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Review

Can "Integrated Multi-Trophic Aquaculture (IMTA)" adapt to climate change in coastal Bangladesh?

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ABSTRACT

The coastal aquaculture sector in Bangladesh is dominated by export-oriented freshwater prawn and saltwater shrimp farming. However, the culture of prawn and shrimp in coastal Bangladesh has been accompanied by recent concerns over climate change. Different climatic variables, including cyclone, drought, flood, rainfall, salinity, sea level rise, and sea surface temperature have had adverse effects on prawn and shrimp production. Considering vulnerability to the effects of climate change on coastal aquaculture, one of the adaptation strategies is "Integrated Multi-Trophic Aquaculture (IMTA)". Open-water IMTA in coastal Bangladesh would be a novel process of growing different finfish and shellfish with seaweeds in an integrated farm. IMTA is considered an ecosystem approach adaptation strategy to climate change which could generate environmental and economic benefits. We suggest institutional support to facilitate IMTA in coastal Bangladesh.

Contents

1. Introduction

Bangladesh is one of the most suitable countries in the world for coastal aquaculture because of its favorable biophysical resources and agro-climatic conditions. Its coastal aquaculture sector is dominated by export-oriented freshwater prawn (*Macrobrachium*

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rosenbergii) and saltwater shrimp (*Penaeus monodon*) farming,[1] both known as "white gold" because of their export value (Islam, 2009; Ahmed, 2013). The coastal aquaculture sector has become a multimillion dollar industry in Bangladesh due to huge demand for prawn and shrimp in global markets, particularly the European Union and the United States of America (USA). In 2014–2015,[2] Bangladesh earned US$506 million from exporting prawn and shrimp (FRSS, 2016). Thus, prawn and shrimp farming play an important role in the economy of Bangladesh.

Despite economic benefits, the culture of prawn and shrimp in coastal Bangladesh has recently been threatened by climate change that could have severe effects on export earnings and further consequences for the economy of Bangladesh (Ahmed, 2013; Ahmed et al., 2014; Ahmed and Diana, 2015a, 2015b). According to the Global Climate Risk Index, Bangladesh was ranked 1st in 2012 among countries vulnerable to climate change while it is ranked 6th in 2016 (Harmeling and Eckstein, 2012; Kreft et al., 2015). Considering vulnerability of social-ecological systems in coastal Bangladesh to the effects of climate change on prawn and shrimp farming, adaptation strategies must be developed. Adapting coastal aquaculture to climate change will require a combination of strategies and policies.

One of the adaptation strategies to climate change is "Integrated Multi-Trophic Aquaculture (IMTA)" (Sreejariya et al., 2011; Chung et al., 2013; Geere, 2014; Clements and Chopin, 2016). IMTA is a process of growing different species of finfish and shellfish with seaweeds from different trophic levels in an integrated farm. IMTA is a practice in which the by-products from one species are recycled to become inputs (feed, nutrients) for another. The principle of IMTA is the co-cultivation of fed fish, organic extractive species, and inorganic extractive species (Troell et al., 2009; Chopin, 2011; Chopin et al., 2012). The concept of IMTA is to create balanced systems for environmental sustainability, economic viability, and social acceptability (Barrington et al., 2009). IMTA is currently operated in over 40 countries on experimental and commercial basis, including Canada, Chile, China, Japan, the USA, and many European countries (Chopin, 2011). In Bangladesh, IMTA has taken recent consideration for research and development to diversify production (Sarker et al., 2014; Kibria, 2016).

This review paper illustrates the impacts of climate change on coastal aquaculture in Bangladesh. Considering the effects of climate change on coastal aquaculture, this article identifies the opportunities and challenges for the development of IMTA in coastal Bangladesh. The aim of this paper is to highlight key issues in developing IMTA as an adaptation strategy to climate change.

2. Coastal Bangladesh: land of multiple disasters

Bangladesh is one of the most disaster-prone countries in the world because of its geographical location (Fig. 1). Bangladesh is considered as "nature's laboratory on disasters" due to existing most climatic threats. Coastal Bangladesh is subject to seasonal changes in climatic conditions. The increasing risk from a combination of climatic variables, including: (1) cyclone, (2) drought, (3) flood, (4) rainfall, (5) salinity, (6) sea level rise, and (7) sea surface temperature (Ahmed et al., 2013; Ahmed and Diana, 2015a, 2015b).

