SUSTAINABLE AQUATIC RESEARCH

Sustainable Aquatic Research (2023) 2(2):129-144
DOI: 10.5281/zenodo.8302192
e-ISSN: 2822-4140

SUSTAINABLE AQUATIC RESEARCH
www.saquares.com

RESEARCH PAPER

Spawning Season, Spawning and Nursing Grounds Identification of Asian Seabass, *Lates calcarifer* (Bloch, 1790) in the Bay of Bengal, Bangladesh

Mohammed Ashraful Haque[1,2*], Md. Istiaque Hossain[2], Shanur Jahedul Hasan[1], Probin Kumar Dey[3], Md. Ashekur Rahman[2], Yahia Mahmud[1]

[1]*Bangladesh Fisheries Research Institute, Mymensingh, Bangladesh*
[2]*Department of Fisheries, University of Rajshahi, Rajshahi, Bangladesh*
[3]*Department of Fisheries, University of Chittagong, Chittagong, Bangladesh.*

Citation

Haque, M.A., Hossain M.I., Hasan, S.J., Dey, P.K., Rahman, M.A., Mahmud, Y. (2023). Spawning Season, Spawning and Nursing Grounds Identification of Asian Seabass, *Lates calcarifer* (Bloch, 1790) in the Bay of Bengal, Bangladesh. *Sustainable Aquatic Research*, *2*(2), 129-144.

ArticleHistory

Received: 26 June 2023
Received in revised form: 19 August 2023
Accepted: 21 August 2023
Available online: 31 August 2023

Corresponding Author

Mohammed Ashraful Haque
E-mail:ashrafbfri@gmail.com,
Tel: +880-1712-781357

Keywords

Lates calcarifer
Spawning ground
Nursery ground
Bay of Bengal
Gonadosomatic Index

Abstract

The Asian seabass is a coastal perciform fish, faces limitations in natural recruitment due to a lack of suitable spawning and nursing habitats in the coastal waters of Bangladesh. This study aimed to uncover the spawning season, as well as spawning and nursery grounds, for seabass in the Bay of Bengal, Bangladesh. The research employed direct seabass collection, supported by the Gonadosomatic index and histological study, to identify the spawning phase. Findings revealed that seabass spawning aligns closely with the lunar cycle, with spontaneous spawning occurring during the new and full moon during the transitional monsoon period (April-June). Local fishermen have been harvesting seabass in the Moheskhali channel for over 50 years. A total of 762 running ripe males and females were captured from spawning grounds, exhibiting a male-to-female sex ratio of 4:1. Approximately 80% of females were observed in egg-releasing condition, with some partially spent and others initiating egg-laying post-capture without abdominal pressure. The peak spawning period was in May, with the entire spawning season spanning from April to June. Among 17 sampling sites, three were identified as seabass spawning grounds (Fadarchar, Bukkhilanirchar, and Barchar), while eight were identified as nursery grounds (SM para, Nuniarchara, Ghativanga, Chowfaldandi, Ramu, Gomatoli, Dulahazara, and Badarkhali). Seabass nursery periods extended from May to September, with the catch per unit effort of seabass larvae in nursery grounds ranging from 50-80 individuals/hour. The study underscores the need for habitat conservation and management to enhance reproductive and recruitment success, ultimately enhancing Asian seabass populations in Bangladesh.

Introduction

Asian seabass, *Lates calcarifer* (Bloch, 1790), is a popular food fish of the family Latidae distributed widely across the Indo-West Pacific region, including the Bay of Bengal, Bangladesh (Haque et al., 2019). This species is known by various common names in different parts of its range, including "Bhetki/Coral" in Bangladesh and "Barramundi" in Australia (Siddik et al., 2016). *L. calcarifer* is a catadromous species inhabiting rivers before returning to seawater to spawn, as well as protandric hermaphrodites showed one of the most complicated life histories among fishes (Moore, 1979; Moore and Reynold, 1982; Vij et al., 2014). Due to its high market value, it has turned into an appealing item for both large and small-scale aquaculture companies. To ensure a year-round rather than a seasonal supply of fish seed, induced breeding techniques are essential to reach the production target (Rahman et al., 2020).

Spawning and nursery grounds are important areas for fish survival and reproduction and play a key role in supplementing fishery resources (Hossain et al., 2014). As a critical and vulnerable period in the life cycle of a fish population, the distribution of hatchlings and fish larvae is influenced not only by the spawning behavior of fish and ocean dynamics (currents, eddies, and upwelling, etc.) but also by water temperature, salinity, water depth, and topography (Frost et al., 2006). The Asian seabass is a commercially important and popular food fish in Bangladesh (Siddik et al., 2016). Seabass was abundant in the coastal and estuarine ecosystems of Bangladesh (Islam et al., 2023). Very little information was available on seabass spawning season as well as spawning and nursery grounds. In Bangladesh, naturally collected seabass fries and fingerlings were sold to farmers in Cox's Bazar and Satkhira regions. There seems to be steadily increasing seabass fry demand in coastal areas for aquaculture purposes in Bangladesh (Haque et al., 2019). Being a native coastal fish of the Bay of Bengal, unfortunately, Bangladesh did not take any successful initiative for adopting the technologies for breeding and aquaculture of Asian seabass, yet.

Therefore, the aim of the current study was to identify the spawning season and spawning and nursing ground identification through different approaches. It is essential to determine the spawning season, spawning and nursery grounds identification of Asian seabass and its ecological characteristics in the Bay of Bengal, Bangladesh, to conserve the sustainable seabass fishery in this region as well as breaking the bottleneck of the failure to an develop artificial breeding technology in Bangladesh.

Materials and Methods

Study area and period

The study was led in the Moheskhali Channel and its tributaries, the north-eastern part of the Bay of Bengal, Bangladesh. A total of seventeen sampling sites were selected for identifying seabass spawning and nursery grounds in the Northeast Bay of Bengal, Cox's Bazar, Bangladesh, as shown by the geographic positions in Figure 1 and Table 1. The study was performed from July 2018 to June 2021. Both primary and secondary data were collected to identify the spawning season, spawning, and nursery grounds of Asian seabass. The indigenous knowledge of local seabass fishers was collected through field surveys (180 respondents) and three focus group discussions (FGD).

