Indian Journal of Geo Marine Sciences
Vol. 49 (08), August 2020, pp. 1425-1434

Economic analysis of Barramundi (*Lates calcarifer*) (Bloch 1790), in Pakistan and opportunities for its aquaculture development

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Received 26 June 2019; revised 24 July 2019

Barramundi, (*Lates calcarifer*) is one of the most commercially important fish species. In Pakistan, farming of this species is relatively new. Article delivers the economic analysis of Barramundi and its fishery resources in Pakistan. The analysis includes the capture production, aquaculture production and market price. The Capture production of Barramundi in Pakistan has shown a declining trend by average at 18 t y^{-1} from 605 t in 1986 to 121.2 t in 2018. Similarly, wholesale and retail market prices witnessed an increase from 2003 to 2018. During this period, the wholesale price rose to 384.3 PKR/kg from 69 PKR/kg, while the retail price surged to 395.2 PKR/kg from 97 PKR/kg. On the other hand, the increasing operational fishing fleets from 15513 (1990) to 30000 (2018) has reduced Fishery resources of barramundi i.e. from 312 ton to 130 and its body weight from 13.42 kg to 3.5 kg during the period from 1990 to 2018. On the contrary, aquaculture production registered a rising trend by average of 0.5 t y^{-1} from 05 t in 2009 to 8.2 t in 2018. The rise in aquaculture production of Barramundi is not satisfactory when compared to its growth rate in other countries like Bangladesh, Thailand, Australia, China, India etc. In this study, we find out the major causes of non-satisfactory rise in aquaculture production by the using AGR model. Results show that the main reasons beyond decline in the growth included inaccessibility of Barramundi Seed, unavailability of Barramundi Hatcheries and lack of government Support.

[**Keywords**: AGR model, Aquaculture Production, Barramundi, Capture Production, Pakistan, Strategies]

Introduction

Barramundi *Lates calcarifer* (Bloch 1790) commonly known as Seabass in Asia, is a widely considered *euryhaline* member of the *Centropomidae* family. This species is mainly found in coastal, estuaries and in the fresh water-logged areas[1], range from the Indo-West Pacific region from the Arabian Gulf to the China, Taiwan, Papua New Guinea and in Northern Australia. It is a prominent predatory, stenothermic, rapid grower and long-lived fish species[2-6]. The life cycle of Barramundi *L. calcarifer* passes from different stages in different ecosystems such as from the coastal waters to estuaries, lagoons, brackish waters and then in the fresh water. It usually lives between 10-40 meters (m) water depths and its body size ranges from 25-200 cm[7-9]. According to Davis[10], Barramundi is immensely fecund species and it can produce about 10-40 million eggs with an average body size of 100-120 cm. Besides, Barramundi is rich in nutrition to provide calcium, vitamin A, iron and zinc that helps to alleviate the nutritional deficiencies and facilitate to cure various diseases[11,12]. Barramundi is commonly caught by the local gears including gillnet, bag nets, line gears and others[13]. Barramundi flesh has repute bearing premium edible properties including; affectionate, white, steadfastly and mild-tasting with boneless fillets[14,15]. Owing to high qualities, it is very popular in the markets, served as live or whole as plate size from 300-500 g and also served as large whole fish almost 2 kg in size or fillet in Asian markets and restaurants[16,17]. Due to unique physiological characteristic, Barramundi *L. calcarifer* is considered as one of the preferred species among marine animals for aquaculture business because of its high market demand, rapid growth, *euryhaline* nature, *stenothermic* and plain breeding to rearing in hatchery[18-20]. It is a fact that fisheries products are major source of food for society and contributes to the global economy[21-23].

