# Assessment of Environmental Quality of Coastal Fishpond Areas Using Macrobenthic Structure: Multivariate and Graphical Approaches

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## Abstract

Environmental degradation that results in decreased quantity of farmed fish production is an issue that often arises in rapid aquaculture industry. This study aims to develop the method of environmental quality assessment of aquaculture using macrobenthic structure to ensure the sustainability of its activity. The research was conducted at three fish farming sites along coastal of Sayung, Demak Regency, Central Java, i.e. milkfish ponds, shrimp ponds, and mixture pond. Determination of the environmental quality of the farms was done by analyzing data and environmental parameters and macrobenthic abundance and biomass using multivariate and the graphical methods. The results of Principle Component Analysis (PCA) projected from an aquatic environment parameters showed no signs of grouping based on three types of ponds, but there are signs of grouping by time sampling, indicating fluctuations in physico-chemical conditions of waters over time. Based on the macrobenthic abundance, study sites were dominated by gastropods (97%), the rest of bivalves (2%) and polychaetes (1%). Results from ordination analysis, ABC curves and k-dominance showed no signs of clustering by types of pond, but between sampling times. This implies that multivariate and graphical methods can sensitively detect any environmental change, particularly changes in macrobenthic community, water quality and sediment over time.

**Keywords:** environmental quality, multivariate, graphical method, macrobenthic structure, fish farming.

## 1. Introduction

Macrobenthic animals are invertebrate animals that are relatively small and retained on sieve size of 500 μ m and stayed at the bottom habitat by digging a hole in the substrate or sediment, either have home tube (tubicolous) and do not have the tube [1]. The animal has an important role in the formation of sedimentary habitats. These organisms can stimulate and improve the process of mineralization of organic matter and improve the exchange of particles in the boundary layer between water and sediments [2]. They play an important role in the food chain through the transfer of organic carbon back to the pelagic ecosystem [3]. Through mechanisms such as increasing the N cycle throughout nitrification and denitrification, increase the rate of oxidation of sediments, benthic organisms are very responsive to eutrophication and hipoxia [4], and can therefore be used as organic enrichment bioindicator [5]. Vertical distribution of the processes performed by microbes in sediments influenced *infauna* animals through activities, including eating, digging holes, and the formation of the tube home [6]. The presence *bioturbation* activity, such as mixing or stirring and relocation of sediments is one of the most important factors in controlling the processes that occur around the oxic-anoxic sediment layer [7].

Several studies on the effects of fish farming activities on water quality and sediment have been conducted, among others, the existence of organic enrichment, *eutrophication*, sediment anoxic (without oxygen), decrease in redox potential, oxygen consumption increased in the sediment, increasing the total organic carbon, sulfite, nitrogen components, and phosphate. However, the results of these studies generally varied and inconsistent, indicating that *abiotic* environmental variable alone is not sufficient to determine the quality of the environment more comprehensively. In the last decade, analysis of macrobenthic *infauna* has been applied as one of the main criteria in determining the quality of the environment for aquaculture management in various countries. Efforts to determine the response of macrobenthic community to environmental changes can be done by using a multivariate analysis, and graphical method. Multivariate analysis and graphical method have been applied by several researchers to determine the rate of changes in the number of species, abundance, and biomass in response to environmental changes, especially by organic enrichment. Approach to community analysis using these methods is considered to be more accurately assessed in determining the level of disturbance, given the response at the individual/ specific taxa to environmental changes are often specific and highly variable [8, 9, 10].

## 2. Methods

Measurement of physical-chemical water carried out *in situ* using a Horiba U-10 Multiprobe Tester. Parameters measured include pH, dissolved oxygen (DO), temperature, turbidity, salinity, conductivity, and depth. Measurements were made around the bottom (adjacent to the sediment), and in surface water. Turbidity was measured using a Secchi disk. Sediment sampling was carried out by using the Eckman Grab, operated directly by using the hand strap. Determination of the quality of sediments was carried by several physico-chemical parameters of sediments, including the composition of the physics/particles of sediment and organic matter content.

