ORIGINAL ARTICLE

Implications of the deteriorating environmental conditions of River Pra estuary (Ghana) for marine fish stocks

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ABSTRACT

Ghana's marine fish stocks have been declining in the last two decades. Efforts to address this trend have focused mainly on curbing overcapacity, overexploitation and inappropriate fishing methods with little attention to degradation of the country's coastal lagoons and estuaries, which serve as nursery habitats for juvenile marine fishes. To demonstrate the need to factor coastal ecosystems into fisheries management plans, this study assessed the quality of the waters of the River Pra Estuary, the second largest estuary in Ghana. This estuary is silted from activities of illegal alluvial gold miners upstream. Temperature, turbidity, salinity, conductivity, dissolved oxygen, pH, nitrate and phosphate concentrations were monitored from February 2012 to December 2013. Turbidities greater than 500 ppm known to have detrimental effects on estuarine organisms were recorded in the estuary from March to October each year. Dissolved oxygen concentration in the estuary in 2012 was below 5 mg/L, the threshold for survival of aquatic life in running waters. Although nitrate and phosphate concentrations in the estuary far exceeded the optimum levels (nitrate = 1.0 mg/L; phosphate = 0.1 mg/L) for primary productivity in estuaries, the high turbidity hampers light penetration and consequently limit primary productivity in the estuary. The possible effects of this estuary on recruitment of juvenile fish into the marine fishery are discussed with recommendations for management considerations.

Keywords: Pra estuary, Water quality, Ecosystem management, Fisheries production

Introduction

Ghana's marine fish stocks have been declining over the past two decades, and landings of small pelagics which form the backbone of the fishery are currently less than 20% of the historical highest catch of 140,000 mt recorded in the year 1998 (Lazar *et al.*, 2018). Reasons for the dwindling landings are iteratively attributed to increased fishing effort, overexploitation and use of inappropriate fishing gears and methods (MoFAD, 2015). In this regard, the Fisheries Management Plan for Ghana (2015-2019) focuses on actions to control overcapacity, overfishing and illegal fishing practices as well as establishing marine protected areas (MPAs), and protection of breeding grounds around oil installations. It however makes no provisions for managing coastal wetlands, lagoons and estuaries, although these habitats contribute immensely to fisheries production (see Boesch & Turner, 1984; Lenanton & Potter, 1987; Blaber, 1997; Lamberth & Turpie, 2003; Able, 2005). In addition to producing and transporting organic matter and nutrients to the connecting coastal seas to boost primary productivity in the ocean (Chester, 1990; Bianchi, 2013; Araujo et al., 2014; Sharples et al., 2017), estuaries also importantly serve as nursery grounds for most commercially harvested marine fish species (Boehlert & Mundy, 1988; Laegdsgaard & Johnson, 1995; Blay, 1997; Beck et al., 2001; Okyere et al, 2011; Levy et al, 2015).

In spite of their ecological and socio-economic importance, Ghana's coastal wetlands, lagoons and estuaries have seen a high level of degradation within the last two decades. The most common forms of degradation are pollution from effluents, solid waste disposal, and siltation (Biney, 1982; Karikari et al., 2006), as well as encroachments and reclamation (Aheto et al., 2011). The damage these practices do to the primary productivity and fish production in the marine waters cannot be underrated. For instance, a report by Aheto et al. (2016) suggests that the flow regime of the Volta River system changed after it was dammed between 1960 and 1980 for hydroelectric power generation. This may have resulted in reduced nutrient flow and fish production in the Volta estuary which compelled the small scale fishers to shift from fishing to mangrove cultivation in the 1990s (Aheto et al., 2016).

With rising sea surface temperatures already affecting productivity in the marine waters of Ghana (Wiafe et al. 2008), degradation of lagoons and estuaries will negatively affect the fishery through decline in recruitment, food supply and overall productivity if not given management priority. This work presents results of a study on some environmental factors in the River Pra Estuary and their possible effects on the fishery of the area.

