INT. J. BIO. BIOTECH., 9 (3): 283-292, 2012.

OYSTER CULTURE IN MANGROVES-DOMINATED ESTUARINE ENVIRONMENT OF AMBRAH CREEK OF GAROH AND WARI CREEK OF SHAH BUNDER IN INDUS DELTA, SINDH, PAKISTAN

Syed Viqar Ali [1] and D. Khan [2]

[1] *Sindh Coastal Community Development Project, Sindh Coastal development Authority, Karachi, Pakistan*
[2] *Department of Botany, University of Karachi, Karachi, Pakistan.*

ABSTRACT

Growth of *Crassostrea gryphoides* (Schlotheim 1813) cultured through rafts at Ambrah creek, Garho and Wari creek, Shah Bunder has been described. The spats established in three months in Ambrah creek and 4 months in Wari creek. Growth data were collected from June 2011 to May 2012 from 10 rafts in Ambrah creek and eight rafts in Wari creek. The growth at the two places was continuous, however, slower in Wari creek. When cultured through rafts, the oyster reached to an average size of 12.14 ± 0.07 cm in length in a year in Ambrah creek and c 7.94 ± 0.02 cm in Wari creek with an overall rate of 1.01 $cm.Moth^{-1}$ and 0.71 $cm.Month^{-1}$, respectively. The growth was significantly affected by age as well the rafts and the two factors interacted significantly at both places. RGR in both creeks declined regularly through out the year. In both creeks spat growth was faster than that of the adult oysters. Comprehensive studies pertaining to the growth of oysters in Indus delta are in progress to elucidate economic aspects of this venture and quantity and the quality of meat obtained.

Key Words: Oyster culture, *Crassostrea gryphoides*, Ambrah creek, Wari creek, Indus Delta, Pakistan

INTRODUCTION

Mariculture of oysters was historically practiced by ancient Romans as early as first century BC on the Italian Peninsula (Higginbotham, 1997) and later in Britain and the France in 18 century (wikipedia. com). Pakistan has no previous history of oyster culture. Some research has, however, been conducted regarding oysters. Earlier investigations on Oysters of Pakistan were undertaken by Kazmi (1953), Hasan (1960), Ahmed (1971 & 1975), Asif (1979) and Ahmed *et al.* (1982). Ansari and Ahmed (1972) published data on the oysters' reproductive biology - seasonal gonadal changes, hermaphroditism and sex reversal. Kay (1979) stated that the exterior colour of the shell of genus *Crassostrea* is dirty white to gray, while the interior is bright white with a deep purple or red-brown muscle scar. Buroker (1983) reported that *Crassostrea* has a lifespan of up to 20 years growing to 100-115mm in length in two years. Individuals can reach sexual maturity at 4 months. He further stated that female of genus *Crassostrea* can produce 15-114 million eggs in a single reproductive cycle. The adult *Crassostrea* can live in salinities up to 35ppt. Meyers and Townsend (2000) reported that the shell of the genus *Crassostrea* is thick, flattened, and highly variable in shape. They further stated that large reefs provide habitat for numerous fish and invertebrate species, reduce water turbidity through filter-feeding, and physically serve as filter removing large material from the water as it passes over the reef. Grizzle *et al.* (2002) stated that the *Crassostrea* forms extensive reefs both inter tidally and sub tidally on the eastern coast of Florida including the estuaries of the Indian River lagoon. Siddiqui and Ahmed (2002) reported nine species of oysters from Pakistan including *Crassostrea gryphoides* which are protandric individuals first mature as males then typically change to female in later life. The factors determining sex are varied and complex. Wilson *et al.* (2005) reported that genus *Crassostrea* appears to have a higher tolerance of salinity fluctuation than other oysters. The optimal salinity for growth and reproduction is said to be 10-28ppt. Larvae do not settle and metamorphose into spat when salinity is less than 6 ppt. *C. gryphoides* may grow to a size of 170 mm and occurs in the intertidal zone and down up to a depth of seven meters. Restoration of oyster populations are encouraged for ecosystem services they provide including water quality maintenance, shoreline protection and sediment stabilization and nutrient cycling. (www.nature.org.ourinitiatives/habitats /oceancoasts /howwework/ shellfish-habitat.xml).

Molluscan fishery is not well-organized in Pakistan. It is carried on small scale with traditional harvesting and sold in the market for human consumption. The oyster culture is a common practice in several countries of the world. Since oysters are economically very important and could be an alternate source of income to local fishermen and there is a great potential of oyster culture in the Sindh estuarine environment, Fisheries department of Sindh Coastal Community development Project, Government of Sindh, undertook oyster culture in five creeks of Indus delta in 2010 and 2011. Twenty rafts have so far been established in Hajamro creek of Keti Bunder and 10 each in Wari creek of Shah Bunder, Patiani creek of Daryapeer, Mirpur Sakro and Ambrah creek of Garho in the mangrove-dominated estuarine environment. The work of rafts establishment in five other creeks of the delta is underway. Mahar and Awan (2012) have presented brief bimonthly data on growth of *C. gryphoides* for a period of June 2010 to June 2011 for five rafts out of ten rafts established by the Directorate of Fisheries (SCCDP, SCDA), in Ambrah creek. Ali (2012) has also described *C. gryphoides* from Ambrah creek along with its predation and its growth when cultured in Ambrah creek through rafts. The present paper describes the growth of *C. gryphoides* through rafts at two mangrove dominated places in Indus delta viz. Ambrah creek, Garho and Wari creek, Shah Bunder

DESCRIPTION OF THE AREA

Ambrah Creek is a relatively small creek around 4 -5 km from Garho town. At high tide it is around eight feet deep and in ebbing around 5 ft. Wari creek in Shah Bunder is relatively shallower. The salinity of seawater is around 4% (EC: > 40 dS. m^{-1}) varying seasonally along the coast and pH varies generally around 8 but may reach to 9.6 (Siddiqui and Qasim, 1990). The sites were free from hazards of environmental pollution such as domestic and industrial wastes. The physico-chemical properties of seawater along the coast of Pakistan are given in Table 1. Detailed physico-chemical characteristics of Ambrah creek water may be seen in Mahar and Awan (2012).

