0.15	0.08	0.08
Station 2 – started incubation at 0530 – ended at 1000										
May 30, 2014	7.30	6.90	6.40	0.50	-0.40	0.90	4.5 hrs	0.11	-0.09	0.20

Dissolved oxygen and respiration data indicated that at station 1, on the western portion of Puerto Mosquito Bay, there was an increase in oxygen concentration in the light bottle compared to the initial concentration. This indicates that phytoplankton community was predominant, giving a net productivity of 0.30 milligrams per liter (mg/L) of oxygen in 4.25 hours for a net rate of 0.07 mg/L per hour of oxygen. In the dark bottle the oxygen concentration decreased from the initial by 0.30 mg/L of oxygen in 4.25 hours, giving a respiration rate of 0.07 mg/L per hour also. Although oxygen production and respiration were the same, it can be concluded that most of the respiration if not all was by phytoplankton trapped inside the dark bottle rather than plankton since without light phytoplankton can only respire and not photosynthesize. However, there may have been planktonic organisms also but at a lower concentration.

Dissolved oxygen and respiration data indicated that at station 2, on the eastern portion of Puerto Mosquito Bay, there was a decrease in oxygen concentration in the light bottle compared to the initial concentration. This indicates that plankton community was predominant with no net productivity. In the dark bottle the oxygen concentration decreased from the initial by 0.90 mg/L of oxygen in 4.5 hours, giving a respiration rate of 0.20 mg/L per hour. Here, respiration was more vigorous with no oxygen production indicating that at this portion of the bay, plankton community was predominant. Although not detected by the assay, phytoplankton may have been present at lower concentrations.

Based on the results presented above it can be concluded that at the time of the light and dark bottles incubation, the phytoplankton populations were mostly located to the west (closer to station 1) of Puerto Mosquito Bay. The wind speed and direction could have made that phytoplankton populations drifted to that area as winds were gusting at about 15 knots (17 miles per hour) from the eastern direction just before incubation, and were sustained at about 4 knots

(5 miles per hour) during incubation (fig. 4). Plankton populations on the other hand are motile and can relocate at will.

Wind data collected at the National Oceanographic and Atmospheric Administration (NOAA) station 9752695, Esperanza,Vieques, Puerto Rico from May 29-30, 2014 indicate that winds were predominantly from east-southeast at about 15 knots (17 miles per hour) during day hours (NOAA, 2014, fig. 3). As stated above data collected at stations 1 and 2 of Puerto Mosquito Bay between November 2011 and August 2012 showed an almost similar homogeneous trend with the exception of dissolved oxygen concentrations in which bottom values were consistently lower than top values. Although not presented in this document, tidal patterns for sampling events between November 2011 and August 2012 showed a prolonged biweekly above-mean-sea-level episodes followed by harmonic above and below mean sea level periods. Previous and current data on field determinations suggest effective water mixing of the bay as well as substantial water recycle rate in Puerto Mosquito Bay.