Materials and Methods

The Pra River joins the Gulf of Guinea at Shama, Ghana (5° 01' 06" N and 1° 35' 56"W). The estuary has several hectares of adjoining wetlands which provide resources for communities living along the banks. The estuary, which is the next largest to the Volta, has been severely silted by pervasive illegal alluvial gold mining upstream resulting in its persistent murky colouration over the past decade.

Aquatic environmental parameters were monitored from February 2012 to December 2013 at seven locations in the nearshore marine environment (Station A), the estuary (Stations B, C, D and

E), and the adjoining wetland (Stations F in a mangrove swamp and G in a marsh) (Figure 1). The following conditions at the stations were measured monthly at low and high tides with a water quality checker (Horiba, U-10): surface temperature, salinity, conductivity, turbidity, dissolved oxygen (DO) and pH. Data for each parameter from the marine, estuary and wetland stations were pooled for computation of their means.

Nitrate and phosphate concentrations were assessed during the dry season (December to February) and the wet season (June to August). Samples of water were transported to the laboratory (with samples for phosphates stored separately on ice) to determine nitrate concentration by the U.V. spectrophotometric screening method (American Public Health Organization,1992; Vogel and Mendham, 2000) and total phosphates by the ascorbic acid spectrophotometric method (Vogel & Mendham, 2000).

Results

Turbidity, salinity, conductivity, DO and pH

Results of the monthly fluctuations and levels of the physico-chemical parameters in the three habitats investigated are shown in Figure 2. The highest turbidities were recorded during the rainy season in June 2012 (542±20 ppm in the nearshore waters, 785±21 ppm in the wetland, and 1000 ppm in the estuary) while the lowest occurred during the dry season in February 2013 (55±2 ppm in the sea, 55±3 ppm in the wetland, and 60±3 ppm in the estuary) (Figure 2a). The estuary was the most turbid habitat throughout the study period, being two to five times turbid than the marine and wetland waters in most months. In most months turbidity of the estuary exceeded 500 ppm a level known to have detrimental effects on estuarine organisms (Schubel, 1977).

On average, salinity of the sea varied between 30.0 ‰ and 35.0 ‰ (Figure 2b), except at the peak of the wet season in June 2012 when a low value of 13.5± 1.3 ‰ was recorded. The fluctuation patterns of conductivity and salinity were similar; conductivity of the ocean was about two to three times that of the estuary and wetland in 2012, and much higher in the wet season of 2013 (Figure 2 c). Conductivity was lowest in the three habitats during the wet seasons. Dissolved Oxygen (DO) ranged from 4.4±0.2 mg/L to 7.4±0.1 mg/L in the marine environment, 4.0±0.3 mg/L to 7.1±0.2 mg/L in the estuary and 3.4 mg/L±0.1 to 6.4±0.2 mg/L in the wetland (Figure 2d). While DO was greater than 5 mg/L (the threshold for survival in running waters; Hynes, 1970) in the sea, concentrations in the estuary and the wetland were low, reaching below 4.5 mg/L in 2012 although it improved in 2013. The pH of the sea water varied from 6.4 to 8.9, 6.9 to 8.0 in the estuary, and 6.4 to 8.6 in the wetland (Figure 2e). In general, the ecosystems were alkaline during the study period, except between August and October 2012 when the pH reduced to levels between neutral (7.0) and slightly acidic (6.5).