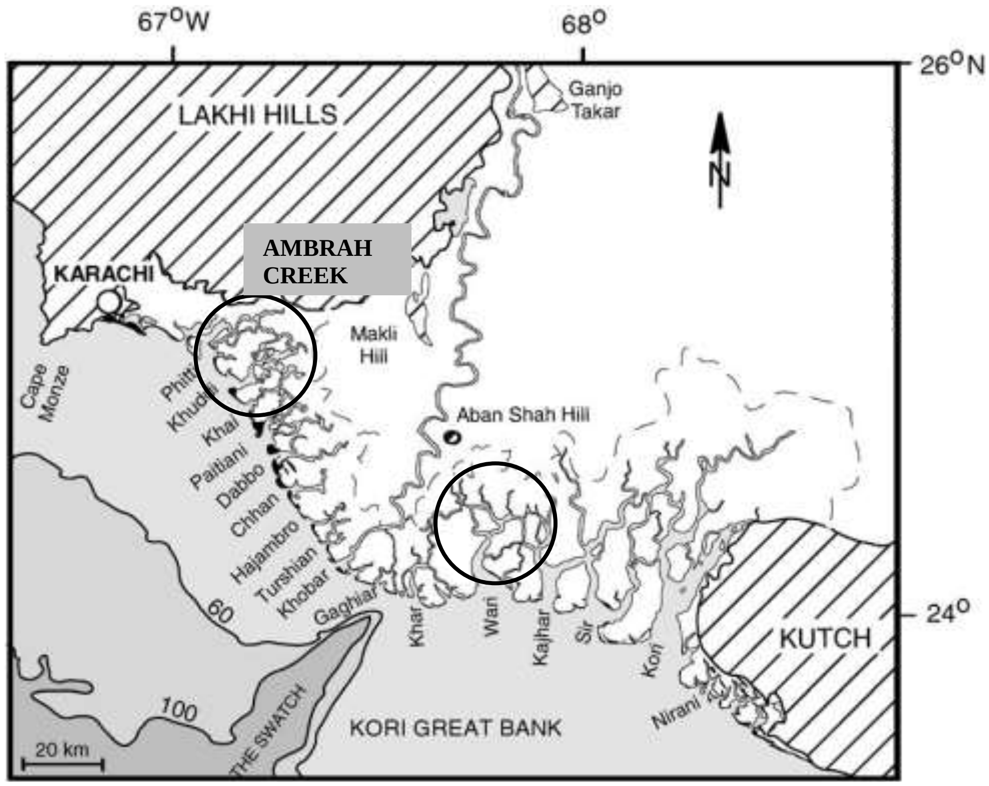

Fig.1. Map of the Indus delta region with the names of the main tidal creeks along the delta shown. Several sandy barrier islands front the delta coast (black-filled pattern). Image adopted and modified from Giosan *et al.,* (2006).

MATERIALS AND METHODS

Ten rafts each at Ambrah creek, Garho (24° 20.11 N; 67°35.20 E) and Wari creek, Shah Bunder (24°20.17N; 67°88.70 E) were established. The size of rafts was 20ft x20ft made by wooden bamboo like roof. These rafts were pilot rafts installed by Director Fisheries, under the project of Sindh Coastal Community Development Project. This project is running under the executive control of Sindh Coastal Development Authority. The main donor is Asian Development Bank with a soft loan of $36 million. This rafts structure was fixed in soil with help of another set of 16 heavy wooden bamboos functioning as beam having size length of 18ft each. These wooden bamboos were placed parallel to each other at about 1.5 ft-2 ft distance. This research was carried out from June 2011 to May 2012. All ten rafts were given a separate identification name as A, B, C, D, E, F, G, H, I and J. In each rafts 36 wooden bamboos were arranged in square manner and tied with 400 nylon ropes usually 12ft long and hanging from wooden bamboos in a series. On each hugging point of horizontal bamboo a strong rope having five big empty oyster shells having size about 20-33cm lengths was hang in shape of cultch or spat collector, which can easily swing in high tides. The cultch was around 0.5m below the mean water which is considered to the optimum depth (Coco *et al.,* 2006). The rafts structure is presented in Fig. 1 and 2. After some days the spats were attached with the empty oyster shells in shape of colony. The length of oysters was measured on monthly basis during the year on five specified samples from each raft. Relative growth rates were estimated after Hunt (1982) on the basis of oyster length as; $RGR = \log_e L_2 - \log_e L_1 / T_2 - T_1$, where L is the length and T is the time and subscript 1 and 2 are the first and second consecutive mean readings. The data were analyzed statistically.

Fig.2. Structure of bamboo rafts and the opened oyster shell. **A**, Four rafts established in Ambrah creek adjacent to a green mussel (*Perna viridis*) reef visible in background. At low tide – the mussel reef established when a jetty constructed by GOS in 1980 was abandoned and the solid mass of the jetty provided substratum for mussels to attach. The reef and the rafts get submerged at high tides. **B**, Six more rafts established in Ambrah creek at some distance; **C** and **D**, rafts in Wari creek, Shah Bunder; **E**, a floating raft in Ambrah creek established recently (mid 2012); **F**, an oyster around 4-5 cm in size, cultured through raft, opened to show inclusion, on palm of the author.

Table. 1. Physico-chemical properties of seawater along Sindh Coast.

