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Variability and Biogeographical Distribution of Harmful Algal Blooms in Bays of High Productivity off Peruvian Coast (2012-2015)

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Abstract

Harmful Algal Blooms are increasing worldwide problems observed in inshore ecosystems, which support a growing anthropogenic activity that impacts on resources. Results of seasonal and interannual variability of toxic phytoplankton in four bays of the Peruvian sea (Sechura 04°S, Samanco 09°S, Miraflores 12°S and Paracas 14°S), are shown during spring and summer from 2012 to 2015. Toxic species such as *Pseudo- nitzschia* Grupo *delicatissima, Grupo P. seriata, Alexandrium peruvianum, Dinophysis caudata, D. acuminata, Gonyaulax spinifera, Azadinium* sp, *Karlodinium* sp., *Karenia* sp., *Protoceratium reticulatum* and *Prorocentrum minimum* were registered, associated with the presence of toxic events, more frequently of okadaic acid (lipophilic toxin - DSP) in Sechura and Samanco for 2012, 2013 and 2014 and saxitoxin (Paralytic Toxin - PSP) in Paracas 2012. Sea surface temperature for spring fluctuated between 16.3° to 19.9°C (Sechura-Paracas), and for the summer between 19.3° to 24.1°C (Paracas - Sechura). Physical dynamics were related with seasonal variations, associated to local effects, with slow surface marine currents during austral summer and intense currents during spring, with average values of <13.91 and 25.0 cm/s, respectively, associated with clockwise gyres that influenced the harmful algal blooms. Spearman correlations (p<0.05) between the biological and physical-chemical component were found mainly with temperature (r=0.665), silicates (r=0.45), phosphates (r=0.48) and nitrates (r=0.50).

Keywords: HABs; Peruvian Sea; Coastal bays; Harmful algal bloom

Introduction

Algal blooms or ´red tides´ are natural monospecific proliferations of certain species of phytoplankton belonging to different taxonomical groups and some photosynthesizer ciliates that cause changes in the color of the sea turning it reddish, brownish, dark brown or even without color; forming irregular spots or patches that can reach some kilometers [1]. Harmful Algal Blooms are increasing worldwide problems observed in peruvian coastal ecosystem, which supports a growing anthropogenic activity that impacts on resources. For the Northern Humboldt Current Ecosystem (Peruvian Sea), red tides records are available since 1980 with information from coastal laboratories of IMARPE, and a monitoring program was established since 2003. Harmless and harmful (potentially toxic) phytoplankton species have been recorded. Among harmless dinoflagellates, *Akashiwo sanguinea, Prorocentrum micans, P. gracile, Ceratium fusus* v. *fusus, C. dens* were reported with much frequency. Harmless diatoms such as *Pleurosigma* sp., *Amphiprora* sp, *Skeletonema costatum*, *Leptocylindrus danicus*, *Entomoneis alata* v. *alata* and silicoflagellates such as *Dictyocha fibula* were reported as well. The first reports of potentially toxic phytoplankton were realized by Pisco-Paracas Coastal Laboratory at IMARPE from 2005-2007, three new species were registered belonging to Prorocentrales, Order: *Prorocentrum minimum*, *P.* cf. *balticum*, and *P. lima* considered as potentially toxic Cabello et al. [2], concluded that the intense industrial activity of the fishing factories at the inner part of the bay favored the development of a harmful algal bloom caused by *Prorocentrum micans* exerting a negative synergic effect on the quality of the water column and sediments, which caused the mortality of the scallops. Here, we assess seasonal and interannual variability of toxic phytoplankton in four bays of the Peruvian sea from 2012 to 2015 looking for relationship between biological and physical-chemical components.

Materials and Methods

The sampling was carried out during summer and spring from 2012 to 2015 in four bays of the Peruvian sea (Sechura 04°S, Samanco 09°S, Miraflores 12°S and Paracas 14°S). Water samples were collected with Niskin bottles at surface and bottom depths for phytoplankton, salinity, nutrients, oxygen, chlorophyll and pH. Temperature was measured with surface thermometer, and water column currents with ADCP. Integrated-depth samples were obtained by using a detachable hose in sections [3]. The quantitative analysis was done by Utermöhl methodology [4], giving the results in cell L^{-1} (Figures 1 and 2).