According to the FAO 2018, globally the fisheries sector has producuded 170.9 million metric tons (MT) in 2016, i.e. 90.9 MT from catch fishery (87 % from marine and 13 % from inland waters, respectively) and 80.1 MT from aquaculture (64 % from Inland and 36 % marine, respectively)[24]. Furthermore, according to the FAO statistics, the capture fishery production from marine waters has declined by 2.33 % from 81.2 MT in 2015 to 79.3 MT in 2016. The world capture production of Barramundi has shown an increase from 1950 to 2014 as it was 900 t in 1950, which increased to 27147 t in 1989 and 102401 t in 2014. Furthermore, the rapid growth period of Barramundi production has started from 1989 to 2014. During the period under review, the average production growth rate and its percentage was calculated as 2992 t y^{-1} and 4.1 % y^{-1} (Fig. 1). The world catch production of Barramundi then registered a decline from 2015 to 2016; in 2015 it decreased by -3 % (3714 t) and by -19 % (17052 t) in 2016 as compared to 2014[(ref. 25)]. In the early 1970s, Thailand was the first country in the world, which had innovated breeding and cultivation techniques of Barramundi. Later on, from 1980s to 1990s the breeding and cultivation of Barramundi had rapidly expanded to China, India, Indonesia, Malaysia, Philippines, Singapore, Vietnam and Australia[26]. Presently, the USA, Netherlands, UK and Israel have adopted Barramundi farming, while some of these countries are encouraging active research and advancement in farming techniques of Barramundi[27-29].

According to the FAO, in 1963 the total production of Barramundi by Aquaculture was 5 t globally[30]. Afterwards, the decade from 1963-1978 was the revolutionary period of farming techniques, which had primarily expanded Barramundi farming. In that period, production increased year after year and the average estimation of production was computed about 243.6 t y^{-1}. Subsequently, during the decade (1979-1988), the estimated production was 2234 t y^{-1}. Then, for the decades (1989-1998) and (1999-2008), the average estimation of Barramundi production by aquaculture was 16027 and 29672 t y^{-1}, respectively. From 2009-2016, the appearance of high-level research, law, policies implementation, innovations and management practices uplifted the aquaculture standard and ensured its presence in globalmarket[31]. During the period under review, the average production of Barramundi by aquaculture has been estimated at 67609 t y^{-1}. During the entire study period of 1955-2016, yearly flow of Barramundi capture and aquaculture production is presented in Figure 1.

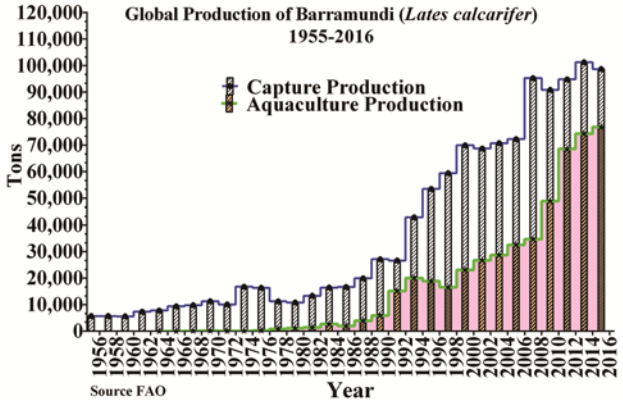

Fig. 01 — Global production of Barramundi (*L. calcarifer*) 1955-2016

Aquaculture of Barramundi spread throughout the Southeast Asia; Australia, the United States and it also rose in western at Massachusetts and Florida[15]. Due to advance application in aquaculture practices, Barramundi farming widely expanded in far regions of tropic areas (Southern Australia and in the northeastern USA)[32]. Moreover, Barramundi aquaculture was also introduced in other countries such as Iran, French Polynesia, Guam, USA (Hawaii and Massachusetts) and Israel. From the experiences and practices of other developed and developing countries, the UK government imitated Barramundi farming on trial basis[30]. The total production of Barramundi by Aquaculture in Southeast Asian countries was 76.498 MT in 2015. Malaysia was accounted as the largest Barramundi farming country and in 2015 it has produced 29.13 MT of Barramundi by aquaculture. Although, at same time Thailand has produced 16.90 MT, Taiwan 14.01 MT and other Southeast Asian countries produced 16.44 MT. According to Rutledge (1990)[(ref. 33)], the farming of Barramundi fish species is cost effective and easy to handle. Also according to many experts and farmers; Barramundi is sustainable alternative to grouper, snapper and others commercial fish species and also it can be produced with mixture of other species at varying densities including grouper and snapper in pond farms, pen farms and small cage farms[34-36].