Place	pH	Temp (^{o}C)	EC (dS.m^{-1})	PPT	TDS / TSS	Dissolved O_2 (mg /L)
			Salinity			
Karachi Harbour! (Estuarine Ecosystem)	7.3-8.1	19.8-21.05	-	31.6-36.0	Total suspended solids (TSS: 122-166 mg.L^{-1}	-
Korangi creek ***	7.3-7.9	Low (17.5 – 20 ^{o}C) in Dec. to Feb. and relatively higher (24.8 -30 ^{o}C) in summer (Apr-Oct.) **	51.4-55.3	28* 39-41***	Ambrah Creek – TDS low in Oct. – Feb. and high in June ** (see text below)	Ambrah Creek – Dissolved O_2 high in Oct. – Feb. and low in June ** (see text below)
Khudi creek	-		-	30 *		
Ambrah creek			-			
Bakran ****	6.4 - 9.6		-			
Keti Bunder	-		-	41*		
Shah Bunder	-		-	39-41*		
Clifton ***	8.0 - 8.2		50.9-55.6	37-41		
Manoda ***	8.2 - 8.5		43.7-50.8	28-36		
Indus delta***	7.3 - 8.3		46.6-56.6	32.45		

!, Ali *et al.* (2012), *, IUCN – Pakistan; **, Mahar and Awan (2012) – Low TDS' 10,000 – 40,000 mg / L and high TDS, reaching up to 90,000 mg /L. The dissolved O_2 as per this data relates inversely with TDS (r = - 0.617). ***, Qureshi *et al* (2000); ****, Siddiqui and Qasim (1990).

RESULTS AND DISCUSSION

Oysters are known to exhibit great morphological plasticity as adults, but quite static morphology and behaviour as larvae. The former is due to tremendous environmental variability and lack of selection on adult form, and the latter is due to evolutionary forces constraining the single motile life stage upon which the species is dependent for long-term persistence in a highly variable and ever changing estuarine environment. The foot and adductor muscle, present only during larval stages, is reabsorbed after metamorphosis resulting in the monomyarian condition. Valves are asymmetrical with the left valve generally thicker and more deeply cupped than the right. When closed there is no gap between the two halves. *C. gryphoides* settle on the left valve leaving the right valve always on top. Shell shape and thickness is variable and differs depending on the environment in which the oyster grows. The shells are thicker when growing on hard substrates. In silt environments or on reefs, ambones grow generally straight, but shells are more fragile than those growing on hard substrates. The interior of the shell has a prominent purple-pigmented adductor muscle scar located close to the dorsal end of the valve. The purple pigmentation of the adductor muscle scar differentiates the *Crassostrea gryphoides* from similar species (Berquist *et al.*, 2006).

C. gryphoides spats settled on the rafts in 3 months in Ambrah creek and around 4 months in Wari creek. The growth of oysters cultured through rafts was observed monthly for a year (2011-2012) at the two sites. The growth during this period was continuous (Table 2 and 4), However, the oysters after 4 months in Wari creek died in two rafts (I and J) due to the attack of mud crabs. These two rafts were excluded from sampling. In Ambrah creek, from initial spat length of 0.21 ± 0.006 cm in June 2011 the oyster reached to 5.05 ± 0.042 cm in length in November 2011 and 12.14 ± 0.066 cm after a year in May 2012, which is said to be marketable size (Fig.3). As indicated by Two Way ANOVA, oyster growth at Ambrah varied significantly with rafts ($p < 0.0001$) and also the age ($p < 0.0001$) of the oyster and raft and age interacted significantly ($P < 0.0001$). The overall rate of growth in Ambrah creek was 1.0096 cm.Month^{-1}($r^2 = 0.9902$) (Fig.4). The influence of age growth is obvious, the influence of rafts on oysters growth may presumably attributed to heterogeneity of spat distribution in seawater and time lag in their attachment onto the shells suspended through rafts. As obvious from Figure 5, the relative rate of growth declined progressively with increasing age in quadratic manner. It, however, began to increase in summer (from April, 2012). The highest growth rate was in initial month i.e. spats grew faster than the adult oysters. The oyster growth was slower in Wari creek and from initial spat length of 0.15 ± 0.088 cm in June 2011 the oyster reached to 4.68 ± 0.016 cm in length in November 2011 and 7.94 ± 0.025 cm after a year in May 2012 (Fig. 6). ANOVA of the growth data (Table 5) indicated that , oyster growth at Wari creek varied significantly with rafts ($p < 0.05$) and also the age ($p < 0.0001$) of the oyster and raft and age interacted significantly ($P < 0.05$). The overall rate of growth in Wari creek was 0.71cm.Month^{-1}($r^2 = 0.9796$) (Fig.7). The relative rate of growth in Wari creek declined progressively as power function and unlike Ambrah creek did not increased on the onset of summer (Fig. 8).

The oyster size obtained through rafts in a year was comparable to in natural reefs in adjacent areas within one year. In addition invertebrate species known to be associated with *C. gryphoides* oyster reefs were found at densities equivalent to those on the natural reefs. The length of 12.14 cm reached in a year in Ambrah creek appears to be normal as compared to the data of Chatterji *et al.* (1985) for *C. gryphoides* collected from Chapora estuary, Goa, India. The oyster growth at Ambrah is similar to the previous year growth as reported in Mahar and Awan (2012).

This data is in contradiction to that of Buroker (1980) who reported that *C. gryphoides* reached to 10-11.5 cm in length in two years of growth in the Gulf of Mexico. The growth of this oyster in Ambrah water appears to be faster.

Table 2. Monthly growth of oysters cultured through rafts in Ambrah creek of Sindh.

