Journal of Environmental Management 193 (2017) 108–117

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Temporal variations in water quality in a brackish tidal pond: Implications for governing processes and management strategies

Wenhui Cui, Ting Fong May Chui*

Department of Civil Engineering, The University of Hong Kong, Pokfulam, Hong Kong

ARTICLE INFO

Article history:
Received 29 April 2016
Received in revised form
24 January 2017
Accepted 28 January 2017
Available online 11 February 2017

Keywords:
Water quality
Dissolved oxygen
Shrimp pond
Water exchange
Sustainable management

ABSTRACT

Brackish tidal ponds have been constructed along coastal areas in many parts of the world for aquaculture, including some Ramsar Sites. Such ponds are considered a sustainable, wise use of wetlands if managed properly, but they can also pose serious environmental problems if mismanaged. To understand the governing processes and to promote sustainable management strategies, this study examines the different temporal variations in water quality parameters in a brackish tidal pond located within the wetland complex of the Mai Po Ramsar Site in Hong Kong, China. The variations are compared with those of the receiving bay, and the water channel that connects the pond and the bay. Equations are then developed to link the dissolved oxygen (DO) concentrations in the pond with the governing processes, and to analyze their relative contributions to DO levels. Field data show seasonal patterns in water temperature and salinity in response to the seasonal variations in solar radiation and rainfall. For the pond and the channel, DO, chlorophyll and pH exhibit fortnightly variations due to the bi-weekly water exchange between the pond and the bay. There were also diurnal variations in water temperature and DO in response to changes in solar radiation for both locations, and the tidal flushing for the water channel. Analysis of the findings indicates that water exchange influences the DO concentration more strongly than solar radiation. The DO equation links pond water quality with the time of day, and the time in a water exchange cycle, and thus provides some guidance for determining water exchange and water sampling schedules. The study sheds light on the governing processes and management strategies related to the sustainable management of a brackish tidal pond. The results are thus beneficial in elucidating and promoting the sustainable management and wise use of wetlands in other locations.
© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Wetlands, as mosaics of diverse landscapes with high biological productivity, have enormous resource potentials and environmental functions (Thakur and Gill, 2013). They provide food and habitats that support plants, animals and even humans (WWF, 1992). However, urbanization, industrialization and population growth in coastal areas place tremendous pressure on many coastal wetlands. Brackish tidal ponds are often constructed in coastal wetlands for aquaculture. They can become sources of pollution if not managed properly, but they can also be affected by increasingly polluted water in the surrounding area (Neller and Lam, 1994; Yu et al., 2000; Shen et al., 2010). These threats necessitate improved understanding and management to conserve and restore coastal wetlands.

The Ramsar Convention was established to provide a framework for national action and international cooperation in the conservation and wise use of wetlands. Within the various Ramsar Sites (i.e., wetlands of international importance), aquaculture is commonly practiced, such as in Asia (Binh, 1997; John et al., 2002; Mabwoga et al., 2010; Krumme et al., 2010), Europe (Gerakis and Kalburtji, 1998; Psilovikos et al., 2006) and North America (Warnock et al., 2002). Tidal ponds have been used in Southeast Asia (Wong, 1986; Vanucci, 1987; Naamin, 1987; Anh et al., 2010) and parts of South America (Gautier, 2002) for many years. Some tidal ponds are artificially fertilized, discharging effluents with high levels of nutrients and suspended solids, which causes eutrophication, oxygen depletion, siltation and the spread of diseases in the receiving waters (Lee, 1992; Anh et al., 2010; Burford et al., 2003; Herbeck et al., 2013). Other tidal ponds are more sustainable and rely on natural tidal actions for water exchange to bring in stocks of larvae and nutrients. No fry or fertilizers are required, and minimal manpower is needed. Such systems demonstrate sustainability and

* Corresponding author.
E-mail address: maychui@hku.hk (T.F.M. Chui).

http://dx.doi.org/10.1016/j.jenvman.2017.01.073
0301-4797/© 2017 Elsevier Ltd. All rights reserved.

"self-organization", but tend to have limited production.

This type of environmentally sound aquaculture is commonly recognized as a sustainable coastal resource management system that has been successfully implemented in the southern part of China and countries in Southeast Asia such as the Philippines and Indonesia. However, its operation mainly depends on traditional experience, with a limited number of scientific studies examining its governing processes and management strategies. For example, Johnston et al. (2002) monitored the water quality and plankton densities in the mixed shrimp–mangrove forestry farming systems in Vietnam; Piyankarage et al. (2004) discussed seasonal variations in water quality and the processes affecting it in the brackish coastal wetlands of southern Sri Lanka; and Damme et al. (2009) examined the interaction between a freshwater tidal marsh and an impacted estuary. However, most previous studies have been based on seasonal or monthly water quality data, which may fail to capture the processes of shorter time scales. They have also seldom examined the water exchange between tidal ponds and their surrounding environment, even though such interaction is vital to the sustainability of the pond, the receiving water and the integrated system.

