Dynamics and Stock Status of the Artisanal Fishery of Bay of Bengal, Bangladesh

Partho Protim Barman
Sylhet Agricultural University

Artisanal mechanized fishing boats in the Bakkhali River estuary, Cox's Bazar. (Photo: P.P. Barman, 2018).

Using twelve years (2007-2018) of catch-effort data and one-year monthly catch data, this chapter evaluated the catch-effort dynamics and stock status of the artisanal fishery in the Bay of Bengal. Though artisanal fishing depends on the season and condition of the Bay, September to March is reported as the standard fishing period in Bangladesh. A total of 62 fish and shrimp species were reported from artisanal fishery catch. The stock information indicates the unsustainable status of the fishery that is affected by overfishing. Moreover, the biomass level is not sufficient to produce maximum sustainable yield (MSY). The overfishing hurts the coastal and marine ecosystem by changing the food chain and truncating the food web, threatening the ocean health. To reverse the overfishing, it is strongly recommended that the annual catch of artisanal fishery should not exceed the MSY limit (529,000 t year^{-1}). In addition, some immediate management strategies should be put in place to ensure the sustainability of the artisanal fishery and protect the livelihoods of artisanal fishers of Bangladesh.

Introduction

The marine fisheries of Bangladesh are divided into two subsectors, namely industrial and artisanal fisheries (Shamsuzzaman et al., 2017). As a whole, marine fisheries contribute only 20-24 percent to the national fish production, while artisanal fishing represents more than 80 percent (534,600 tonnes in 2018) of the total marine production (DoF, 2018; Alam et al., 2021). In the Bay of Bengal, fish is harvested at three different ranges: (a) ≤ 40 m from the coast, where artisanal fishing is done; (b) between 40-200 m from the coast, where mid-water trawlers operate; and (c) from 200 m up to the end of the Exclusive Economic Zone (EEZ) where long-liner trawlers operate (Akhtar et al., 2017; Islam et al., 2017). In Bangladesh, artisanal fisheries play a pivotal role for the communities in the coastal areas. Usually, artisanal fishers harvest fish from nearshore water for their livelihoods, using traditional fishing techniques and gears such as simple traps and traditional boats (Batista et al., 2014).

Despite the importance of artisanal fisheries, the marine fisheries management is predominantly focused on the industrial fisheries sector, which led to an uncontrolled expansion of fishing efforts in the past decades. As a consequence, artisanal fishing has already become non-remunerative and unregulated. In recent time, poor small-scale fishers have been using more fine mesh nets to catch less valued and undersized fish in order to survive. Additionally, extreme pressure from the growing coastal communities is causing over-exploitation and decline of the artisanal fish stocks at an alarming rate (Shamsuzzaman et al., 2017). Therefore, scientific research and studies are needed to ensure the sustainability of the artisanal fishery in the coastal water of Bangladesh. However, there are very few studies on the livelihood, opportunities, and challenges of artisanal fishing; the comprehensive knowledge or reflections on the artisanal fishery stock in Bangladesh is usually inadequate or absent. Therefore, this study aimed to focus on the catch-effort trends and stock status scenario and to provide baseline management information to the concerned stakeholders or policymakers with regards to achieving the Sustainable Development Goal 14b that will contribute towards the sustainability of the artisanal fishery of Bangladesh.

In this study, a total of 12 years (2007-2018) catch, and effort data were used from the Yearbook of Fisheries Statistics (YFS), produced by the Department of Fisheries (DoF) in Bangladesh. In addition, the month-based catch biomass data, gear efficiency, species composition, etc. were collected from different published literature (Ghosh et al, 2016; Nazrul et al., 2018). To estimate the catch-effort trend, biomass status, exploitation status, and stock scenario of the artisanal fishery of Bangladesh, the CMSY$^+$ model was used. The CMSY$^+$ is a Monte Carlo-based approach where a Bayesian state-space implementation of the Schaefer Model (BSM) is incorporated that provides important management information (see details at Froese et al., 2017). An R-code (CMSY_2019_9f.R) downloaded from http://oceanrep.geomar.de/33076/ was applied to run the CMSY$^+$ and BSM model.