Results and Discussion

The composition of phytoplankton communities reflects life-forms selections modulated by species-specific features [5]. Therefore, species assemblages registered, tend to share characteristics in response to the ecological history of the body of water in which they are found in the different bays studied. Physical dynamics were related with seasonal variations, associated to local effects, with slow surface marine currents during austral summer and intense currents during spring, with average values of <3.91 and 25.0 cm/s, respectively, with clockwise gyres that influenced harmful algal blooms (Figure 3).

Statistical analysis

To explore data dispersion and distribution, boxplots were graphed using MINITAB 16. Spearman's correlation coefficients between potentially toxic phytoplankton abundances (diatoms and dinoflagellates) and physical-chemical parameters were obtained with

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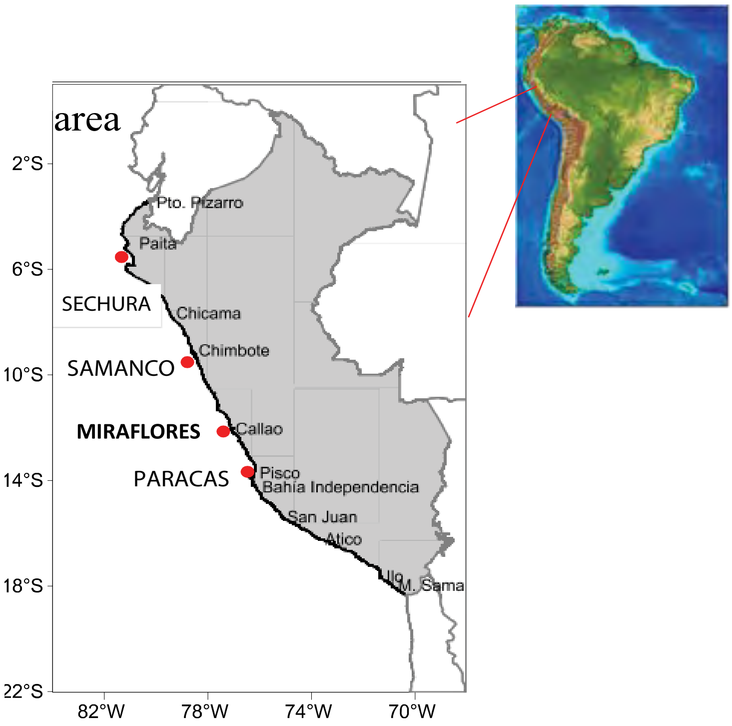

Figure 1: Study area.

Figure 2: Water sampling by Niskin bottle.