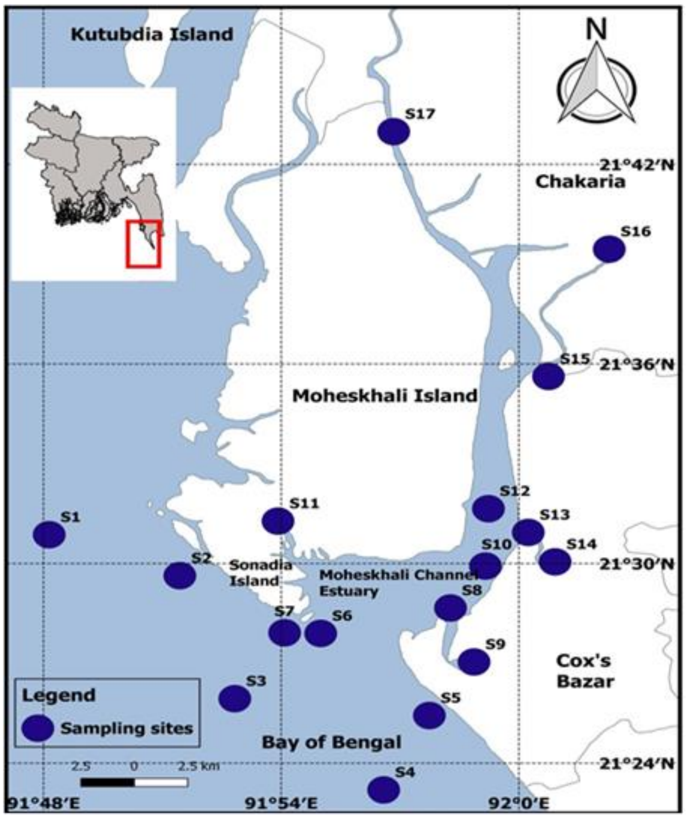

Figure 1. The sampling sites map for spawning and nursery ground identification of Asian seabass in the Northeast Bay of Bengal, Cox's Bazar, Bangladesh.

Table 1. The geographic position of seabass spawning and nursery grounds sampling sites.

SL	Sampling sites	Water body	Latitude	Longitude
S1	West Sonadia	Inshore Bay of Bengal	21.51˚N	91.80˚E
S2	Barchar	Submerged islets	21.49˚N	91.85˚E
S3	Offshore estuary	Offshore Bay of Bengal	21.43˚N	91.88˚E
S4	Darianagar	Inshore Bay of Bengal	21.38˚N	91.94˚E
S5	Laboni inshore area	Inshore Bay of Bengal	21.42˚N	91.96˚E
S6	Fadarchar	Submerged islets	21.46˚N	91.91˚E
S7	Bukkhilanirchar	Submerged islets	21.46˚N	91.90˚E
S8	Nuniarchara	Bakkhali river-Moheskhali channel estuary	21.47˚N	91.97˚E
S9	SM para	Bakkhali riverside tidal swamps	21.44˚N	92.011˚E
S10	Khuruskul	Brackishwater channel	21.49˚N	91.98˚E
S11	Ghativanga	Mangrove swamps	21.52˚N	91.89˚E
S12	Majerchar	Brackishwater riverine islets	21.52˚N	91.98˚E
S13	Chowfaldandi	Tidal canal and salt field swamps	21.51˚N	92.00˚E
S14	Askarkhil, Ramu	Upper tidal pits & monsoon lagoon	21.44˚N	92.08˚E
S15	Gomatoli	Mangrove swamps	21.59˚N	92.01˚E
S16	Dulahazara	Upper tidal Matamuhuri river	21.64˚N	92.05˚E
S17	Badarkhali	Upper Moheskhali channel	21.71˚N	91.94˚E

Seabass spawning season identification through GSI and gonadal histology

Gonadosomatic index (GSI)

For identifying the spawning and peak spawning season, a total number of 152 mature seabass females were collected from the Moheshkhali channel estuary, northeastern Bay of Bengal, Bangladesh. In the laboratory, the total length (TL) of wild gravid seabass was measured with a measuring scale to the nearest 0.1 cm accuracy, and body weight with a digital balance to the nearest 0.1 g. The gonads were dissected. Before weighing, the moisture was thoroughly wiped out from the ovaries with the help of blotting paper. The gonadosomatic index (GSI %) was calculated by the formula:

GSI (%) = (Gonad weight/Fish body weight) × 100 (Han, 1978)

Histological study of gonad

The ovary was taken out in a perforated plastic holder covered by perforated steel plates. The cleaning, infiltration, and dehydration processes were carried out in an automatic tissue processor. Paraffin-embedded blocks were cut by microtome knife at 4-5 µm size and left the sections into a water bath at a temperature of 37°C. The sections were placed on a glass slide and kept overnight on a slide drier hot plate at 20°C. Then, the sections were stained routinely with hematoxyline and eosin according to the specific staining method described by Humason (1972). The sample containing the slide was covered by a coverslip and mounted with Canada balsam. Next, photographs were taken under a compound microscope (Olympus, CX-41). The histological procedure of gonad following Haematoxylin-Eosin protocol Gonad maturing stages was identified by following Lowerre-Barbieri et al. (2011).

Direct harvesting and observation of the spawning broodstock

To identify the spawning grounds of Asian seabass, nine (9) sampling sites were selectedby using seabass fisher's indigenous knowledge, and data were taken throughout the three (3) years of the study period for identifying the nursery grounds, the larvae, post-larvae, and juveniles from eight (8) sampling stations of Moheshkhali Channel were selected. A specialized drift gill net (Koral jal) for seabass harvesting was deployed during the evening just after the full moon and new moon transition period to catch the gravid seabass. Developing embryo and larvae samples were taken fortnightly during seabass spawning season, using a 90 cm mouth diameter and 0.5 mm mesh size plankton net provided with a flowmeter to calculate the volume of water filtered. The collected samples were preserved on board in 95% ethanol seawater for further analysis.

Environmental parameters of seabass spawning and nursery grounds

The environmental conditions of seabass spawning grounds were assessed through different environmental parameters like temperature, salinity, dissolved oxygen, and pH (HANNA multiparameter, HI98194, Romania), rainfall (from Bangladesh Meteorological Department), water depth (Garmin Striker 4 Fathometer, United States), water current (Ekman current meter, Russia), etc., throughout the study period. Regarding the environmental conditions of nursery grounds, data were collected from May to September each year.

Statistical analysis

After data collection from the survey and FGD, data were coded. All the collected survey data were summarized, scrutinized, and recorded. All the collected survey information was accumulated and analyzed by Microsoft Excel and then presented in textual, tabular, and graphical forms. Multiple regression analysis was done by Microsoft Excel from the recorded environmental parameters and presented as mean ± standard deviation.

Results and Discussion

Spawning season identification by using GSI and gonadal histology study

The month of May was the peak spawning period of Asian seabass in Bangladesh. The GSI was maximum during May when the majority of female fishes were harvested from the Moheshkhali channel estuary and became the least in the post-monsoon period. From September to December, there were no traces of the development of gonads; hence the GSI values were almost nil. In Asian seabass, the development of gonads showed a very fast growth rate during the breeding season (Figure 2).

