Pakistan J. Zool., vol. 49(3), pp 869-876, 2017. DOI: http://dx.doi.org/10.17582/journal.pjz/2017.49.3.869.876

Assessment of Growth Performance and Meat Quality of Black Fin Sea Bream, *Acanthopagrus berda* (Forsskal, 1775) Reared in Brackish Water Ponds: A Preliminary Investigation

Abdur Rahim[1], Ghulam Abbas[1,*], Sara Ferrando[2], Lorenzo Gallus[2] and Abdul Ghaffar[3]

[1]*Centre of Excellence in Marine Biology, University of Karachi, Karachi-75270, Pakistan*

[2]*Department of Earth, Environment and Life Sciences (DISTAV), University of Genoa, Italy*

[3]*Department of Life Sciences, The Islamia University of Bahawalpur, Bahawalpur, Pakistan*

Article Information
Received 18 March 2016
Revised 23 May 2016
Accepted 30 June 2016
Available online 28 April 2017

Authors' Contribution
GA conceived and designed the study and wrote the article. AR performed experimental work. AG analyzed the data. SF and LG helped in preparation of manuscript.

Key words
Sea bream (*Acanthopagrus berda*), Growth, Nutrient utilization, Body composition, Brackish water ponds, Artificial feed.

ABSTRACT

In the present study, growth potential of juvenile black fin sea bream, *Acanthopagrus berda* was examined in brackish water ponds. Fish were stocked @ 1500 individuals per pond (2 treated and 2 control) of approximate dimensions, 13.72 m × 10.97 m × 1.52 m (229 m^3). In treated ponds, fish were fed with artificial diet (protein 42%, lipid 20% and energy 25.2 kJ g^{-1}) for 120 days in three equal meals. On the other hand, control ponds remained without additives. During the whole study period, water quality parameters of the experimental ponds remained as salinity (15‰ -20‰), dissolved oxygen (5.6 to 7.5ml/l), temperature (25°C to 28°C). p^H (7.6-7.8), ammonia (NH_4-N) and `nitrites (NO_2-N) less than (0.001mg/l), Secchi's disc visibility (8 cm to 46 cm). Higher percent weight gain (2665 g), specific growth rate (2.76±0.5 % day^{-1}), best feed conversion ratio (0.14), condition factor (4.1), viscerosomatic index (7.1), hepatosomatic index (1.4) were significantly (P< 0.05) higher of fish treated with the artificial diet as compared to those in control ponds. Length-weight relationships of the juveniles showed significant (P < 0.0 I) growth and condition factor associated to feed application in treated ponds. Body composition of the fish was not significantly (P>0.05) different in both the treatments, though protein and lipid contents of fish in treated ponds were greater than that of control ponds. The moister content of liver, muscle, viscera and whole body were not significantly different in control and treated ponds. These results concluded that feed including 42% protein and 20% lipid are best for culture of black-fin sea bream *A. berda* (body weight 8.5 to 235 g) in brackish water earthen ponds.

INTRODUCTION

Aquaculture production is growing greatly since last two decades in the world over, wherein Asia is contributing about 87% of the total global aquaculture output (Ahmed and Lorica, 2002; FAO, 2006). Aquaculture now produces one third of seafood being used worldwide (FAO, 2006). To resolve future stress on seafood, aquaculture production must be increased by 50 million metric tonnes by 2050 (Tacon and Forster, 2001). According to FAO (2015), no access to appropriate technology and economic resources, together with environmental effects and diseases are the major problems in enhancing this production coming from aquaculture sector. Generally, mariculture already removes a considerable fraction of food from the oceans (Naylor *et al*., 2000). Beside that fish is an important part of human food (Abbas *et al*., 2011), as it is a best source of protein. In addition, fish as diet can be steadily and gradually resolve the intimidating crisis of malnutrition. Keeping in view the dietary as well as medicinal significance of fish, it is necessary to utilize all the accessible resources to develop this industry (Naylor *et al*., 2000). One of the living example in this regard is Bangladesh, where a 1.5 million ponds of different sizes covered an area of 146,955 hectares of land providing 60%–80% of the animal protein needs (Toufique and Gregory, 2008).