Artisanal fisheries characteristics: gears, crafts, and effort status

Artisanal fishing activities in the coastal water of Bangladesh were carried out by traditional wooden, non-mechanized craft until the mid-1960s (Ghosh et al., 2016). Later, the Bangladesh Fisheries Development Corporation (BFDC) and the Bangladesh Jatio Matshyajibi Samobay Samity (BJMSS) introduced marine engines to start the mechanization of artisanal fishing boats. Today, different types of traditional gears are mostly used in artisanal fishing. While some gears are operated by mechanized boats, the majority are operated by non-mechanized boats or without a boat. Presently, 34,810 non-mechanized and 32,859 mechanized boats are operating in coastal and marine artisanal fishing activities in Bangladesh (DoF, 2018). Artisanal fishers in the coastal area of Bangladesh use 3 kinds of cast nets, 9 kinds of fixed nets, 11 kinds of drag nets, 3 types of set bag nets (i.e., marine set bag net, estuarine set bag net, and large mesh set bag net), 5 types of gill nets (i.e., large mesh gill net, fixed gill net, mullet gill net, drift gillnet and bottom set gill net), 16 types of trammel, many types of mosquito nets, 26 kinds of traps, 9 kinds of harpoons, and many kinds of hooks and bottom long-lines (Hoq et al., 2013). More than half of the total artisanal catch is caught by the gill nets, while estuarine set bag net (ESBN) contributed to 30% of the total artisanal catch from the coastal waters of Bangladesh. Many studies reported that ESBN is a widely used fishing gear for artisanal fishing in the coastal waters of Bangladesh. The ESBN can catch juveniles, young fish and other aquatic animals, and as a result, the catch per unit effort (CPUE) value is higher than for other artisanal fishing gears. However, the gear selectivity often depends on the type of fishery as well as the finances and logistic support available to the fishers. In addition, gear selection depends on the water depth and different types of gears operated by fishers at different water depths. The marine set bag net (MSBN) is operated in up to 25 m of depth, while ESBN is operated in up to 20 m of depth. Drift gill net and large mesh drift gill net can suitably operate in up to 30 m of depth, trammel net can operate in up to 20 m of depth, and beach seine net can only operate in up to 10 m of depth in the coastal waters of the Bay of Bengal. A couple of decades ago, artisanal fishing was done only within the shallow waters - up to 10 m. Still, due to the innovation of modern fishing technologies, artisanal fishers are allowed to do fishing up to 40 m. But the desire to catch more fish, on the other hand, leads the artisanal fishers to fish to depths of more than 40 m (Ghosh et al., 2016). Here, the depth refers to the water depth (in meters) during high tide.

Artisanal fisheries catch dynamics

The catch composition of artisanal fisheries varies greatly depending on the fishing season. The season or month of fishing directly affects the catch and production of the artisanal fishing. January is the lean period for artisanal fisheries in Bangladesh. However, from April, the catch is sharply increasing until it reaches its peak production in July. July belongs to the monsoon season when the coastal waters of Bangladesh offer a suitable environment for both migratory and native species. Because of the high richness of species and the high abundance of fish, artisanal fishers can harvest a large volume of catch in July. The artisanal fishing activity mostly depends on the weather conditions in the Bay of Bengal. However, in Bangladesh, the period between September to March is recognized as the artisanal fishing period when the weather is favorable, and the sea is calm. The total annual catch also varies with the use of different fishing technologies. The data from the last decade (2007-2018) shows a trend of gradual increase in the amount of the annual catch of artisanal fishery (Figure 1). The highest catch was recorded to be 534,600 t in 2018 and the lowest catch was 452,047 t in 2007.

On the other hand, the maximum number of gear (242,450) was recoded in 2012 and 2013 while the minimum effort was observed in 2018 (188,707). Thus, the fishing effort was increasing until 2013, after which it has been on a decline. This is a result of a few management strategies that have been implemented, such as licensing a fishing vessel or craft, controlling the use of illegal fishing gear, and banning fishing (Ghosh et al., 2016; DoF, 2018).