Phosphates and Nitrates

Phosphate concentration was higher in the wet season than the dry season at all stations (Figure 3a). Values ranged from 0.01 mg/L in the dry season in all three systems to 0.06±0.01 mg/L in the sea, 0.36±0.07 mg/L in the wetland and 0.41±0.04 mg/L in the estuary during the wet season. The highest concentration of phosphate was recorded in the riverine reaches of the estuary (Station E). Comparatively, phosphate levels were higher in 2012 than 2013. Nitrate concentration was higher in the dry season than in the wet season at almost all the stations sampled (Figure

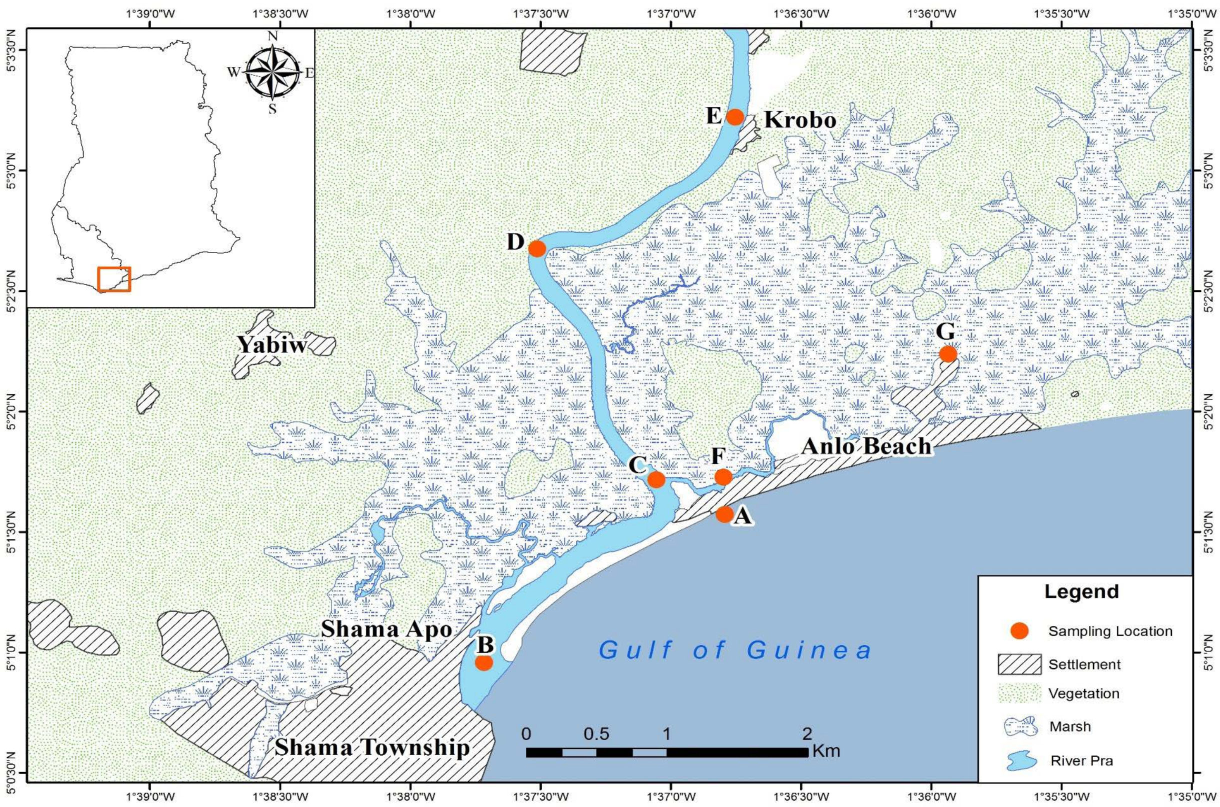

Figure 1: Map showing the Pra estuary and the sampling stations

3b). Concentrations ranged from 1 to 2 mg/L in the wet season in all three habitats but this increased appreciably in the dry season, reaching 4.3±0.6 mg/L in the sea, 14.6±1.7 mg/L in the wetland, and 78.2 ±2.3 mg/L in the estuary. Like phosphate, the riverine reaches of the estuary (Station E) had the highest nitrate levels in the dry (78.2 mg/L) and wet (24.4 mg/L) seasons. Concentrations of the two nutrients in the three habitats far exceeded the optimum values of 0.1 mg/L for phosphate and 1.0 mg/L for nitrate in estuaries that prevent algal bloom (NOAA/EPA, 1988).