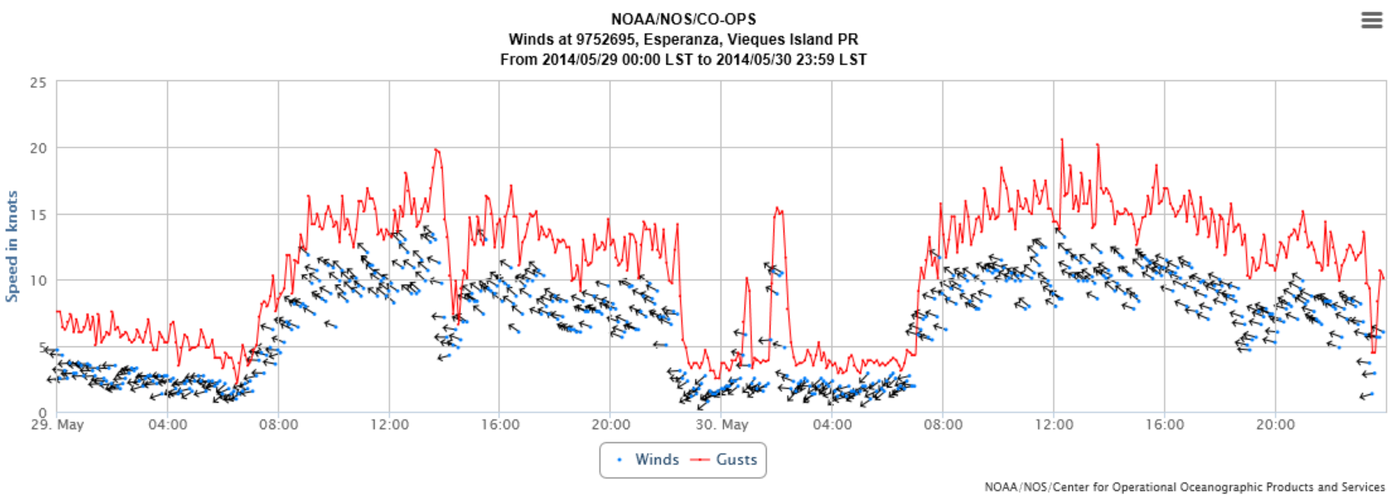


Figure 4. Wind speed and direction recorded by the National Oceanographic and Atmospheric Administration (NOAA) station 9752695, Esperanza,Vieques, Puerto Rico, May 29-30, 2014.

Tides data for May 30, 2014 indicated that by the time of sampling (between 5:15 am and 12:00 m, including the light/dark and field determinations samplings) water levels were dropping and went below mean sea level and most probably water was exiting the bay, also known as ebb flow (fig. 5).