The science and art of mariculture is yet to be developed in Pakistan, though some beginning has been

* Corresponding author: abbas.cemb@yahoo.com
0030-9923/2017/0003-0869 $ 9.00/0

made with shrimps (Hassan and Haq, 1975; Hassan, 1980; Amjad, 1988; Amjad and Jones, 1992). No attempt has so far been made to culture marine finfish species, particularly on commercial scale, though information about fish larvae and juveniles is available to some extent (Niazi, 1980; Ahmed, 1982, 1985, 1987, 1988; Hassan, 1983, 1987, 1988, 1989, 1992a, b; Abbas and Siddiqui, 2009, 2013; Abbas *et al*., 2011). In Pakistan, marine aquaculture is now capable to grow because of the awareness of public and government sector due to significant declining of capture fisheries in the last decade (Anonymous, 2012). There are some freshwater farming practices in Pakistan but are focused on Indian major carps which have been considered as low productive, due to improper management and technology *e.g.,* low stocking, inadequate fertilization and feeding. Virtually, mariculture in our country is lacking, beside that due to its high quality meat, *Acanthopagrus berda* is extremely popular with consumers as protein source of their food (Anonymous, 2012). But during the last 15 years, the natural habitat of *Acanthopagrus berda* has been despoiled considerably as the steady deterioration of aquatic ecosystems combined with the reduction of estuaries (Hussain and Mazid, 2001). Therefore, aquaculture of this species is the need of time. Similarly for sustainable aquaculture the feed production techniques for *Acanthopagrus berda* are essential to compensate its landing deficit.

Some studies for developing artificial feed for other species has been conducted by many scientists (Abbas and Siddiqui, 2009, 2013), but are confined to the experimental trails in laboratory. No attempt has, so far, been made for evaluation of feed in the field. Although, balanced artificial feed for *A. berda* has recently been investigated (Rahim *et al*., 2015). Although, sea bream is known to be adoptable to brackish and marine pond conditions (Sadek *et al*., 2004), but no published record is available about its culture in our country. Therefore, first attempt was made to test artificial feed in brackish water ponds to evaluate efficacy of this feed along with assessment of the suitability of *A. berda* for aquaculture in Pakistan. The present investigation may be important for zoologists who would like to work on fish nutrition for developing sustainable pond fish farming in coastal areas, keeping in view that fish belongs to Phylum Chordata.

MATERIALS AND METHODS

Feed preparation

A feed was formulated to contain 42% protein and 20% lipid using fish meal as the major source of protein and fish (cod) liver oil as lipid source (Rahim *et al*., 2015; Table I). Tapioca was used as a source of carbohydrates. Ingredients were ground and mechanically mixed for 15 min to ensure homogeneity, and fish oil was added, and then mixed again for 15 min. Water (250 ml kg^{-1} dry ingredients mixture) was added and mixed for another 15 min to attain a consistency appropriate for pelleting. The wet mixture was then passed through a mincing machine; the resultant vermicellies were oven-dried at 30°C for 24 h. Thereafter, the crispy material was cut into 2-mm diameter pellets which were stored in polythene bags at –20˚C until used. About 50 g of diet was ground in a mortal for chemical analysis.

Table I.- Feed formulation and chemical analysis.

Ingredients[1]	**g 100 g^{-1} diet (dry)**
Fish meal	37.5
Tapioca flour	13.6
Lupine seed meal	6.8
Corn gluten meal	7.5
Wheat flour	12
Vitamin-mineral premix	2.6
Cod liver oil	20
Proximate composition[2]	
Moisture	7.6±0.5
Crude protein[3]	42.1±2.3
Crude lipid	20.0±1.0
Crude fiber	3.4±0.7
Ash	13.6±0.9
Carbohydrates[4]	20.9±1.6
Energy (kJ/g)	25.2±1.9

[1]Rahim *et al*. (2015).
[2]Dry matter (%): number of samples = 5.
[3]Measured as $N \times 6.25$.
[4]Carbohydrates = 100 – (%protein + % fat + % ash + %fiber).