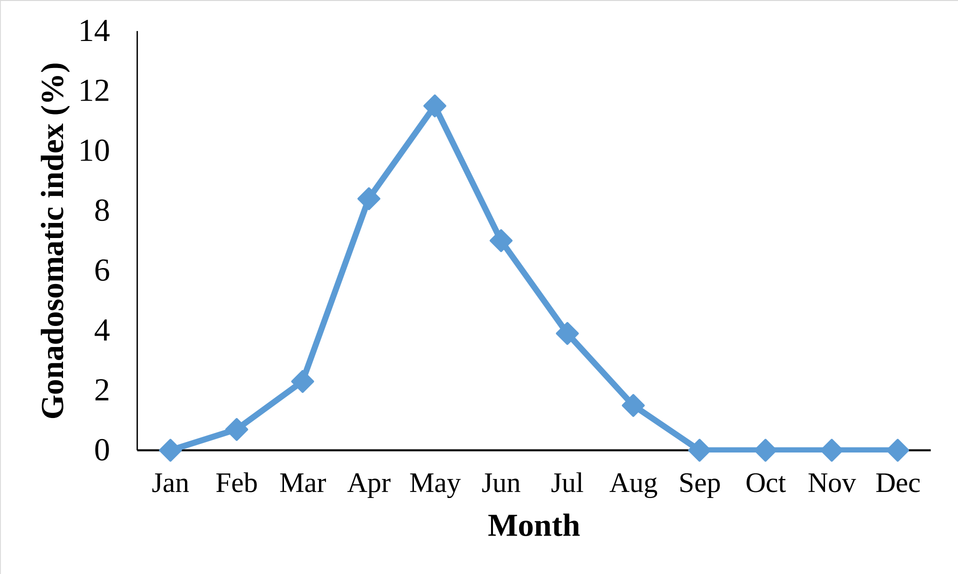

Figure 2. Asian seabass spawning season in Moheshkhali channel estuary Northeastern Bay of Bengal, Bangladesh

The spawning season of seabass varies from place to place. In Bangladesh, single-peak spawning was observed during the transitional monsoon from late April to early June which is similar to the previous study in Bangladesh by Das (2000). Moore (1982) in Papua New Guinea, Mathew (2009) in the Philippines, Lim et al. (1986) in Singapore, Patnaik and Jena (1976), and De (1971) in India also reported that late dry season or transitional monsoon is the peak breeding season of seabass. Only Mathew (2009) reported two breeding seasons in Thailand, mentioning the Northeast monsoon and Southeast monsoon, but no other scientists reported any other countries in this region, even any part of the world regarding the two breeding seasons of seabass. Parween et al. (1993) reported that the GSI increases with the maturation of fish, being maximum during the period of peak maturity and declining abruptly thereafter. In this study, the GSI was maximum during May when the majority of fishes were found as mature.

In the seabass gonadal histology study, the chromatin nucleolar stage oocytes (primary oocyte growth) were found in early March (Figure 3a), the perinucleolar stage was found in late March (Figure 3b), the yolk vesicle formation stage was found in early April (Figure 3c), vitellogenic (yolk) stage was observed in late April (Figure 3d), ripe (mature) stage observed in May (Figure 3e) and resting stage found in September (Figure 3f). The Asian seabass oocyte developmental stages through photomicrographs are shown in Figure 3.

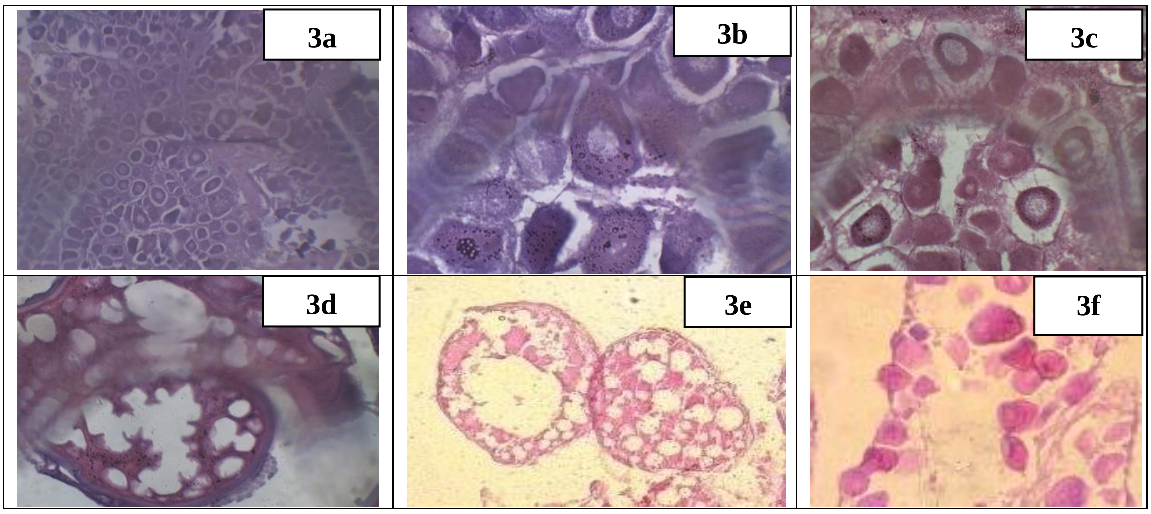

Figure 3. Histological staging of Asian seabass gonad through cross-sections of the ovary (a) Chromatin nucleolar stage oocytes (b) Perinucleolar stage (c) Yolk vesicle formation stage (d) Vitellogenic (yolk) stage (e) Ripe (mature) stage (f) Resting stage

Spawning ground identification by using seabass fisher's indigenous knowledge

Local seabass fishers and their forefathers of Cox's Bazar regions have been harvesting seabass in tidal chars of the Moheskhali channel estuary of the Bay of Bengal, Bangladesh. There were four categories of time span: less than ten years, less than twenty-five years, less than fifty years, and more than fifty years. However, all the respondents mentioned that they got gravid seabass in Moheshkhali channel estuary area for more than fifty years, and the Moheshkhali channel area is famous for female seabass fishing.

Respondents mentioned that almost 100% of female seabass fishes are caught in the transitional period between summer and monsoon. Katersky and Carter (2005) observed the seasonal migration of adult seabass for breeding purposes. Though there are other three categories (summer/pre-monsoon, monsoon, and post-monsoon), no fish were being caught except during the transitional period.

The major portion of seabass broodstock came to Fadarchar islets and the surrounding submerged islets area in the Moheskhali channel estuary for breeding purposes during transitional monsoon. Primarily respondents mentioned that West Sonadia inshore, Barchar, Offshore BoB, Darianagar inshore, Laboni inshore area Fadarchar, Bukkhilanirchar, Nuniarchara, and Majerchar are the spawning ground of Asian seabass. After having the data, it was found that all the respondents (100%) mentioned Fadarchar as the most abundant area for mature seabass. Besides Fadrarchar, Bukkhilanirchar (60%) and Barchar (30%) are also the areas where gravid seabass was subsequently found. Hossain et al. (2014) reported that fishers' indigenous knowledge was very helpful in identifying the Hilsha spawning ground in Bangladesh, where the accuracy level was almost 90%.