Pakistan is blessed with enormous fisheries resources. The coastline of Pakistan has been divided according to UNCLOS 1982, with its coastline extended to a distance of 1050 km (650 miles) while the Exclusive Economic Zone (EEZ) boundary extended from 200 nm to 350 nm covering an area

2,900,00 km^2 approved by UNCLS in 2015. The Pakistan coastline has been divided into two geographical locations, *viz*. Baluchistan (800 km) and Sindh (250 km), respectively. Moreover, the country coastline and inland reserves covers an area of approximately 8.56 million hectors. For fish processing and handling the government has established four landing jetties[37]. In addition, Figure 2 shows various fish harbors and landing sites along Baluchistan and Sindh Coast. According to Jarwar[38], variety of commercially important fish fauna such as demersal, shrimp, crabs, prawn small, medium and large pelagic, squid (octopus/cuttlefish) and lobsters are found in coastal, marine and fresh waters of Pakistan[38]. In Pakistan, fisheries sector plays an important role in poverty alleviation, food security and supporting livelihood to the families living along the coastal and inland water areas. The contribution of fisheries sector to national Gross Domestic Product (GDP) has increased by 5.3 % in the fiscal year of (2016-17) [refs. 39,40]. In 2017, share of agriculture sector was about 19.53 % in GDP including its four major sub-sectors viz. crops, livestock, fisheries and forestry. The share of fisheries in agriculture was 2.12 % and in GDP was 0.41 %[ref. 41]. The fisheries sector in Pakistan (marine and inland) provide 0.4 million (m) directly and 0.6 m indirectly employment opportunities, which accounts to 1 % of national labour force[42-44]. In addition, the fisheries produced 0.658 MT i.e. 77 % (0.503 MT) by capture and 23 % (0.154 MT) by aquaculture.

Despite the growth in fisheries sector, there is still an adequate and appropriate need of development. Sustainable measures are necessary to overcome the natural and social issues in country. Due to strict capture applications on marine fishery, there is and will be more pressure of overexploitation on marine fishery resources. Pakistan fisheries sector lacks an appropriate planning and management towards sustainable development, which is a prerequisite to overcome the issue especially to develop sustainable aquaculture.

The objective of this study is to analyze the economic importance and continually increasing aquaculture of Barramundi across the world. In addition, we investigate the major issues like decreasing capture production, non-satisfactory growth in aquaculture sector and non-implementation of rules and regulations of the fisheries sector in Pakistan.

Materials and Methods

Data acquisition for Pakistani fisheries sector

Data was collected from different sources such as previously published reports, news, project reports, scientific review, short communication articles, research articles and online database. The research project was drafted by gathering global production data of Barramundi *L. calcarifer* by capture and aquaculture from 1955 to 2016, which was collected from Food and Agriculture Organization of The United States (FAO)[30]. The total Pakistan fisheries

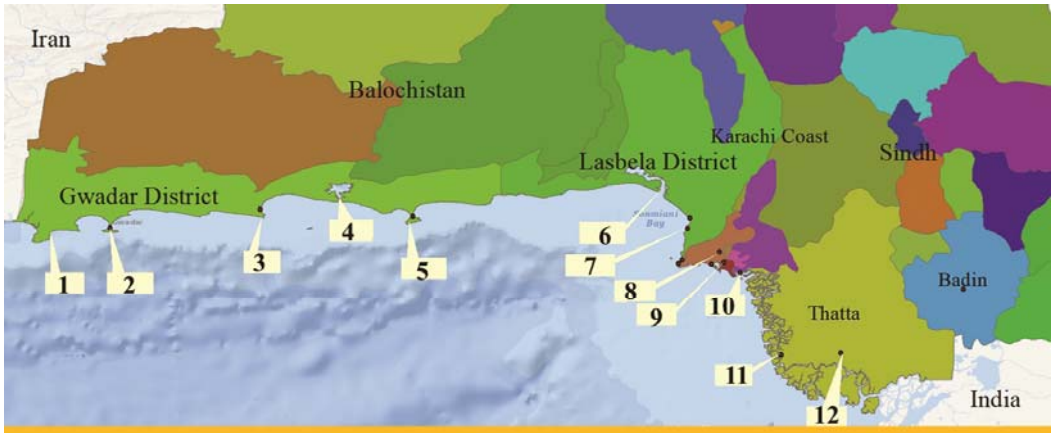

Fig. 2 — Pakistan coastline and regular functioning fish landing centers along the Sindh and Baluchistan coast

production data of capture production and aquaculture production was collected from FAO and Handbooks of Fisheries Statistics of Pakistan by Marine Fisheries Department (MFD)[45-48]. Specific production (capture and aquaculture) of Barramundi from 1950 to 2017 was collected from Handbooks of Fisheries Statistics of Pakistan by Marine Fisheries Department MFD and Sea around Us[49], respectively.