Juvenile collection and stocking

Juvenile black fin sea bream (*A. berda*) were collected from Sonari Channel, Hawks Bay, Karachi and Bhambhore, a small historical town located 72 km from Karachi in August, 2015. Keeping in view the habitat of the specie, experimental ponds were prepared in that area where the saline as well as fresh water was available for the quick management of salinity and water quality as well. The salinity of pond water was maintained as 20‰. Fish juvenile (mean weight 8.5 g) were stocked in four earthen seawater ponds (2 treated and 2 control) of approximate dimensions, 13.72 m × 10.97 m × 1.52 m (229 m^3). Initially, fish were fed for one week with live feed to adopt the new environmental condition of ponds. After one week of acclimatization, fish were fed with artificial feed for four months in treated ponds. While control ponds remained on natural food (zooplankton, phytoplankton and little quantity of minced trash fish). Water was added weekly due to decrease in water column by evaporation which caused increasing salinity. Fish were fed with balanced diet @ 2.5% live body weight with feeding frequency of three times per day for 120 days in treated ponds (Rahim *et al*., 2015). Twenty fishes were randomly sampled from each pond fortnightly so as to measure length and weight for growth assessment of fish.

Water quality

Water samples were regularly collected from all ponds once a week. Air and water temperatures were recorded by thermometer. Light penetration was measured with the help of Secchi's disc. The pH of water samples was determined with pH meter. Dissolved oxygen contents were measured by Winkler's technique. Nitrates and phosphates were estimated as well (Boyd, 1981).

Chemical analysis

After the completion of experiment, three fishes from each pond were taken for dissection to calculate the weight of viscera and liver, hepatosomatic index (HSI) and viscrosomatic index (VSI). Subsequently, three fishes were collected and killed for the proximate analysis of the viscera, liver, muscle and whole body composition. Crude lipid (CL), moisture and crude protein (CP) were determined by using the standard procedures of AOAC (2000). Moisture was determined by drying into an oven (Labostar-LG 122, Japan) at 105°C for 24 h; ash by burning in a muffle furnace (Isuzu, Japan) at 550°C for 18 h; crude protein by the Kjeldahl method ($N \times 6.25$) using an automatic Kjeldahl System (Buchi 430/323, Switzerland); crude fiber by acid detergent fiber analysis, crude lipid by chloroform/methanol (2:1, v/v) extraction procedure (Folch *et al*., 1957). The carbohydrate content was calculated by subtracting the content of lipids, total protein and ash from the dry weight, and gross energy estimation was made using an automatic bomb-calorimeter (Parr Instrument, model 1265, USA).

Calculations and statistical analysis

The data was analyzed by one way analysis of variance (ANOVA) to calculate the growth performance of fish. Difference Among means was calculated by 5% probability levels addressing Duncan's multiple range tests. The efficacy of artificial feed for black fin sea bream *A. berda* was determine by the maximum percent weight gain of fish. Percent weight gain (%WG), specific growth rate (SGR), protein efficiency ratio (PER), feed conversion ratio (FCR), feed intake (FI) and condition factor (CF), hepatosomatic index (HSI) and viscrosomatic index (VSI) were calculated by the following formulae:

WG, % of initial weight =100×[final W–initial W/initial W].
CF =100 × weight / length^3
SGR =100 × (ln final W – ln initial W/period).
FCR = diet given / WG)
HSI=wet of liver (g)/empty fish weight (g)×100; total of initial was1.24%.
PER = wet WG / N×6.25 intake.
VSI=100×[wet weight of visceral organs and associated fat tissue (g) / wet body weight g].
.

RESULTS

.

Chemical composition of the experimental diet

The nutrient balanced diet (42% protein) was given to the juveniles of *A. berda* as suggested by Rahim *et al*. (2015). The chemical analysis of test diet showed that feed contained approximately 42.1% protein, 20.0% lipid, 13.6 % ash, 20.9% carbohydrate, 7.6 % moisture and 25.2 kJ/g energy (Table I).

Table II.- Physico-chemical parameters of the treated and control ponds.

Parameter	Experimental ponds	
	Treated	Control
pH	7.6-7.7	7.7-7.8
Temperature (°C)	25-27	25-28
Salinity (‰)	15-20	15-20
Dissolved oxygen (ml/l)	5.6-7.0	5.6--7.5
Ammonia	0.001-0.01	0.001-0.01
Secchi's disk visibility (cm)	18-46	8-18

Concentration was taken in mg/liter. Different superscripts show significant (P>0.05) difference among treatments.
[1]WG, % of initial weight =100 × [final W – initial W / initial W.
[2]SGR =100 × (ln final W – ln initial W / period).
[3]FCR = diet given / WG).
[4]SGR =100 × (ln final W – ln initial W / period).
[5]CF =100 × weight / length.
[6]HSI = wet of liver (g) / empty fish weight (g) ×100: total of initial was1.24%.
[7]VSI = 100 × [wet weight of visceral organs and associated fat tissue (g) / wet body weight g].