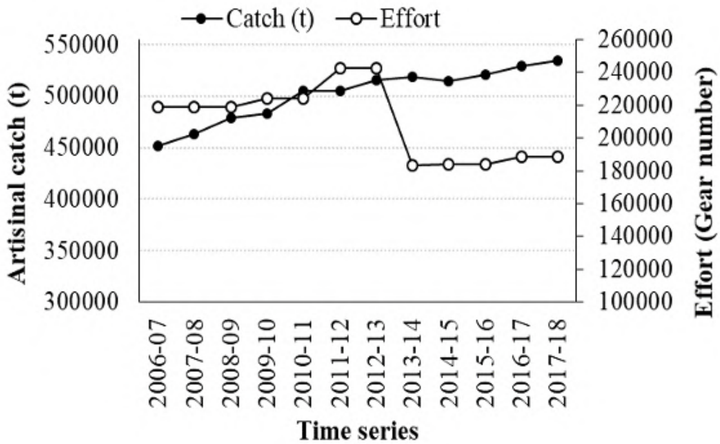

Figure 1. Catch-Effort trend of artisanal fisheries in Bangladesh

A total of 52 species of finfish and 10 species of shrimp were reported from the artisanal catch in the coastal waters of Bangladesh (Table 1). Among them, *Otolithoides argenteus, Trichiurus haumela, Tenualosa ilisha, Escualosa thoracata, Harpadon nehereus, Arius sp., Leigonathus sp., Johnius argentus, Cynoglossus sp* are the most abundant and have the highest commercial value. Among the shrimp, *Penaeus monodo*n is the main target species because of its high market demand; at the same time, *Metapenaeus monoceros* was reported as the highest contributing species among the total shrimp catch (Ghosh et al., 2016).

Table 1. Available fish and shrimp species harvested by the artisanal fishers from the Bay of Bengal water, Bangladesh, with their IUCN status (LC=Least Concern, NT=Near-threatened, NE=Not Evaluated, DD=Data Deficient)

SL	Scientific Name	Local Name	English Name	IUCN Red List Status
1.	*Lates calcarifer*	Bhetki	Giant Seaperch	LC
2.	*Cynoglossus lingua*	Kukur jeeb	Long Tung Sole	LC
3.	*Cynoglossus bilineatus*	Kukkurjib	Fourlined tonguesole	LC
4.	*Arius gagora*	Gagla	Gagora catfish	NT
5.	*Mystus gulio*	Nuna Tengra	Long whiskers catfish	LC
6.	*Ephippus orbis*	Hatir Kaan	Spade Fish	NE
7.	*Gerres filanmentosus*	Dom Machh	Silverbiddies	LC
8.	*Pentaprion longimanus*	Jagiri	Longfin Mojarra	LC
9.	*Harpadon nehereus*	Loittya Machh	Bombay duck	NT
10.	*Drepane longimanna*	Pann Machh	Sicklefish	NE
11.	*Lactarius lactarius*	Sadha Machh	False Trevally	NE
12.	*Lutjanus johni*	Ranga Choukya	Red Snapper	LC
13.	*Lujanus sanguineus*	Ranga Choukya	Blood Snaper	LC
14.	*Lutjanus malabaricus*	Ranga Choukya	Malabar Red Snapper	LC
15.	*Leigonathus brevirostris*	Taka Chanda	Shortnose Ponyfish	NE
16.	*Mene maculata*	Chan Chanda	Moon Fish	NE
17.	*Upeneus sulphureus*	Sonali Bata	Goat Fish	LC
18.	*Planiliza tada*	Gool Bata	Tade Grey Mullet	DD
19.	*Liza subviridis*	Khurul Bata	Green Back Grey Mullet	NE
20.	*Mugil cephalus*	Khorul Bata	Flathead Gray Mullet	LC
21.	*Valamugil speigleri*	Patha Bata	Speigler's Gray Mullet	NE
22.	*Nemipterus japonicus*	Rupban	Threadfin Bream	LC
23.	*Pomadasys hasta*	Sadha Datina	Lined Silver Grunter	LC
24.	*Pomadasys maculatus*	Guti-Datina	Blotched Grunter	LC
25.	*Polynemus indicus*	Lakhua	Indian Salmon	NE
26.	*Polynemus paradiscus*	Tapsi	Paradise Threadfin	LC
27.	*Eleutheronema tetradactylum*	Thailla	Fourfinger Threadfin	NE
28.	*Platycephalus indicus*	Murabaila	Flat-head Fish	DD
29.	*Priacanthus tayenus*	Pari Machh	Purple-spotted Big Eye	LC
30.	*Psettodes erumei*	Samudra Serboti	Indian Halibut	DD
31.	*Rachycentron canadus*	Samudra Gajar	Cobia	LC
32.	*Saurida tumbil*	Achila	Greater Lizard Fish	LC
33.	*Sillago domina*	Tolar Dandi	Lady Fish	NE
34.	*Otolithiodes pama*	Lambu	Pama Croacker	DD
35.	*Otolithes maculatus*	Gotipoa	Toothed Croacker	LC
36.	*Otolithes cuvieri*	Poa	Tiger-toothed Croacker	LC
37.	*Protonibea diacanthus*	Kala Katina	Spotted Croacker	NT
38.	*Johnius argentatus*	Lalpoa	Silver Pennah Croacker	LC
39.	*Argyrops spinier*	Lal Datina	Longspine Sea Bream	LC
40.	*Sphyraena forsteri*	Dharkuta	Forster's Barracuda	NE
41.	*Pampus chinensis*	Rup Chanda	Chinese Pomfret	NE
42.	*Pampus argenteus*	Foli Chanda	Silver Pomfret	NE
43.	*Coilia dussumieri*	Olua	Pointed Tail Anchovy	LC
44.	*Escualosa thoracata*	Hichiri Machh	White Sardine	LC
45.	*Ilisha fillgera*	Choukya	Big Eye Ilish	DD
46.	*Hilsa ilisha*	Ilish/Hilsa	Hilsa Shad	LC
47.	*Sardinella fimbriata*	Takhia	Fringe-scale Sardine	LC
48.	*Chirocentrus dorab*	Karatia-Chela	Wolf Herring	LC
49.	*Parastromateus niger*	Hail Chanda	Black Pomfret	LC
50.	*Scomberooides commersonianus*	Chapa Kori	Talang Queen Fish	LC
51.	*Selar boops*	Moori/Salar	Oxeye scad	LC
52.	*Alepes djeddaba*	Moori	Djeddaba crevalle	LC
53.	*Penaeus monodon*	Bagda Chingri	Giant black tiger Shrimp	NE
54.	*Penaeus semisulcatus*	Bagatara Chingri	Green Tiger Shrimp	NE
55.	*Penaeus japonicus*	Dorakata Chingri	Tiger	NE
56.	*Penaeus indicus*	Chaga Chingri	Indian white Shrimp	NE
57.	*Penaeus merguiensis*	Baga Chingri	Banana Shrimp	NE
58.	*Metapenaeus monoceros*	Horina Chingri	Brown/Speckled Shrimp	NE
59.	*Metapenaeus brevicornis*	Loilla Chingri	Brown/Yellow Shrimp	NE
60.	*Metapenaeus spinulatus*	Chingri/Icha	Brown	NE
61.	*Parapenaeopsis sculptilis*	Ruda Chingri	Pink/Rainbow Shrimp	NE
62.	*Parapenaeopsis stylifera*	Rida Chingri	Pink/Kiddi Shrimp	NE