Data preparation and construction

The results obtained were constituted graphically by using Microsoft Excel 2013 and Graphpad Prism 6.01 commercial scientific software .In addition, similar software was also utilized to calculate percentages and annual growth rates. Annual growth rates were calculated as:

$$GR = (PreV - PasV)/PasVx\ 100$$

Where, GR =Growth rate; Pre V = Present year value; Pas V = Past year value.

Relationship between operational fishing vessels and fishery resource of Barramundi

Data acquisition

Primary and secondary data was used to make comparison between increasing operational fishing vessels and decreasing natural resource of barramundi (length x Weight = total production) in Pakistani marine waters. The primary data on Barramundi's body size (length & weight) was collected through questionnaire, while secondary data on capture production and operational fishing vessels was collected from old records of Harbor authority and Handbooks of Fisheries Statistics of Pakistan[45-48].

Data evaluation

The data was simply evaluated by using Microsoft Excel 2013 and simple analysis methods.

Market price

Data acquisition

Month-wise wholesale and retail price data of Barramundi *L. calcarifer* from 2003-2009 was collected from the Handbooks of Fisheries Statistics of Pakistan published by Marine Fisheries Department (MFD)[47]. The additional data from 2010 to 2018 was collected from the document of government authority (Fish harbor Karachi).

Data evaluation

The time series market price data of *L. calcarifer* from 2003 to 2018 was statistically inspected by using following equation (1) to evaluate the yearly average wholesale and retail price of Barramundi in Pakistan.

$$F_{py} = \sum_{F_p^d} /30^d = F_p^m = \sum_{F_p^m} /12^m = F_{py} \quad \ldots (1)$$

Where, F_{py} = Fish price per year; F_p^d = Daily fish price; ^{d} = Days; F_p^m = Fish price per month; and ^{m} = Months

Application of Garret Ranking

Data acquisition

The data related to key factors affecting Barramundi farming in Pakistan was collected through semi-structured questionnaire from 90 fish farmers in Sindh and Punjab provinces.

Data evaluation

The Garrett's ranking technique was used to grade the issues[50]. The collected ranking data converted into score value by following formula:

$$\text{Percent position} = 100\ (R_{ij} - 0.5)/\ N_j$$

Where, R_{ij} = Rank given for the i^{th} variable by j^{th} respondent; and N_j = Number of variable ranking by j^{th} respondent.

Results

Fisheries production in Pakistan

Pakistan fisheries sector has produced nearly 16.52 MT (14.3 MT by capture and 2.22 MT by aquaculture) in the entire period of (1990-2017). The average estimation of Fisheries production was computed at 0.59 MT y^{-1} (0.51 MT y^{-1} by catch and 0.079 MT y^{-1} by aquaculture). In deep analysis, the capture fishery production was 0.556 MT y^{-1} during 1990-1999; similarly in the next decade (2000-2009), average estimation of production was 0.49 MT y^{-1} and in 2010-2017, it was estimated at 0.47 MT y^{-1}. The capture fishery trend has been decreasing year by year from 1999 to 2011. In 1999, the capture production recorded at 0.46 MT and it reduced to 0.45 MT in 2011 by 9120 t y^{-1}. While, from 2011 to 2017 it has been increasing year after year and the estimated growth is calculated at 8235.63 t y^{-1}. Nonetheless, for stability of human livelihoods, the pressure on capture fishery resources has been increasing due to a rise in number of operational fishing fleets i.e. Trawlers, Gillnetters, Mechanized-Cum-Sail Driven Boats and