Sediment samples were taken from Eckman Grab put in 4% formalin solution and stored in plastic jars. Sediments were filtered through a 1 mm mesh-size sieve to retain macrobenthic animals. Organisms retained on the sieve were put into a solution of 70% ethanol for further analysis, which includes sorting, counting, identification, counting the number of species, density, and classification of taxa, and biomass. Determination of dry weight after drying of each animal taxa macrobenthos in an oven at a temperature of 60$^{o}$C for 24 hours.

Principal Component Analysis (PCA) using the Euclidean distance were performed to determine differences in environmental variability between sampling areas. Graphical method of Abundance / Biomass Comparison (ABC) was used to determine the extent of changing patterns of macrobenthic structure based on biomass and abundance of each sampling station in space and time [11, 12]. The *k*-dominance curves for both biomass and abundance will be projected in the same graph. Multivariate analysis using the ordination and cluster by the method of Non-metric Multi Dimensional Scaling (NMDS) of Bray-Curtis similarity was conducted to assess differences in macrobenthic structure between sampling stations in two dimensions [13]. Multivariate analysis and graphical methods performed using the software Primer Version 6.1.5 [12].

## 3. Results

### 3.1. Physico-chemical quality of waters

The results of measurements of physical-chemical parameters of waters at fishpond areas of Sayung, Demak show a normal range. The average measurements of chemical physics waters at the location of the entry of water (*inlet*) indicated low variability across the fishpond type, especially the measurement of conductivity, turbidity and brightness. Turbidity indicates the optical properties of water, resulting in the refraction of light into the water. Turbidity limits the entry of light into the water. Turbidity is influenced by the floating material, and the breakdown of certain substances, such as organic materials, microorganisms, sludge, clay and other fine floating objects. The more turbid of the water, electrical conductivity and solid will be higher [14]. Conductivity values are generally closely related to the salinity of the waters, while the brightness is influenced by both organic solute particles (the excess of animal feed and feces of farmed fish) and inorganic (particles of silt/soil). Highest brightness was located in the milkfish ponds. Brightness is also affected by the microscopic aquatic organisms, especially microalgae (phytoplankton). When the population of microorganism in the waters increases, the brightness of the waters will be decreased. Results from Principle Component Analysis (PCA), which is projected from water environment parameters of each type of fishpond showed no obvious grouping (Fig. 1.A). This means that in general the condition of waters in the three locations are relatively similar, with little variability of the value. However, if the PCA is projected based on the sampling time, it appears that stations of sampling I occurred grouping to the left and sampling II clustered to the right (sampling II) of the ordinate (Fig. 1.B). This clustering indicates that the values of physico-chemical parameters of waters fluctuated from time to time, although no extreme values were recorded. Based on water physico-chemical measurements, all three locations of the fishpond are relatively conducive to the cultivation area.

### 3.2. Macrobenthic Structure: spatial and temporal

Taxa of macrobenthos identified at the study site were dominated by gastropods (97%), the rest of the class consists of bivalves (2%) and the polychaetes (1%). Member of gastropods inhabiting fishpond areas consist of 27 species. Species dominated in the area of milkfish ponds, shrimp ponds, and mixed pond was *Syrmilasma venustula* (Thiaridae) with a mean abundance of 67.5 individuals/grab, followed by *Cerithidea quadrata* (Potamididae) with a mean abundance of 9.9 individuals/grab and *Thiara sermilla* (Thiaridae) with a mean abundance of 6.3 individuals/grab. In contrast to gastropods, bivalves found relatively few, i.e. 7 species with a relatively low in abundance. No dominant species was found at any sampling station. Similarly, members of polychaetes were 5 species with relatively low in abundance.

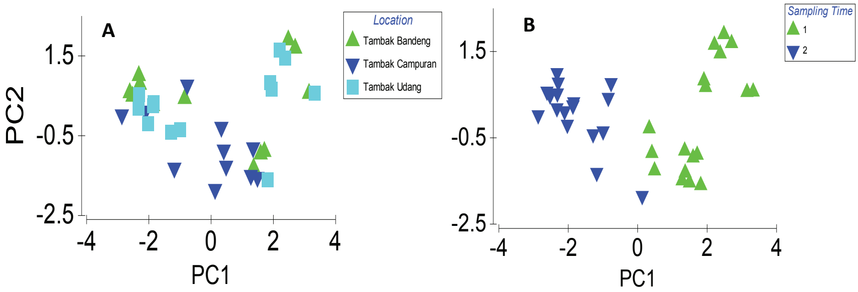

**Fig 1.** Principle Component Analysis (PCA) generated from the water parameter data, projected by: (A) Type of fishpond, (B) The time of sampling.