Stock status and management information

Both the CMSY and BSM models delivered important stock information and biological reference points (BRPs) for the artisanal fishery in the coastal waters of Bangladesh. The BSM-derived BRPs are considered as the management information. The BSM delivered maximum carrying capacity (*k*) of $3{,}784 \times 10^3$ t, where CMSY produced *k* was $3{,}383 \times 10^3$ t. The catchability coefficient (*q*) estimated from the BSM model was 1.28e-06. The catch fit diagram (Figure 2(a)) showed the fit represented by the median of predicted catch posterior, with 95% confidence limits (grey shaded), compared to the observed catch, and the CPEU fit (Figure 2(b)) shows a similar graph for predicted versus observed CPUE. The catch fit diagram depicted a gradual increase of both observed and predicted catch till 2011; later, the observed catch was higher than the predicted catch. The CPUE fit diagram displayed a baleful fluctuation between observed and predicted CPUE after 2011, during the highest number of fishing efforts reported. The observed CPUE was higher from 2014 to 2016 compared to the predicted or expected CPUE, which could lead to the decline of stock biomass and limit or hamper the production of the Maximum Sustainable Yield (MSY) of the artisanal fishery in the coastal water of Bangladesh. However, because of the control of the fishing effort in later 2016, there was no remarkable variation between the predicted and the observed catch and CPUE respectively in the last year (2018). This is a good sign for retaining the sustainability of this fishery. Nevertheless, this finding is not enough to justify and ensure the sustainability of artisanal fisheries of Bangladesh because MSY is considered to be the most important target reference point for sustainable fisheries management. The catch diagram (Figure 2(c)) of the artisanal fishery shows the relative catch estimation of MSY from the BSM model, with an indication of 95% confidence limits in the grey area. The BSM analysis results revealed that catches have been steadily increasing from 2007 to 2018, crossing the MSY line. Meanwhile, MSY for 2018 was 529×10^3 t year^{-1}, with 95% CL ranging from 445×10^3-630×10^3 t

$year^{-1}$. The catch value in 2018 was estimated as 534,600 t (534.6×10^3 t $year^{-1}$), which was higher than the previous year's MSY value (529×10^3 t in 2018), indicating the impacts of overfishing in the coastal waters of Bangladesh. To maintain the safe status of artisanal fishery in Bangladesh, the total allowable catch in a year should be strongly maintained as per the delivered MSY limit of BSM.