Rafts	2011							2012				
	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
A	0.15± 0.018	1.06 ± 0.017	2.02± 0.032	3.20 ± 0.025	4.20± 0.027	5.01 ± 0.28	5.93± 0.034	6.84 ± 0.035	7.55± 0.038	8.25 ± 0.039	9.16± 0.039	11.4 ± 0.056
B	0.20± 0.007	1.11 ± 0.011	1.92± 0.012	3.11 ± 0.0103	4.12± 0.0084	4.92 ± 0.0102	5.81± 0.012	6.71 ± 0.015	7.43± 0.016	8.35 ± 0.014	9.26± 0.012	11.5 ± 0.0124
C	0.15± 0.009	0.95 ± 0.012	1.86± 0.011	3.09 ± 0.017	4.10± 0.044	4.93 ± 0.049	5.90± 0.044	6.81 ± 0.042	7.64± 0.039	8.41 ± 0.027	9.38± 0.030	12.0 ± 0.10
D	0.12± 0.017	1.06 ± 0.015	1.99± 0.025	3.19 ± 0.0146	4.28± 0.048	5.14 ± 0.056	6.07± 0.061	7.01 ± 0.06	7.86± 0.039	8.41 ± 0.044	9.60± 0.041	12.2 ± 0.090
E	0.21± 0.007	1.14 ± 0.012	2.03± 0.016	3.30 ± 0.040	4.40± 0.038	5.27 ± 0.034	6.21± 0.035	7.16 ± 0.041	7.99± 0.082	8.70 ± 0.039	9.66± 0.043	12.0 ± 0.043
F	0.19± 0.007	1.15 ± 0.010	2.19± 0.085	3.21 ± 0.060	4.43± 0.074	5.30 ± 0.083	6.25± 0.079	7.22 ± 0.0758	8.07± 0.077	8.94 ± 0.075	9.87± 0.0733	12.2 ± 0.0820
G	0.20± 0.010	1.14 ± 0.014	2.06± 0.015	3.31 ± 0.041	4.46± 0.035	5.40 ± 0.376	6.37± 0.039	7.24 ± 0.043	8.18± 0.038	8.90 ± 0.055	9. 82± 0.049	12.1 ± 0.056
H	0.21± 0.010	1.16 ± 0.0139	2.09 0.0146	3.34 ± 0.0413	4.64± 0.0345	5.52 ± 0.0376	6.50± 0.0389	7.33 ± 0.0432	8.18± 0.0384	9.03 ± 0.0545	9.99± 0.049	12.9 ± 0.122
I	0.21± 0.011	1.17 ± 0.0163	2.09± 0.0217	3.34 ± 0.0258	4.64± 0.138	5.52 ± 0.141	6.50± 0.145	7.45 ± 0.142	8.31± 0.127	9.34 ± 0.180	10.17± 0.118	12.5 ± 0.122
J	0.21± 0.011	1.21 ± 0.019	2.15± 0.158	3.40 ± 0.056	4.60± 0.033	5.50 ± 0.025	6.50± 0.023	7.45 ± 0.021	8.33± 0.025	9.23 ± 0.021	10.20± 0.018	12.5 ± 0.040

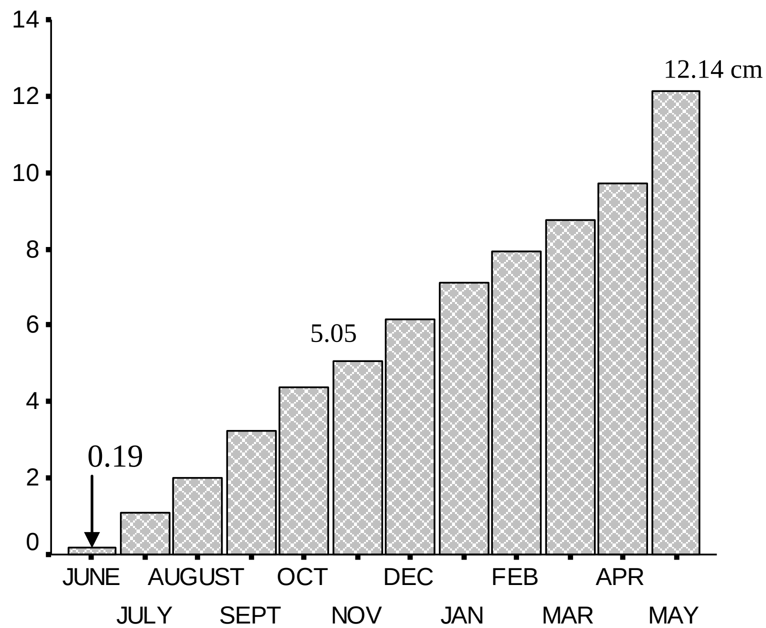

Fig. 3. Mean length of the oyster during initial year (2011-2012) of culture though rafts in Ambrah creek, Sindh. Each bar represents a mean value of 50 observations.

Table 3. Two-way ANOVA. Oyster growth in Ambrah Creek, Garho.

Source	SS	df	MS	F	p
Rafts	25.34775	9	2.81644	95.596	0.0001
Months	7395.289	11	672.299	22819.59	0.0001
Raft x Months	14.7275	99	0.14876	5.0494	0.0001
Error	14.1415	480	0.02946		
Total	7449.506	599			
$LSD_{0.05}$ (Raft): 0.06158			$LSD_{0.05}$ (Month): 0.06745		

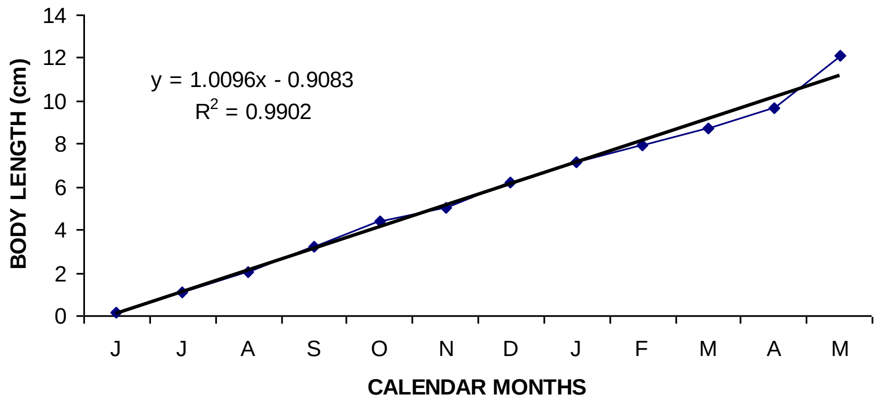

Fig.4. Body length of oyster as a direct linear function of monthly growth when cultured through rafts during June 2011 and May 2012 in Ambrah creek of Sindh estuarine ecosystem. X in the equation, Y =a + bX denotes the serial value of the month on the X-axis. Each data point is a mean of 50 observations. Standard errors being small are covered by the points.