Discussion

Alabaster and Lloyd (1980) reported a pH range of 5.0 to 9.0 as the tolerable limits for freshwater fish, and Wood (1967) reported 6.5 to 9.4 for estuaries. Furthermore, USEPA (1976) has explained that shallow biologically active marine waters in tropical areas naturally experience large pH changes during daytime (pH of up to 9.5) due to photosynthetic activities, and communities in these systems are adapted to such variations. The pH recorded in the three ecosystems during the period (6.5 - 9.0) was therefore suitable for aquatic life. However, turbidity, dissolved oxygen, nitrate and

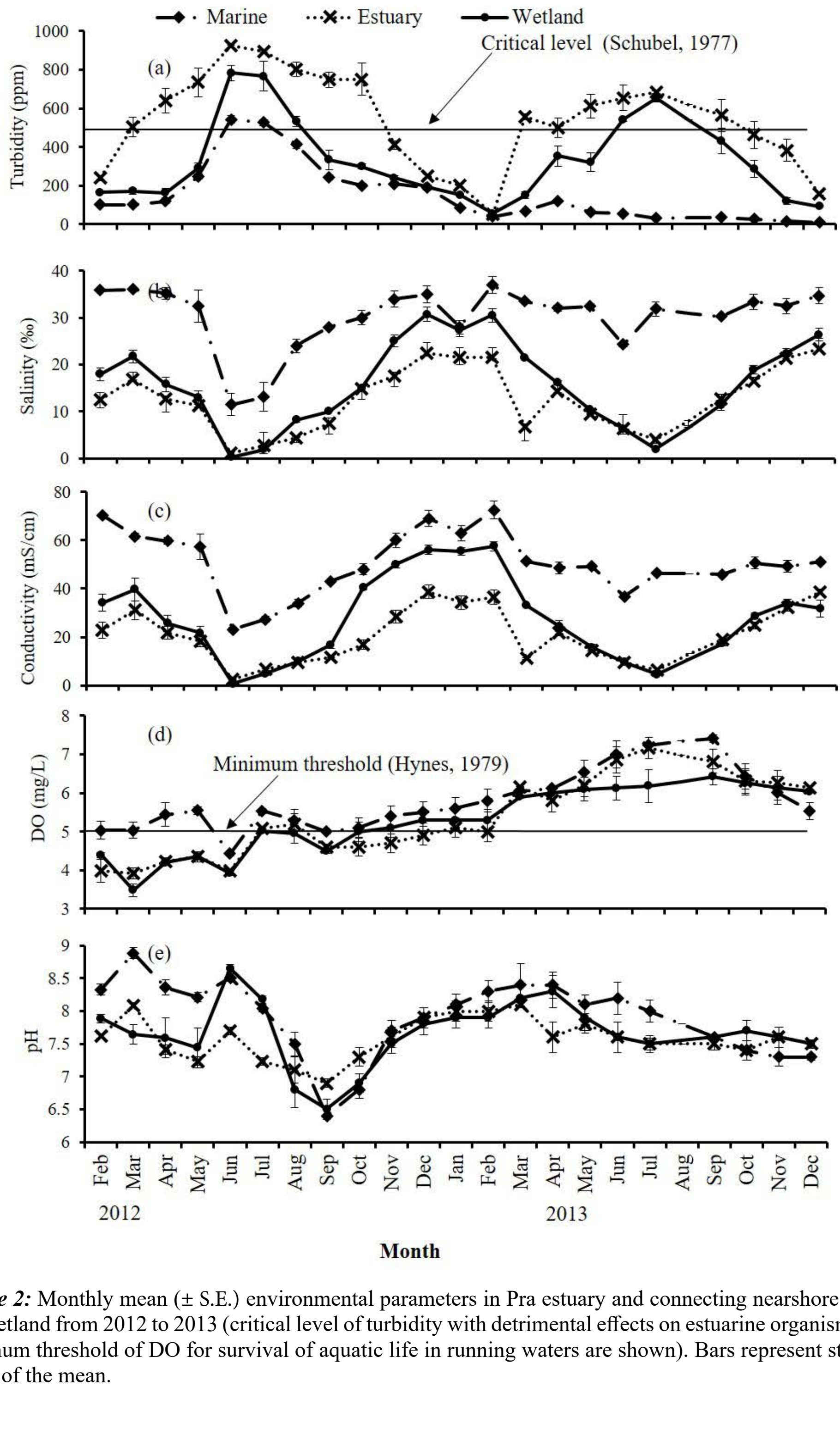

Figure 2: Monthly mean (± S.E.) environmental parameters in Pra estuary and connecting nearshore waters and wetland from 2012 to 2013 (critical level of turbidity with detrimental effects on estuarine organisms, and minimum threshold of DO for survival of aquatic life in running waters are shown). Bars represent standard errors of the mean.

phosphate concentrations were at critical levels at the stations in the estuary and adjoining ecosystems which should be of concern because of their potential negative effects on primary and fisheries productivity of the estuary and the ocean. High turbidity caused by suspended silt poses a threat to many coastal environments around the world (Gordon & Baretta, 1982; Airoldi, 2003). The persistent brownish color of the estuary is attributed to silt inflow from illegal mining activities upstream, and is responsible for turbidity readings of 1000 ppm in its upper reaches (Station E). Such silt related turbidities influence other physico-chemical factors in aquatic ecosystems (Ishaq & Khan, 2013). Because suspended silt in turbid water absorbs more of the sun's energy than clear water, high turbidity leads to higher water temperatures, and consequently reduce oxygen concentration (LaSalle, 1990; Bilotta & Brazier, 2008). Furthermore, suspended particles scatter incident light entering aquatic environments thereby reducing photosynthetic activity and oxygen production (da Costa *et al.*, 2013). This may have accounted for the dissolved oxygen concentrations below 5 mg/L which is reportedly the minimum for survival of organisms in lotic waters (Hynes, 1970; Palanna, 2009).

