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The Relationship between the Harmful Algal Blooms (HABs) Phenomenon with Nutrients at Shrimp Farms and Fish Cage Culture Sites in Pesawaran District Lampung Bay

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Abstract

The phenomenon of harmful algal blooms (HABs) in the Lampung Bay has been reported by many researchers. The occurrence of HABs may be due to the increase of nutrient (N and P) as results of waste water of aquaculture (shrimp farms, hatcheries and fish cage farms). This study aimed to determine the relationship between N and P concentrations in some aquaculture sites with harmful algal blooms. The analysis revealed the differences concentration of N and P at each different shrimp farms and fish cage farms sites (Hurun, Sidodadi, Ringgung, and Cikunyinyi Bay). The result showed that the increase of N and P concentration were followed by the increase of harmful phytoplankton populations. High density HABs were found in this study, such as: *Ceratium furca* with the highest density at 5.314 x 10^6 cells/l, *Trichodesmium erithraeum* 1.05 x 10^5 cells/l and *Noctiluca scintilans* 5.99 x 10^4 cells/l. The Multiple regression and canonical corelation analysis (CCA) also indicated a strong positive relationship between N and P with the HABs at the shrimp farms and fish cage farms sites in the Lampung Bay.

Abstrak

Hubungan antara Fenomena Harmful Algal Blooms (HABs) dengan Unsur Hara di Perairan Sekitar Lokasi Budidaya Perikanan Kabupaten Pesawaran Teluk Lampung. Fenomena *Harmful Algal Blooms* (HABs) di Teluk Lampung, khususnya di Teluk Hurun, telah banyak dibahas oleh beberapa peneliti. Fenomena HABs diduga akibat peningkatan unsur hara (N dan P) dari limbah pertambakan, pembenihan (*hatchery*) dan budidaya ikan dalam karamba jaring apung. Masukan N dan P ke perairan akan menyebabkan eutrofikasi perairan yang selanjutnya dapat memicu terjadinya ledakan populasi fitoplankton yang dapat berbahaya bagi organisme perairan. Penelitian ini bertujuan menganalisis hubungan kadar nutrient N dan P dengan kemunculan fitoplankton berbahaya, akibat limbah budidaya perikanan yang berbeda pada lokasi penelitian. Secara deskriptif hubungan unsur hara N dan P terhadap kelimpahan fitoplankton dapat dilihat dengan adanya kecenderungan peningkatan unsur hara tertentu yang diikuti oleh peningkatan kelimpahan total fitoplankton atau kelimpahan salah satu jenis fitoplankton. Beberapa fitoplankton berbahaya yang ditemukan dengan kelimpahan tinggi pada penelitian ini adalah *Ceratium furca* dengan kepadatan tertinggi mencapai 5.314 x 10^6 sel/l, *Trichodesmium erithraeum* dengan kelimpahan mencapai 1.05 x 10^5 sel/l and *Noctiluca scintilans* dengan kelimpahan mencapai 5.99 x 10^4 sel/l. Hubungan unsur hara N dan P dengan HABs juga ditunjukkan dengan analisis regresi berganda dan *canonical corelation analysis* (CCA) yang menunjukkan adanya korelasi positif yang kuat antara konsentrasi unsur hara N dan P dengan potensi kemunculan HABs pada berbagai lokasi budidaya perikanan di Teluk Lampung.

Keywords: phytoplankton, harmful, nutrients, Lampung bay

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1. Introduction

The phenomenon of Harmful Algal Blooms (HABs) in the Lampung Bay has been reported by [1] who stated that the existence of *Pyrodinium sp*. in Hurun Bay was known in 1999, to have a density of 8.9 x 10^4 cells/l and increased to 2. 3 x 10^9 cells/l, in 2003. Whereas in normal conditions, it is found only less than 10^2 cells/l. *Noctiluca scintilans* bloom has also been reported by [2], who stated that in August 2005 there was an increase in population of *N. scintilans*, reaching 6.18 x 10^5 cells/l. It is suspected that the explosion of phytoplankton population in the Hurun Bay occurred due to the increased of waste input from shrimp farms, fish cage farms (KJA), hatcheries, and domestic waste, which resulted in an increase of nutrients in the Hurun Bay.

Hurun Bay, Sidodadi, Ringgung and Cikunyinyi Bay water are important area for shrimp farming and "KJA" development in Lampung Bay. The use of additional feed to the aquaculture activities in these water results in an increase of organic matter from the excess feed and feces of the cultured organisms. Input of nutrients (N and P) enriches the water will triggered a rapid growth of phytoplankton (blooming) and the emergence of various types of HABs that are harmful to aquatic organisms [3]. This study aims to analyze the relationship between the emergence of HABs with levels of N and P in the water, as a result of aquaculture activities waste at different research sites. The results of this study are expected to provide information on the nutrient concentration of N and P in the water around the aquaculture locations in Lampung Bay water, as well as identify the variety of potential HABs appearing (blooming) in the water, as a basis for environmental management.