This study mainly examines the temporal variations in water quality parameters in a brackish tidal pond; particularly, those with shorter time scales. In addition to direct field water quality measurements, this study also aims to develop an equation linking the key water quality parameters with the governing processes, most notably the water exchange between the pond and the bay. To understand the water quality fluctuations within the pond, its water quality is compared with those of the bay and the water channel that connects the pond and the bay. Water quality is also discussed in the context of phytoplankton growth kinetics. Data analysis and equation development generate insights into governing processes and management strategies.

2. Methods

2.1. Site description and sustainable practices

The tidal pond observed in this study is situated within the Mai Po Ramsar Site, which includes a brackish coastal wetland system managed by WWF-Hong Kong. It is located in northwestern Hong Kong, borders mainland China (see Fig. 1), and is connected to Deep Bay, a shallow estuary with an average depth of 2.9 m that receives river discharges from both Hong Kong and the mainland. There are various wetland landscapes within Mai Po, including 2 km^2 of freshwater fish and brackish tidal shrimp ponds. Each tidal shrimp pond is a rectangular impoundment with remnant mangrove stands that is connected to Deep Bay through a water channel. The water exchange between the pond and the bay is controlled by tidal actions, and a simple sluice gate situated at the interface between the pond and the water channel. During spring tides, the sluice gate is opened and water with high nutrients enters the pond at high tides, flushing the biomass generated by phytoplankton out of the pond at low tides. The entire water exchange generally lasts three to four days. There are also some channels built within the pond to allow more efficient water exchange. Natural shrimp larvae are flushed into the pond from the bay during spring tides from late November onwards. Between November and late March or April, migratory birds flying along the East Asian–Australasian Flyway rest in Mai Po and feed on the fish and shrimp (WWF-HK, 2013). The pond's entire operation does not require intensive input, except some manpower that is needed in opening and closing the sluice gate during water exchange based on good command of traditional knowledge (WWF, 2003). It also produces a minimal environmental impact on the receiving bodies of water. Such a traditionally and sustainably operated pond is rare on a global scale, and thus it serves as a good example of coastal wetland management (Shutes, 2001). It demonstrates the proper use and maintenance of a naturally highly productive estuary and semi-artificial habitats to support tremendously diverse wildlife.

2.2. Data collection

The temporal variations in water quality over different time scales for both the pond and the bay were examined in this study. First, six years' of monthly water quality data from the pond and the bay (i.e., from Jan 2008 to Dec 2013) were obtained from Hong Kong's Agriculture, Fisheries and Conservation Department and EPD, respectively, to characterize long-term variations. The long-term data included water temperature, salinity, pH, DO concentration and nitrate concentration. Meanwhile, to understand the possible influence of rainfall, monthly total rainfall was also obtained from Hong Kong Observatory. Second, frequent sampling was performed at 15-min intervals using the YSI Multiparameter Water Quality Sonde 6600: in the pond from December 19, 2013 to January 14, 2014, and in the water channel within the mangrove forest from December 19, 2013 to January 3, 2014. As Fig. 1 shows, the pond measurement location was in the middle of the pond 13, and the water channel measurement location was within the water channel that connects the pond 13 to the bay. The measured parameters included water temperature ($\pm$0.15 °C), salinity ($\pm$0.1 ppt), pH ($\pm$0.2), chlorophyll concentration ($\pm$0.2 μg/l) and DO ($\pm$0.2 mg/l). The frequent sampling was performed during a month with minimal rainfall to capture the effects of other processes, particularly the water exchange between the pond and the bay.

2.3. Correlation analysis and wavelet decomposition

All of the parameters measured in this study could theoretically be incorporated into the water quality equation, as demonstrated in some previous studies (Guerrero-Galvan et al., 1999; Damme et al., 2009; Ferreira et al., 2011). However, the resulting equation would be too complex and indirect. To avoid redundancy and compose a concise equation, a correlation analysis was first applied to the data from frequent sampling to detect any correlations between the parameters. The parameters that were highly correlated with each other, and thus behaved in similar ways, were discarded except for one. The remaining parameter, which was more relevant and/or easier to obtain, was used to develop the equation.

A water quality time series is usually complicated, nonlinear, non-stationary and multiscale in nature (Di et al., 2014). To obtain its inherent structural characteristics and to extract the different temporal scales of the fluctuations induced by various environmental factors or changes, wavelet decomposition was applied to reveal hidden trends and information (Soltani, 2002; Cazelles et al., 2008; Cazelles et al., 2014). A data series can be transformed into different main trends, and the residuals from the main trends at different decomposition levels in the wavelet analysis. More details regarding wavelet decomposition can be found in Joo and Kim (2015). The approach adopted in this study consisted of three main steps: (1) removing the noises in the data series using the soft thresholding method; (2) using wavelet analysis to decompose the original time series into the main trend and the variation from the trend; (3) determining the optimal decomposition level. The soft thresholding method used in the first step is usually regarded as the optimal wavelet method for de-noising (Donoho and Johnstone, 1994; Joo and Kim, 2015). Daubechies wavelets for a one-dimension time series were applied in the second step as a basic function in which small changes to scaling signals can significantly improve performance in new transforms (Mayer et al., 1999). In the

Download English Version:

https://daneshyari.com/en/article/5116815

Download Persian Version:

https://daneshyari.com/article/5116815

Daneshyari.com