Turbidity may have also influenced the high concentrations of phosphates and nitrates in the habitats as the highest concentrations of these nutrients were recorded at the location with the highest turbidity. Large amounts of accumulated nitrates and phosphates in soils from industrial and agricultural activities upstream are washed into estuaries during rains (National Research Council, 2000; Iida and Shock, 2007) when turbidity also increases. Similar nutrient pollution due to high levels of nitrates (33.8±0.5 mg/L) and phosphates (3.9±0.1 mg/L) in the Pra Estuary has earlier been reported (Tufuor *et al.*, 2007). Clearly, the concentrations recorded at most stations in the three habitats were by far higher than the optimum limits of 0.1 mg/L phosphate and 1.0 mg/L nitrate recommended as the suitable levels in estuaries and other coastal ecosystems that prevents algal blooms (NOAA/EPA, 1988). Although the high concentrations of nutrients in the brackish water systems confers a capacity for high primary productivity, this is hampered by limited light penetration due to the extreme turbid conditions.

The current conditions in the estuary could have negative repercussions for fish recruitment into the marine stocks and fisheries productivity in Ghanaian marine waters. Aquatic organisms including fish are particularly susceptible to the effects of increased sediments and turbidity (Bilotta and Brazier, 2008). High silt content of the water decreases visibility thereby obstructing fish feeding activities, smothers fish eggs, and can clog the gills of filter feeders (Simenstad, 1990). Since acute effects of turbidities on organisms in estuaries occur at levels beyond 500 ppm (Schubel, 1977), turbidities around 1000 ppm in the Pra estuary may be responsible for the dwindling population of the mangrove oyster (*Crassostrea tulipa*) as reported by community members in the catchment area of the estuary (Pers. comm.). As juveniles of a number of commercially valued marine fishes utilize estuaries along Ghana's coastline as nurseries (Blay, 1997; Okyere et al., 2011; Levy et al, 2015), the turbid condition of the Pra estuary may decrease fish nursery activities and consequently affect recruitment into the marine stocks.