2. Methods

Based on the form of aquaculture activities conducted at each location, four study sites were selected (Fig. 1). Two research stations were specified at each locations which are: 1) Hurun Bay; located in the north, has an area waters of 1.5 km^2, with 25.5 ha intensive shrimp aquaculture activity, and 80 units KJA that is managed by comunity and private companies, and marine fish hatcheries that is managed by the Center for Marine Culture Development (BBPBL) Lampung. 2) Sidodadi Bay; constitutes more open waters, there are approximately 102.6 ha of intensive shrimp farming systems that are managed by the community. 3) Ringgung Bay; has approximately 1,590 units of KJA. It is the largest cage fish farming site in the Lampung Bay, and 4) Cikunyinyi Bay which has 113.2 hectares of intensive shrimp farms land which is owned by private and communities.

Plankton sampling was carried out actively using a plankton-net. Plankton-net withdrawals were taken vertically from the bottom water up to the surface. Samples were preserved with Lugol's iodine solution

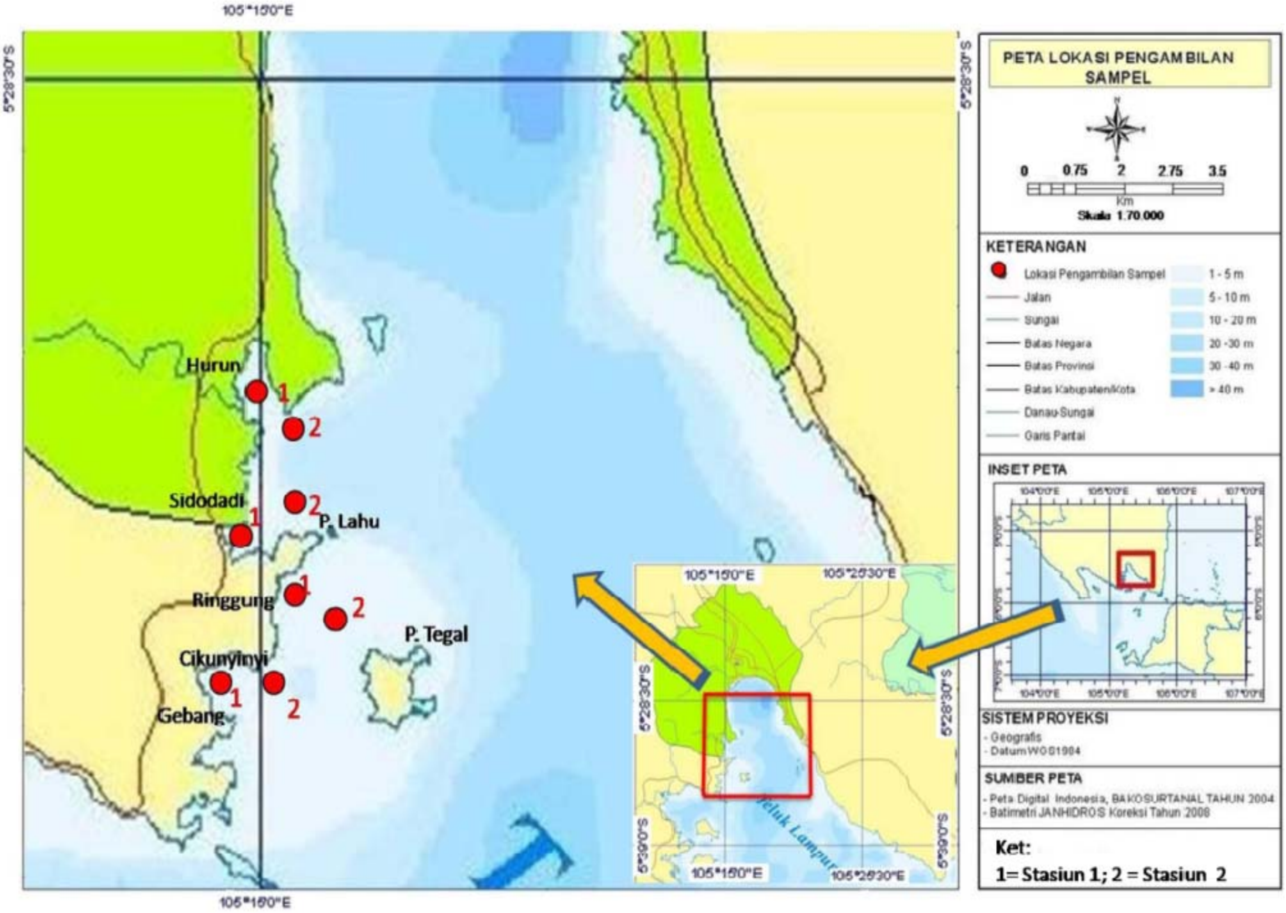


Figure 1. Map of Site Research

1% and 3% formaldehyde [4]. Sampling was conducted on September 8th to October 13rd 2011, a total of six times, over a span of seven days. Due to the rapid growth of phytoplankton, especially the diatoms that can cleave within 24 hours or sooner. Identification and classification of HABs are based on references [3,5-11]. Enumeration of phytoplankton was performed with Sedgwick-rafter counting chamber. The abundance of phytoplankton was calculated per liter using the Shannon-Wiever diversity index, and Pielou uniformity index [12], with the following formulation:

