Effects of hydrographic conditions of ponds on juvenile fish assemblages in the Kakum mangrove system, Ghana

Article · August 2015

DOI: 10.1016/j.rsma.2015.08.007

4 authors, including:

Evan S. Levy
Colorado College

Noble Kwame Asare
University of Cape Coast

Daniel Wubah
Washington & Lee University

Regional Studies in Marine Science xx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Regional Studies in Marine Science

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

Effects of hydrographic conditions of ponds on juvenile fish assemblages in the Kakum mangrove system, Ghana

Q1 Evan S. Levy[a], Noble K. Asare[b,*], Kobina Yankson[b], Daniel A. Wubah[c]

[a] Department of Organismal Biology and Ecology, Colorado College, Colorado Springs, CO, USA

[b] Department of Fisheries and Aquatic Sciences, University of Cape Coast, Ghana

[c] Office of the Provost, Washington and Lee University, VA, USA

HIGHLIGHTS

- Role of hydrographic conditions in the use of mangrove ponds as fish nursery assessed.
- Pond selectivity by juvenile fishes largely influenced by salinity and pond size.
- Smaller juveniles preferred lower salinity conditions and shallower pond depth.
- Diversity and abundance of fish higher in ponds closer to the estuary.
- Three fish species out of 18 better adapted to changing hydrographic conditions.

ARTICLE INFO

Article history:
Received 14 June 2015
Received in revised form
2 August 2015
Accepted 4 August 2015
Available online xxxx

Keywords:
Juvenile fishes
Nursery ground
Mangrove tidal ponds
Hydrographic conditions

ABSTRACT

The importance of mangrove ecosystems as nursery grounds for fishes is well established and documented. This paper reports on the possible role of hydrographic dynamics in the selection and utilization of tropical mangrove ponds as nursery habitats for juvenile fishes of ecological and commercial importance. The study was conducted in the Kakum River Estuary mangrove ecosystem near Elmina in the Central Region of Ghana during the peak of the monsoon season. Fish assemblages were sampled using a cast net and a pole seine. Aspects of hydrographic conditions of the ponds were studied. A total of 265 fish specimens, belonging to 18 species and 12 families were sampled. The commonest fish was the blackchinned tilapia *Sarotherodon melanotheron*, a typical brackishwater fish in West Africa, which accounted for 66.4% of the total fish sampled. Ten of the 18 species belonging to 7 families, namely *Elops lacerta*, *Eucinostomus melanopterus*, *Porogobius schlegelii*, *Gobionellus occidentalis*, *Mugil bananensis*, *Liza falcipinnis*, *Epinephelus* sp., *Serranus accraensis*, *Penaeus notialis* and *Callinectes amnicola* were of marine origin. Spatial and temporal variations in the prevailing hydrographic conditions appeared to influence the fish species composition, density and size classes to varying degrees. Changes in salinity, dissolved oxygen, pH, conductivity and pond size correlated significantly with abundance of juvenile fish. Major fluctuations in fish species composition occurred on a weekly basis with changing pond depth and volume, indicating the dynamic nature of mangroves ponds that may serve the ecological needs of different species over time. Smaller juvenile fishes seemed better adapted to the high variations in hydrographic conditions compared to larger juveniles. Higher fish densities and low species diversity were encountered when the ponds were shallow compared to deep ponds. The utilization of mangrove tidal ponds as nurseries by juvenile fish may therefore be influenced primarily by the salinity and pond size.

1. Introduction

Human growth and development has caused the degradation and/or disappearance of many mangrove ecosystems worldwide. In the last half century, more than a third of the world's mangroves have been lost (Alongi, 2002) at a considerably high rate of 1%–2% per annum (Di Nitto et al., 2014). With the continued threat of sea level rise from climate change, increased deforestation and pollution due to burgeoning human populations in the tropics, the health of mangrove ecosystems face an uncertain future (McLeod and Salm, 2006).

Mangrove ecosystems provide essential ecological services such as nursery habitat for a host of ecologically and commercially

* Corresponding author.
E-mail address: nasare@ucc.edu.gh (N.K. Asare).

http://dx.doi.org/10.1016/j.rsma.2015.08.007
2352-4855/© 2015 Published by Elsevier B.V.

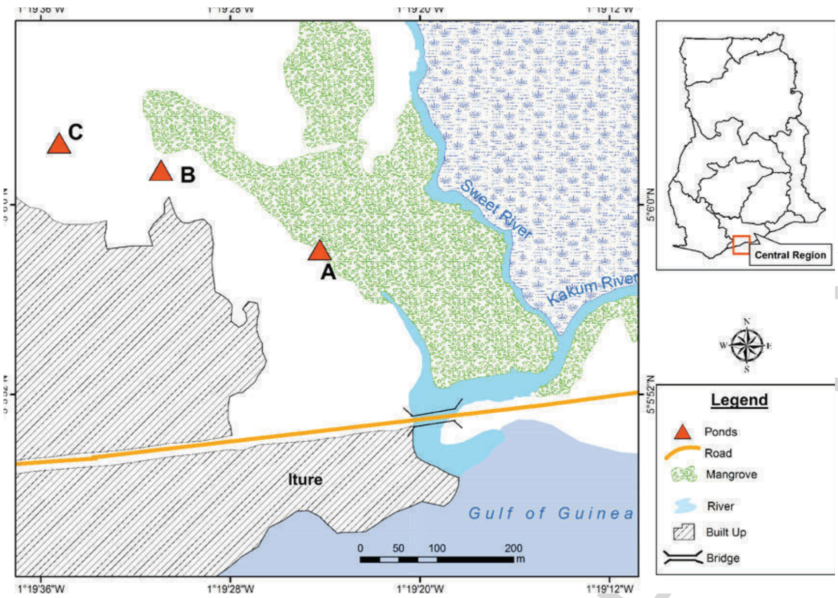


Fig. 1. Map of the study area showing selected ponds within the Kakum mangrove system.

important marine, brackish, and fresh water fish assemblages (Robertson and Duke, 1987; Laegdsgaard and Johnson, 2001) and contribute significantly to recruitment of adult marine fishes (Camp et al., 2011). Many studies have shown that juveniles account for 70%–90% of the fish fauna occurring in mangrove ecosystems, serving as evidence of their importance as nursery grounds (Nagelkerken et al., 2008; Mwandya et al., 2009). In addition, 20%–90% of commercial fishery catches have been directly linked to the health of nearby mangrove ecosystems (Nagelkerken et al., 2008). Recent analyses have quantified the economic value of mangroves to be 200,000–900,000 US$ per hectare, and up to 3000,000 US$ per kilometer of coastline (Alongi, 2002; Wells et al., 2006). This high value is primarily due to the ability of mangroves to protect the shore against erosion, reduce local pollution, and contribute to fisheries.