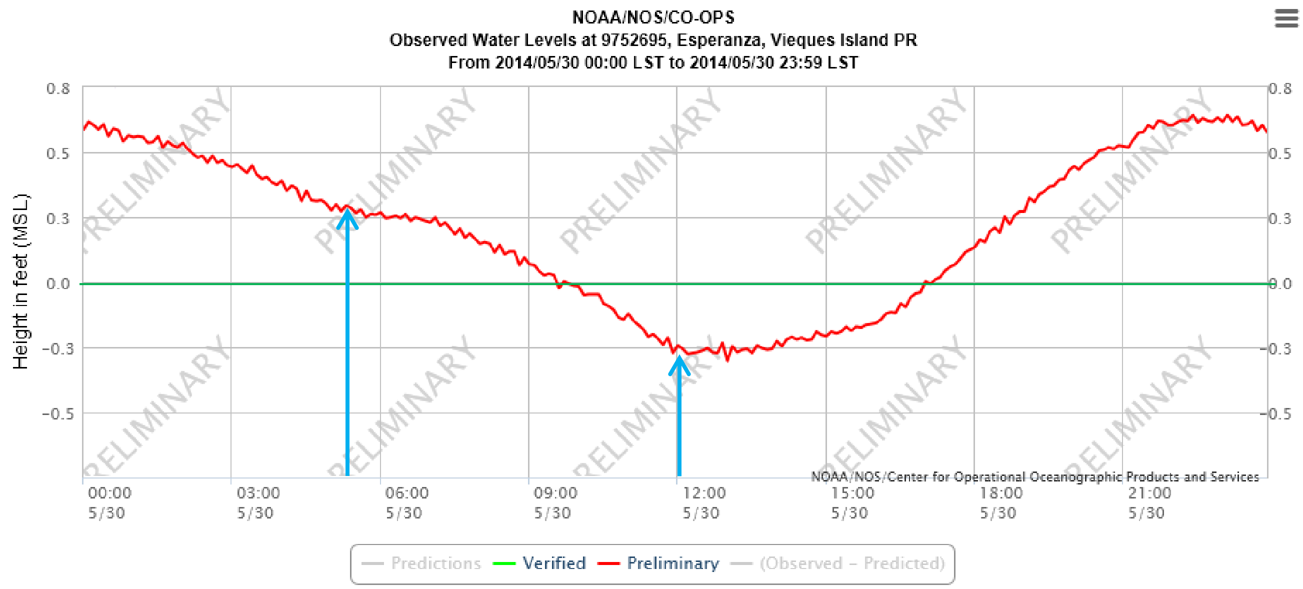
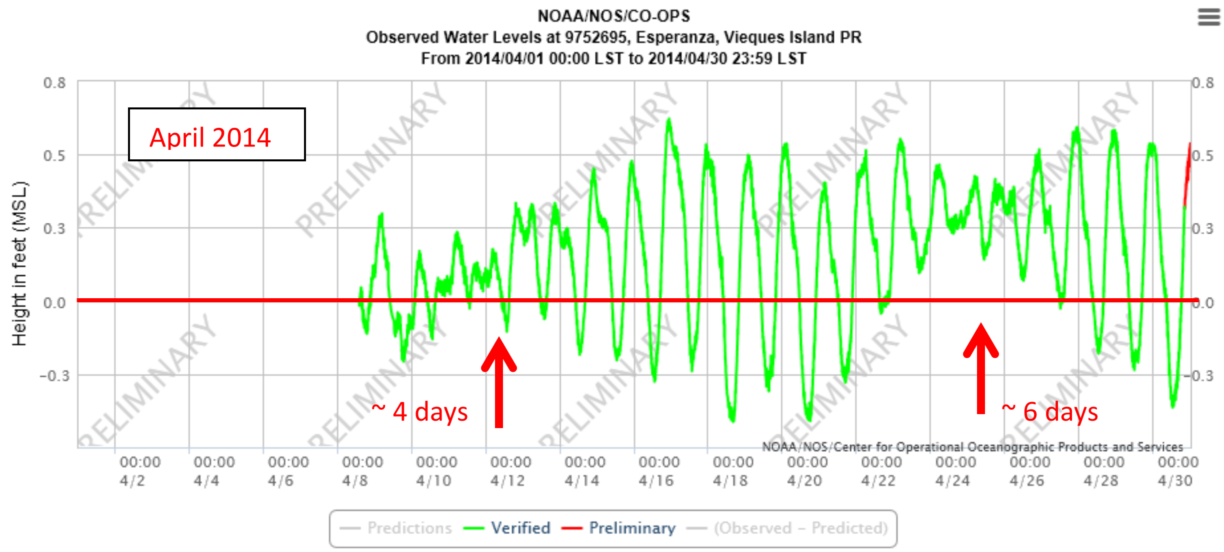
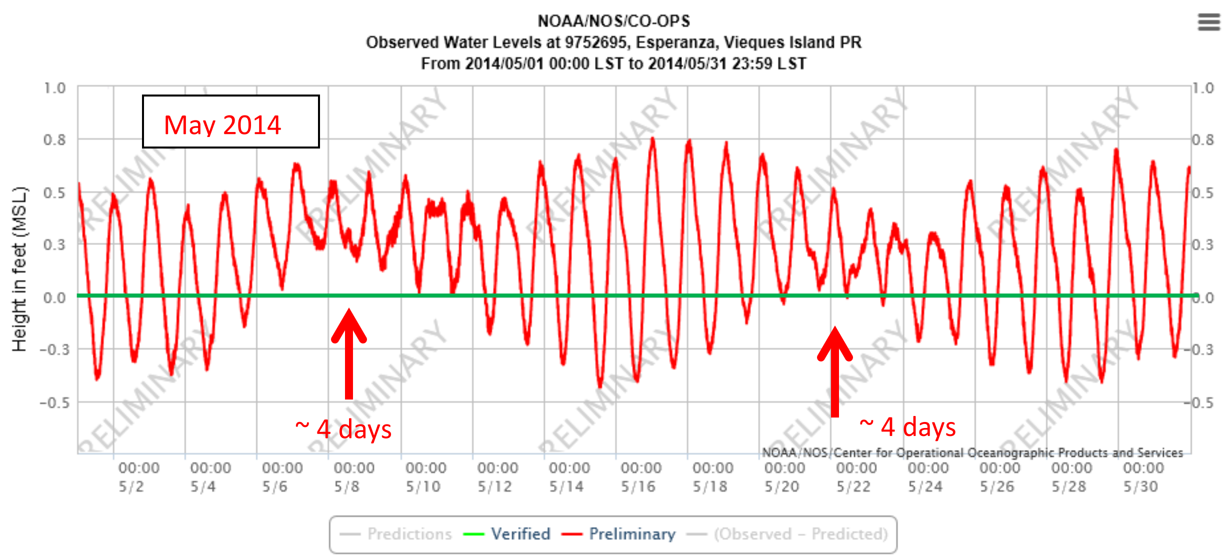


Figure 5. Tidal variations recorded by the National Oceanographic and Atmospheric Administration (NOAA) station 9752695, Esperanza,Vieques, Puerto Rico, May 30, 2014.