$$N = \frac{T}{L} \; X \; \frac{P}{p} \; X \; \frac{V}{v} \; X \; \frac{1}{w} \tag{1}$$

$$H' = -\sum_{i=1}^{s} \frac{ni}{N} \, ln \, \frac{ni}{N} \tag{2}$$

$$e = \frac{H}{Ln \;\; S} \tag{3}$$

Note: e = uniformity index, H’ = diversity index, L = wide field of view (mm^2), N = number of plankton per liter, ni = number of cell types to-i, P = number of plankton enumerated, p = number of sites observed, S = number of species, T = area of glass cover (mm^2), V = volume of filtered sample (ml), v = volume of plankton at the glass cover (ml), and w = sample volume of filtered (liter).

Three approaches were applied in Quantitative analysis, which were: 1) analysis of variance (ANOVA) to analyze whether there are differences in the concentration of N and P between research stations, 2) Canonical Correlation Analysis (CCA) to describe the relationship of environmental parameters on the occurrence of HABs [13], and 3) Multiple regression analysis between environmental parameters with an abundance of HABs at the research station. Analyses were performed with Microsoft Excel 2007 and Canoco for Windows 4.

3. Results and Discussion

During the study period, 62 species of phytoplankton were found at each stations, which are divided into four classes: *Bacillariophyceae/diatome* (40 species) with abundance percentage of 2.204-73.681%; *Chrisophyceae* (1 species) with an abundance percentage of 0-0.183%; *Cyanophyceae*/*Blue-green algae* (3 species) with an abundance percentage of 0.750-36.752%, and *Dinophyceae/ Dinofalellata* (18 species) with an abundance percentage of 11.069-97.044%. Large number of phytoplankton species included in the *Bacillariophyceae* and *Dinophyceae* in comparison to the number of other classes is a common and consistent premise authenticated by previous studies of phytoplankton in the water of Lampung Bay, particularly in Hurun Bay and surrounding areas, such as by [1-2,14-15].

The highest abundance of phytoplankton was found in Cikunyinyi Bay 1 (55,309-5,314.318 cells/l, average of 1,145,938 cells/l). In contrast, Cikunyinyi Bay 2, has lower phytoplankton abundance (20,538-51,175 cells/l, with average 34,254 cells/l). The second highest phytoplankton abundance was found at Sidodadi 1, (57,199-134,976 cells/l, with average of 85,061 cells/l) (Table 1). High abundance of phytoplankton in Cikunyinyi Bay 1, and Sidodadi 1, might be caused by high nutrient input from shrimp farming activities on the site.

The lowest diversity index value (H') was found at Cikunyinyi Bay 1 (0.039) on September 22, 2011, and at Sidodadi 1 (0.990) on September 15, 2011. Mean while the highest diversity index (2.943) was found at Cikunyinyi Bay 2 on October 13, 2011. Low value of diversity index in Cikunyinyi Bay 1 and Sidodadi 1 occurred due to a population explosion of *Ceratium furca, Noctiluca scintilans* and *Trichodesmium erithraeum*. Uniform index value (e) ranged from 0.011 (Cikunyinyi 1) and 0.752 (Cikunyinyi 2). These values of H' and e varied a little with the studies conducted by [14], who found that the value of H' in the Lampung Bay ranged from 1.00 to 2.46, and the value of *e* is between 0.39 to 0.86.

Based on a review of various sources such as: [2,5-11], from the 62 species of phytoplankton, 24 species were potentially as HABs (Table 2). *Trichodesmium erythraeum* is a species of HABs encountered inprofusion at all the research stations.

Several species of phytoplankton were found in relatively small amounts, but increased significantly at certain times, for example *Chaetoceros vorticella* (321-21,120 cells/l at Ringgung 2), *Protoperidinium* sp (1,598-11,433 cells/l at Sidodadi 1), *Pyrodinium bahamense* (0-10,888 cells/l at Cikunyinyi 1), and *Noctiluca scintilans* (54,956 cells/l at Sidodadi 2 (2nd week) and 59,885 cells/l at Sidodadi 1 station (3rd week). The highest population explosion was *Ceratium furca* in Cikunyinyi 1 that reached a peak at week 3 (5.314×10^6 cells/l), and then decreased at 4th week (1.451×10^6 cells/l) and continued to decrease to only 473 cells/l at the end of the study. Increased abundance of *C. furca* is thought to be due to the increased nutrients as stated by [7]. This results are consistent with previous research [15], who found that the dominant phytoplankton in the Hurun Bay are *Ceratium* sp, *Prorocentrum* sp, and *Chaetoceros* sp. [2] also reported *N. scintilans* bloom (6.18×10^5 cells/l). While [1], found an increased population of *P. bahamense* (8.9×10^4 cells/l) in 1999 and increased to 2.3×10^9 cells/l in 2003. Various species of HABs population explosions need to be monitored because they can be harmful for aquatic organisms [9,16].