Three hypotheses have been postulated as to why mangrove ecosystems are such effective nursery grounds for fish stocks: (1) juveniles face less predation in the mangroves, (2) mangroves provide more food for juvenile fish than other ecosystems and (3) the structural heterogeneity of mangroves attracts juveniles (Laegdsgaard and Johnson, 2001; MacDonald et al., 2009; Nanjo et al., 2014).

In western Africa, mangrove ecosystems remain understudied (Aheto et al., 2014). Ghana, which has a 550 km of coastline, has over 100 estuaries and lagoons (Yankson and Obodai, 1999; Ryan and Ntiamoa-Baidu, 2000). The Kakum River Estuary and its associated salt marshes and mangrove ecosystems have previously been surveyed for their fish and macroinvertebrate fauna (Blay, 1997; Okyere et al., 2012; Aheto et al., 2014). The fringing mangrove ecosystem of this estuary is home to six of the eight true species of mangrove trees found in West Africa (UNEP, 2007) which is considered to be the highest diversity in Ghana (Sackey et al., 1993), making it a botanically important ecosystem. This mangrove ecosystem also has several established heterogeneous microhabitats due to its exposure to anthropogenic influence therefore presenting an ideal ecosystem to investigate ecological dynamics.

Several factors including water depth, temperature, pH, salinity, turbidity and dissolved oxygen have been shown to influence the composition of fish assemblages in brackish water ecosystems (Lin and Shao, 1999; Singkran and Sudara, 2005; Green et al., 2009; Nip and Wong, 2010). Sediment characteristics of brackishwater ecosystems have also been established to be of importance to juvenile fish (Camp et al., 2011) and pollution has become an increasingly important characteristic in determining mangrove faunal species composition including fish (Singkran and Sudara, 2005; McLeod and Salm, 2006; Sharma et al., 2013). However, little is known about the underlying factors that determine selectivity of ponds in mangrove ecosystems as nursery grounds by fish species. This study therefore seeks to investigate how changes in the hydrographic characteristics in tidal mangrove ponds of the Kakum River Estuary influence their selection and utilization as nursery grounds by fish species.

2. Methods

2.1. Study site

The Kakum River Estuary mangrove ecosystem is located near Elmina in the Central Region of Ghana (5° 5′ 40″N and 5° 6′ 12″N; 1° 19′10″ W and 1° 19′ 40″W) (Fig. 1).

Several ponds in the Kakum mangrove ecosystem provide habitats and refuge for a variety of fish and macroinvertebrate fauna. These ponds are largely temporary occurring during the wet season and disappearing during the dry season. This is because, many of the ponds are inundated when the adjacent Sweet River overflows its banks or from surface runoffs during the raining season (from May to June and to a lesser degree in October) whilst remaining virtually dry during the rest of the year. Several existing ponds are also interconnected by narrow channels and experience varying degrees of influence from periodic tidal exchanges. Three ponds (A, B and C) of varying sizes, morphology and hydrodynamics were selected for this study (Fig. 1). Pond A was the closest to the estuary, and experienced regular tidal influence. Pond B was the smallest of the three ponds with some tidal influence and connected to a few other smaller ponds. Pond C was the largest and farthest from the estuary with minimal tidal influence. Ponds B and C also experienced intermittent freshwater influx from the adjacent Sweet River.

2.2. Data collection

Weekly samples of fish, water and sediment were taken in June 2014 to coincide with the peak of the monsoon season. In

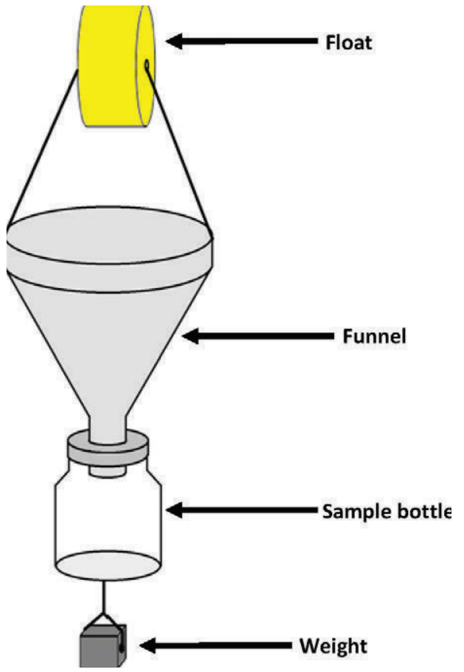


Fig. 2. Illustration of a sediment trap used in this study.

addition, the following hydrographic conditions of the ponds were measured: sedimentation rate, sediment organic matter content, pond surface area, water depth and volume, biochemical oxygen demand and other water quality parameters (salinity, water temperature, dissolved oxygen concentration, pH, total dissolved solids and conductivity).

2.2.1. Fish sampling

A cast net (with stretched mesh size of 2 cm) and a pole seine net (with stretched mesh size of 0.5 cm to enhance species composition determination) were used to sample finfish and shellfish from the three ponds. To standardize the sampling activity, a total of three cast net throws and one haul of the pole seine were carried out in each pond once a week for four weeks. The cast net was deployed randomly at approximately 3 min intervals. Fish samples were preserved in 10% formalin for further analyses in the laboratory. Fish from each fishing operation were identified to the lowest possible taxon with the aid of identification manuals (Schneider, 1990; Paugy et al., 2003) and each species counted. The fish were measured for total length and standard length.

2.2.2. Estimation of sedimentation rate

Four sediment traps (designed to capture vertically settling particles) were deployed in each pond. The traps were modeled after the original time-series sediment trap design (Honjo and Doherty, 1988). The device has a funnel with an aperture diameter of 14 cm, feeding into the lid of a sealed plastic sample bottle of 300 ml capacity (Fig. 2).

The traps were set such that the aperture of the funnels were at least 10 cm below the surface of the water. To keep the traps in a vertical position in shallow ponds, they were embedded directly in the soft pond substratum. In deep ponds, the traps were suspended vertically and moored with corks attached to the funnels and metal weights at the base of the bottles.

The traps were retrieved at the end of each week and the sample bottles removed to decant wet sediment. New bottles were installed and the traps redeployed in the same locations within the ponds. Sediment from each bottle was oven dried at 105 °C in a glass beaker until no weight changes were realized. Mean sedimentation rate of each pond was estimated as a function of the total dry weight of the trapped sediment, estimated aperture area of the trap funnel, and the number of days sediments were trapped.

2.2.3. Surface area and water depth measurements

The surface area of each pond was estimated from its average diameter, or length and width during each sampling. The average water depth for each pond was determined by measuring the depth at each location of a sediment trap with the aid of a graduated rule.