Macrobenthic abundance varied between stations (spatially) and sampling time (temporally). Results from ordination of Non-Metric Multidimensional Scaling (NMDS) projected based on transformed data of log (x +1) of macrobenthic abundance showed no grouping if it was projected by fishpond types (Fig. 3.a). The absence of grouping patterns among the three types of farms indicates that the abundance and number of species in all three types of ponds are relatively similar, except for stations TU02SD2B (shrimp ponds; outlet; sampling II) and TC01SD1B (Pond mixture; inlet; sampling I), which are projected separately from the other group of stations. Projection of station to the right of the ordinate indicates a decline in abundance and number of species that can be caused by environmental disturbance [11].

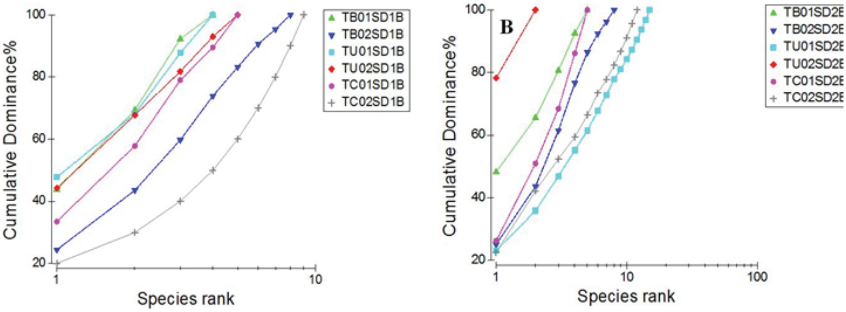

**Fig 2.** Cumulative k-dominance curves projected for each station based on the time of sampling: (A). Sampling I (July 2009), and (B). Sampling II (October 2009)

On the contrary, the ordination based on the sampling time indicates grouping of sampling stations I and II sampling (Fig. 3.b).These groupings may be due to differences in composition and abundance of species found between the two sampling time.

Based on sampling time, results from cumulative *k*-dominance analysis projected for each station stations placed curve of site TC02SD1B (mixed fishpond; outlet; sampling I) at the bottom of the graph. This indicates the highest evenness and species diversity among other stations (Figure 4.A). Whilst curve of site TU02SD2B (shrimp ponds; outlet; sampling II) was positioned at the top (Figure 4.b). This indicates the lowest diversity and evenness among the other stations [12]. Level of environmental disturbance can be determined by comparing the abundance and biomass of macrobenthic community. This method is known as an Abundance-Biomass Comparison (ABC) [15]. In stable environmental conditions or interference levels are considerably low, macrobenthic community will be dominated by conservative species, i.e. species that have a life strategy "*K*-selection", large body size, relatively long life span, dominant in biomass but low in the number of species. Under conditions of disturbed areas, macrobenthic communities will be dominated by organisms that have a strategy of "*k*-selection" in his life, or so-called opportunistic species, characterized by a relatively small body size, short life span, dominant in the number, but low in biomass, has potentially high reproductive rate and early maturation [16]. Depending on the level of disturbance, biomass curves can be positioned above or below the abundance curve, or the two curves can be similarly shaped adjacent and parallel to each other or intersect each other once or several times along the curve [11, 17].

Results from the analysis of abundance and biomass of macrobenthos projected as ABC curve showed variability between stations (Fig. 3 and Fig. 4). Based on the criteria proposed by Clarke & Warwick (2001) [11], all the sampling stations on the sampling time I (July 2009) is categorized as a disturbed/ polluted area, except station TC01SD1B (mixed ponds; inlet) and station TC02SD1B (mixed pond; outlet), as shown in Fig. 3. This area is used as mixtures to obtain the flow of water directly from the River Ronggolawe. The river is still affected directly by the tidal wave, so the quality of water used is still relatively good. While the input water for shrimp and milkfish ponds are from mixed pond, so that water quality has been affected by the activity of farming in the mixed pond.