The physical parameters of the water at the research sites were relatively uniform. Water depths range from 5.4-23.4 m. Brightness ranges from 2.5 m to 13.8 m.

Table 1. The Range and Average Total Density of Phytoplankton at the Study Site

Sites	Stations	N total (cells/l)		H’	Notes
		range	average	range	
Hurun	I	35,032-108,475	65,656	2.328–2.729	
	II	26,477-64,193	40,675	1.991–2.493	
Sidodadi	I	57,199-134,976	85,061	0.990–2.859	Blooms of *N. scintilans*: 12,924 (Sept 15, 2011), 59,885 (Sept 22, 2011). *T. erythraeum*:105,663 (Sept 15, 2011)
	II	31,339-147,671	77,511	1.091–2.773	
Ringgung	I	21,550-95,620	45,793	1.907–2.854	
	II	19,615-102,011	52,661	1.881–2.722	
Cikunyinyi	I	55,309-5.314 x 10^6	1.145 x 10^6	0.039–2.933	Blooms of *Cerarium furca:* 5.314 x 10^6 (*Sept. 22, 2011*); 1.451 x 10^6 (*Sept 29, 2011*)
	II	20,538-51,175	34,253	1.945–2.943	

Table 2. Harmful Phytoplankton Abundance Ranges during the Study

Species	Abundance of Phytoplankton (cells/l)								notes
	Hurun 1	Hurun 2	Sidodadi 1	Sidodadi 2	Ringgung 1	Ringgung 2	Cikunyinyi 1	Cikunyinyi 2	
BACILLARIOPHYCEAE									
Cerataulina bergonii	0–379	0–199	0–85	0–184	0–63	0–156	0–331	0–103	Anoxius [5]
Chaetoceros didymus	1172–28309	2074–10992	1231–33915	805–15213	563–18463	2264–35135	504–20593	1572–8353	Mucus production,
C. peruvianis	107–1610	243–2130	308–3011	127–2216	82–2100	216–2435	75–2051	136–337	*clogging*
C. pseudocrinitus	0–320	81–497	166–2358	85–2183	53–790	220–1405	275–1420	437–1555	[5], [10]
C. vorticella	458–3503	142–1160	71–1250	184–1184	69–2946	321–21120	0–170	265–856	
Nitzschia lanceolata	237–8237	57–3295	0–2301	0–6759	0–2952	0-5234	0–4155	0–4718	ASP [8]
N. sigma	0–199	0	0–2301	0–544	0–450	0–733	0–2982	0–151	
Pseudo-nitzchia	0–3077	142–2784	0–1420	0–1988	0–1266	31–1583	348–1894	95-2142	DSP [8],[10].
CYANOPHYCEAE									
Annabaena sp	0–1172	0	0–71	0–93	0	0	0–170	0	Anatoxin α[5]
T. erythraeum	6391–11362	8521–20025	6817-105663	9832–81507	3759–31042	652–10284	4471–11632	6087-1362	Anoxius [8]
DINOPHYCEAE									
C. extensum	0–331	41–227	57–426	55–166	14–106	0–484	26–398	57–203	Anoxius,
C. furca	95–3645	162–1449	95–966	53–1142	146–2560	78–2951	473-5314318	120–19207	Oxygen
C. tenue	0–142	0–199	36-199	0–123	0–98	0–118	0–174	0–203	depletion
C. tripos	28–379	0–653	142–881	0–118	0–70	12–118	0–227	0–47	[5],[7],[8].
Dinophysis homunculus	0-663	0–199	0–497	28–118	0–59	12–183	0–142	19–168	DSP [5],[10].
Gonyaulax apiculata	0–739	0–544	0–189	24–546	0–1149	0–375	0–92	0–867	Saxitoxin [5]
Gymnodinium	0–178	0	0	0	0–94	0	0	0	NSP/PSP[10]
Noctiluca scintilans	227–663	166–1079	57–59885	170–54956	94–1134	133–1934	75–504	0–757	Anoxius [5],
Peridinium depressum	178–1065	0–189	0–1449	0–1089	0–200	0–873	0–682	97–284	Anoxius [8]
P. oceanicum	0–473	0–61	0–107	0–402	0–239	0–367	0–348	31–609	
Prorocentrum lima	0–521	57–568	0–284	28–263	0–188	0–93	92–398	19–561	CFP [8],
P. micans	0–142	0–24	0–114	0	0–122	0–243	0–1171	0–34	[10]
Protoperidinium sp	2059–2888	118–4616	1598–11433	312–3761	0–982	0–882	75–4024	303–3514	Anoxius [8]
Pyrodinium bahamense	142–4024	0–805	0–1278	0–8630	270–7310	681–6939	0–10888	0–626	PSP [8],[10]

Note: ASP=Amnesic Shelfish Poisoning, CFP=Ciguatera Fish Poisoning, DSP=Diarhetic Shelfish Poisoning, NSP=Neurotoxic shelfish Poisoning, PSP=Paralytic Shelfish Poisoning.