From the homogeneous distribution of parameters, with no vertical stratification, it is suitable to conclude that wind and tides have an effect on the water mixing in the bay. By examining tide patterns for April, May, and June 2014 it is observed a distinct repetitive cycle that takes place where higher than normal water levels occurs at about every two weeks and stay above mean sea level for a period that ranges from 4 to 6 days, followed by harmonic tidal cycles with above and below mean sea level episodes. This suggests that the bay is flooded higher than normal from 4 to 6 days about every two weeks followed by harmonic ebb and flood flows (fig. 6).

During November 2013, the Laguna Grande in Fajardo, another bioluminescent lagoon, had a similar episode of decreasing in brightness and when investigated, it was noted that the episode coincided with the occurrence of tides of high magnitude and duration (Soler-López, 2013, unpublished information). Therefore, the higher-than-normal tides pattern observed biweekly in Puerto Mosquito Bay may play some role in the bioluminescence decrease. Tidal data from April to June 2012 (between November 2013 and April 2014 the NOAA Esperanza station was not operational) were analyzed to examine if the same tide pattern was observed previously (fig. 7). Tides data for April, May, and June 2012 showed the same biweekly above-mean-sea-level pattern, however to general knowledge the bay did not experience any reported decrease in bioluminescence. Although previous years data suggests that tidal patterns do not play a role in brightness loss, the hydraulics imposed by those conditions are favorable for the recycle of large volumes of water in Puerto Mosquito Bay and potentially decrease dinoflagellates populations by dilution and subsequent flushing.


NOAA/NOS/CO-OPS
Observed Water Levels at 9752695, Esperanza, Vieques Island PR
From 2014/04/01 00:00 LST to 2014/04/30 23:59 LST
April 2014
Height in feet (MSL)
~ 4 days
~ 6 days
NOAA/NOS/Center for Operational Oceanographic Products and Services
Predictions
Verified
Preliminary
(Observed – Predicted)


NOAA/NOS/CO-OPS
Observed Water Levels at 9752695, Esperanza, Vieques Island PR
From 2014/05/01 00:00 LST to 2014/05/31 23:59 LST
May 2014
Height in feet (MSL)
~ 4 days
~ 4 days
NOAA/NOS/Center for Operational Oceanographic Products and Services
Predictions
Verified
Preliminary
(Observed – Predicted)