Sail Boats. The total registered fishing fleets in 2011 were 25316, which increased to 29754 in 2017[48]. Therefore, from 2012 to 2017 the trend of capture fishery has been increased due to increasing number of operational fishing boats shown in (Fig. 3). Along with the capture fishery, aquaculture has a sustaining role to produce fish and support livelihood options in Pakistan. The aquaculture production in 1990 was 0.01 MT, which increased to 0.155 MT in 2017, approximately 0.12 % of the global aquaculture production. Our study has conducted review from the period of 1990 to 2017; the aquaculture has produced 2.22 MT in whole period, which is estimated at 0.079 MT y^{-1}. During 1990-1999, aquaculture production was recorded very low in amount and its average was estimated at 0.014 MT y^{-1}. In next decade (2000-2009), the production is estimated at 0.089 MT y^{-1}. During 2010-2017, the production estimation was 0.147 MT y^{-1}. Whereas, the aquaculture is most growing sector in the world including Pakistan nevertheless, Pakistan fisheries sector still has to promote aquaculture sector to achieve better growth rate and increase its contribution to the economy.

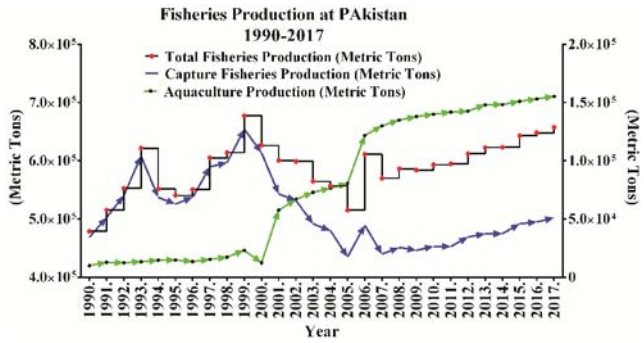

Fig. 3 — Fisheries sector production 1990-2017 (Pakistan)

Barramundi production in Pakistan

Figure 4 represents the trend of Pakistan fisheries production and Barramundi production by capture and aquaculture. During 1947, Barramundi production by catch was almost 1 % of total fish production. In the first decade (1947-1956), Barramundi average produce by capture was about 274 t y^{-1}. In the next decade (1957-1966), it increased to 350.6 t y^{-1} and in the same way it surged slightly to 352.4 t y^{-1} during the period of 1967-1976. For the period 1977-1986; it rose to 478.1 t y^{-1}. Furthermore, in the decade of (1987-1996) capture production decreased to 295.1 t y^{-1} and in the subsequent decade (1997-2006), the production estimated at 155.2 t y^{-1}. While, during 2007-2016, capture production of Barramundi was 134.1 t y^{-1} and its average was estimated at 122.05 t y^{-1} for the period of 2017-2018. The capture production of Barramundi was 241 t in 1947, which decreased to 129.4 t in 2018 (including Barramundi farming production).In addition, the trend of Barramundi aquaculture production in Pakistanis is highlighted in the upper graph (Fig. 4). Barramundi farming in Pakistan is not properly developed and disseminated yet. However, its farming gained bit popularity among some farmers during 2005-2009 and they initiated