On the small bay stations wich close to the beach, such as Hurun Bay 1 (3.0-4.9 m) and Cikunyinyi Bay 1 (2.5-5.7 m), have relatively low rates of brightness due to the input of suspended particles from the mainland carried by a small river was exist at both locations. Enclosed bays also impede the flow of sediment particles carried out of the bay. Flow velocity ranges from 0.021 m/s to 0.167 m/s. In general, the flow velocity of station 2 at each location is higher than station 1. The temperature at the study site was relatively high (28.4-31.4 °C). This condition is consistent with the results of study [17], which stated that the temperature of Hurun Bay waters range from 28.6-31.1 ^oC in the rainy season and 29.2-30.3 ^oC in the dry season.

Salinity range was almost similar at all stations, usually 33‰, except in Hurun Bay 1 and Cikunyinyi 1 which have ranges of 32-33‰ in salinity. This condition occurs because at the time of the study there was no or little freshwater input into the waters. Although Hurun Bay, Ringgung and Cikunyinyi Bay have a small river, due to a long drought, the river was dry. The pH range during the study illustrates that the water were in alkaline condition (7.9-8.18). Several chemical-physics parameters such as calm water flow velocity and salinity together with an increase of nutrient in waters can support the emergence of various species of HABs in the waters [18].

Observations on nutrients N and P during the study were represented by nitrite (NO_2^-N), nitrate (NO_3^-N), ammonium (NH_4^-N) and orthophosphate (PO_4^-P). Levels of nitrite in waters range between 0.001-0.247 mg/l. Levels of nitrate (NO_3^-N) range between 0.002-0.320 mg/l. This condition was higher than the levels of nitrate in natural waters (generally 0.1 mg/l). Nitrate levels exceeding 0.2 mg/l can result in eutrophication and trigger Harmful algal bloom [11]. According to [19], an phosphate increase from 0.15-5% and nitrate concentrations of 5-28% has the potentialy to lead to an emergence of HABs. The increase of N in water might be effected by the use of urea [20] in shrimp pond activities. Several cases of HABs emerging due to nutrients increased have been widely stated by various researchers, among others [21-23].

Levels of orthophosphate (PO^4-P), during the study ranged between 0.001-0.2 mg/l. According to [24] orthophosphate levels rarely exceed 0.1 mg/l even though the waters are eutrotophic. Orthophosphate levels in locations close to aquaculture (Sidodadi Beach and Cikunyinyi Bay) tend to be higher than at the fish cage locations. Such conditions may be due to the presence of manure and feed waste that is higher than at the aquaculture cage site as it is known that intensive shrimp culture systems which used fertilizers with TSP (Triple Super Phosphate). According to [25] and [26], the semi-intensive shrimp farming pond uses approximately 100 kg/ha TSP fertilizers. Diatom growth in shrimp farming uses 75-150 kg ha^{-1} of urea and 25-50 kg ha^{-1} of TSP, and for the growth of diatome "klekap' it is necessary to use urea and TSP at 75 kg ha^{-1}. In addition, shrimp farming also uses artificial feed that contains elements of P, but only 20-40% are converted into fish or shrimp meat while the rest is passed into the water as waste [24]. The Anova test (CI:95%), was concluded that there were differences in nutrient levels between study sites (p = 0.0048). This was presumably due to differences in the form and quantity of aquaculture activities between study sites.

The increase of N and P was tend to be followed by the increase acertain species of phytoplankton or total phytoplankton abundance (Fig. 2 and 3). This was proven in Cikunyinyi Bay 1, Sidodadi 1, and Sidodadi 2. In Cikunyinyi Bay 1, an increase in orthophosphate on September 15, 2011 was followed by *C. furca* population explosion from 77,939 cells/l to 5,314 x 10^6 cells/l on September 22, 2011 and 1,451 x 10^6 cells/l on September 29, 2011. The *C. furca* density explosion was also triggered by high levels of nitrite [21] on September 8 and September 15, 2011. Similar conditions have occurred in Mexican Pacific waters [21]. At Sidodadi 1, orthophosphate levels were high on September 8, 2011, followed by an increase in population of *T. Erythraeum* from 31,955 cells/l to105,663 cells/l on Sept 15, 2011. Additionally *N. scintilans* increased from 6,710 cells/l to 12,924 cells/l on September 15, 2011, and continued to increase to 59,885 cells/l on September 22, 2011. At Sidodadi station 2, the increase of ammonia on September 29, 2011 (62,603 cells/l), was followed by an increase in

Table 3. Range of Physic-Chemical Parameters Value of Water at the Research Stations