Our results indicated that almost three-fourths (73%) of the total catch was 6-10 kg sized seabass, and around one-fifth (21.9%) was 11-15 kg sized seabass. Small (less than 5 kg) and very large (more than 20 kg) sized fish were also caught, but in negligible quantities (Figure 4

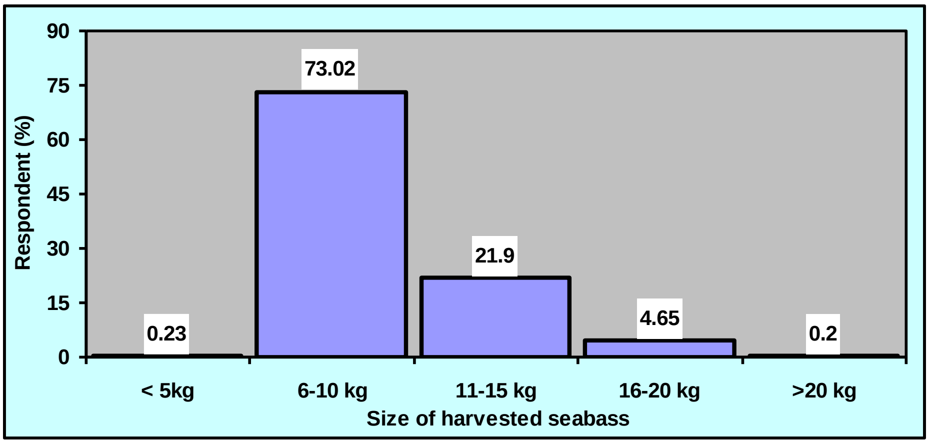

Figure 4. The average individual size of harvested seabass during the breeding season in the study area.

Spawning grounds identification through direct harvesting and observation

A total of 762 ripe males and females were harvested in the Moheshkhali channel estuary during the entire study period. The sex ratio (male: female) of commercial catches in April was 4:1, increasing in May to 4.7:1. The maximum number of running ripe and spent seabass caught in the month of April and May in Fadarchar at the Moheshkhali channel estuary was during the full moon and new moon. About 80% of females were found in egg-releasing condition, some were partially spent, and some were beginning to lay eggs just after catching without any pressure on the abdomen. The monthly catch composition of seabass in the spawning season by drift gill net from the Moheshkhali channel estuary is shown in Table 2.

Table 2. Monthly catch composition of seabass by drift gill net during spawning season from Moheshkhali channel estuary, Cox's Bazar.

Year	Month	Total seabass caught	Male seabass		Female seabass		Reproductive condition (%)
			Nos Percentage (%)	Avg. Wt. (Kg)	Nos Percentage (%)	Avg. Wt. (Kg)	
2019	April	96	77 80.2	4.5	19 19.8	8.7	5 running ripe
	May	124	94 75.8	4.62	30 24.2	9.9	25 spent 35 running ripe
2020	April	128	98 76.6	4.55	30 23.4	9.0	6 running ripe
	May	162	128 79.0	4.6	34 21.0	10.2	30 spent 40 running ripe
2021	April	114	93 81.6	4.48	21 18.6	8.8	4 running ripe
	May	138	104 75.4	4.57	34 24.6	10.0	27 partially spent 40 running ripe

To identify the spawning season and spawning ground of seabass, the spent fish percentage of total seabass catch was measured. Almost 30% of spent fish were found in the Moheshkhali channel in the month of May. Rahman et al. (2015) also found 36.60% spent Hilsa during the major breeding period in the Hilsa spawning grounds of Bangladesh. Davis (1986) reported about aggregations of seabass with ripe-and-running gonads that have been found in the lower estuaries of rivers and their adjacent foreshores. In Bangladesh, the spawning grounds of Hilsa were recognized by the existence of mature and running (oozing) males and females and by catching Hilsa larvae with tentative fishing methods (Rahman et al., 2015). Ellis et al. (2002) stated that mature fish with running eggs or sperm can be indicative of spawning grounds. The quantitative abundance indicates the availability of the gravid seabass at different months and the possible breeding ground of seabass in Cox's Bazar. The gravid seabass was generally available in different locations of the Moheskhali channel estuary in Cox's Bazar. It was observed that gravid seabass was found in three different sites, i.e., Barchar, Fadarchar, and Bukkhilanirchar in the study area. Generally, gravid seabass was available from March to May in different sampling sites at varying degrees. Larvae were moderately abundant in Fadarchar and Bukkhilanirchar from April to May. Some gravid seabass was observed in Barchar from April to May. Matured seabass abundance became higher in late April and May.

Environmental conditions of seabass spawning ground sampling sites

The yearly mean environmental conditions of spawning ground sites are given in Table 3. No significant difference ($P > 0.05$) was found among the environmental conditions of the spawning grounds. The water temperature ranged from 26.67±2.88 to 27.29±2.80 ºC in the study area. Salinity ranged from 22.49±6.63 to 26.02±6.23. Dissolved oxygen varied from 5.10±0.23 to 5.52±0.46 ppm. pH ranged from 7.68±0.03 to 7.77±0.04. The average rainfall in the sampling sites was 258.70±361.26 to 270.51±349.59 mm. Water current and depth were more or less similar in the sampling sites. It was found that more gravid seabass was caught in three sampling sites, i.e., Barchar, Fadarchar, and Bukkhilanirchar, where turbulence formation was observed, while the rest had no turbulence in the study area.

Table 3. Environmental conditions of seabass spawning ground in the sampling sites in the Bay of Bengal, Bangladesh.

Sampling stations	Water temperature (ºC)	Salinity (ppt)	DO (ppm)	pH	Rainfall (mm)	Water current (m/s)	Water depth (m)	Turbulence
West Sonadia	27.1±2.9	25.0±6.2	5.1±0.2	7.6±0.0	263.8±353.3	1.4±0.2	5.4±0.2	
Barchar	27.2±2.9	24.5±6.3	5.3±0.4	7.4±0.1	259.6±361.5	1.5±0.2	2.9±0.3	+
Offshore estuary	27.2±2.9	26.0±6.2	5.2±0.2	7.7±0.0	266.3±372.9	1.5±0.2	4.8±0.4	
Darianagar	27.3±2.7	25.2±6.0	5.1±0.3	7.8±0.1	258.2±362.3	1.4±0.2	4.7±0.4	
Laboni inshore	27.3±2.8	24.7±6.2	5.2±0.3	7.8±0.0	263.9±355.8	1.5±0.2	4.8±0.4	
Fadarchar	27.2±2.9	24.3±6.4	5.5±0.5	7.8±0.1	258.7±361.3	1.9±0.2	3.0±0.3	+
Bukkhilanichar	27.2±2.9	24.4±6.4	5.5±0.4	7.7±0.01	260.6±377.8	1.5±0.2	3.1±0.4	+
Kuruskul	27.2±2.9	22.2±6.7	5.4±0.3	7.7±0.1	270.5±349.6	1.4±0.2	4.2±0.2	
Majerchar	26. 7±2.9	22.5±6.6	5.4±0.3	7.7±0.1	262.9±369.7	1.4±0.2	4.1±0.2	

Note: + means present.