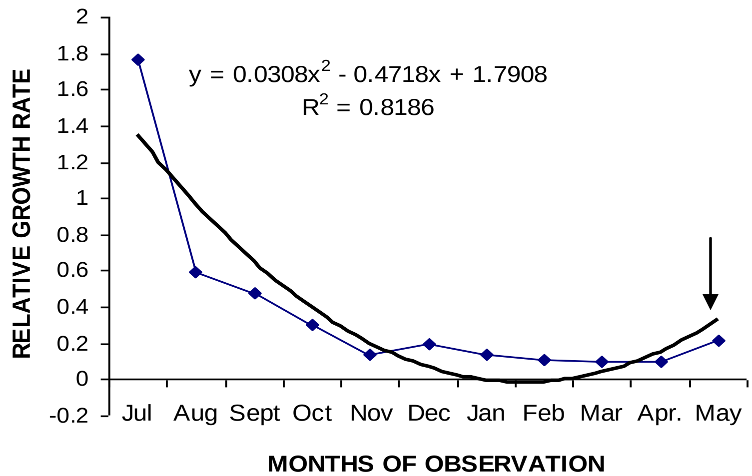

Fig.5. Length-based relative growth rate (RGR) of oyster growth in Ambrah creek. Arrow represents the promotion in RGR on summer commencement.

Table 4. Monthly growth of oysters cultured through rafts in Wari creek of Shah Bunder, Sindh. Oysters of rafts I and J died after four months of growth. They were excluded from the analysis

Rafts	2011							2012				
	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
A	0.20± 0.032	0.96 ± 0.051	1.94± 0.024	2.98 ± 0.037	3.82± 0.037	4.56 ± 0.024	5.26± 0.060	5.92 ± 0.037	6.46± 0.051	7.02 ± 0.020	7.46± 0.025	8.06 ± 0.040
B	0.12± 0.02	1.02 ± 0.058	2.00± 0.032	3.02 ± 0.037	3.96± 0.051	4.78 ± 0.086	5.32± 0.037	5.86 ± 0.040	6.40± 0.032	6.96 ± 0.040	7.36± 0.024	7.90 ± 0.045
C	0.12± 0.02	0.92 ± 0.037	1.94± 0.024	2.94 ± 0.051	3.98± 0.020	4.66 ± 0.081	5.40± 0.032	5.94 ± 0.024	6.60± 0.032	7.02 ± 0.037	7.46± 0.024	7.94 ± 0.051
D	0.12± 0.02	0.93 ± 0.030	1.90± 0.071	2.96 ± 0.051	4.02± 0.037	4.74 ± 0.051	5.36± 0.068	5.95 ± 0.077	6.50± 0.071	6.96 ± 0.051	7.54± 0.024	8.10 ± 0.055
E	0.18± 0.02	0.98 ± 0.037	1.83± 0.043	2.94 ± 0.050	4.02± 0.040	4.72 ± 0.049	5.30± 0.031	5.84 ± 0.024	6.44± 0.024	6.98 ± 0.037	7.46± 0.024	7.90 ± 0.032
F	0.16± 0.007	1.04 ± 0.051	2.04± 0.060	2.98 ± 0.040	4.02± 0.058	4.78 ± 0.037	5.24± 0.040	5.68 ± 0.037	6.32± 0.037	6.86 ± 0.051	7.40± 0.045	7.90 ± 0.054
G	0.12± 0.010	0.98 ± 0.020	1.97± 0.037	2.94 ± 0.051	3.80± 0.045	4.48 ± 0.060	5.24± 0.024	5.90 ± 0.070	6.46± 0.024	7.02 ± 0.037	7.44± 0.044	7.88 ± 0.058
H	0.12± 0.02	0.98 ± 0.02	1.98± 0.037	3.06 ± 0.050	3.94± 0.025	4.72 ± 0.037	5.32± 0.037	5.88 ± 0.037	6.42± 0.037	6.94 ± 0.024	7.40± 0.032	7.80 ± 0.84

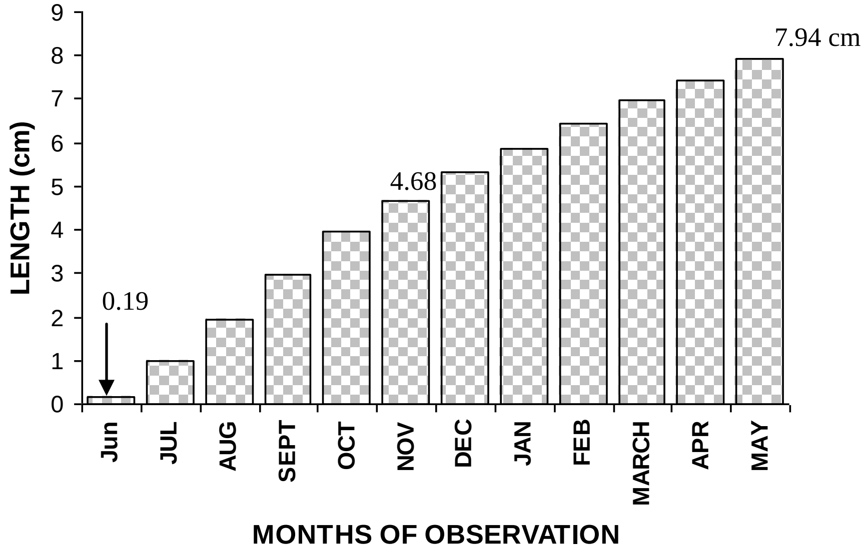

Fig.6. Mean length of the oyster during initial year (2011-2012) of culture though rafts in Wari creek of Shah Bunder, Sindh. Each bar represents a mean value of 40 observations.