Physico-chemical parameters

During the whole study period, salinity in both (treated and control) ponds was maintained at 15‰ -20‰; dissolved oxygen (DO) ranged from 5.6 to 7.5ml/l and temperature was recorded as 25°C to 28°C. The pH (7.6 -7.8) was found slightly alkaline in both ponds (Table II). Ammonia (NH_4-N) and nitrites (NO_2-N) were less then than 0.001mg/l in this study. Secchi's disc visibility was found to be ranged from 8 cm - 46 cm in both the ponds (Table II).

Table III.- The weight gain (WG%), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER), condition factor (CF), hepatosomatic index (HSI) and viscerosomatic index of juvenile black fin sea bream, *A. berda* in brakish water earthen ponds.

Parameter	Experimental ponds	
	Control	Treated
Final weight	87±1.4[a]	235±3.8[b]
WG%[1]	817.64±0.4[a]	2664.7±0.8[b]
SGR[2]	1.84±0.3[a]	2.76±0.5[b]
FCR[3]	1.2±0.4[a]	0.14±0.3[b]
PER[4]	1.2±0.1[a]	1.4±0.3[b]
CF[5]	2.1±0.1[a]	4.1±0.2[b]
HSI[6]	1.2±0.2[a]	1.4±0.1[b]
VSI[7]	5.1±0.1[a]	7.1±.03[b]
Survival	98a	100b

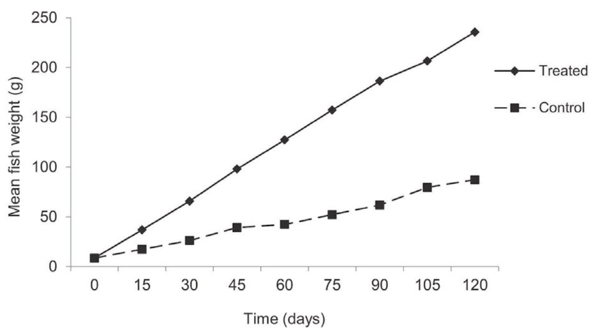

Fig. 1. Increase in body weight of juvenile black fin sea bream, *A. berda* fed diet containing 42% protein and 20% fish oil for 120 days.

Growth performance and nutrient utilization

No symptoms of disease was found during the entire study period. Although, 100% survival rate was noted in the treated ponds, the control ponds showed 98% survival rate. Two percent mortality in the control ponds might have been due to the deficiency of dietary nutrients in such competent and poor food circumstances. Higher weight gain (2664.7%) was observed in treated ponds as compared to the control ponds (817.64%) (Tables III, IV). Best specific growth rate (SGR) value (2.76) was noted in the pond treated with artificial feed, while in contrast the SGR value of controlled ponds was low (1.84) as shown in Table III. Protein efficiency (PER) value of treated ponds was better than that of controlled ponds. Condition factor (CF) of treated ponds was considerably greater than that of control ponds. The hepatosomatic index (HSI) and viscrosomatic index (VSI) of ponds treated with artificial feed were slightly greater than that of without artificial feed (Table III).

Table IV.- Length-weight relationship of the experimental fishes at stocking and harvest.

Para-meters	Length-weight relationship		Residual standard deviation	
	Control	Treated	Control	Treated
At stocking	$W=2.552\ L^{1.669}$ $r^2=0.97$	$W=2.867\ L^{1.689}$ $r^2=0.99$	0.35	0.79
At harvest	$W=2.549\ L^{2.59}$ $r^2=0.94$	$W=2.652\ L^{2.699}$ $r^2=0.97$	0.365	0.88

Data are means of 2 treated and 2 control ponds.

Table V.- Body composition (% wet weight basis) of muscle, liver, viscera and whole body of *A. berda* in control and treated ponds.