Das (2000) found the range of water temperature at Bakkhali as 23 to 30˚C. Mahmood and Khan (1980) recorded the surface water temperature maximum in

May and minimum in January in the Bakkhali-Moheskhali channel estuary. The water temperature recorded at the Moheshkali channel, and its tributaries more or less coincide with the other studies. The movement of fish to spawning areas and the maturation of gonads were triggered by an increase in water temperature at the end of the dry season (Haroon et al., 2005). Water temperature during the spawning season ranged from 28 to 34°C in Songkhla Lake, Thailand (Maneewongsa and Tattanon, 1982).

Maneewongsa and Tattanon (1982) observed that salinity during the spawning season was high at about 28 to 32 ppt in Songkhla Lake, Thailand. Mathew (2009) observed that sexually mature fish were available in the estuary and in the coastal area where salinity was between 30-32 ppt, and similar results were also observed by Grey (1986), Ayson and Ayson (2012), Yue et al. (2012). The positions of spawning grounds probably differ slightly from year to year, depending on coastal salinities (Moore, 1982; Mathew, 2009). The highest and lowest DO recorded during the present investigation agree with the results of FAO (1985), where the highest and lowest DO were recorded as 4.73 ppm and 6.61 ppm, respectively. Kamal (1982) reported some variations in the DO content of the Moheshkhali channel in the range of 4 to 7.63 ppm. Ahmed (2004) recorded a pH value from 6.5 to 8.3 in the Moheshkhali channel, which is similar to the present study. Boyd (1989), Hossain (2001), and Das (2000) considered standard pH levels from 6 to 9.5 for seabass breeding. Piferrer et al. (2012) reported seabass spawning begins at the onset of or just prior to the monsoon season. The salinity of the estuarine water might be reduced by the increased rainfalls, i.e., due to heavy freshwater mixing (Edwards, 1973). The present investigation found a strong correlation between spawning and saline and freshwater mixture which agrees with the reports of Mclusky and Elliot (2004) and Ahmed (1983).

In this study, it was observed that various factors, i.e., water temperature, salinity, current velocity, pH, DO, water depth, etc., influenced the spawning of Asian seabass. No single factor is solely responsible for spawning. All the environmental parameters are correlated and pre-requisite for natural seabass spawning in the Moheshkhali channel estuary, Bay of Bengal, Bangladesh. Blaber (2000) mentioned that fluctuation of environmental parameters was very frequent due to changes in seasons. Moheskhali channel estuary had significant temporal and seasonal differences in environmental factors during the present study.

Seabass nursery grounds identification

From the study, it was observed that the early stages of larvae and post-larvae of seabass occurred in the supralittoral zone of upper tidal canals connected with the Moheshkhali channel according to the settlement place with almost freshwater environment, e.g., mangroves, coastal swamps and submerged floodplain paddy fields where tidal waters were accessible from the Bay during the highest high tide of the new moon and full moon. The supralittoral zone of upper tidal canals connected with the Moheshkhali channel, the floodplain paddy fields or lagoons were characterized by high natural production due to a combination of intensive solar energy and high nutrients, turn to get enriched tertiary production from organic matter. During the monsoon period, the water level of these areas rises considerably and overflows the coastal swamps, and paddy fields (floodplain lagoon), thus increasing the catchment area of seabass larvae and juveniles. The larvae of seabass ranging from 4.5 to 7.3 cm in length were caught in May-June from the edges of the river and the feeding canals near mangroves and tidal pits where depth varied from 1-2 m. These areas were characterized by smooth bottoms where there were no obstacles like rocks, snags, etc. The juvenile seabass over 20 cm in length were also caught from the edges, but their maximum availability was in the areas where the depth was comparatively greater (2-4 m). Seabass larvae abundance in different sampling stations of the Moheskhali channel and connected rivers and tidal creeks of Cox's Bazar is shown in Table 4.

Table 4. Seabass larvae abundance in sampling stations of Moheskhali channel and connected rivers and tidal creeks, Cox's Bazar.

Sl.	Sampling Sites	Types of habitats	Sampled stage	Sampling gear	Abundance (CPUE)	Period
1	SM para	Floodplain lagoon	Larvae and post larvae	Push net	70-80 ind./hour	Monsoon June -July
2	Nuniarchara	Estuary with mangroves	Larvae	Plankton net	65-75 ind./hour	Early Monsoon May-June
3	Ghativanga	Mangroves	Larvae and post larvae	Push net	60-70 ind./ hour	Early Monsoon May -July
4	Chowfaldandi	Estuary with mangroves	Larvae	Plankton net	60-65 ind./hour	Early Monsoon May-June
5	Ramu	Floodplain lagoon	Juvenile	Push net	80-90 ind./hour	Monsoon June -July
6	Gomatoli	Estuary with mangroves	Larvae	Set bag net	60-65 ind./hour	Early Monsoon May-June
7	Dulahazara	Coastal swamp	Juvenile	Set bag net	50-55 ind./hour	Monsoon June -July
8	Badarkhali	Coastal swamp	Juvenile	Push net	40-50 ind./hour	Monsoon June -July

Note: CPUE, Catch per unit effort.

The quantitative abundance indicates the availability of the seabass larvae at different months and the possible breeding ground of seabass in Cox's Bazar. Seabass larvae are generally available in different locations of the Moheskhali Channel and connected rivers and tidal creeks in Cox's Bazar. Generally, seabass larvae were available from late April to July in different locations of Cox's Bazar at variable degrees. Larvae were highly abundant in Ramu, SM Para, and Ghativanga from May to June. In the June-July months, only a minor number of seabass larvae were observed in Dulahazara and Badarkhali sampling sites. Ahsan et al. (2014) reported that spawning grounds of Hilsa were recognized by the existence of mature and running (oozing) males and females and by catching Hilsa larvae with tentative fishing methods in Bangladesh.

Environmental conditions of seabass nursery grounds sampling sites

The environmental conditions of seabass nursery grounds sampling sites are given in Table 5. No significant difference ($P > 0.05$) was found among the sampling stations. Environmental conditions of nursery grounds data were collected from May to September each year because seabass larvae were found at this time.