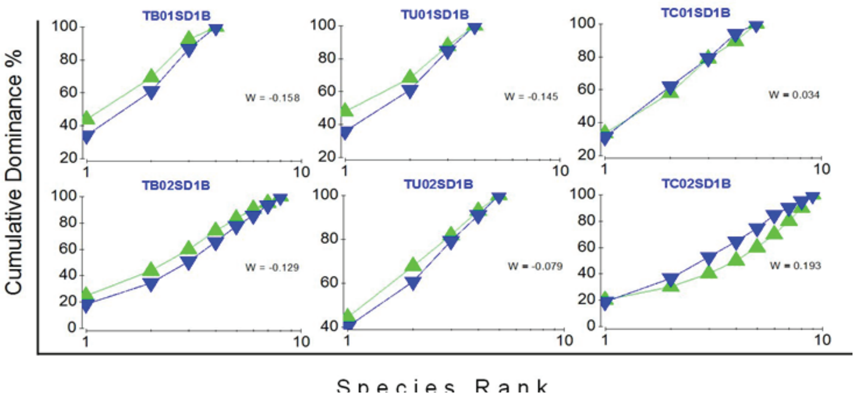

**Fig 3.** Abundance Biomass Curves Curve (ABC) is projected based on data transformation log (X +1) of abundance (▲) and biomass (▼) macrobenthos in the first sampling time .

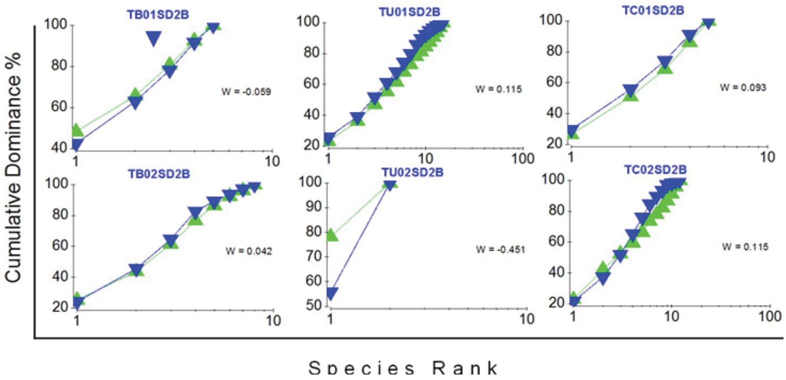

**Fig 4.** Abundance Biomass Curves Curve (ABC) is projected based on data transformation log (X +1) of abundance (▲) and biomass (▼) macrobenthos in the second sampling time.

Unlike the sampling time I, the curve shown for each station on the sampling II (October 2009) is categorised as undisturbed areas (unpolluted), except station TB01SD2B (milkfish ponds; outlet) and station TU02SD2B (shrimp ponds; outlet) (Fig. 4). This indicates that the two stations above have been disturbed in October's samples. Based on the results of interviews with the owner/manager of shrimp farms (personal communication), the condition of shrimp pond a week before sampling II (early October 2009) has been environmentally disturbed, resulting in most of the stocked shrimp died (more than 70% of total population). It is not yet known the cause of the disturbance, but is expected related to the quality of feed and less aeration in the pond. Poor feed quality will reduce or even eliminate appetite of the animals. This can cause the accumulation of feed into body water and partially decomposed into sediment. The presence of high organic matter can trigger the growth of toxic microalgae and pathogenic bacteria in the waters, so it can result in lowered resistance of the cultured animals against the diseases.

## 4. Conclusion

Macrobenthic animals are very sensitive to changes in the environment, particularly water quality and sediment. In general, the disturbance or physical-chemical changes in the environment will respond to changes in the composition and abundance the animals. Approach to multivariate and graphical methods, especially using ordination analysis MNDS, ABC curves and *k*-dominance, can sensitively detect any environmental change, particularly changes in macrobenthic community, water quality and sediment over time.

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