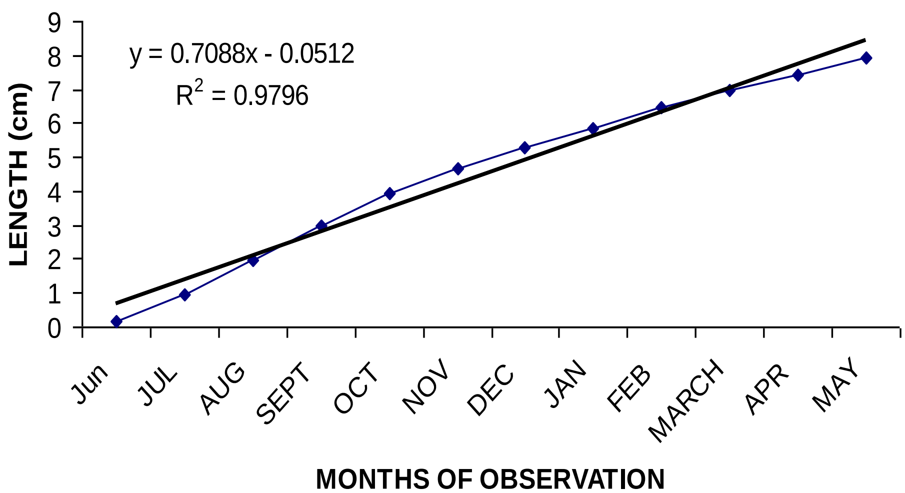

Fig.7. Body length of oyster as a direct linear function of monthly growth when cultured through rafts during June 2011 and May 2012 in Wari creek of Shah Bunder, Sindh estuarine ecosystem. X in the equation, Y = a + bX denotes the serial value of the month on the X-axis. Each data point is a mean of 40 observations. Standard errors being small are covered by the points.

Table 5. Two-way ANOVA. Oyster growth in Wari Creek, Shah Bunder.

Source	SS	df	MS	F	p
Rafts	0.15665	7	0.022378	2.610	0.05
Months	2937.081	11	267.007	31145.45	0.0001
Raft x Months	4.287	77	0.055677	6.494	0.05
Error	3.292	384	0.008573		
Total	2944.816	479			
$LSD_{0.05}$ (Raft): 0.03324			$LSD_{0.05}$ (Month): 0.04071		

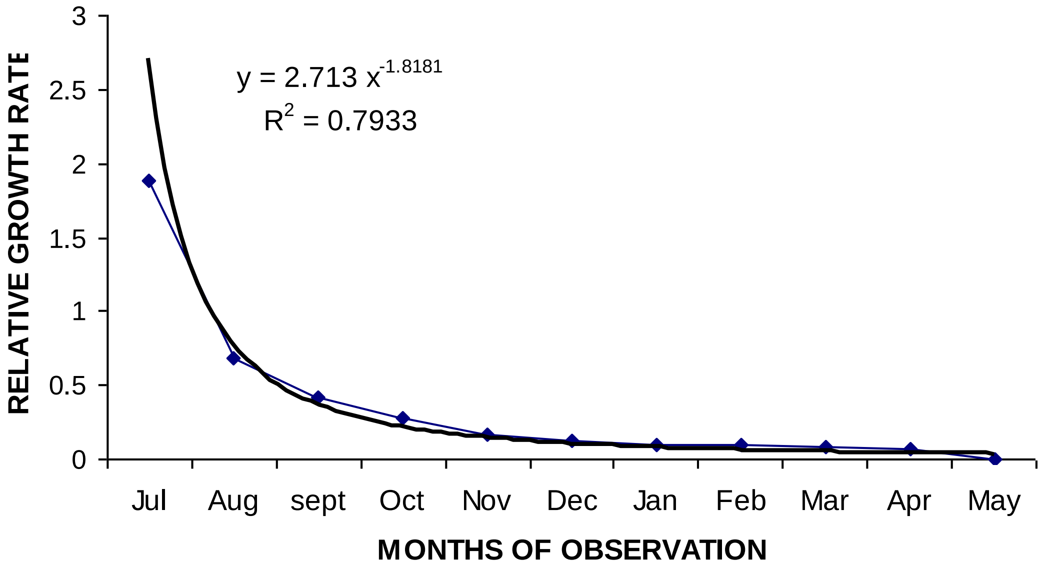

Fig. 8. Length-based relative growth rate (RGR) of oyster growth in Wari creek.