ST/Var	Hurun Bay		Sidodadi		Ringgung		Cikunyinyi Bay	
	I	II	I	II	I	II	I	II
Weather	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny
Depth (m)	8.2–10.9	17.1–20.1	5.4–8.2	8.4–10.0	13.9–15.9	21.8–23.4	6.8–8.5	7.5–11.1
Brightness (m)	3.0–4.9	5.1–8.9	4.1–6.4	4.6–7.8	6.8–12.4	7.0–13.8	2.5–5.7	4.5–11.1
Velocity (m/s)	0.045–0.167	0.046–0.139	0.034–0.167	0.028–0.167	0.021–0.160	0.050–0.167	0.023–0.147	0.025–0.125
Temperature(^oC)	28.9–31.4	28.8–31.2	28.5–30.6	28.5–30.4	28.4–29.9	28.4–30	28.5–29.5	28.4–29.9
Salinity (‰)	32–33	33	33	33	33	33	32–33	33
pH	8.039–8.169	8.025–8.184	7.942–8.166	8.039–8.187	7.997–8.129	8.015–8.192	7.973–8.121	8.003– .176
DO(mg/l)	5.26–5.75	5.94–6.19	5.35–5.94	5.64–6.01	5.57–6.01	6.00–6.04	5.42–6.03	5.81–6.01

Table 4. Range of Nutrient Levels of N and P Water at the Study Site

Var	Hurun Bay		Sidodadi		Ringgung		Cikunyinyi Bay	
	I	II	I	II	I	II	I	II
NO_2 (mg/l)	0.003–0.049	0.002–0.093	0.002–0.024	0.001–0.012	0.003–0.006	0.001–0.005	0.002–0.072	0.001–0.247
NO_3 (mg/l)	0.023–0.240	0.002–0.227	0.023–0.240	0.002–0.227	0.006–0.173	0.025–0.146	0.003–0.074	0.019–0.320
NH_4 (mg/l)	0.001–0.077	0.001–0.051	0.001–0.079	0.001–0.225	0.001–0.078	0.001–0.090	0.001–0.083	0.001–0.091
PO_4-P(mg/l)	0.009–0.050	0.013–0.04	0.006–0.200	0.004–0.056	0.009–0.071	0.001–0.074	0.035–0.156	0.013–0.053