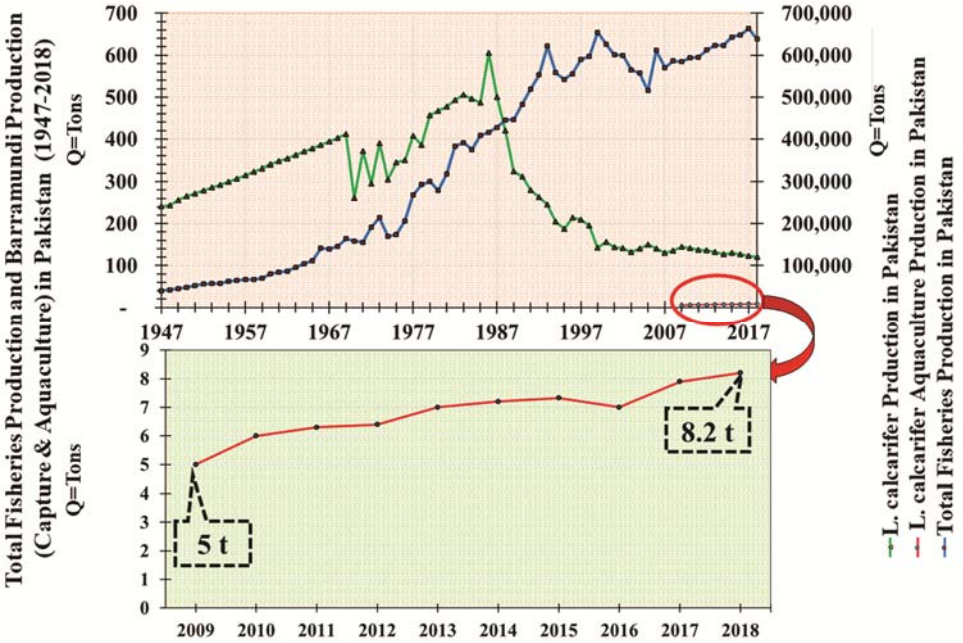

Fig. 4 — The total fisheries production (*L. calcarifer*) capture and aquaculture at Pakistan from 1947-2018

poly-culture farming pilot trails with brackish and freshwater fish species respectively. In 2009, production of Barramundi by aquaculture was 5 t, which increased to 8.2 t in 2018 with growth rate of 0.5 t y^{-1}. The growth in Barramundi farming is not as encouraging but it is increasing on slow mode.

The relationship between Barramundi fishery and operational fishing fleets in Pakistan

The questionnaire was developed after reviewing published literature of fishery sector and the comprehensive meetings with stakeholders including fishery officials, brokers, fishermen, salesmen and fish farmers. The length weight data (decade wise) of Barramundi was collected through the Questionnaire from stakeholders at different Fish harbors (Sindh & Baluchistan) and coastal regions of Pakistan.

The continuous rise in number of operational fishing fleets caused a constant decline in Barramundi capture as well as its size (length and weight) from the decade of 1980s. Figure 5 illustrates the situation of Barramundi fishery resources including size and increasing ratio of registered operational fishing boats from the 1990 to 2018. In 1990, total registered fishing fleets were 15513 and during same period, total capture of Barramundi was 321 t with the maximum average size of 104 cm (weight 13.42 kg) and minimum average size of 89.5 cm (8.3 kg body weight). The number of licensed operational fishing boats in 2000 has increased to 20956; while the capture of Barramundi has registered a decline by more than half at 156 t when compared to its capture in 1990. During period under review, its maximum average size reduced to 88.5 cm (weight 8.4 kg) and the minimum average size decreased by 81 cm (weight 6.1 kg). Similarly, the number of operational fishing boats in 2010 had increased to 24546 and on contrast, the capture of Barramundi reduced to 139 t; while its maximum average size also shrank to 71 cm (weight 4.4 kg) and minimum average size to 57 cm (weight 2.2 kg). In the same way, the fishing boats have further increased to 30,000 in 2018 and on contrary, capture of Barramundi including farmed fish decreased to 130 t; whereas the average maximum size has reduced to 67 cm (weight 3.5 kg) and average minimum size to 52 cm (weight 1.6 kg).

Forecast of catch and effort cost of Barramundi in Pakistan

From 1985 to 2017, the estimated average catch production of barramundi was calculated as 213.5 t y^{-1}. In1985, the catch production was 487 t and it rose to 605 tin next year (1986). During early decade of 1985 to 1995, the average catch was estimated 348 t y^{-1} and in the last decade of study 2008-2017, the average capture was estimated 132.3 t y^{-1} (Fig. 6). Although, the forecast of capture estimation in next eight years from 2018 to 2025 was calculated as 113.7 t y^{-1}, with a decrease of almost -2.12 t y^{-1} (Fig. 7). Another part of Figure 6 displays the

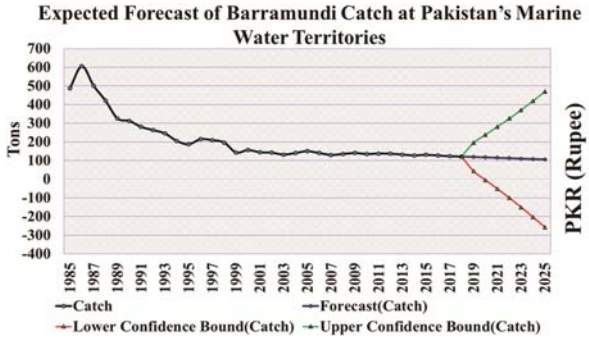

Fig. 6 — Expected forecast of Barramundi catch at Pakistan's marine water territories