The stock biomass size exhibits the growth of relative total biomass (B/B_{MSY}), with the grey area specifying the uncertainty (Figure 2(d)). In 2018, Biomass (B) was estimated as $1,777 \times 10^3$ with 2.5^{th} percentile to 97.5^{th} percentile, ranging from, $1,161 \times 10^3$ to $2,407 \times 10^3$ t. The artisanal fishery population size at the maximum growth rate (B_{MSY}) was measured as $1,892 \times 10^3$ t with a 95% confidence level, ranging from $1,234 \times 10^3$ to $2,902 \times 10^3$ t. Further, the value of B/B_{MSY} was calculated as 0.939 with 2.5^{th} percentile to 97.5^{th} percentile ranging from 0.614 to 1.270. Here, the estimated biomass (B) value is smaller than the value of Biomass that can produce MSY (B_{MSY}). The $B < B_{MSY}$ directed that the biomass level is insufficient to produce MSY in artisanal fishery in the Bay of Bengal.

The exploitation figure explains relative exploitation (F/F_{MSY}), with F_{MSY} corrected for reduced recruitment below 0.5 B_{MSY} (Figure 2(e)). Maximum rate of fishing mortality F_{MSY} (the proportion of a fish stock exploited and removed by fishing) was 0.28,with 95% CL = 0.182 - 0.431 (if $B > 1/2\ B_{MSY}$ then $F_{MSY} = 0.5\ r$) and $F_{MSY} = 0.28$, 95% CL = 0.182 - 0.431 (r and F_{MSY} are linearly reduced if $B < 1/2\ B_{MSY}$). The fishing mortality (F) in 2018 was estimated at 0.299 with 2.5^{th} percentile to 97.5^{th} percentile ranging from 0.221 to 0.458. The exploitation (F/F_{MSY}) was 1.08 and the $F > F_{MSY}$ showcases that the overfishing is occurring. In addition, the exploitation figure shows that the relative exploitation line was always above the MSY line, indicating the excessive harvesting of fish in the Bay of Bengal.

To show the existing stock status and exploitation rate to target reference points (TRPs) such as F_{MSY} and B_{MSY}, Kobe phase plot was used. There are four color quadrants (orange, red, yellow, and green) in a Kobe plot defined for the stock biomass and fishing mortality relative to B_{MSY} andF_{MSY}, respectively. The orange-colored area specifies the healthy stock sizes that are about to be depleted by overfishing. The red-colored quadrant indicates that the stock is overfished and is undergoing overfishing conditions where the biomass levels are not capable to produce maximum sustainable yields. The yellow quadrant shows the too low biomass level, but the stock can be restored or recovered in a sustainable state if the fishing pressure is reduced. The green-colored area is the target area for the management, indicating sustainable fishing pressure and a healthy stock size capable of producing high yields close to MSY. In the Kobe phase plot, the 'banana' shape around the assessment of the final year triangle indicates uncertainty, with yellow for 50%, grey for 80%, and dark grey for 95% confidence levels. The legend in the upper right of the plot indicates the probability of the last year falling into one of the colored areas, such as that there is a 31.0% probability that the stock is in the green area, a 5.5% probability that it is in the yellow area, a 57.2% probability that it is in the red area and a 6.3% probability that it is in the orange area. However, the BSM-derived management information indicated that the Bay of Bengal artisanal fishery stock status is now in the red quadrant (Figure 2(f)). Furthermore, F/F_{MSY} is >1 while the B/B_{MSY} value is <1, estimated based on the BSM model. The calculated F/F_{MSY} on B/B_{MSY} and the stock in the red quadrant indicates that the stock is being overfished with current biomass levels being too low to produce the MSY.