2.2.4. Determination of biochemical oxygen demand (BOD_5)

Biochemical oxygen demand (BOD) of the ponds was determined as a pollution indicator. This was achieved by incubating diluted water samples (with a dilution factor of 4) at approximately 25 °C for five days in the dark. Dissolved oxygen (DO) concentration before and after the incubation period was determined by the Winkler titration method (Strickland and Parsons, 1968). The BOD for each sample was then estimated with the appropriate adjustment for the sample dilution factor using the formulae below:

$$BOD_{mg/l} = (DO_{initial} - DO_{final}) \times \text{Dilution Factor} \quad (1)$$

$$\text{Where Dilution Factor} = \text{Volume of BOD bottle/Volume of sample used.} \quad (2)$$

2.2.5. Determination of sediment organic matter content

All the trap sediment samples were analyzed for organic matter content using the loss on ignition (LOI) method (Schulte and Hopkins, 1996). Approximately 1 g of ground, dried sediment samples were placed in pre-weighed crucibles and combusted at 550 ± 10 °C for 2 h in a muffled furnace (Carbolite CWF 1200). The samples were then cooled to room temperature in a desiccator and weighed. A comparative analysis was also conducted between the trap samples and substrate sediment taken near the trap.

2.2.6. Measurement of water quality parameters

Salinity, water temperature, DO, pH, total dissolved solids (TDS) and conductivity were measured *in situ* in the vicinity of the sediment traps using a multiparametric probe (Oakton PCD650).

2.3. Data analysis

A one-way analysis of variance (ANOVA) was used to compare observed hydrographic data and fish biodata (abundance, size classes, species diversity and richness) on a temporal and spatial scale. Pond volume was calculated based on the estimated water depth and surface area. The pond surface area was estimated based on whether it was circular (Ponds A and B) or rectangular (Pond C). A regression analysis was used to test the relationship between hydrographic parameters and fish biodata. The diversity of fish species was assessed by the Shannon–Weiner diversity index:

$$H' = -\sum_{i=1}^{s} P_i(\ln P_i) \quad (3)$$

where s is the number of species encountered in a pond and P_i is the proportion of individuals belonging to species i in the fish community (Krebs, 1999).

Species richness was determined by Margalef's index (d) given as

$$d = (s - 1)/(\ln N) \quad (4)$$

where s is the number of species sampled and N is the total number of fish in the sample.

Table 1
Analysis of variance for spatial and temporal variations in hydrographic factors of the Kakum River Estuary mangrove ponds.

Source of variation	df	Temporal			df	Spatial		
		MS	F	*p*		MS	F	*p*
Temperature	3	57.3	16	<0.001	2	42.6	7.8	0.0013
Salinity	3	71	75.7	<0.001	2	5	0.9	0.42
DO	3	48.4	35	<0.001	2	6	1.3	0.28
pH	3	2.2	30.6	<0.001	2	0.05	0.2	0.79
Conductivity	3	70.5	32	<0.001	2	8.5	0.9	0.43
TDS	3	17.4	37	<0.001	2	5.5	2.5	0.11
BOD_5	3	23.8	4.1	0.05	2	1.8	0.2	0.85
Pond area	3	1.10E+06	1.7	0.24	2	1.80E+06	3.3	0.09
Pond depth	3	2.90E+03	11.5	<0.001	2	1.70E+03	4.9	0.012
Pond volume	3	5.80E+05	2	0.19	2	7.50E+05	2.3	0.19

Underlined figures represent statistically significant values.

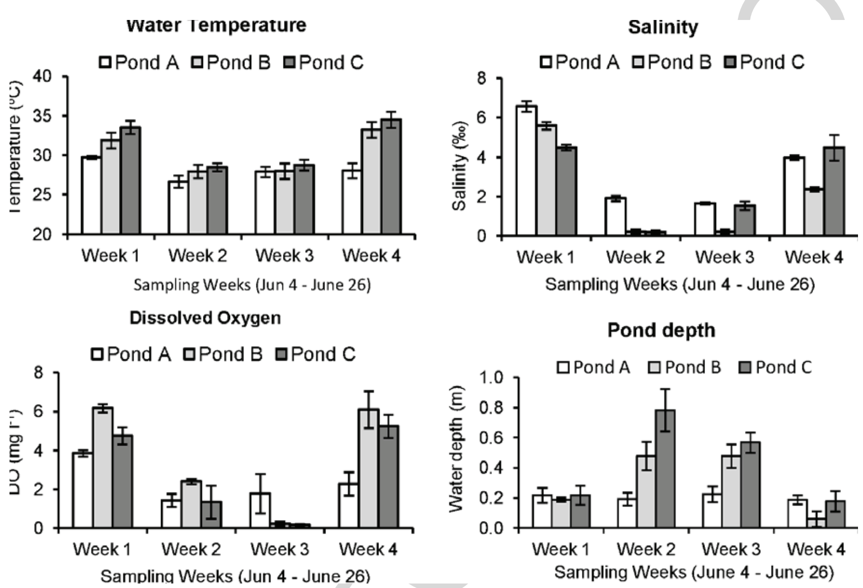


Fig. 3. Spatial and temporal variations in temperature, salinity, dissolved oxygen and water depth of selected ponds in the Kakum mangrove system.

3. Results

3.1. Physicochemical factors

Fig. 3 shows the weekly changes in water temperature, salinity, DO and pH in the three ponds during the study period. Water temperature ranged from 26.1 to 35.9 °C, salinity from 0.1 to 6.8‰, dissolved oxygen from 1.2 to 6.7 mg l^{-1} and pH from 5.8 to 7.6 with respective mean values of 29.8 ± 2.7 °C, 2.9 ± 2.3‰, 3.8 ± 1.7 mg l^{-1} and 6.7 ± 0.5. These factors exhibited significant temporal variations from Week 1 to Week 4. However, only water temperature showed a significant spatial variation between the three ponds (Table 1) with average water temperatures increasing from 28.1 °C in Pond A (closest to the estuary) to 31.3 °C in Pond C (farthest from the estuary). Salinity did not differ significantly between the three ponds although it showed a decrease from Pond A to Pond C throughout the period. Dissolved oxygen concentration and pH did not register any clear trends in spatial variations with no statistical significance to the observed variations (Table 1).

3.2. Biochemical oxygen demand

Changes in the biochemical oxygen demand (BOD) in the ponds are shown in Fig. 4. The mean BOD value ± SE for all three ponds over the four sampling weeks was estimated at 11.0 ± 0.7 mg l^{-1}. BOD values for the first and fourth weeks were similar (13.2 mg l^{-1} and 13.3 mg l^{-1} respectively), as were the values for the second and third weeks (8.8 mg l^{-1} and 8.0 mg l^{-1} respectively).