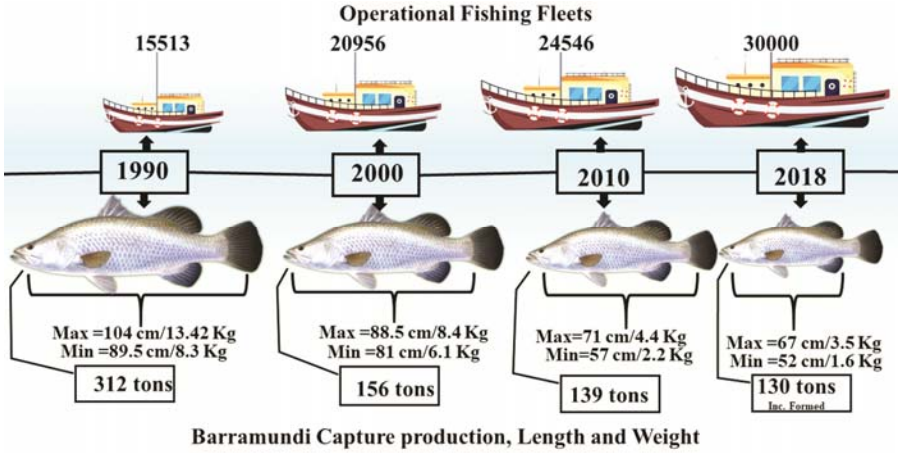

Fig. 5 — Barramundi fishery in Pakistan

forecast of effort cost. In 1985, the efforts cost was 5824 PKR, which increased to 15177.2 PKR in 2017. The rise in effort cost from 1985 to 2017 has shown a surge by 263.7 PKR y^{-1}. As per our calculated forecasting, the effort cost may increase to 16557 PKR by 2025 with average growth rate of 172.5 PKR y^{-1}.

Market price of Barramundi in Pakistan

Figure 8 shows wholesale and retail market price at a major Karachi fish harbor market from 2003 to 2018. In 2003, wholesale and retail prices were 69 and 97 PKR per kg, respectively, and in 2018, the wholesale and retail prices increased to 384.3 and 395.2 PKR kg^{-1} correspondingly. The average per year growth rate of wholesale and retail prices from 2003 to 2018 were calculated as 21 PKR and 19 PKR y^{-1}, respectively. During the period of 2003 to 2008, the average growth rate of wholesale and retail prices were 8 and 7.3 PKR y^{-1}, respectively. While, from 2009 to 2018, the average growth rate for wholesale and retail price was calculated as 29.7 PKR, respectively.

Major issues in Barramundi farming in Pakistan

The major issues of Barramundi aquaculture in Pakistan were ranked in Table 1 given below. During analysis, the first issue is noticed as inaccessibility of Barramundi seed. The second one is unavailability of hatcheries. Third one is the lack of government support to expand farming. Fourth issue includes lack of modern farming techniques. Fifth issue is the lack of easy access of feed. Sixth issue is lacking easy access to fisheries markets. Last seventh issue is hurdles in Transporting of seed to farming.

Discussion and Conclusion

Globally, Barramundi farming is increasing year after year, and many countries around the world is applying the latest farming techniques to improve Barramundi farming. According to our literature story, the Barramundi fish contains unique physiological characteristic which is supporting the aquaculture [Listed below].

1. *Euryhaline:* Able to adapt/ tolerate to a wide range of salinities (can live in fresh water, brackish water, or salt water).
2. *Stenothermic*: capable of living or surviving within a narrow temperature range.
3. *Protandrous/ hermaphrodites*: Change sex from male to female.
4. Prominent predatory: denoting an animal or animals preying naturally on others.
5. Rapid grower: (350 g to 3 kg in four months to one years) in nature.
6. large body size: (from 25-200 cm)
7. Immensely fecund (it can produce about 10-40 million eggs with an average body size of 100-120 cm).
8. Rich in nutrition (provide calcium, vitamin A, iron and zinc that helps to alleviate the nutritional deficiencies and facilitate to cure various diseases).