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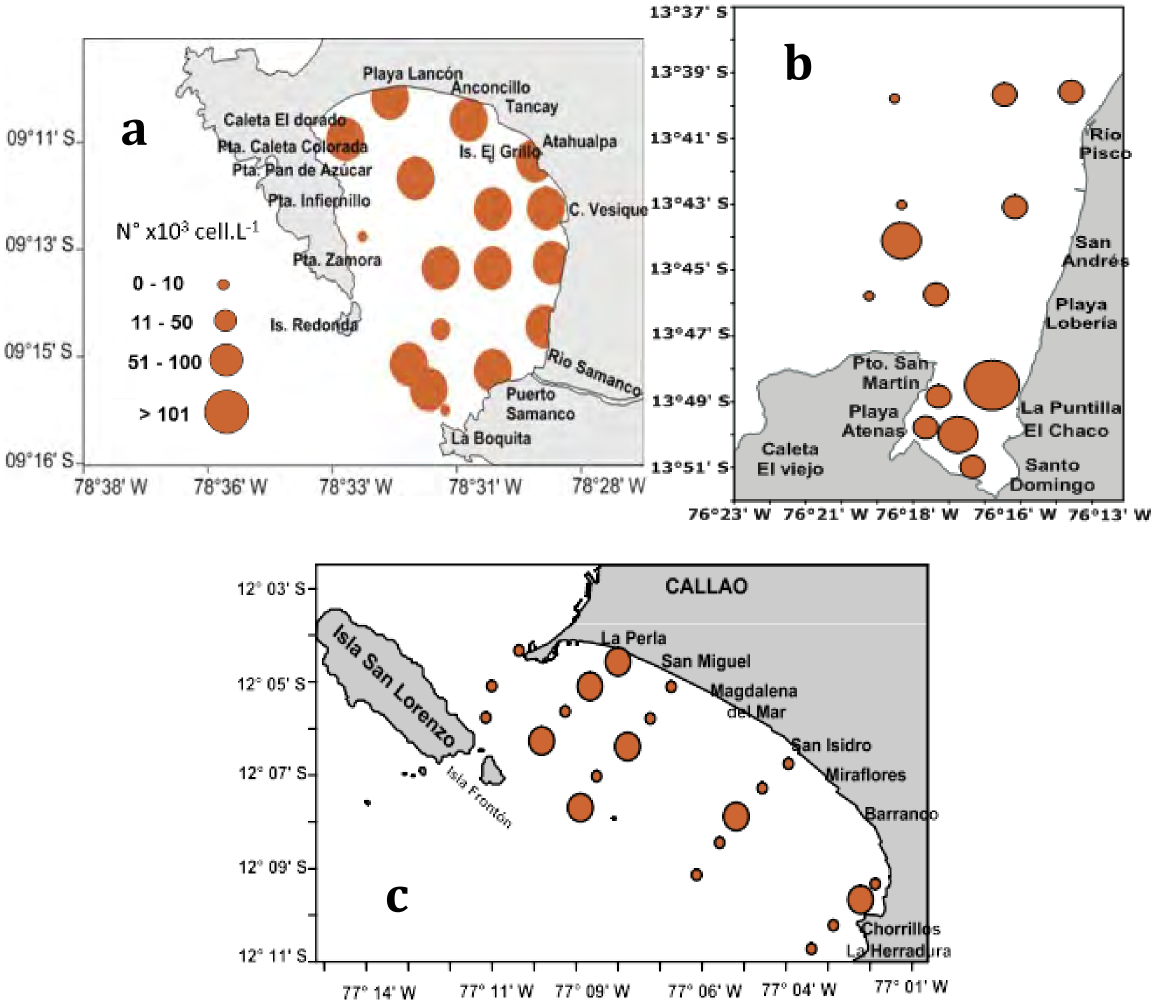

Figure 3: Potentially toxic dinoflagellates abundances in Samanco (**a**, Spring 2013), Paracas (**b**, Summer 2013) and Miraflores (**c**, Summer 2014) bays.

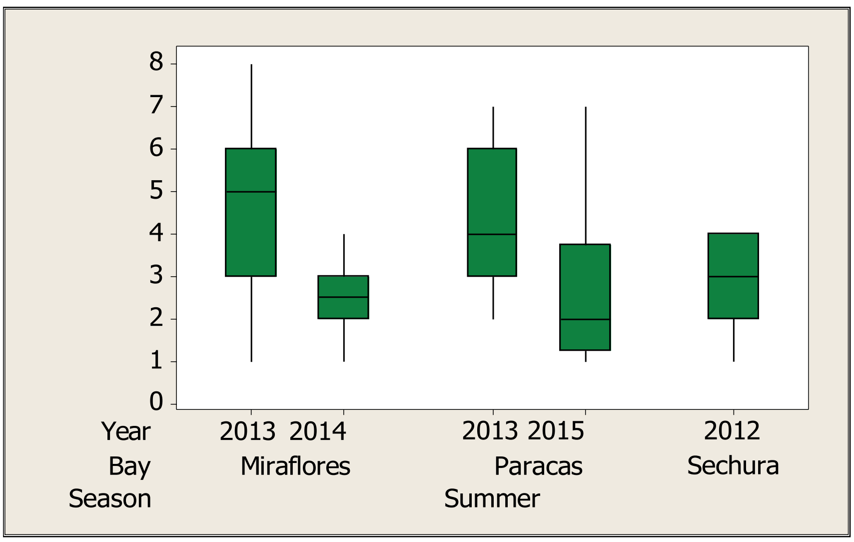

Figure 4: Boxplot diagrams according to bay and study period: Potentially species during austral summer.