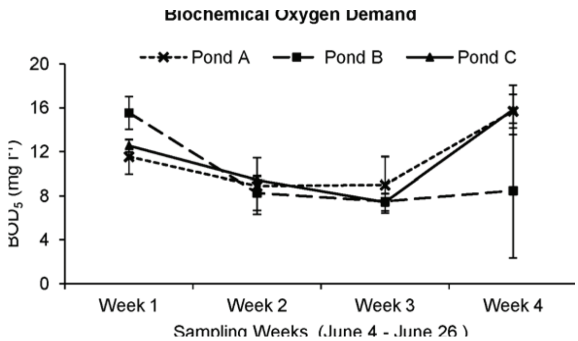


Fig. 4. Spatial and temporal variations in BOD (with SE bars) of selected ponds in the Kakum River Estuary mangrove system.

From the results, there was an observable variation in the mean BOD values from Week 1 through to Week 4 of sampling in all three ponds. From the ANOVA, spatial variations were not significant. This is further confirmed by the SE bars in Fig. 4. However, the recorded temporal variations were significantly different (see Table 1).

3.3. Water depth and volume of ponds

The average depth and volume of the ponds changed drastically over the sampling period. Temporally, water depth for all the three selected ponds varied between 0.06 m and 0.78 m with mean water

Table 2
Occurrence and diversity of fish species in three selected ponds in the Kakum River Estuary mangrove ecosystem.

Family	Species (Ecological range)	Pond A	Pond B	Pond C
Finfish				
Cichlidae	*Tilapia zillii* (BW–FW)	−	+	+
Cichlidae	*Sarotherodon melanotheron* (BW–FW)	+	+	+
Clariidae	*Clarias sp.* (FW)	−	+	−
Clariidae	*Heterobranchus sp.* (FW)	−	+	+
Eleotridae	*Kribia kribensis* (FW)	−	−	+
Elopidae	*Elops lacerta* (MN–BW–FW)	+	−	−
Gerreidae	*Eucinostomus melanopterus* (MN–BW–FW)	+	−	−
Gobiidae	*Porogobius schlegelii* (MN–BW–FW)	+	−	−
Gobiidae	*Gobionellus occidentalis* (MN–BW–FW)	+	+	−
Mugilidae	*Mugil bananensis* (MN–BW–FW)	+	+	+
Mugilidae	*Liza falcipinnis* (MN–BW–FW)	+	−	+
Poecilidae	*Aplocheilichthys spilauchen* (FW–BW)	−	−	+
Serranidae	*Epinephelus sp.* (MN–BW)	+	−	−
Serranidae	*Serranus accraensis* (MN)	+	−	−
Shellfish				
Graspidae	*Sesarma huzardii* (BW)	−	+	−
Pinnaedae	*Penaeus notialis* (MN–BW)	+	−	−
Portunidae	*Callinectes amnicola* (MN–BW)	+	+	+
Unknown	Fresh water shrimp (FW–BW)	+	−	−
Total number of families sampled		9	6	6
Total number of species sampled		12	8	8

MN (Marine); BW (Brackishwater); FW (Freshwater); + (Present); − (Absent).

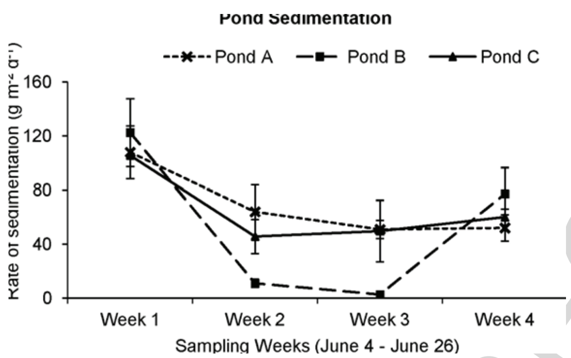


Fig. 5. Spatial and temporal variations in sedimentation rate (with SE bars) of selected ponds in the Kakum River Estuary mangrove system.

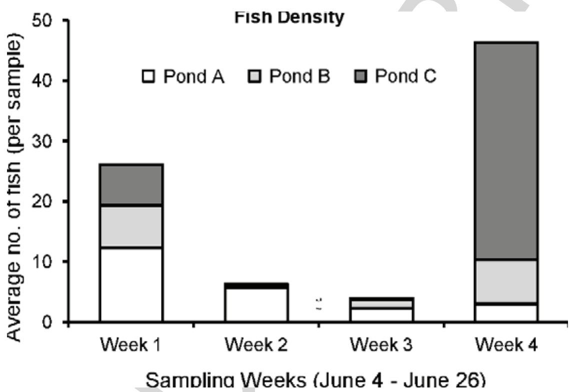


Fig. 6. Cumulative average number of fish specimens from selected ponds within the Kakum River Estuary mangrove system.

depths ± SE for Ponds A, B and C as 0.21 ± 0.02 m, 0.30 ± 0.21 m and 0.41 ± 0.28 m respectively. Water depth also exhibited significant spatial and temporal variations (Table 1). Pond B showed the largest variation in water volume with estimated minimum and maximum volumes of 8.1 m^3 and 916.8 m^3 over the study period, increasing 100 fold between the first and second sampling weeks whilst Pond A exhibited marginal variation between the weeks. The volume of B and C increased in the second week, maintaining this volume in the third week, but decreased in the fourth week.

3.4. Sedimentation rate and sediment organic matter content

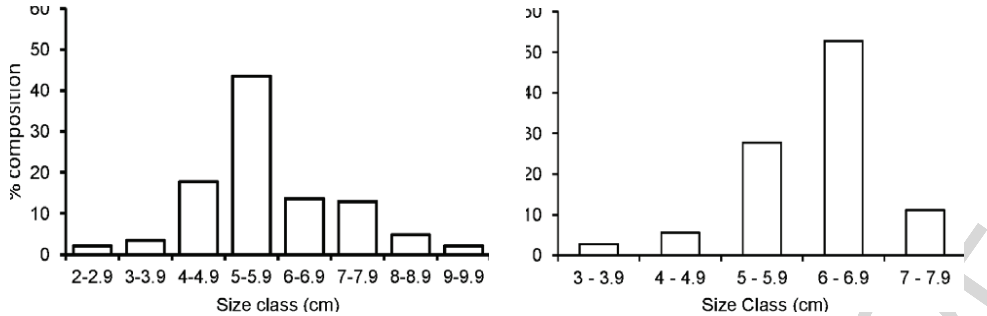
Mean sedimentation rates (±SE) of 68.8 ± 19.9 g m^{-2} d^{-1}, 53.4 ± 13.4 g m^{-2} d^{-1} and 65.3 ± 17.0 g m^{-2} d^{-1} were recorded in Ponds A, B, and C during the study period. Pond B exhibited the largest temporal variation in sedimentation rate ranging from 2.6 g m^{-2} d^{-1} in Week 3–122.5 g m^{-2} d^{-1} in Week 1 (Fig. 5). The mean sediment organic matter content by mass was 15.5 ± 5.5% (SE). Temporally, the sediment organic matter content varied significantly ($p = 0.03$) in all the ponds, with an average of 19.2% when there was freshwater influx and 16.3% during the period of receding water.