Table 5. Environmental conditions of seabass nursery grounds sampling sites in the Bay of Bengal, Bangladesh.

Sampling stations	Water temperature (ºC)	Salinity (ppt)	DO (ppm)	pH	Rainfall (mm)	Water depth (m)
SM paara	30.01±0.96	7.00±5.03	6.07±0.05	7.68±0.09	587.9±387.82	0.27±0.03
Nuniarchara	28.21±2.90	14.35±7.08	5.43±0.34	7.74±0.05	589.38±375.66	1.04±0.15
Ghativanga canal	29.50±0.88	15.00±9.75	6.20±0.06	7.72±0.06	588.65±381.85	0.77±0.05
Chowfaldandi	29.65±0.83	7.10±3.96	6.07±0.08	7.68±0.09	570.81±385.54	0.27±0.05
Ramu	29.39±0.78	5.01±3.74	6.06±0.05	7.76±0.05	591.26±383.65	0.44±0.07
Gomatoli	29.78±0.87	3.10±2.02	6.09±0.09	7.64±0.07	578.92±364.17	0.51±0.06
Dulahazara	29.59±0.81	4.10±3.03	6.21±0.04	7.72±0.08	582.47±377.27	0.62±0.08
Badarkhali	29.63±0.95	4.00±3.09	6.04±0.08	7.69±0.06	567.90±385.61	0.55±0.10

The water in Bakkhali ranged in temperature from 23 to 30 ºC (Das, 2000). Mahmood and Khan (1980) recorded the water temperature maximum in May and minimum in January in the Bakkhali-Moheskhali channel estuary. From this study, it was found that most of the nursery habitat's (except Nuniarchara and Ghativanga canal) ecological characteristics of Asian seabass in Bangladesh were almost freshwater where the salinity level was 3-4 ppt which is similar to the findings of previous research. Bhatia and Kungvankij (1971) found the newly hatched seabass larvae were distributed along the coast of the brackish water estuaries, while the 1 cm larvae were found in freshwater bodies such as rivers, lakes, etc. Krishna et al. (2016) reported that seabass is a top predator in the adult stage but in early larval stages, they are omnivorous in nature. Thus, the distribution pattern of different life stages is diverse in various ecosystems, such as coastal waters, estuaries, and even freshwater. Atiullah (1976) reported that seabass larvae were available in the inshore area of the feeding canals of Karnaphuli river, and dissolved oxygen was 5.92 mg/L which was similar to the present study. Atiullah (1976) recorded that seabass larvae and juveniles were available in the water pH of 7.55 to 7.78, which agrees with the present study. Moore (1979) observed that the spawning season and duration of the seabass breeding period varied from place to place, but breeding was synchronized with the wet season so that larvae could take advantage of the aquatic habitat resulting from rain, which provides a food-rich, predator-free environment for the development of young fish. Atiullah (1976) reported that seabass larvae and juveniles were available in the earlier monsoon (June-July) in the Northeast Bay of Bengal. The findings of the present study were similar to Huda et al. (2003), Atiullah (1976), and Sirikul (1982), who mentioned that seabass fry was abundant in monsoon shallow lagoons, submerged paddy fields, mangrove areas where the depth was 0.12 to 1.0 meter.

Spawning and nursery grounds with geographical map in Moheshkhali channel

The spawning and nursery grounds on a geographical map in the Moheshkhali channel are shown in Figure 5. Other research (Hossain et al., 2014; Russell and Garrett, 1983; Davis, 1984) supports the present results. Moreover, Maneewongsa and Tattanon (1982) reported the conditions of the spawning ground of seabass along Songkhla Lake in Thailand. Spawning begins in April and lasts till October or before the rainy season. In Thailand, spawners are found in the river mouths, salt-water lakes, and along the coastal area (Ruangpanit, 1986). The spawning grounds are generally located in coastal waters near coastal swamps in Papua New Guinea (Moore, 1982), which is similar to this study. In Australia, spawners are found in central and southern Queensland, just inside and outside of river and creek mouths; in northeast Queensland rivers, in shallow side gutters near the mouths (Garrett, 1986); and around coastal mudflats, near the mouths in the southern Gulf of Carpentaria (Davis, 1985; 1986).

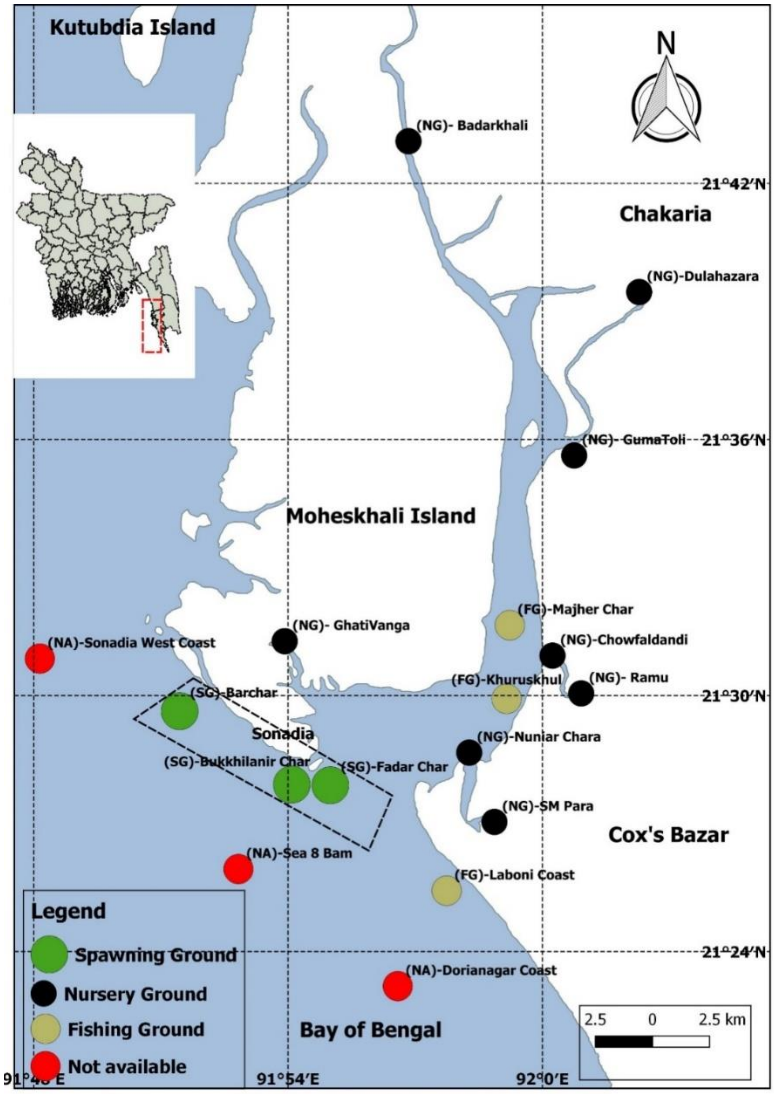

Figure 5. Identified spawning, nursery, and fishing grounds of Asian seabass in the Moheskhali channel estuary, Bay of Bengal, Bangladesh.