Parameters	Experimental ponds	
	Control	Treated
Muscle		
Moister	72.4±1.9[a]	71.8±1.5[a]
Protein	13.1±1.2[a]	13.4±1.4[a]
Lipid	1.6±0.6[a]	1.4±0.9[b]
Ash	1.1±0.2[a]	0.9±0.1[a]
Liver		
Moister	63.1±1.7[a]	63.3±1.2[a]
Protein	11.4±1.3[a]	10.6±0.9[a]
Lipid	7.4±1.0.6[a]	8.3±1.2[b]
Ash	1.2±0.1[a]	1.3±0.3[a]
Viscera		
Moister	58.1±1.8[a]	57.9±1.3[a]
Protein	14.4±1.0[a]	13.8±0.8[a]
Lipid	15.4±1.6[a]	18.2±1.4[b]
Ash	1.2±0.2[a]	1.4±0.1[a]
Whole body		
Moister	72.5±1.2[a]	70.5±0.9[a]
Protein	16.8±0.8[a]	19.5±1.4[a]
Lipid	10.1±0.3[a]	14.1±0.7[b]
Ash	5.4±0.5[a]	4.3±0.3[a]

Similar superscripts show no significant ($P>0.05$) difference among treatments. Initial body proximate composition was: moisture 77.2%, protein 18.4%, and lipid 6.2% and ash 5.1%, and total lipid content of liver, viscera and muscle were 8.2%, 12.5% and 0.8%, respectively.

Body composition

The body composition of harvested sea bream was not significantly different in both treatments (Table V). Anyhow moister contents was not significantly affected by the treatments, while protein and lipid contents of fish whole body was greater in treated ponds than that of control ponds (Table V). In contrast, the ash content of treated ponds was less than that of controlled ponds. The moister and protein of viscera of both treated and control ponds were similar but lipid contents of treated ponds were greater than that of controlled (Table V). Ash contents of liver did not show any significant difference among treatments. The liver composition shows high lipid level in pond treated with artificial feed while moister, protein and ash content was not significantly different in treated and control ponds. No significant difference in muscles composition of treated and controlled ponds were noted in the present study.

DISCUSSION

In the present study, water quality of control and treated ponds was suitable for good growth of *A. berda* that is evident by the recommended physico-chemical parameters (Boyd, 1981). Salinity of both the ponds was ranged from 15 to 20 ppt. This level of salinity is considered as best for estuarine specie like sea bream and sea bass (Ercan *et al*., 2015).Water temperature of both the ponds was feasible for such warm water fish (Mizanur *et al*., 2014). Ammonia in both control and treated ponds was less. Generally, ammonia and nitrates concentration remained in little quantity as fertilizers were not added in the ponds and were usually not harmful for fish pond productivity (Mahboob and Al-Ghanim, 2014). Dissolved oxygen (DO) in treated and control ponds ranged from 6.6-7.5 ml/l, although no aeration was provided to the ponds. However, DO was best due to strong wind flow in the coastal region (Hussain *et al*., 2014).

Fish in treated ponds showed 100% survival rate, while in control pond the survival rate was 98%. Only 2% mortality might have been due to poor nutrient circumstance in such competent environment. Higher percent weight gain (WG) and production was observed in pond 1 and 2 (treated pond). This indicates the best efficacy of the diet which is already observed in glass tanks in previous study (Rahim *et al*., 2015). While weight gains of fish in control ponds were considerably less than that of the treated ponds. This shows that sea bream being carnivores' fish need high protein diet for maximum growth (Abbas *et al*., 2015; Rahim *et al*., 2015). The 98% survival in control pond shows that fish utilized the natural feed of the pond for their body maintenance but this natural feed was not sufficient for their best growth. The specific growth rate of treated ponds were considerably higher than the control pond. This reveals that high protein diets enhance the growth of fish agreeing with the finding of Sadek *et al*. (2004) for gilthead sea bream. While low specific growth of treated ponds shows that in this case sea bream utilizing the primary productivity, maintaining the slow growth but not improved the growth in poor protein and energy circumstance. In treated pond the protein (42%) and energy (20%) are sufficient for the growth performance of the fish, while in control ponds the balanced diet was not available for growth which caused poor growth performance (Eisawyand Wassef, 1984). It also shows that plankton present in controlled ponds does not fulfill the requirements of the sea bream.