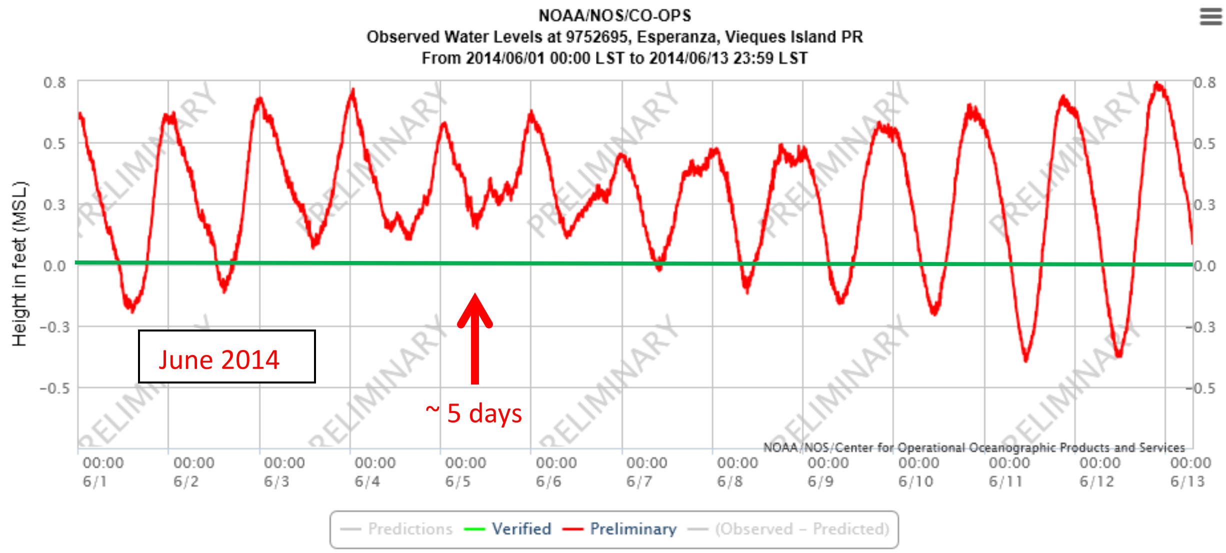
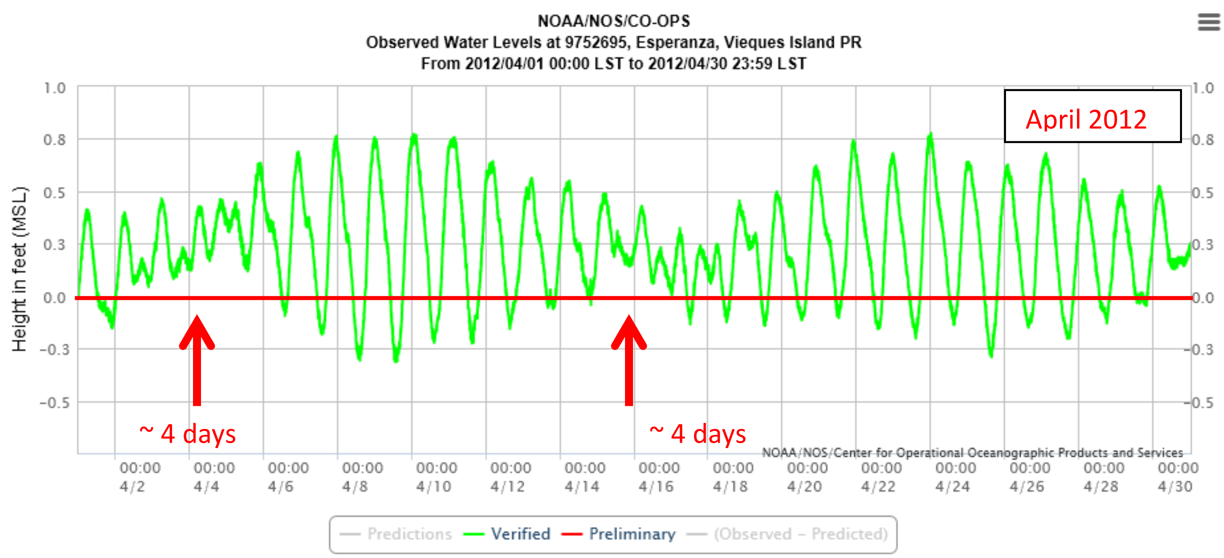


Figure 6. Tidal patterns for April, May, and June 2014 at the National Oceanographic and Atmospheric Administration (NOAA) station 9752695, Esperanza,Vieques, Puerto Rico.