In conclusion, high turbidities (> 500 mg/L) were prevalent in the Pra estuary, and this may have occasioned the low dissolved oxygen levels in 2012 and high concentration of nutrients. Given that estuaries function as fish nursery habitats of many

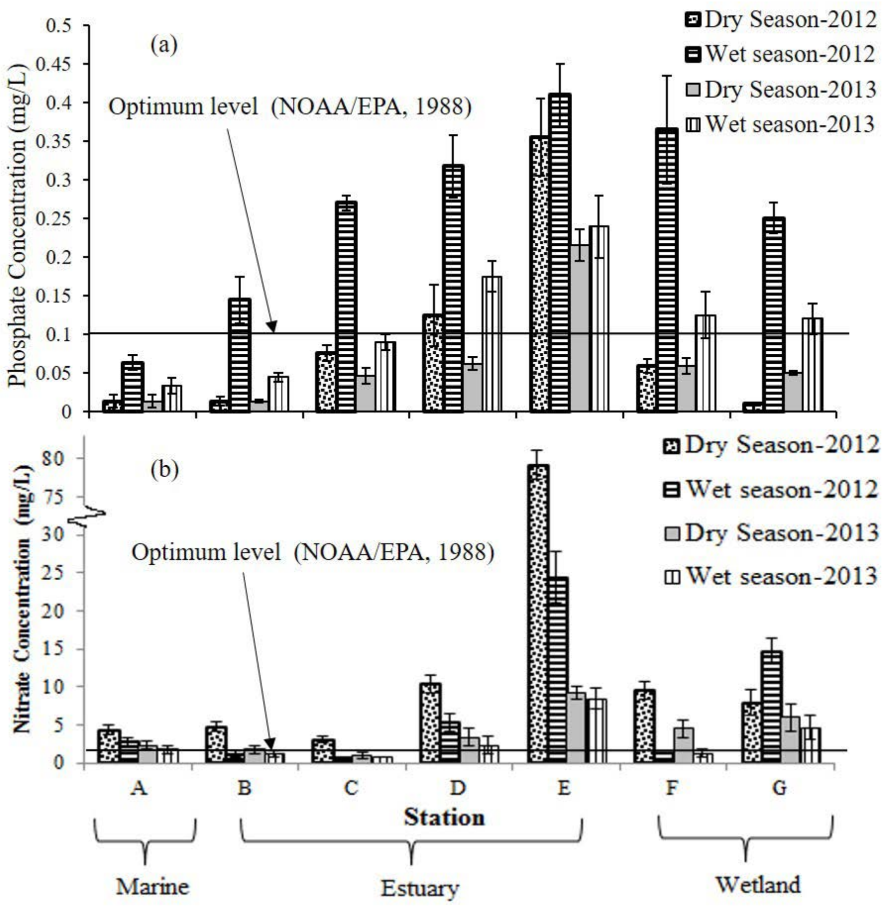

Figure 3: Mean concentration of (a) phosphates and (b) nitrates at the stations in the three habitats in the wet and dry seasons (vertical bars represent standard errors)

commercial species and additionally transport nutrients into the sea, it is imperative that future fisheries management planning gives attention to estuaries and other such coastal systems which have come under severe degradation in Ghana. For the Pra estuary in particular, urgent measures are needed to improve the excessively high siltation situation caused by illegal gold mining activities upriver. To this end, the ban on illegal small scale mining in the country will go a long way to remediate the deteriorated state of the estuary.

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