Conclusions

This study presents valuable data about the seabass spawning season, spawning and nursery grounds with environmental parameters, and experienced indigenous knowledge in the Moheshkhali channel estuary, Northeast Bay of Bengal, Bangladesh, and these findings can be used for the induced breeding of seabass. This is one of the important baseline data to provide vital information needed to plan management and conservation strategies for Asian seabass in Bangladesh.

Ethical approval

The author declares that this study complies with research and publication ethics.

Informed consent

Not available.

Conflicts of interest

There is no conflict of interest in publishing this study.

Data availability statement

Data will be made available for reasonable requests.

Funding organizations

The authors gratefully acknowledge the National Agricultural Technology Program II Project, Bangladesh Agricultural Research Council, Farmgate, Dhaka, and BFRI Marine Fisheries Research Strengthening and Infrastructural Development Project.

Author contribution

Mohammed Ashraful Haque: Writing original draft, Conceptualization, Investigation, Data curation, Formal analysis.

Md. Istiaque Hossain: Methodology, Software, Supervision.

Shanur Jahedul Hasan: Project administration, Resources.

Probin Kumar Dey: Investigation, Methodology, Review.

Md. Ashekur Rahman: Data curation, Formal analysis.

Yahia Mahmud: Editing.

References

Ahmed. (2004). Soil quality analysis and considerations in the selection of sites for sustainable aquaculture in the south-east coast of Chittagong specially Halishahar area. MSc. Thesis, IMS, CU, p. 75.

Ahmed, M.K. (1983). A checklist of prawn fauna of Bangladesh with some new records, Res. Reports No 7. Freshwater Fish Res. St. Chandpur, Bangladesh, p. 9.

Ahsan, D.A., Naser, M.N., Bhaumik, U., Hazra, S., Bhattacharya, S.B. (2014). Migration, spawning patterns and conservation of Hilsa Shad (*Tenualosa ilisha*) in Bangladesh and India. Ecosystems for Life: A Bangladesh-India Initiative, IUCN. p. 95.

Atiullah. (1976). Studies on the biology of *Lates calacarifer* and its fishery in the Northeast part of the Bay of Bengal. M.Sc. thesis, Institute of Marine Science, University of Chittagong. p. 225.

Ayson, E.G., Ayson, F.G. (2012). Reproductive biology of Asian seabass *Lates calcarifer*. In Jerry Dean, R. (Eds.) Biology and culture Asian seabass *Lates calcarifer*. CRC press, Boca Raton, FL, USA. 67-76 pp.

Bhatia, U., Kungvankij, P. (1971). Distribution and abundance of seabass fry in coastal area of the provinces facing Indian Ocean. Annual report, Phuket Marine Fisheries Station, p. 14.

Blaber, S.J.M. (2000). Tropical Estuarine Fishes: Ecology, exploitation and conservation, Blackwell Science, Oxford.

Bloch, M.E. (1790). Naturgeschichte der ausländischen Fische. Morino, Berlin. Vol. 4, i–xii+1–128, 217-252 pp.

Boyd. (1989). Water quality management and aeration in shrimp farming, Fisheries and allied aquaculture department, series No. 2. Allied aquaculture Experimental station, Alabama University. Alabama, 70 pp.

Das, N.G. (2000). Development of breeding technology of Bhetki (*Lates calcarifer*). Bangladesh Agricultural Research Council (BARC), 18 pp.

Davis, T.L.O. (1984). Estimation of fecundity in barramundi *Lates calcarifer* (Bloch), using an automatic particle counter. *Australian Journal of Marine and Freshwater Research*, 35(1), 111-118.

Davis, T.L.O. (1985). Seasonal changes in gonad maturity, and abundance of larvae and early juveniles of Barramundi, *Lates calcarifer* (Bloch), in Van Diemen Gulf and the Gulf of Carpentaria. *Australian Journal of Marine and Freshwater Research*, 36, 177-190.

Davis, T.L.O. (1986). Migration patterns in barramundi, *Lates calcarifer* (Bloch), in Van Diemen Gulf, Australia, with estimates of fishing mortality in specific areas. *Fisheries Research*, 4, 243-58.

De, G, K. (1971). On the biology of post larvae juvenile stages of *Lates calcarifer* (Bloch). *Journal of the Indian Fisheries Association*, 1(2), 51-64.

Edwards, R.R.C. (1973). Production ecology of two Caribbean marine ecosystems. II, Metabolism and energy flow. *Estuarine and Coastal Marine Science*, 1, 319-333.

Ellis, T., North, B., Scott, A.P., Bromage, N.R., Porter, M., Gadd, D. (2002). The relationships between stocking density and welfare in farmed rainbow trout. *Journal of Fish Biology*, 61, 493-531.

FAO. (1985). Pilot survey of set bag net fisheries of Bangladesh. BOBP/WP/34. FAO, Rome. 26 pp.

Frost, L.A., Evans, B.S., Jerry, D.R. (2006). Loss of genetic diversity due to hatchery culture practices in barramundi (*Lates calcarifer*). *Aquaculture*, 3, 1056-1064.

Garrett, R.N. (1986). Reproduction in Queensland Barramundi (*Lates calcarifer*). Management of wild and cultured seabass, Barramundi (*Lates calcarifer*). Proceedings of an international workshop, Darwin: 38-43 pp.

Grey, D. L. (1986). An Overview of *Lates calcarifer* in Australia and Asia. Management of wild and cultured Seabass/Barramundi (*Lates calcarifer*). Proceeding of an international workshop, Darwin: 15-21 pp.

Han, M. H. (1978). The reproductive biology of dab, *Limanda limanda*, in the North Sea: Gonadosomatic index, hepatosomatic index and condition factors. *Journal of Fish Biology*, 13, 369-378.

Haque, M.A., Hossain, M.I., Uddin, S.A., Dey, P.K. (2019). Review on distribution, culture practices, food and feeding, brood development and artificial breeding of seabass, *Lates calcarifer* (Bloch 1790): Bangladesh perspective. *Research in Agriculture, Livestock and Fisheries*, 6(3), 405-414.

Haroon, A.K.Y., Zaher, M., Sayed, I.A. (2005). Development of broods for mass seed production of seabass (*Lates calcarifer*), Marine Fisheries and Technology Station, Cox's Bazar. Bangladesh Fisheries Research Institute, Mymensingh. 113-117 pp.