3.5. Fish composition and abundance

A total of 265 fish specimens were sampled comprising 256 finfish and 9 shellfish. Their occurrence in the three ponds is presented in Table 2. Twelve species belonging to 9 families were sampled in Pond A, and 8 species from 6 families were caught in each of Ponds B and C. Therefore, Pond A that occurred nearer the estuary was utilized by more species than the other two ponds that were situated farther away from the estuary. The blackchinned tilapia *Sarotherodon melanotheron*, the gray mullet *Mugil bananensis* and the swimming crab *Callinectes amnicola* were found in all three ponds.

Fig. 6 shows the fish catches per week in the ponds during the study period. *S. melanotheron* accounted for 66.4% of the total fish caught. The mullets *Liza falcipinnis* and *M. bananensis* accounted for 13.6% and 11.7% of the catch, respectively. Together, these three species accounted for 91.7% of all fish caught.

The number of fish caught varied significantly between the weeks sampled ($p < 0.05$), with the mean catch varying from 1.3 to 15.4 fish specimens per cast. The highest fish densities in the ponds were recorded in Weeks 4 and 1, and the lowest in Weeks 2 and 3.



(a) *S. melanotheron*. (b) *L. falcipinnis*.

Fig. 7. Size (TL) distribution of (a) *Sarotherodon melanotheron* and (b) *Liza falcipinnis* in the selected ponds of the Kakum River Estuary mangrove system.

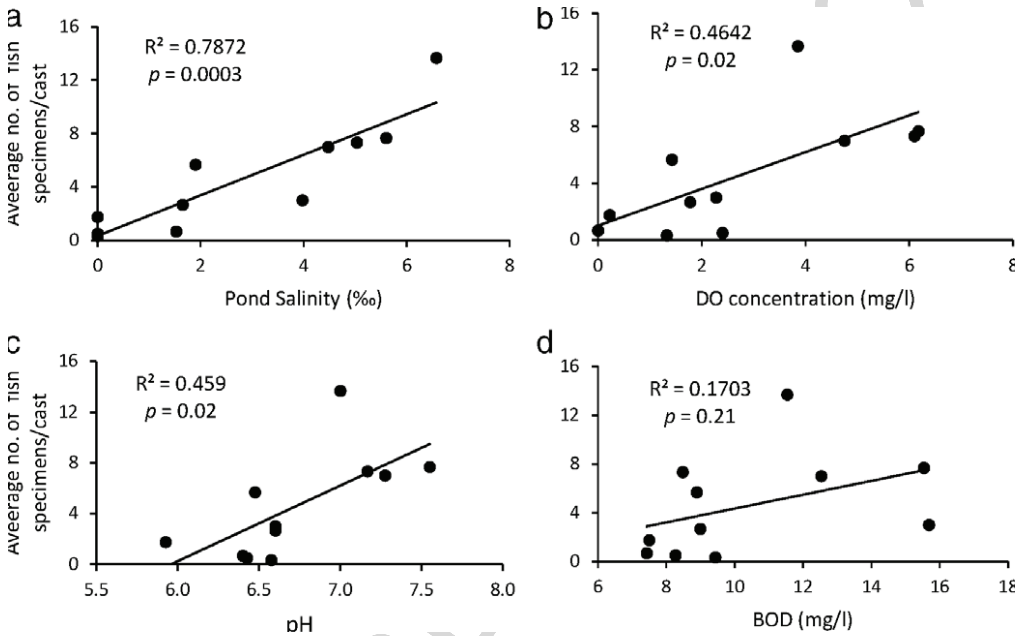


Fig. 8. Relationship between fish abundance and (a) salinity, (b) DO concentration, (c) pH, and (d) BOD in the selected ponds of the Kakum River Estuary mangrove system.

3.6. Fish size distribution

The *S. melanotheron* specimens measured from 2.6 to 9.9 cm TL with a modal size of 5.0–5.9 cm TL (Fig. 7) representing over 43% of the population. *L. falcipinnis* had a modal length of 6.0–6.9 cm TL representing 53% of their population. *M. bananensis* ranged in length from 3.0 cm to 9.9 cm TL with a modal length of 8.0–8.9 cm accounting for 39% of specimens.

3.7. Fish species diversity and richness

Shannon–Wiener diversity index (H') values of 1.44, 1.28, and 0.78 were determined for Ponds A, B and C while Margalef richness index (d) values of 2.5, 1.8 and 1.4 were computed for Ponds A, B, and C respectively. Pond A therefore registered the highest species diversity and richness amongst the ponds studied in the mangrove ecosystem. Fish species diversity and richness declined from Pond A through to Pond C.

3.8. Relationship between hydrographic factors and fish biodata

Table 3 presents results of the ANOVA for regression analyses between various hydrographic factors and fish abundance in the three ponds. Fish abundance was significantly related to salinity, dissolved oxygen concentration, pond depth, pond volume, pH and conductivity. Water temperature, total dissolved solids and biochemical oxygen demand were not significantly related to fish abundance in the ponds.

Salinity and DO were the most significantly correlated hydrographic factors ($p = 0.0003$ and 0.02 respectively) to fish density (Fig. 8). From analysis, an increase in pond salinity and DO corresponded to an increase in observed fish abundance, sizes and diversity. However, increasing pond volume and depth resulted in a reduction in fish abundance (Fig. 9). Mean sizes of fish species encountered were also found to be significantly related to salinity

Table 3
Analysis of variance for the relationship between fish density and hydrographic factors in selected ponds in the Kakum River Estuary mangrove ecosystem.

Source of variation	df	Fish density		
		MS	F	p
DO	1	78.0	7.7	0.02
Salinity	1	132.5	33.0	0.0003
Temperature	1	43.4	3.1	0.11
Conductivity	1	75.5	9.6	0.037
TDS	1	46.8	4.7	0.12
pH	1	76.7	7.5	0.023
Pond Volume	1	80.4	8.0	0.022
Pond Depth	1	74.8	7.2	0.025
BOD	1	366.3	5.2	0.21

Underlined figures represent statistically significant values.