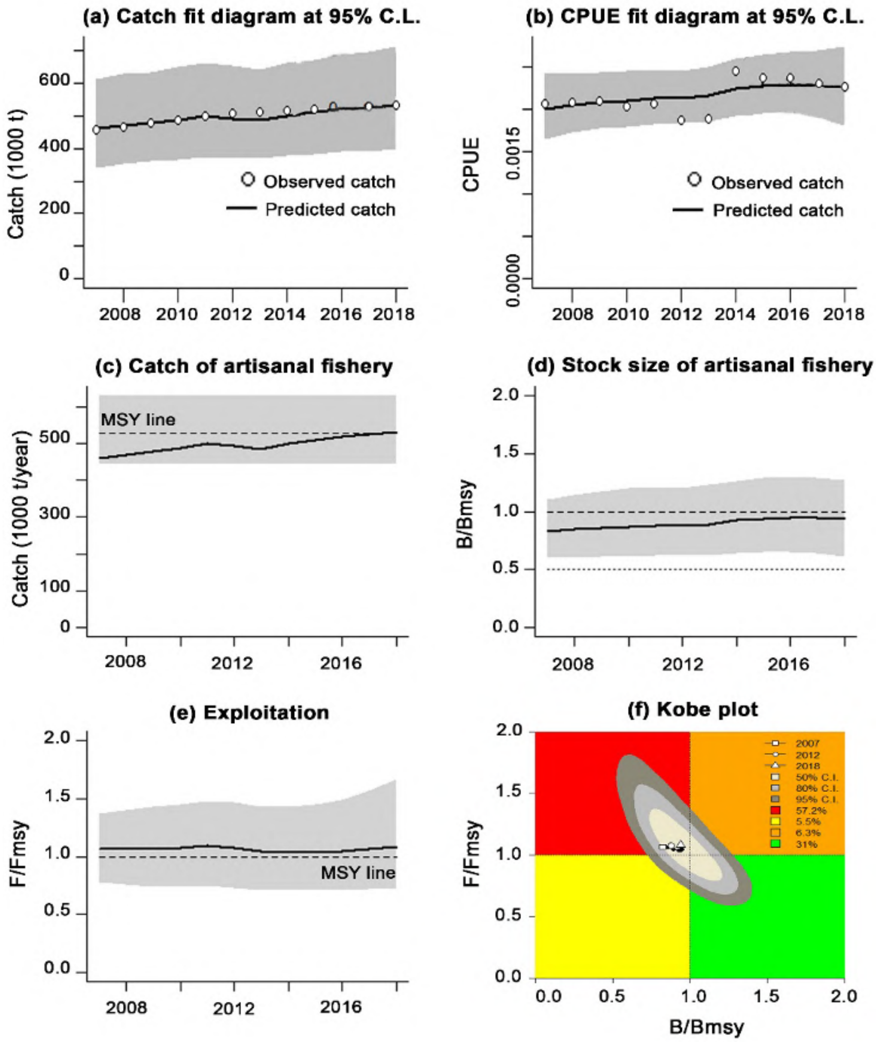

Figure 2. The CMSY and BSM-derived information representing the stock status of the artisanal fishery of Bangladesh.

Conclusion

For a long time, the artisanal fishery has been contributing a major portion of marine catches and has played a significant role in the livelihood of millions of people in coastal areas of Bangladesh. Year after year, the number of fishers and fishing efforts are increasing, resulting in exploitation of this important fisheries sector. Though fish is a renewable resource, overfishing causes the depletion of fish biomass and decreases the fishery. As such, continuous scientific stock-assessment is important to ensure the sustainability of such exploited fishery. This study provided basic information about the stock status and indicated the unsustainable status of the artisanal fishery of Bangladesh. The people of the coastal region are considered to be the most vulnerable communities due to natural disasters and marine challenges. Furthermore, mismanagement or unsustainability of artisanal fisheries resources can be a big threat to the existence of the artisanal fisheries community in Bangladesh. Based on the findings of this research, the government and related stakeholders should take immediate measures to save the fishery and thus ultimately secure the future of the artisanal fishing communities of Bangladesh.

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Author the author

Partho Protim Barman has been a faculty of the Department of Coastal and Marine Fisheries at Sylhet Agricultural University (SAU) since October 2013. He has completed BSc. in Fisheries and Master's in Coastal & Marine

Fisheries from SAU. Currently, he is a doctoral fellow in the Laboratory of Fish Population Dynamics, College of Fisheries, Ocean University of China, Qingdao, China. His research focuses on stock assessment and management of the Bay of Bengal Fisheries, Bangladesh. Mr. Barman aims to work for the sustainability of the fisheries resources of the Bay of Bengal using different statistical methods.