Hossain, M.S. (2001). Biological aspects of the coastal and marine environment of Bangladesh. *Journal of Ocean & Coastal Management*, 44 (3-4), 261-282.

Hossain, M.S., Sarker, S., Chowdhury, S.R., Sharifuzzaman, S.M. (2014). Discovering spawning ground of Hilsa shad (*Tenualosa ilisha*) in the coastal water of Bangladesh. *Ecological Modelling*, 282, 59-68.

Huda, M.S., Haque, M.E., Babul, A.S., Shil, N.C. (2003). Field guide to finfishes of

Sundarban, Aquatic resources division, Sundarban, Boyra, Khulna, Bangladesh.

Humason, G.L. (1972). Specific staining methods. Animal tissue techniques. WH Freeman and Co., San Francisco, CA, 183-185 pp.

Islam, M.A., Bosu, A., Hasan, M.M., Yasmin, F., Khan, A.B.S., Akhter, M., Ullah, M.R., Karim, E., Rashid, M.H., Mahmud, Y. (2023). Culture technique of seabass, *Lates calcarifer* in Asia: A review. *International Journal of Science and Technology Research Archive*, 4(1), 6-17.

Kamal. (1982). Studies on the green mussel, *Perna viridis* inhabiting Moheshkhali Channel, Bay of Bengal. M.Sc. thesis. Institute of Marine Science, University of Chittagong.

Katersky, R.S., Carter, C.G. (2005). Growth efficiency of juvenile barramundi, *Lates calcarifer*, at high temperatures. *Aquaculture*, 250(3-4), 775-780.

Krishna, P.V., Panchakshari, V., Prabhavathi, K. (2016). Feeding Habits and Stomach Contents of Asian seabass *Lates calcarifer* from Nizampatnam Coast, Andhra Pradesh, India. *International Journal of Advanced Research*, 4(4), 168-172.

Lim, L.C., Heng, H.H., Lee, H.B. (1986). The induced breeding of Sea bass, *Lates calcarifer* (Bloch) in Singapore. *Singapore journal of primary industries*, 14, 81-95.

Lowerre-Barbieri, S.K., Brown-Peterson, N.J., Murua, H., Tomkiewicz, J., Wyanski, D., Saborido-Rey, F. (2011). Emerging issues and methodological advances in fisheries reproductive biology. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*, 3, 32-51.Mahmood, N., Khan, Y.S.A. (1980). On the occurrence of post larvae and juvenile penaeid prawn at Bakkhali estuary and adjacent coastal area of Cox's Bazar with notes on their utilization in Aquaculture. Final report, research program, UGC, Dhaka: 26.

Maneewongsa, S., Tattanon, T. (1982). Collection and selection of Seabass spawners. In: Report of training course on seabass spawning and larval rearing, Songkhla, Thailand. FAO/SCS/GEN/82/39.

Mathew, G. (2009). Taxonomy, identification, and biology of seabass (*Lates calcarifer*). In: Course manual: National training on cage culture of seabass. CMFRI & NFDB, Kochi, India, 38-43 pp.

McLusky, D.S., Elliott, M. (2004). The Estuarine Ecosystem: Ecology, Threats and Management, third ed. University Press, Oxford. p. 214.

Moore, R. (1979). Natural sex inversion in the giant perch (*Lates calcarifer*). *Australian Journal of Marine and Freshwater Research*, 30(6), 803-813.

Moore, R. (1982). Spawning and early life history of Barramundi, *Lates calcarifer* (Bloch), in Papua New Guinea. *Australian Journal of Marine and Freshwater Research*, 33, 647-661.

Moore, R., Reynold, L.F. (1982). Migration patterns of barramundi, *Lates calcarifer* (Bloch), in Papua New Guinea. *Australian Journal of Marine and Freshwater Research*, 33, 671-682.

Parween, S., Begum, N., Rahman, M.H., Hossain, M.A. (1993). On the breeding periodicity of *Esomus danricus* (Hamilton). *University Journal of Zoology Rajshahi University*, 12, 31-34.

Patnaik, S., Jena, S. (1976). Some aspects of biology of *Lates calcarifer* (Bloch) from Chilka Lake. *Indian Journal of Fisheries*, 1,2, 65-71.

Piferrer, F., Ribas, L., Díaz, N. (2012). Genomic approaches to study genetic and environmental influences on fish sex determination and differentiation. *Marine Biotechnology*, 14, 591-604.

Rahman, M.A., Ullah, M.R., Kabir, M.A., Alam, M.A., Rahman, M., Hossen, M.F. (2020). Artificial propagation of indigenous yellowtail catfish (*Pangasius pangasius*):

Experiences and challenges. *Aquaculture*, 523, 735215. https://doi.org/10.1016/j.aquaculture.2020.735215

Rahman, M.A., Flura, Ahmed, T., Pramanik, M.M.H., Alam, M.A. (2015). Impact of fifteen days fishing ban in the major spawning grounds of Hilsa (*Tenualosa ilisha* Hamilton 1822) on its spawning success. *Research in Agriculture, Livestock and Fisheries*, 2, 491-497.

Ruangpanit, N. (1986). Developing hatchery techniques for Seabass (*Lates calcarifer*): a Review. In: Management of Wild and Cultured Seabass/Barramundi *Lates calcarifer*. Proceeding of an international workshop held at Darwin, N.T. Australia. 132-135 pp.

Russell, D.J., Garrett, R.N. (1983). Use by juvenile barramundi, *Lates calcarifer* (Bloch), and other fishes of temporary supralittoral habitats in a tropical estuary in northern Australia. *Marine and Freshwater Research*, 5, 805-811.

Siddik, M.A.B., Islam, M.A., Hanif, M.A., Chaklader, M.R., Kleindienst, R. (2016). Barramundi, *Lates calcarifer* (Bloch, 1790): A New Dimension to the Fish Farming in Coastal Bangladesh. *Journal of Aquaculture Research & Development*, 7, 461. doi: 10.4172/2155-9546.1000461

Sirikul, B. (1982). Contribution to the FAO UNDP training course on seabass spawning and larval rearing held at the National Institute of Coastal Aquaculture (NICA) Songkhla, Thailand.

Vij, S., Purushothaman, K., Gopikrishna, G., Lau, D., Saju, J.M., Shamsudheen, K.V., Kumar, K.V., Bashee, V.S., Gopalakrishnan, A., Hossain, M.S., Sivasubbu, S. (2014). Barcoding of Asian seabass across its geographic range provides evidence for its bifurcation into two distinct species. *Frontiers in Marine Science*, 1, 30.

Yue, G.H., Xia, J.H., Liu, F., Lin, G. (2012). Evidence for female-biased dispersal in the protandrous hermaphroditic Asian seabass, *Lates calcarifer*. *PLoS ONE*, 7, e37976.