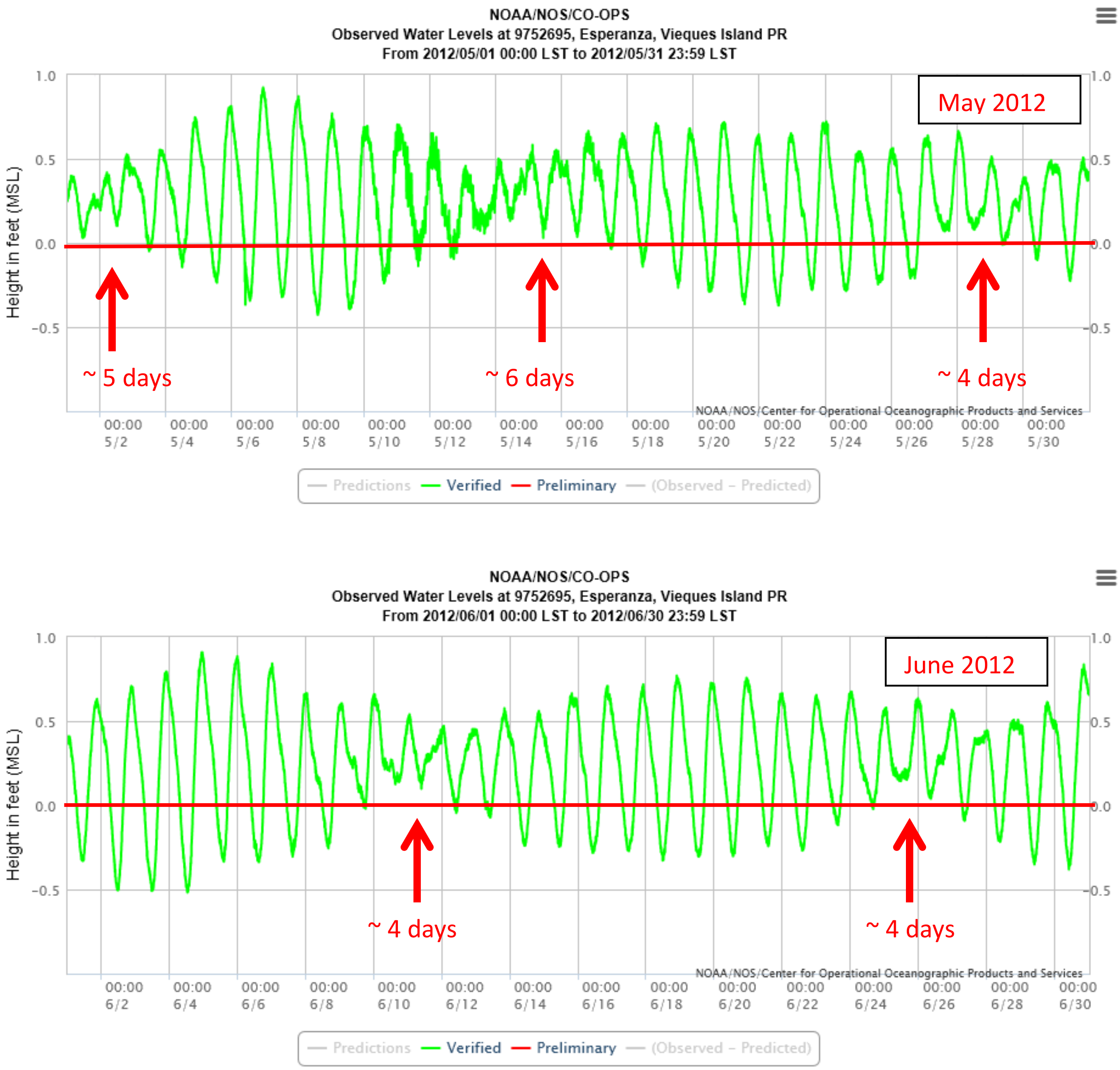


Figure 7. Tidal patterns for April, May, and June 2012 at the National Oceanographic and Atmospheric Administration (NOAA) station 9752695, Esperanza, Vieques, Puerto Rico.

Conclusions

Field determinations, water transparency, and water column productivity data showed no atypical conditions that could affect dinoflagellate populations. The homogeneous distribution with no vertical stratification of field determinations however indicate effective water mixing which can be the result of higher than normal tides that occur periodically. Although historical data suggests that tidal patterns do not play a role in bioluminescence loss, the hydraulics imposed by these conditions are favorable for the recycling of large volumes of water in Puerto Mosquito Bay and potentially decrease dinoflagellates populations by dilution and subsequent flushing. Having defined the tidal patterns in Puerto Mosquito Bay, it would be useful to conduct sampling for dinoflagellates concentrations for the duration of these above-mean-sea-level episodes and immediately after when tides revert to harmonic above and below mean sea level patterns. This information can help to determine if tidal patterns affect the concentration of dinoflagellates and the changes in bioluminescence observed in Puerto Mosquito Bay.

References cited

Clesceri, L.S., Greenberg, A.E., and Eaton, A.E., eds., 1998, Standard Methods for the examination of water and wastewater (20th ed.): Washington D.C., American Public Health Association, 1,220 p.

Lee E. Mitchell, 2004, Developing a GIS of the Bioluminescent Bays on Vieques, Puerto Rico, NGPA PA 04-201, 10 p.

National Oceanic and Atmospheric Administration, 2014, benchmark sheet for station number 9752695, Esperanza, Vieques Island, PR, http://tidesandcurrents.noaa.gov/benchmarks.html?id=9752695 accessed on June 11, 2014.