The oyster growth in Wari creek was substantially slow with overall decline of 34.60 % as compared to that at Ambrah. Oyster growth is obviously the function of near shore oceanic properties. Comprehensive physico-chemical properties of seawater of Indus delta are not available. It is however, evident that salinity in Shah Bunder area has increased due to decline in Indus discharge which may be one of the many reasons of slow growth of oyster in Shah Bunder. It is a euryhaline species occupying estuarine areas. Pollution is reported to reduce its size (even to 40 mm in Bombay (Rao, 1987). They play a key ecological role in the estuary; they reduce suspended sediments in water and also may reduce the detrimental effects of eutrophication and phytoplankton blooms through filtering processes (Newell, 1988). Because oysters are filter feeders, their growth rates tell us about the food availability in the water. When measured in terms of linear shell extension, growth generally declines with distance from the ocean (Mc Coy, 2112). Chlorophyll contents in the water are important as oysters eat phytoplanktons, algae, eelgrass detritus, benthic microalgae, etc. Intermediate rates of sedimentation are most conducive to oyster growth. There are, however, several confounding factors such as season which should be active at times. Chesapeake Bay's Decline of *Crassostrea virginica* population is opined to be due to high suspended sediments concentration (SSC) consisting primarily of soft sediments which impairs water quality and directly inhibits healthy oyster growth (Gonda-King *et al.,* 2010). SSC increases tissue abrasions, smothers oysters' bed and leads to mortality (Haradaway *et al.*, 2000). Turbidity affects the availability of oysters to filter because high turbidity and sediments load trigger oyster to close and stop filtering (Coco *et al*., 2006). Least amount of accretion is conducive to higher growth rate. In short, high salinity, wide temperature fluctuates, high sediment load and turbidity and consequent oxygen levels, all lead to mortality of oysters (Widdows *et al.*, 1989; Coco *et al.*, 2006; Soletchnik *et al.*, 2007). Spat and larvae are more sensitive to suspended sediments than adults (Davis and Hidu, 1969). Natural oyster population is rarer in Shah Bunder as compared to Garho. Total suspended solids in an estuarine ecosystem of Karachi horbour is recently reported to be varying from 122 to 166 mg.L^{-1}. (Ali *et al*., 2012). Water should obviously be more turbid at Shah Bunder being near the mouth of River Indus; consequently Shah Bunder water should have comparatively low oxygen level. The adjacent Gulf of Kuchchh is reported to be highly turbid with suspended sediment concentration (SSC) during October and November (2002 data) ranging from 0.5 to 674 mg.L^{-1} mainly due to re-suspension of sediments by strong tidal currents and main source of sediments is said to be the River Indus. Although Indus discharge has been severely curtailed in the recent decades, the Gulf of Kuchchh continues to receive re-suspended sediments from the meso- and macro-tidal creeks of Indus delta (Ramaswamy *et al.,* 2007). Relatively clear water SSC is less than 10mg.L^{-1}. The carbonate minerals, calcite and aragonite in water are known to help oysters develop their shells faster.

Barnacle population is relatively higher in Shah Bunder as may be adjudged from their dense attachment on bamboo rafts and the shells. Spat density in water is also relatively low which may be reason of late spat attachment in Wari creek. Whatever may be the reason (s), the oyster growth has evidently been slower in Wari creek than Ambrah creek. Comprehensive studies are needed to be undertaken to elucidate the environmental relations of the oysters' growth in Indus delta with such parameters as density and diversity of oysters (and others organisms) on the rafts, body weight (shell and meat), quantitative availability and quality of meat along with physical and chemical dynamics the seawater of the Indus delta. Being filter feeders, a number of human pathogens have been reported in the tissues of bivalves even much higher in concentration than those in the surrounding water, (Bouchriti and Goyal, 1993). Enriquez *et al.*, (1992) have reported the presence of Hepatitis –A virus 100-fold higher in mussel tissue than the surrounding water. Bivalves, however, have some antiviral agents in their body (Chatterji *et al.*, 2002). A great deal of research is needed on oysters and their environment in Pakistan. Bacteriological (fecal and total coliform) quality of Pakistani coastal water has been published by Mashiatullah *et al.* (2010) but virological information is not known at all.

Acknowledgements: I thank Mr. Muhammad Umer Memon, Project Director, Sindh Coastal Community Development Project (SCCDP), Sindh Coastal Development Authority (SCDA), Government of Sindh, for his constant encouragement and motivation during this research. The authors are thankful to Mr. Zahoor Hussain Abbasi, Director Fisheries, SCCDA (SCDA), Mr. Khawar Pervaiz Awan, Director Hatchery, Fisheries Department and Mr. Zulfiqar Ali Lariq, Deputy Director SCCDP, SCDA, Government of Sindh, for providing facilities of research at the site

REFERENCES

Ahmed, M. (1971). Oyster species of West Pakistan. *Pakistan. J. Zool.,* 3**:** 229-238.

Ahmed, M. (1975). Speciation in living oysters. *Adv. Mar. Biol.,* 13: 357-397.

Ahmed, M., S. H. N Rizvi and M. Moazzam (1982). The distribution and abundance of intertidal organisms on some beaches of Makran coast in Pakistan (Northern Arabian Sea. *Pakistan. J. Zool.,*14: 175-184.

Ali, I., I. Tamiz, A.B. Khan, T.M.A. Khan, A. Shahzad, S.S. Shaukat and S. Afroz (2012).Mapping spatial variation of environmental pollutants in an estuarine ecosystem at Karachi harbour: An application of geographic Information System (GIS). *Int. J. Biol. & Biotech.* 9 (1-2): 1-8.

Ali, S.V. (2012). Redescription of *Crassostrea gryphoides* (Schlotheim, 1913) (Ostreidae: Ostreoidea: Bivalvia) from Ambrah Creek Garho, district Thatta, Sindh with growth, predators and its culture through rafts. *FUUAST J. Biol.* 2(2): 135-139.

Ansari F. and M. Ahmed (1972) Seasonal gonadal changes in the oyster. *Crassostrea glomerata* Gould. *Pakistan J. Zool*. (4): 35-43.

Asif, M. (1979). Hermaphroditism and sex reversal in the four common oviparous species of oysters from the coast Karachi. *Hydrobiologia,* 66: 49-55.

Berquist, D.C., J.A. Hale, P. Baker and S.M. Baker (2006). *Estuaries and Coasts*, 29: 353-360.

Bouchriti, N. and S.M. Goyal (1993). Methods for the concentration and detection of human enteric viruses in shellfish: a review. *New Microbiol*., 16: 105-116.

Buroker, N.E. (1983). Population genetics of the *Crassostrea virginica* along the Atlantic coast and Gulf of Mexico, *Mar Bio.,* 57: 99-112.

Chatterji, A., Z.A., Ansari, B.S. Ingole, and A.H. Parulekar (1985). Length-Weight relationship of giant oyster, Crassostrea gryphoides (Schlotheim). Mahasagar – Bull. National Inst. Oceanography, 18(4): 521-524.

Chatterji, A., Z.A. Ansari, B.S. Ingole, M.A. Bichurina, M. Sovetova and Y.A, Boikov (2002). Indian marine bivalves: Potential source of antiviral drugs. *Current Sci.,* 82 (10): 1279- 1282.