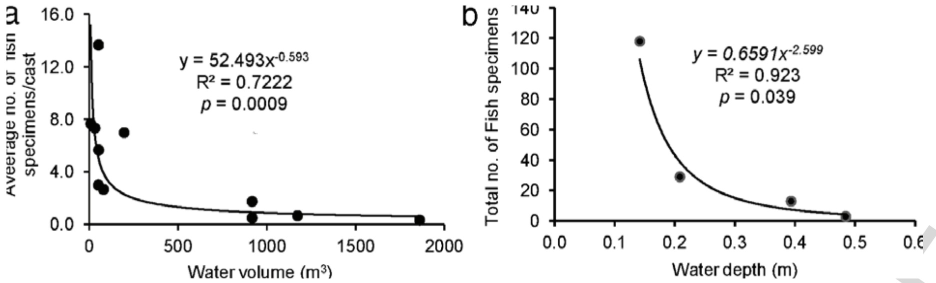


Fig. 9. Relationship between (a) pond volume and fish abundance, and (b) pond depth and abundance of *Sarotherodon melanotheron* in the Kakum River Estuary mangrove system.

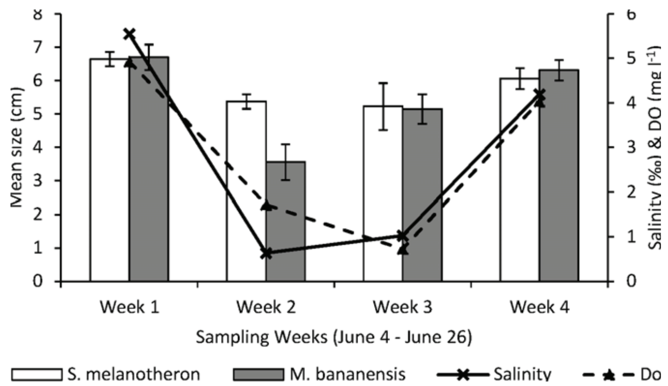


Fig. 10. Weekly mean sizes of juvenile fish of the two commonest species *Sarotherodon melanotheron* and *Mugil bananensis* (with SE bars) in relation to salinity and dissolved oxygen concentration of ponds.

and DO variations. The average sizes of the fishes caught decreased with decreasing salinity and DO (Fig. 10).

4. Discussion

Hydrographic and other environmental conditions play critical roles in the selection of habitats by fish species. Earlier studies in the Kakum River Estuary ecosystem (e.g. Blay, 1997; Okyere et al., 2012; Aheto et al., 2014) have reported many marine finfish and shellfish to utilize this mangrove ecosystem as nursery ground. However, the factors influencing the selection of mangrove ecosystem ponds by fish have not been fully investigated.

In the present study, ponds in the Kakum mangrove ecosystem experienced pronounced spatial and temporal variations in aspects of their hydrographic conditions. In the first week of the study, the selected ponds were generally shallow with low volume of water but with the onset of heavy rains, they increased in sizes (depth and volume) during the second and third weeks before drastically decreasing in size in the fourth week. These changes in pond sizes inherently affected a number of water quality factors such as salinity and suspended particulate matter. Salinity was inversely correlated with pond water volume dictated primarily by fresh water influx from the riverine system instead of tidal pumping.

Fish species found utilizing the mangrove ponds were of mixed-assemblage made up of marine, brackish and fresh water species. The most common fishes encountered in the mangrove ponds surveyed were the blackchinned tilapia *S. melanotheron*, the gray mullets L. falcipinnis, and *M. bananensis*. During the four sampling weeks, juveniles of *S. melanotheron*, *M. bananensis* and *C. amnicola* were present in all three ponds suggesting their better tolerance of the changing environmental conditions thereby making them the most hardy and successful users of mangrove ponds.

Diversity, abundance and size distribution of fish assemblages in the ponds were found to be significantly affected by salinity and DO variations as well as pond size.

Whilst variation in water temperature has been established to influence the community structure of fish from other studies (Whitfield, 1999; Blaber, 2000), the findings of this study did not indicate any significant correlation between temperature and fish abundance. This could be attributed to lack of pronounced temperature variations during the study period.

Although the observed salinity within the three selected ponds over the study period were generally low (maximum of 6.8‰), periods of much lower salinity regimes were associated with low species diversity, abundance and size classes whilst the reverse occurred with increasing salinity. During periods of lower salinity, only fishes of smaller sizes were encountered in the ponds. This observation may suggest that lower salinity conditions are more suitable to juvenile fishes with an apparent better tolerance to declining salinity conditions in comparison with their larger counterparts, who presumably leave the less saline ponds for higher saline areas. This was particularly true for ponds located farther away from the estuary and therefore subjected to less saltwater intrusions. These finding may suggest that early developmental stages of fishes that utilize the mangrove ponds as nursery have a wider salinity tolerance range (Wang et al., 2013). Additionally, freshwater species, such as the catfish *Heterobranchus sp.* and *Clarias sp.* were only encountered in the ponds when salinity levels dropped below 1‰. Site selectivity by juvenile fishes (particularly the gray mullets) within the mangrove is therefore highly influenced by prevailing habitat salinity conditions (Cardona, 2006). The observed correlation between fish abundance and salinity variations from this study was consistent with that of Nip and Wong (2010). However, a similar work conducted in the tropical region of Australia (Laegdsgaard and Johnson, 1995) did not find salinity to have any significant influence on types and abundance of juvenile fishes utilizing mangrove habitats as nursery.

Pond depth was also identified to significantly influence pond selectivity by juvenile fishes with increasing water depth being inversely proportional to the abundance, diversity, and size distribution of the fish present. Hence the shallower the ponds, the higher the abundance of juvenile fish population in general and smaller juveniles in particular. A similar observation has been made by other studies. For example, the work by Wright (1986) in a mangrove system in Nigeria in West Africa observed fish densities to be inversely correlated to water depth whilst Ruiz et al. (1993) observed larger fishes to occur in relatively deeper waters of mangrove habitats. This finding is further complimented by the observation that the density of juvenile fishes in brackishwater habitats during the dry season far exceeded that of the wet season (Akinrotimi et al., 2010) due to the limited freshwater inundation of ponds in the dry season.

The results also indicated that ponds in close proximity to the estuary with frequent connection to the ocean recorded the highest fish diversity and density. This may be due to the higher number of fish species of marine origin that utilize mangrove ecosystems as nursery ground compared to freshwater species and the heterogeneous hydrographic conditions presented in the ponds closer to the ocean.

The high levels of BOD in the ponds were an indication that the ponds had high organic content that could affect the development of fish. This was also reflected in the low average DO values recorded in the three ponds over the study period.

Variations in the observed sedimentation rate in the ponds may not directly influence their selectivity by the fish. However, since juveniles of some fish species of commercial importance that nurse in coastal brackishwater habitats have herbivorous and detritivorous feeding habits (Blay, 1995; Ofori-Danson and Kumi, 2006), sedimentation process may contribute to benthic detrital load of the ponds thereby serving as food source for detritivorous juvenile fishes (Amadeu Santana et al., 2015). It could also contribute to primary productivity in the overlying water (Jørgensen, 1996) which may also support herbivorous fishes. Although the organic matter content in the pond sediment (maximum of 30%) is higher than that reported for estuarine systems (e.g. maximum of 26%—Shynu et al., 2015), and inshore waters (e.g. maximum of 17%—Burone et al., 2003), it is nevertheless unclear whether it is sufficient to meet the energy requirement of the detritivorous fishes in the Kakum River Estuary mangrove ecosystem.