Best FCR values for treated pond clear-cut narrates the significances of the diet. Similar finding was also noted by Abbas and Siddiqui (2013) for red snapper, Sadek *et al*. (2004) for gilthead sea bream, they stated that FCR in pond should be less because in earthen pond with artificial feed the natural feed is also utilized by the fish which is addition to the diet for growth. Similar studies was found by many scientist for different species (Terziyski *et al*., 2007; Ahmed *et al*., 2005; Jasmine *et al*., 2011; Khan *et al*., 2002). According to them, growth of fish can be enhanced with planktonic enrichment by using fertilizer. But, in the present study, the fertilizer was not intentionally used to check the rate of increment in growth performance of sea bream fed with feed and without feed. Beside that sea bream is not strongly planktonivorus fish, therefore, the use of fertilizers were avoided in the present study. However, fertilizers can be successfully used in earthen pond even in carnivorous fish for indirect use of plankton (Mischkea and Zimbab, 2004).

In this study, protein efficiency ratio of treated ponds was slightly greater than that of control pond. The hepatosomatic index (HSI) and viscrosomatic index (VSI) of ponds treated with artificial feed were slightly greater than that of controlled ponds. The body composition of sea bream after four month rearing in earthen ponds showed that whole body moister contents was not significantly affected by the treatment while protein and lipid contents of whole body was greater than that of controlled ponds. These findings are similar to those reported by Abbas *et al*. (2015). The moister and protein of viscera of both treated and control ponds were similar but lipid contents of treated ponds were slightly greater than that of control one. No significant difference in ash contents of liver of the fish in treated and control ponds was noted in the present study. The liver composition shows high lipid level in pond treated with artificial feed while moister, protein and ash content was not significantly different in treated ponds and control ponds (Mischkea and Zimbab, 2004).

CONCLUSIONS

Finally, on the basis of biological and statistical data it was concluded that efficacy of diet containing 42% protein and 20% lipid was best for the growth of black fin sea bream *A. berda* growing from 8.5 g to 235 g in brackish water earthen pond. Water quality of these ponds is strongly recommended as salinity, 15‰ -20‰; dissolved oxygen (DO), 5.6 to 7.5 ml/l; temperature, 25°C to 28°C and pH, 7.6 -7.8 for good growth performance of the sea bream.

ACKNOWLEDGEMENT

The senior author is grateful to the HEC for providing facilities and fellowship to complete this work as a part of Ph. D. research.

Statement of conflict of interest

Authors have declared no conflict of interest.

REFERENCES

Abbas, G. and Siddiqui, P.J.A., 2009. Effects of different feeding level on the growth, feed efficiency and body composition of juvenile mangrove red snapper, *Lutjanus argentimaculatus* (Forsskal 1775). *Aquacult. Res.*, **40**: 781–789. https://doi.org/10.1111/j.1365-2109.2008.02161.x

Abbas, G. and Siddiqui, P.J.A., 2013. The effects of varying dietary protein level on growth, feed conversion, body composition and apparent digestibility coefficient of juvenile mangrove red snapper, *Lutjanus argentimaculatus* (Forsskal 1775). *Aquacult. Res.*, **44**: 807–818. https://doi.org/10.1111/j.1365-2109.2012.03096.x

Abbas, G., Siddiqui, P.J.A. and Jamil, K., 2011. The optimal protein requirements of juvenile mangrove red snapper, *Lutjanus argentimaculatus* fed isoenergetic diets. *Pakistan J. Zool.*, **44**: 469-480.

Abbas, G., Waryani, B., Ghaffar, A., Rahim, A., Hafeez-ur-Rehman, M., and Aslam, M., 2015. Effect of ration size and feeding frequency on growth, feed utilization, body composition and some haematological characteristics of juvenile snapper, *Lutjanus johnii* (Baloch, 1792). *Pakistan J. Zool.*, **47**: 719-730.

Ahmed, I., Abbas, K. and Hafeez-ur-rehman, M., 2005. Growth response of major carps in semi-intensive ponds supplemented with rice polishing. *Pakistan Vet. J.*, **25**: 59-62.

Ahmed, M., 1982. *Baseline chemical and biological survey of the Gharo-Phitti creek system with a view to monitor pollution.* Port Qasim Poll. Study Res. Proj., Final Res. Rept, 1981-82. Centre of Excellence in Marine Biology, University of Karachi, pp. 66.

Ahmed, M., 1985. Winter and spring abundance of juvenile, Penaeid and Caridean shrimps in the Indus Delta (Pakistan: Northern Arabian Sea). *Pakistan J. Zool.,* **17**: 67-70.