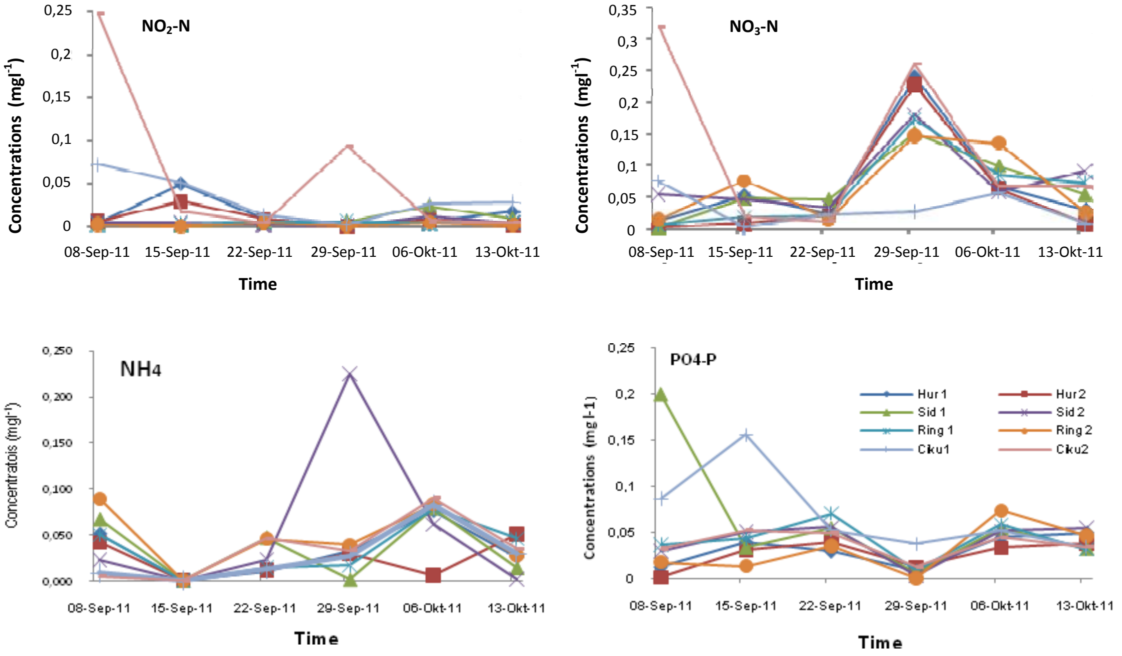


Figure 2. N and P Fluctuations during the Study Period

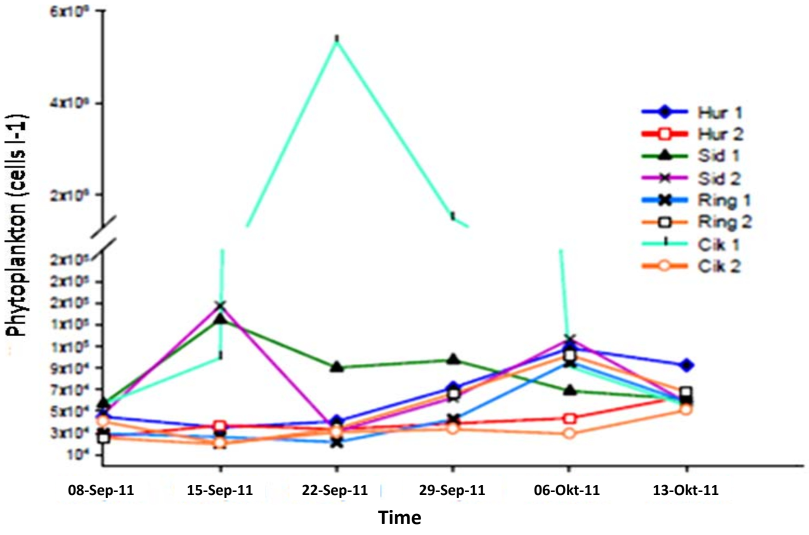


Figure 3. Phytoplankton Abundance Fluctuations during the Study Period

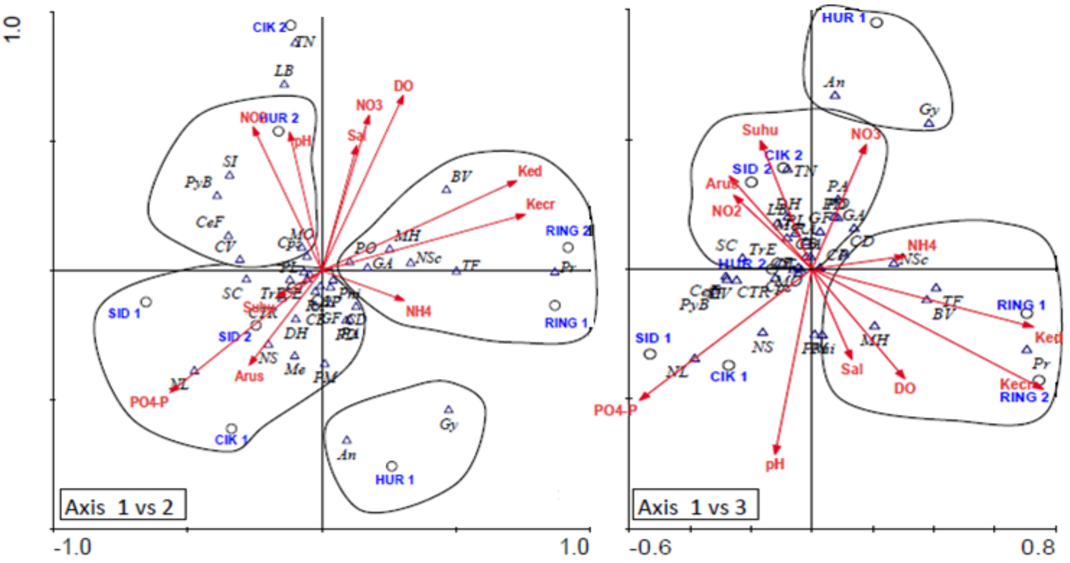
total abundance of phytoplankton to reach 116,878 cells/l on October 6, 2011. The increase was primarily supported by the increase in *Chaetoceros dydimus, Lauderia borealis* and *T. erythraeum*, which respectively reached 15,123 cells/l, 17,753 cells/l and 18,936 cells/l. Elevated levels of nitrate (NO^3-N), at all stations on September 29, 2011, was followed by a total abundance of phytoplankton on October 6, 2011 in nearly all the research stations.

The relationship between environmental parameters with abundance of phytoplankton at the research stations was also indicated by the coefficient regression correlation (CI:95%) (Table 5). At Cikunyinyi 1, and Sidodadi 1 stations the environmental parameters PO_4^-P, NO_2^-N and pH showed a significant influence ($p < 0.05$) against harmful phytoplankton abundance. At Station Sidodadi1 there was a population explosion of *N. scintilans*, while at Station 1 Cikunyinyi there was an explosion of *C. furca*. At Sidodadi Station 2, the flow velocity indicates $p < 0.05$, while NH_4^-N, NO_2^-N and NO_3^-N indicates $p < 0.1$. At Ringgung Station 1, PO_4^-P, NO_2^-N and NO_3^-N have a value of $p < 0.05$, while NH_4^-N shows a value of $p < 0.1$. This suggests that N and P are limit sustainability of phytoplankton life in the waters [27].