Coco, G., F.T. Simons, M.O. Green and J.E. Hewitt (2006). Feedbacks between bivalve density, flow, and suspended sediment concentration on Patch stable States. *Ecology,* 87: 2862-2879.

Davis, H.C. and H. Hidu (1969). Effect of turbidity producing substances in seawater on egg and larvae of three genera of bivalve mollusks. *Veliger,* 11: 336-323.

Enriquez, R., G.G. Froesner, V. Hochstein-Mintzel, S. Riedemann and G. Reinhardt (1992). Accumulation and persistence of hepatitis A virus in mussel. *J. Med. Virol*. 37: 174-179.

Giosan, L., S. Constantinescu, P.D. Clift. A.R. Tabrez, M. Danish and A, Inam. Recent morphodynamics of the Indus delta shore and shelf. *Continental and Shore Research*, 26: 1668 – 1684.

Hasan, A. S. (1960). Oyster fishing resources of Pakistan. Proc. 4th Pan Indian Ocean, *Sci. Congr.,* (Sec. B): 167-171.

Kazmi, M. A. S. (1953). Preliminary investigation on the oyster beds in the Korangi Creek. *Agriculture Pakistan,* 4: 143-150.

Gonda-King, L.M., A.G. Keppel, M.A. Kuschner and C.N. Rookey (2010*). The relation of sedimentation growth rate in the Eastern oyster (Crassostrea virginica)*. Publ. St. Mary's College of Maryland; ST. Mary city, MD 20686.

Grizzle, R.E., J.R. Adams and L.J. Walters (2002). Historical changes in inter tidal oyster (*Crassostrea virginica*) reefs in a Florida lagoon potentially related to boating activities, *J.shel.fish.res.*, 21: 749-756.

Haradaway, C.S. D.A. Mulligan, R. Brinkdley and C.H. Hobbs (2000). Maryland- Delaware Shoreline: Long term trends versus short term variability. In (C.H. Hobbs. *Environmental Survey of Potential Sand Resource Sites offshore Delaware and Maryland*. Final Project Report. Virginia Inst. Mar. Sci. Gloucester Point, VA.

Higginbotham, J.A. *Piscine: artificial fish ponds in Roman Italy*. Univ. N. Carolina Press. P. 247.

Hunt, R. (1982). *Plant Growth Analysis.* Edward Arnold. London.

Kay E.A, 1979, Hawaiian Marine Shells, Reef and Shore Fauna of Hawaii, Section 4: Mollusca, BP Bishop Museum Special Publication, 64(4): 653pp.

Mc Coy, L. (2112). Oyster Growth: Spatial variation in secondary productivity. University of Washington (Ruesink lab.) (Web address: depts. washington.edu/jlrlab/oystergrowth.php).

Mahar, M.A. and K.P. Awan (2012). Cultivation of oyster *Crassostrea gryphoides* (Schlotheim) through rafts at Ambra Creek coastal belt of Arabian Sea, Sindh, Pakistan. *Sindh Univ. Res. Journal (Sci. ser.)* 44(1): 119-124.

Mashiatullah, A., R.M. Qureshi, T. Javed, M.S. Khan, M.Z. Chaudhary and F. Khalid (2010). *The Nucleus* 47(2): 173-180.

Meyer, D.L. and E.C. Townsend (2000). Faunal utilization of created inter tidal *Crassostrea virginica* reefs in the south eastern United states. 23: 34-45.

Newell, R.I.E. (1988). Ecological changers in Chesapeake Bay: are they the result of over-harvesting the American oyster? In: *Understand the Estuary: Advances in Chesapeake Bay Research*. (Lynch, M.O. and E.C. Krome, Eds.) Chesapeake Bay research Consortium, Baltimore, Maryland, USA.

Qureshi, R.M., A. Mashiatullah, M. Fazil, E. Ahmad, H. A. Khan and M.I. Sajjad (2000.). Seawater pollution studies of the Pakistan coast using stable carbon isotope technique. (www.science version.org.pk/ BackIssues/ Vol.17, No.3-4/Vol.17,No.3%264-19-seawater_Pollution_Riffat Qureshi Mashiatullah .pdf)

Ramaswamy, V., B.N. Nath, P. Vethamony and D. Ilangovan (2007). Source and dispersal of suspended sediments in macro-tidal Gulf of Kuchchh. *Pollut. Bull*. 54(6): 708-719.

Rao, K.S. (1987). Taxonomy of Indian oysters (p. 1-6). In: CMFRI Bulletin 38: *Oyster Culture – Stratus and Prospects* (Eds. Nayar, K.N. and Mahadevan, S.). Central Marine Fisheries Res. Inst., Ind. Council of Agric. Res. Cochin, India.

Siddiqui, P.J.A. and R. Qasim (1990). Litter accumulation and physico-chemical conditions in mangrove, *Avicennia marina* (Forssk.) Vierh. Swamps at Karachi back water and Bakran Creek. *J. Isl. Acad. Sci.* 3(1): 15-21.

Siddiqui G. and M. Ahmed (2002) Histological basis of population structure of three species of *Crassostrea* from Pakistan (Northern Arabian Sea). *Pakistan J. Zool.,* 34 (2): 129-137.

Soletchnik, P., M. Ropert, J. Mazurie, P. Gildas Fleury and G.F. Le Coz (2007). Relationship between oyster mortality patterns and environmental data from monitoring databases along the coasts of France. Aquaculture 271: 384-400.

Widdows, J., R.I.E. Newell and R. Mann (1989). Effects of hypoxia and anoxia on survival, energy metabolism, and feeding of oyster larvae. *Biol. Bull.* 1777: 154-166.

Wilson. C., L. Scotto, J. Scarpa, A. Volety, S. Laramore and D. Haunert (2005). Survey of water quality, Oyster reproduction and oyster health status in the St. Lucie Estuary. *J.shel.fish.res.*, 24: 157-165.

(*Accepted for publication July 2012*)