Ahmed, M., 1987. Marine fisheries resources of the Indus delta (Northern Arabian Sea). *Advances in aquatic biology and fisheries,* pp. 139-152.

Ahmed, M. and Lorica, M.L., 2002. Improving developing country food security through aquaculture development lessons from Asia. *Fd. Policy,* **27**: 125–141. https://doi.org/10.1016/S0306-9192(02)00007-6

Ahmed, M.F., 1988. Fish of Pakistan's Mangrove areas. In: *Marine Science of the Arabian Sea* (eds. M.F. Thompson and N.M. Tirmizi). Proceedings of an International Conference, Karachi, Pakistan, 1986. American Institute of Biological Sciences, Washington, DC. pp. 429-438.

Amjad, S. and Jones, D.A., 1992. A review of shrimp nutrition and artificial larval diets. *Mar. Res.,* **1:** 97-110.

Amjad, S., 1988. Breeding of the penaeid 'shrimp, *Penaeus merguiensis* de man, in captivity. In: *Marine Science of the Arabian Sea* (eds. M.F. Thompson and N.M. Tirmizi), Proceedings of an International Conference, Karachi, Pakistan, 1986. American Institute of Biological Sciences, Washington, DC, pp. 263-268.

Anonymous, 2012. *Hand book of fisheries statistics of\Pakistan*. A publication of Marine Fisheries Department, Government of Pakistan. Ministry of Food, Agriculture and Cooperatives (Livestock Division), **20**: 215.

AOAC, 2000. *Official methods of analysis of association of official analytical chemists*. Vol. I. 17th edn. Association of Official Analytical Chemists, Arlington, USA, pp. 684.

Boyd, C.E., 1981. Comparison of 5 fertilization programmes for fish pond. *Trans. Am. Fish. Soc.*, **110**: 541–545. https://doi.org/10.1577/1548-8659(1981)110<541:COFFPF>2.0.CO;2

Eisawy, A. and Wassef, E., 1984. Preliminary studies on rearing of the gilthead seabream, *sparus aurata*, in brackish water ponds, *Aquaculture,* **38**: 255-260. https://doi.org/10.1016/0044-8486(84)90149-2

Ercan, E., Agral, N. and Tarkan. A.S., 2015. The Effects of salinity, temperature and feed ratio on growth performance of European sea bass (*Dicentrarchus labrax* L., 1758) in the water obtained through reverse osmosis system and a natural river. *Pakistan J. Zool*., **47**: 625-633.

FAO, 2006. Use of fishery resources as feed inputs to aquaculture development: trends and policy implications. *Tech. Pap.,* **1018**: 1-99.

FAO, 2015. *World fishing and aquaculture: insight for the international fishing and aquaculture industry*. FAO Fisheries Model 2015, pp. 126.

Folch, A.C., Leed, M. and Sloane-Stanley, G.M., 1957. A simple method for isolation and purification of total lipids from animal tissues. *J. biol. Chem.,* **226**: 497–509.

Hassan, H. and Haq, S.M., 1975. Developmental stages of commercial penaeid prawns of Pakistan. II Post larvae of metapenaeus. *Agric. Pakistan,* **26**: 219-231.

Hassan, H., 1980. Early developmental stages of *Metapenaeus affinis* (Decapoda: Penaeidae) reared in laboratory. *J. Cons. Perm. Inf. Bxplor. Mer.,* **38**: 30-43.

Hassan, H., 1983. *Distribution of Penaeid larvae in the coastal waters of Pakistan*. Ph.D. thesis, CEMB, University of Karachi, 288 pp.

Hassan, H., 1987. Distribution and abundance of Penaeid larvae on the shelf adjacent to Korangi Creek and Manora Channel. *Proc. Pakistan Congr. Zool.,* **7**: 193-197.

Hassan, H., 1988. Pond culture of Penaeid shrimps in the Indus delta area. *Pakistan J. scient. indust. Res.,* **31**: 35-37.

Hassan, H., 1989. Distribution and abundance of penaeid juveniles on Mekran and Sindh Coast. *Pakistan J. Zool.,* **21**: 147-152.

Hassan, H., 1992a. Immigration of *Metapenaeus stebbingi, M. afinis* and *M. monoceros* juveniles in the creeks and backwaters near Karachi. *Pakistan J. scient. indust. Res.,* **35**: 190-193.