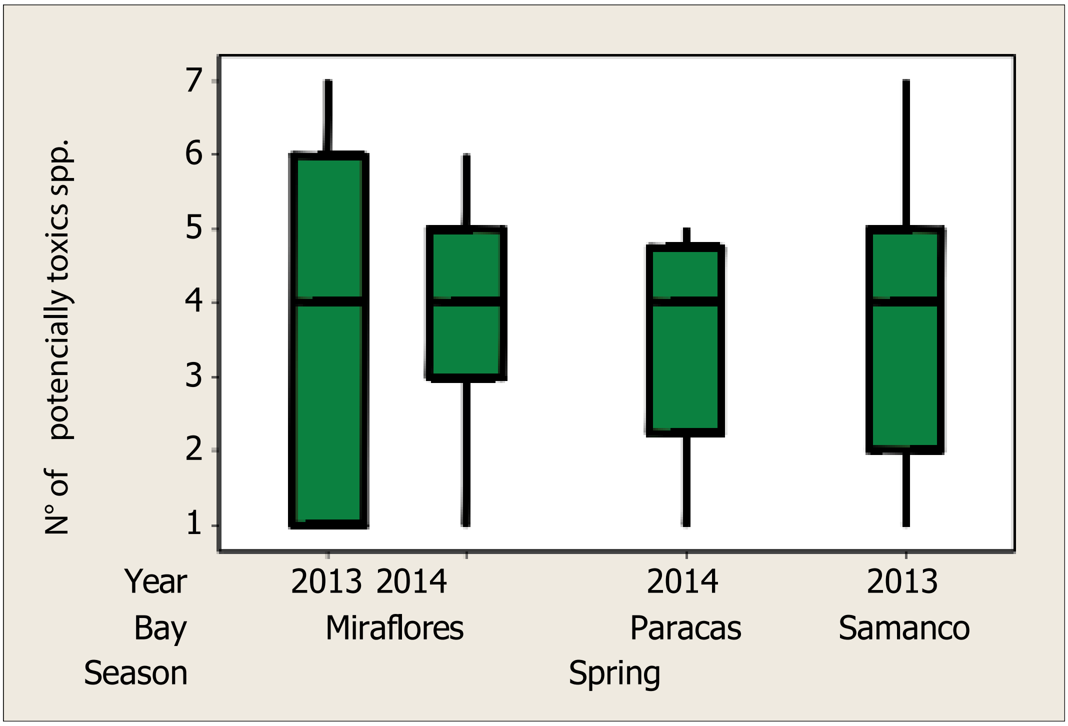

Figure 5: Boxplot diagrams according to bay and study period: Potentially species during spring.