Whilst 18 species were sampled from three ponds in the present study, Aheto et al. (2014) identified 12 species from six ponds in a study conducted in March–April (2011) and November–January (2012–2013). The difference in observed species richness could be attributed to the different study periods. This observed temporal variation in species numbers between the two studies at different sites within the same mangrove ecosystem further underscores the heterogeneity of mangrove ponds. These findings may infer that juveniles of different species of fish readily move into the mangrove nursery ponds during different periods when conditions suit their ecological tolerance range.

The estimated fish species diversity index (H') of 1.25 in the ponds during the study did not differ appreciably from the value determined by Aheto et al. (2014) in wet season ponds ($H' = 1.52$). The diversity index values of the ponds decreased with increasing distance from the ocean, resulting in higher fish diversity in ponds that were more accessible to marine fish species.

Dominance of the fish populations by a few species (*S. melanotheron*, *L. falcipinnis* and *M. bananensis*) in the brackishwater environments was similar to observations from previous studies where a few species made up 80%–90% of the total catch (e.g. Blay and Asabere-Ameyaw, 1993; Lin and Shao, 1999; Green et al., 2009).

Whilst this study did not directly test the three hypotheses for why juvenile fish utilize mangrove ecosystems, the results were found to be more consistent with the predator avoidance hypothesis. This stems from the observation that the same ponds had higher fish density with lower volumes of water when compared with periods of higher volumes. In Pond B, which had the highest change in fish density over the study period, six times more fish were caught when the pond reduced in size and depth compared to when the pond was larger and deep. This observation of higher fish densities in smaller, shallower ponds most strongly supports the predator avoidance hypothesis, which may imply that predators would have a harder time navigating such shallow waters.

5. Conclusions

From the studies, salinity, pond volume, water depth, DO concentration and conductivity were identified to have varying degree of influence on pond selectivity by fish species in the Kakum River Estuary mangrove ecosystem. During the monsoon season, salinity variations, DO concentration and water depth appeared the most important hydrographic factors that influenced the abundance and composition of the fish fauna in the mangrove ponds. Ponds closer to the estuary with pronounced tidal exchanges presented the most heterogeneous hydrographic conditions to fish species whereas ponds farther away from the estuarine system and subjected to less tidal influence showed less heterogeneity. With varying fish species composition, abundance and size distribution observed in the mangrove ponds with respect to spatial proximity and over a relatively short temporal period, it could be inferred that mangroves are exceptionally dynamic ecosystems that serve many fish fauna with different habitat tolerances. The commonest fish species in the mangrove ecosystem were juveniles of *S. melanotheron* and *M. bananensis* and the crab *C. amnicola*. These species were encountered in all three ponds studied, which indicate their adaptation to broader spectrum of hydrographic conditions compared to the other species that utilize the mangrove ponds as nursery ground.

Acknowledgments

Our sincere gratitude goes to Mr. Isaac Okyere and Mr. John Eshun of the Department of Fisheries and Aquatic Sciences, University of Cape Coast, Ghana for their immeasurable assistance in the identification of fish specimens in the laboratory assistance and field data collection respectively during the study.

References

Aheto, D.W., Okyere, I., Asare, N.K., Dzakpasu, M.F.A., Wemegah, Y., Tawiah, P., Dotsey-Brown, J., Longdon-Sagoe, M., 2014. A survey of the benthic macrofaunal and fish species assemblages in a mangrove habitat in Ghana. West Afr. J. Appl. Ecol. 22 (1), 1–15.

Akinrotimi, O.A., Abu, O.M.G., Bekibele, D.O., Uedeme-Naa, B., 2010. Occurrence and distribution of Grey Mullets Liza falcippinis and Liza grandisquamis from Buguma Creek, Niger Delta Nigeria. Res. J. Biol. Sci 5 (1), 1–5.

Alongi, D.M., 2002. Present state and future of the world's mangrove forests. Environ. Conserv. 29 (03), 331–349.

Amadeu Santana, A.R., Werth, M., Benedito-Cecilio, E., 2015. Use of food resources by detritivorous fish in floodplains: A synthesis. Acta Biol. Colomb. 20 (1), 5–14.

Blaber, S.J.M., 2000. Tropical Estuarine Fishes: Ecology, Exploitation and Conservation. Blackwell Science, Oxford, UK.

Blay Jr., J., 1995. Food and feeding habits of four species of juvenile mullet (Mugilidae) in a tidal lagoon in Ghana. J. Fish Biol. 46, 134–141.

Blay Jr., J., 1997. Occurrence and diversity of juvenile marine fishes in two brackishwater systems in Ghana. In: Amlalo, D.S., Atsiatorme, L.D., Fiati, C. (Eds.), Biodiversity Conservation: Traditional Knowledge and Modern Concepts. pp. 113–119.

Blay, J., Asabere-Ameyaw, A., 1993. Assessment of the fishery of a stunted population of the cichlid, Sarotherodon melanotheron (Rueppell) in a "closed" lagoon in Ghana. J. Appl. Ichthyol. 9, 1–11.

Burone, L., Muniz, P., Pires-Vanin, A.M.S., Rodrigues, M., 2003. Spatial distribution of organic matter in the surface sediments of Ubatuba Bay (Southeastern—Brazil). An. Acad. Bras. Ciênc. 75 (1), 77–90.

Camp, A.L., Ryer, C.H., Laurel, B., Seals, K., 2011. Effect of nursery habitat on density-dependent habitat selection in juvenile flatfish. J. Exp. Mar. Biol. Ecol. 404 (1), 15–20.

Cardona, L., 2006. Habitat selection by grey mullets (Osteichthyes: Mugilidae) in Mediterranean estuaries: The role of salinity. Sci. Mar. 70 (3), 433–455.

Di Nitto, D., Neukermans, G., Koedam, N., Defever, H., Pattyn, F., Kairo, J.G., Dahdouh-Guebas, F., 2014. Mangroves facing climate change: landward migration potential in response to projected scenarios of sea level rise. Biogeosciences 11, 857–871.

Green, B.C., Smith, D.J., Earley, S.E., Hepburn, L.J., Underwood, G.J., 2009. Seasonal changes in community composition and trophic structure of fish populations of five salt marshes along the Essex coastline, United Kingdom. Estuar. Coast. Shelf Sci. 85 (2), 247–256.

Honjo, S., Doherty, K.W., 1988. Large aperture time-series sediment traps; Design objectives, construction and application. Deep-Sea Res. 35 (1), 133–149.