Hassan, H., 1992b. Distribution and abundance of Penaeid larvae in the coastal waters of Pakistan, collected by RfV Dr. Fridtjof Nansen 1977. *Pakistan J. Zool.,* **24**: 11-17.

Hussain, M.A., Abbas, S., Zaffar, M.R.K.A.A and Wind, B.J., 2014. Wind speed analysis of some coastal areas near Karachi. *Proc. Pakistan Acad. Sci.*, **51**: 83–91.

Hussain, M.G. and Mazid, M.A., 2001. *Genetic status improvement strategies for endemic and exotic carps of Bangladesh*. Bangladesh Fisheries Research Institute and International Center for Living Aquatic Resources Management, pp. 74.

Jasmine, S., Ahmed, F., Rahman, S.H., Jewel, M.A.S. and Hossain, M.Y., 2011. Effects of organic and inorganic fertilizers on the growth performance of carps in earthen ponds through polyculture system. *Nature*, **9**: 16-20.

Khan, N., Khan, S.H., Masroor, J.I. and Ahmed, I., 2002. Effect of different doses of fertilizer (nitrophos) on the growth performance of major carps. *Int. J. Agric. Biol.,* **4**: 407-409.

Mahboob, S., and Al-Ghanim, K.A., 2014. Effect of poultry droppings on the primary productivity and growth performance of major carps in polyculture system, *Pakistan J. Zool.,* **46**: 799-803.

Mischkea, C.C. and Zimba, P.V., 2004. Plankton community responses in earthen channel catfish nursery ponds under various fertilization regimes. *Aquaculture,* **233**: 219–235. https://doi.org/10.1016/j.aquaculture.2003.09.044

Mizanur, R.M., Yun, H., Moniruzzaman, M., F Ferreira, M.F., Kim, K.W. and Bai, S., 2014. Effects of feeding rate and water temperature on growth and body composition of juvenile Korean rockfish, *Sebastes schlegeli* (Hilgendorf 1880) *Asian Austral. J. Anim. Sci.,* **27**: 690-699. https://doi.org/10.5713/ajas.2013.13508

Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Jason, C.M., Clay, J., Folke, C., LubchencoI, J., Mooney H. and Max, T., 2000. Effect of aquaculture on world fish supplies. *Nature*, **405**: 1017-1024. https://doi.org/10.1038/35016500

Niazi, M.S., 1980. Fishes of Sindh. Creeks. 1, Order Clupeiformes. *Rec. Zool. Surv. Pakistan, 1-16.*

Rahim, A., Abbas, G., Waryani, B., Ghaffar, A., Monwar, M.M., Hafeez-ur-Rehman, M., and Dastagir, G., 2015. Influence of varying dietary lipid levels on growth, feed conversion and chemical composition of meat and liver of the juvenile blackfin sea bream, *Acanthopagrus berda* (Forsskal 1775). *Pakistan J. Zool.,* **47**: 1467-1473.

Rahim, A., Abbas, G., Naeem, M., Ferrando, S., Gallus, L., Khan, N., Hafeez-ur-Rehman, M., Ghaffar, A. and Mateen, A., 2017. Fish meal: production and quality assessment for aqua feed formulation in Pakistan. *Pakistan J. Zool.,* **49**: 319-326. https://doi.org/10.17582/journal.pjz/2017.49.1.319.326

Sadek, S., Osman, M.F. and Mansour, M.A., 2004. Growth, survival and feed conversion rates of sea bream (*Sparus aurata*) cultured in earthen brackish water ponds fed different feed types. *Aquacult. Int.,* **12**: 409–421. https://doi.org/10.1023/B:AQUI.0000042131.29346.93

Tacon, A.G.J. and Forster, I.P., 2001. Global trends and challenges to aquaculture and aquafeed development in the new millennium. *Int. Aqua Feed Direct. Buy. Guide,* pp. 4-25.

Terziyski, D., Grozev, G., Kalchev, R. and Stoeva, A., 2007. Effect of organic fertilizer on plankton primary productivity in fish ponds. *Aquacult. Int.,* **15**: 181–190. https://doi.org/10.1007/s10499-007-9086-1

Toufique, K.A. and Gregory, R., 2008. Common waters and private lands: Distributional impacts of floodplain aquaculture in Bangladesh. *Fd Policy*, **33**: 587–594. https://doi.org/10.1016/j.foodpol.2008.04.001