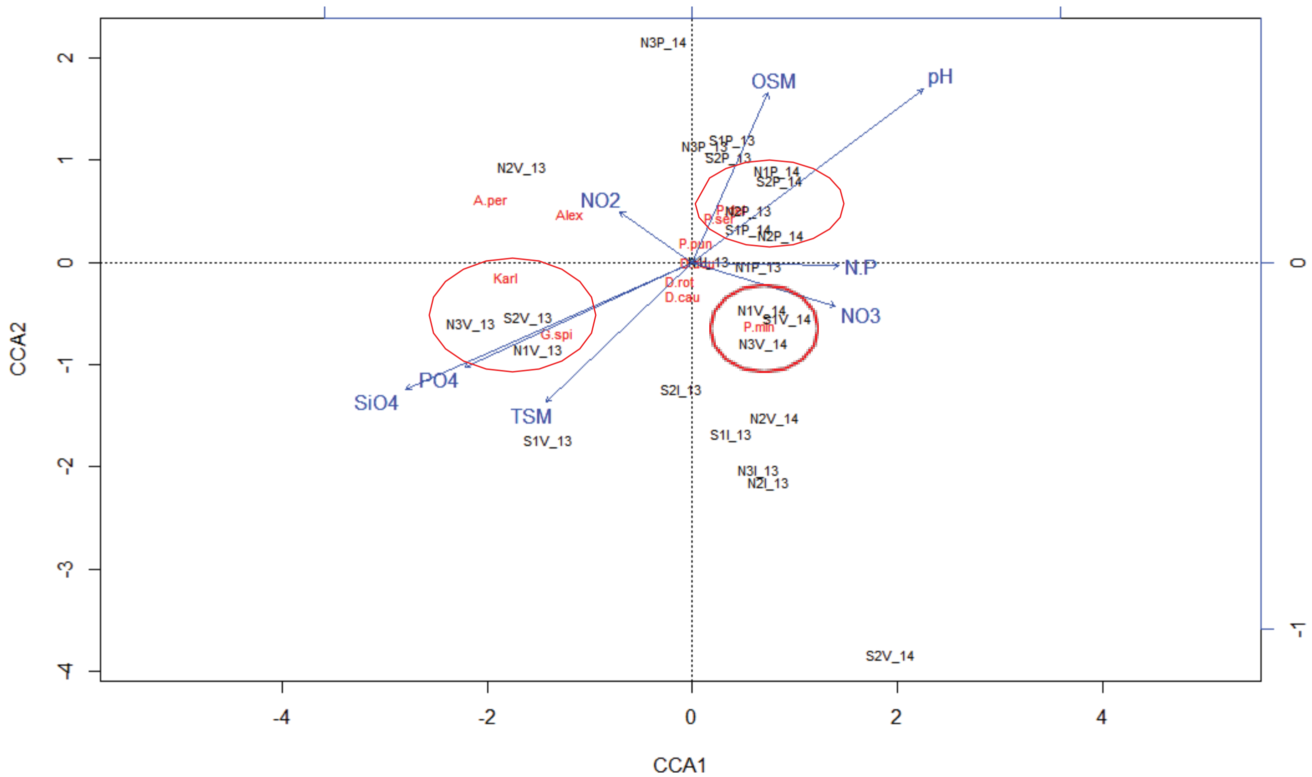

Figure 6: CCA of potentially toxic phytoplankton species cell count and physico-chemical parameters in surface (Miraflores Bay) mainly during summer and spring 2013-2014.

Region	Area	Biotoxin		Year
		Lipophilic	PSP	
Piura 05°12´03´´S 80°37´31´´W	Parachique	1		2007
	Vichayo	3		2008-2009
	Reventazón	2		2008; 2012
	Barrancos	5		2010; 2012; 2013
	Puerto Rico	8		2010;2011;2012;2013
	Chuyillachi	2		2009; 2012; 2013
	Matacaballo	5		2012; 2013
	San Pedro	2		2012; 2013
	Delicias	3		2012; 2013
	Constante	2		2012; 2013
Ancash 09°32´00´´S 77°32´00´´W	Samanco	37	2	2008; 2009; 2010; 2011; 2012; 2013; 2014
	Guaynuna	6		2008; 2010; 2012; 2014
	Culebras	2		2008; 2014
Lima 12°02´´06´´	Callao	5		2007; 2010; 2011
Ica 14°04´00´´S 75°44´00´´	Paracas	5	2	2010; 2011; 2012; 2013
	Total	88	4	

Table 1: Toxic events in Peruvian coastal geographic areas 2007-2014.

R program (R studio).

The coastal morphology and topography of each bay, are associated with physical dynamics, eddies (cyclonic or anticyclonic) which induce toxic species retention and the increasing frequency of biotoxin [6]. The toxic species such as Grupo *Pseudo-nitzschia delicatissima,* Grupo *P. seriata, Alexandrium peruvianum, Dinophysis caudata, D. acuminata, Gonyaulax spinifera, Azadinium* sp., *Karlodinium* sp., *Karenia* sp., *Protoceratium reticulatum* and *Prorocentrum minimum* were registered. Through the years**,** Sechura and Samanco bays were associated with the presence of toxic events, of okadaic acid (lipophilic toxin - DSP) and saxitoxin (Paralytic Toxin - PSP) in Paracas (Table 1).

The highest variability in number of potentially toxic species was recorded off Miraflores and Paracas bays during summer 2013, related to sea surface temperatures between 16.4°and 24.1 °C; however, potentially toxic dinoflagellates abundances were favored with fewer species in summer 2014. Miraflores and Samanco bays showed high number of potentially toxic species associated with great abundances (cell. L^{-1}) during spring (Figures 4 and 5).

A multivariate analysis of ecological data was done for potentially toxic diatoms and dinoflagellates by performing Canonical Correspondence Analysis (CCA) in order to detect patterns or gradients of these species distribution related with environmental parameters. CCA axis 1 and 2 explained 50% of the variance in the species. Three environmental preferences was found. Species such as *Karlodinium* sp. (Karl) and *Gonyaulax spinifera* (G spi) were favoured in low phosphates and silicates waters during summer 2013, while blooms of Group *P. delicatissima* (P del) and G. *P. seriata* (P ser) were positively correlated with high oxygen and pH values during springs 2013 and 2014. Finally, *Prorocentrum minimum* (P min) occured mainly in high nitrates waters during summer 2014 (Figure 6).

Acknowledgements

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