Table 5. Multiple Regression between Environmental Parameters and Abundance of HABs at Each Research Station

Stations	Intersep (βo)	Coeffisien (β)							R^2	F	F tab
		depth	Current	pH	PO_4-P	NH_4-N	NO_2-N	NO_3.N			
Hur1	-12.526				1.221.945**	705.591**		170.834	0,901	6,047	0,145
Hur 2	-2.851.769		530.71	345.517	1.613.404		539.840		0,865	1,599	0,527
Sid 2	346.267*		-1.527.555			541.350**	-13.579.602**	-1.099.121**	0,997	78,033	0,085
Cik 2	95.781*				-1.412.448*	64.702	154.144*	-258.425	0,997	79,77	0,084
Sid1, Cik 1	116.297.773			-14.243.24*	16.352.232*		-94.741.325*		0,973	23,87	0,040
Ring1 & 2	-415.426	23.050				393.240		116.990	0,842	3,557	0,227

Note: *) p<0.05; **) p<0.1



Notes: Diatom: BV= *Bacteriastrum varians*, BP= *Biddulphia pulchella*, BV= *Bacteriastrum varians*,CD= *Chaetoceros didymus*, CP= *C. peruvianis*, CPs= *C. pseudocrinitus*, CV= *C. vorticella*, CF= *Coconeis fusca*, CA=*Coscinodiscus asteromphalus*, GM= *Grammatophora marina*, GF= *Guinardia flaccida*, LB= *Lauderia borealis*, MH= *Melosira hyperborea*, MO= *M. octogona*, NC= *Navicula concellata*, NL= *Nitzschia lanceolata*, NS= *N. sigma*, PS= *Planktoniela sol*, PA= *Pleurosigma affine*, PNi= *Pseudo-nitszchia* sp., RA= *Rhizosolenia alata*, RB= *R. bergonii*, RC= *R. calcaravis*, SI= *Streptotecha indica*, SE= *Surirella eximia*, TF= *Thalassiothrix frauenfeldii*, TN= *Thalassionema nitzchioides*, **Cyanophyceae:** An= *Annabaena* sp, TrE= *T. erythraeum*; **Dinoflagellata:** CE= *Ceratium extensum*, CeF= *C. furca*, CT= *C. tenue*, CTr= *C. tripos*, DH= *Dinophysis homunculus*, GA= *Gonyaulax apiculata*, GAs= *Gonyodoma astenfeldii*, Gy= *Gymnodinium* sp, NSc= *Noctiluca scintilans*, PD= *Peridinium depressum*, PO= *P. Oceanicum*, PL= *Prorocentrum lima*, PM= *P. micans*, Pr= *Protoperidinium* sp, PL= *Pyrocystis lunula*, PyB= *Pyrodinium bahamense*.

Figure 4. The Correlation between Phytoplankton Environmental Variables based on the Triplot Canoco Diagram

Correlation coefficients at all stations indicate significant (Fhit > Ftab). Regression correlation coefficients (R^2) at all stations also showed high valuesof between 0.842 to 0.997 (Table 5). The highest coefficient was found at Cikunyinyi 2 and Sidodadi 2 stations, and the lowest at Ringgung 1 and Ringgung 2 stations. Referring to the statement by [28], it can be concluded that with 95% validity that all independent variables of environmental parameters have contributed significantly to the changes in harmful phytoplankton abundance at all of the research stations.

The Triplot Canoco Diagram show that the phytoplankton which have a strong relationship with PO_4^-P include *C. furca, C. tripos, C. extensum, Nitszchia sigma, N. lanceolata, Chaetoceros pseudocrinicus, Prorocentrum micans, T. erithraeum,* and *Dinophysis homunculus.* This relationship generally occure at Sidodadi 1 and Cikunyini 1 stations. At Hurun 2 and Sidodadi 2 there was a stronge correlation with NO_2^-N with *Ceratium furca*, *Chaetoceros vorticella Pyrodinium bahamense, Melosira octogona, Lauderia borealis, Prorocentrum lima,* and *Streptothaeca indica* species of phytoplankton. At Ringgung1 and Ringgung 2, there is a strong relationship between NH_4^-N with *Noctiluca scintilans, Gonyaulax apiculata, Pseudo-nitszchia, Bacteriastrum variance*, *Chaetoceros dydimus, Chaetocero speruvianis* and *Prorocentrum micans.* While at Cikunyinyi 2 there was a strong relationship between NO_3^-N to *Pleurosigma affine, Gonyaulax apiculata, Guinardia flaccida, Peridinium depressum,* and *Peridinium oceanicum.* The strong relationship between the correlations of environmental variables with phytoplankton found in this study has also been expressed by [13]. An exception to the results of this study was a fraction of harmful phytoplankton such as *Annabaena* sp, *Gymnodinium* and *Protoperdinium* that did not indicate the prooven correlation, but was evident at Hurun 1.

4. Conclusions

Aquaculture activities (ponds and cages), has proven to have an effect on nutrient concentrations of N and P in the waters of Lampung Bay. Anova results for phosphate, nitrite, nitrate and ammonium showed a difference in the quality of water at the study sites. In addition there was a positive relationship between increased levels of N and P with an increasing population of HABs. The relationship was reflected with the trend of an increase in a nutrient at any given time is followed by an increase in total abundance and an increased abundance of a particular phytoplankton. The Triplot Canoco Diagram also showed a positive correlation of HABs towards different types of nutrients. An increase of nutrients N and P have a subsequent effect on the increase of HABs population that is harmful to living organism cultures in site water around Pesawaran District, Lampung Bay.

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