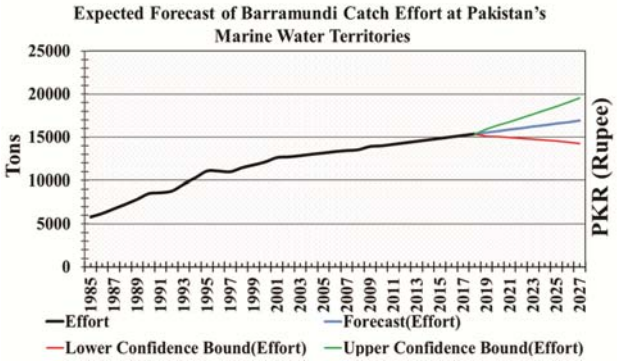

Fig. 7 — Expected forecast of Barramundi catch effort at Pakistan's marine water territories

Fig. 8 — Year wise wholesale and retail price of Barramundi at Karachi fish harbor (Pakistan) 2003 to 2018

Table 1 — Major issues in Barramundi farming at Pakistan

Constraints Major Issues	Average score	Rank
Inaccessibility of Barramundi seed	72.38	1
Hurdles in transportation of seed	30.50	7
Lack of modern farming techniques	42.88	4
Lack of access of feed	38.38	5
Unavailability Barramundi hatcheries	64.50	2
Lack of government support	64.13	3
Lack of easy access to markets	38.25	6

9. Bearing premium edible properties (affectionate, white, steadfastly and mild tasting with boneless fillets).
10. Deep-rooted at the markets: it is served as live or whole as plate size from 300-500 g and also served as large whole fish of 2 kg or more size or fillet.

Above all factors are prominently supporting the Barramundi farming. Therefore, many countries are involved to establish Barramundi farming and going for further improvement to get maximum economic benefits. Our research findings shows that the fishery stock of Barramundi is continually decreasing due to over-catch from Pakistan's marine waters and its over-catch could not controlled due to non-implementation of laws and policy. Moreover, fishermen don't follow rules and regulations to control over-fishing activities because they are not sensitized about laws. Despite increasing in the number of the operational fishing fleets, the government is continually issuing more licenses for operational fishing fleets. Consequently, the inappropriate steps by both government and fishermen as described above, the over-fishing pressure is continually increasing on the insufficient marine fishery resources. As a result, the capture production of most commercial fish species including Barramundi are declining along with the fish size (length & weight). Due to a decrease in production and an increase in the demand, the market prices rose sharply. To bridge the gap between demand and supply, we should utilize the alternative sources i.e. aquaculture to produce more fish in the country. However, the aquaculture of Barramundi is relatively new in Pakistan and just few farmers are engaged in experimental level farming by extensive or semi-intensive farming system with polyculture or monoculture in Sindh and Punjab provinces. Moreover, the availability of Barramundi seed is very difficult because of inaccessibility of seed producing units (hatcheries) in the country. The seed can only be collected [captured] from wild which involves a great effort and its transportation is very expensive. The capture process and improper transportation affect the health and survival of seeds.

In addition, the seed is being imported in small quantities from Thailand, Malaysia and other countries as well and as it costs high prices. Because of very high prices of seed and its transportation risks, the most of farmers are pretermitting the Barramundi farming in Pakistan. Therefore, the seed is a one of the major issue to extend Barramundi farming in Pakistan. Keeping in view above challenges, Pakistan Fisheries industry should collaboratively focus on aquaculture promotion and facilitate farmers as they can get easy access to basic farming facilities. Such steps would enhance aquaculture in the country and help to improve socio-economic conditions. Consequently, it will contribute to national economy.

Acknowledgments

The author is grateful to Marine Scholarship, Chinese Scholarship Council (CSC) funding his PhD Degree. This study was supported by the special research fund of Ocean University of China (OUC) (201022001), key laboratory of mariculture (Ministry of China) Fisheries College, Ocean University of China, Qingdao 266003, China and The Ministry of Agriculture and Rural Affairs of the People's Republic of China (CARS-49).

Conflict of Interest

The authors declared no conflict of interest.

Author Contributions

Manuscript was prepared by SBHS, MY supervised the study, the co-authors NTN, AJ, SO, MA, YL & UN helped for data contribution, data analysis, revision, editing and language improving in manuscript.

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