Jørgensen, B., 1996. Material flux in the sediment. In: Jørgensen, B., Richardson, K. (Eds.), Coastal and Estuarine Studies. American Geophysical Union, pp. 115–135.

Krebs, C.J., 1999. Ecological Methodology, Vol. 620. Benjamin/Cummings, Menlo Park, California.

Laegdsgaard, P., Johnson, C.R., 1995. Mangrove habitats as nurseries: unique assemblages of juvenile fish in subtropical mangroves in eastern Australia. Mar. Ecol. Prog. Ser. 126, 67–81.

Laegdsgaard, P., Johnson, C., 2001. Why do juvenile fish utilise mangrove habitats? J. Exp. Mar. Biol. Ecol. 257 (2), 229–253.
Lin, H.J., Shao, K.T., 1999. Seasonal and diel changes in a subtropical mangrove fish assemblage. Bull. Mar. Sci. 65 (3), 775–794.
MacDonald, J.A., Shahrestani, S., Weis, J.S., 2009. Behavior and space utilization of two common fishes within Caribbean mangroves: implications for the protective function of mangrove habitats. Estuar. Coast. Shelf Sci. 84 (2), 195–201.
McLeod, E., Salm, R.V., 2006. Managing Mangroves for Resilience to Climate Change. World Conservation Union (IUCN), Gland, Switzerland, p. 64.
Mwandya, A.W., Gullström, M., Öhman, M.C., Andersson, M.H., Mgaya, Y.D., 2009. Fish assemblages in Tanzanian mangrove creek systems influenced by solar salt farm constructions. Estuar. Coast. Shelf Sci. 82 (2), 193–200.
Nagelkerken, I., Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G., Meynecke, J.-O., Pawlik, J., Penrose, H.M., Sasekumar, A., Somerfield, P.J., 2008. The habitat function of mangroves for terrestrial and marine fauna: a review. Aquat. Bot. 89 (2), 155–185.
Nanjo, K., Kohno, H., Nakamura, Y., Horinouchi, M., Sano, M., 2014. Differences in fish assemblage structure between vegetated and unvegetated habitats in relation to food abundance patterns in a mangrove creek. Fish. Sci. 80 (1), 21–41.
Nip, T.H., Wong, C.K., 2010. Juvenile fish assemblages in mangrove and non-mangrove soft-shore habitats in Eastern Hong Kong. Zool. Stud. 49 (6), 760–778.
Ofori-Danson, P.K., Kumi, G.N., 2006. Food and feeding habit of sarotherodon melanotheron, Rüppell, 1852 (Pisces: Cichlidae) in Sakumo Lagoon, Ghana. West Afr. J. Appl. Ecol. 10 (1), 9–18.
Okyere, I., Blay, J., Aggrey-Fynn, J., Aheto, D.W., 2012. Composition, diversity and food habits of the fish community of a coastal wetland in Ghana. J. Environ. Ecol. 3 (1), 1–17.
Paugy, D., Lévêque, C., Teugels, G.G., 2003. The Fresh and Brackish Water Fishes of West Africa. Vol. II. IRD Editions, Publications Scientifiques du Muséum, MRAC, p. 815.
Robertson, A.I., Duke, N.C., 1987. Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. Mar. Biol. 96 (2), 193–205.
Ruiz, G.M., Hines, A.H., Posey, M.H., 1993. Shallow water as a refuge habitat for fish and crustaceans in non-vegetated estuaries: an example from Chesapeake Bay. Mar. Ecol. Prog. Ser. 99, 1–16.
Ryan, J.M., Ntiamoa-Baidu, Y., 2000. Biodiversity and ecology of coastal wetlands in Ghana. Biodivers. Conserv. 9 (4), 445–446.
Sackey, I., Laing, E., Adomako, J.K., 1993. Status of the Mangroves of Ghana. In Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions. Part II—Africa. (E.D. Diop, Ed.). International Society for Mangrove Ecosystems and Coastal Marine Project of UNESCO Mangrove Ecosystems Technical Reports (3).
Schneider, W., 1990. FAO species identification for fishery purposes: Field guide to the commercial marine resources of the Gulf of Guinea. FAO pbl. RAFR/F1/90/2, Rome. p. 268.
Schulte, E.E., Hopkins, B.G., 1996. Estimation of organic matter by weight loss-on-ignition. In: Magdo, F.R., et al. (Eds.), Soil Organic Matter: Analysis and Interpretation. In: SSSA Spec. Pub., vol. 46. SSSA, Madison, pp. 21–31.
Sharma, S., Dubey, S., Chaurasia, R., Dave, V., 2013. Macroinvertebrate community diversity in relation to water quality status of Kunda River, (MP), India. Discov. Publ. 3 (9), 40–46.
Shynu, R., Rao, V.P., Sarma, V.V.S.S., Kessarkar, P.M., Murali, R.M., 2015. Sources and fate of organic matter in suspended and bottom sediments of the Mandovi and Zuari estuaries, western India. Curr. Sci. India 108 (2), 226–238.
Singkran, N., Sudara, S., 2005. Effects of changing environments of mangrove creeks on fish communities at Trat Bay, Thailand. Environ. Manage. 35 (1), 45–55.
Strickland, J.D.H., Parsons, T.R., 1968. Determination of dissolved oxygen. In: A Practical Handbook of Seawater Analysis. In: B. Fish. Res. Board Can., vol. 167. pp. 71–75.
UNEP, 2007. Mangroves of Western and Central Africa. In: UNEP-Regional Seas Programme/UNEP-WCMC, ISBN: 978-92-807-2792-0, pp. 1–92.
Wang, Y., Li, L., Cui, G., Lu, W., 2013. Ontogenesis from embryo to juvenile and salinity tolerance of Japanese devil stinger Inimicus japonicus during early life stage. Springerplus 2, 289. http://dx.doi.org/10.1186/2193-1801-2-289.
Wells, S., Ravilious, C., Corcoran, E., 2006. In the Front Line: Shoreline Protection and Other Ecosystem Services from Mangroves and Coral Reefs, Vol. 24. UNEP/Earthprint.
Whitfield, A.K., 1999. Ichthyofaunal assemblages in estuaries: a South African case study. Rev. Fish Biol. Fish. 9, 151–186.
Wright, J.M., 1986. The ecology of fish occurring in shallow water creeks of a Nigerian mangrove swamp. J. Fish Biol. 29, 431–441.
Yankson, K., Obodai, E.A., 1999. An up-date of the number, types and distribution of coastal lagoons in Ghana. J. Ghana Sci. Assoc. 2 (2), 26–31. (Special Edition).

Please cite this article in press as: Levy, E.S., et al., Effects of hydrographic conditions of ponds on juvenile fish assemblages in the Kakum mangrove system, Ghana. Regional Studies in Marine Science (2015), http://dx.doi.org/10.1016/j.rsma.2015.08.007