The entire coastal zone in Bangladesh is prone to violent storms and tropical cyclones which originate in the Indian Ocean and track through the Bay of Bengal. Between 1877 and 1995, Bangladesh was hit by 154 cyclones, including 43 severe cyclones (Dasgupta et al., 2014a). On average, a severe cyclone hits the country every three years (GoB, 2009). A cyclone in 1970 and 1991 resulted in the death of around 300,000 and 138,000 people, respectively. In November 2007, coastal Bangladesh was hit by tropical cyclone Sidr with economic losses of US$1.67 billion (DMB, 2010). In recent years, cyclone Aila, Bijli, Giri, Mahasen, and Nargis devastated coastal life in Bangladesh. The intensity of cyclones has recently increased by 5–10% (FPMU, 2013).

The typical weather of coastal Bangladesh is characterized by drought in the dry season. During the last 50 years, Bangladesh faced 19 droughts (Habiba et al., 2012). Drought in Bangladesh can be divided into agricultural, hydrological, meteorological, seasonal, and socioeconomic drought (Ramamasy and Baas, 2007). Seasonal droughts are common in coastal Bangladesh and the frequency of seasonal droughts has recently increased due to climate change. Drought is linked with lack of precipitation and global warming (Trenberth, 2005). An El Niño[3] event with global warming in the tropical Pacific Ocean can turn the monsoon into a dry mode, causing considerable reductions in precipitation with the possibility of drought (Dai et al., 2004; Conway and Waage, 2010).

Bangladesh is a flood-prone country and one-fifth of the country is normally flooded annually. Since 1980, Bangladesh encountered six extreme floods with over 35% of the country inundated (GoB, 2009). Global warming, monsoon rainfall, higher river discharge, and tidal surges from the Bay of Bengal intensify coastal flooding. It is predicted that average temperature in Bangladesh is likely to increase 1.4 °C by 2050 and 2.4 °C by 2100 (Shahid, 2012). A 2 °C increase in temperature could increase 29% of inundated area in Bangladesh (Mirza, 2011). With over 700 rivers[4] including 57 transboundary rivers, Bangladesh has little or no control over river flooding. Around 14.6 million people in coastal Bangladesh are vulnerable to flood, and this number will increase to 18.5 million by 2050 (World Bank, 2012).

Bangladesh falls in the region of massive rainfall as the country is located in the monsoon belt with the Bay of Bengal in the south and the Himalayas in the north. Annual rainfall in Bangladesh varies from 1400 to 4300 mm (Shahid, 2010). Climate change has profound effects on rainfall intensity and variability, and monsoon rainfall is predicted to intensify about 10–15% by 2030 (Jakobsen et al., 2005). There is a direct influence of global warming on changes in precipitation as the water holding capacity of air increases 6–7% for every 1 °C raise in temperature (Trenberth, 2005). Global warming and increased surface temperature of the Bay of Bengal have altered wind patterns leading to enhanced precipitation. The mean annual rainfall in Bangladesh increased at a rate of 5.52 mm between 1958 and 2007 (Shahid, 2010).

Seawater intrusion is a growing problem in coastal Bangladesh. Saltwater from the Bay of Bengal has entered over 100 km inland (Allison et al., 2003; DMB, 2010). Salinity has recently increased in coastal rivers to 4 ppt in the monsoon and 13 ppt in the dry season (Khan et al., 2011). Sea level rise, cyclones with tidal surges, and upstream removal of freshwater are likely to play a vital role in increasing salinity of coastal Bangladesh (Dasgupta et al., 2014a). About 1.05 million ha of land in coastal Bangladesh has affected by saltwater (FPMU, 2013), and two million ha of land are anticipated to be affected by 2050 (Conway and Waage, 2010). Increased soil salinity is expected to decline 15.6% of rice yield by 2050 in coastal Bangladesh (Dasgupta et al., 2014b).

[1] Prawn is a freshwater species while shrimp for marine and saltwater organism. However, prawn is a catadromous species that hatch or born in marine habitats and migrate to freshwater areas.

[2] Bangladesh fiscal year: 1 July–30 June.

[3] El Niño is the warm phase of the El Niño Southern Oscillation, refers to the cycle of warm temperatures that occurs across the tropical Pacific Ocean.

[4] Bangladesh is often called a "land of rivers".