Acta Ichthyologica et Piscatoria 51(1), 2021, 29–36 | DOI 10.3897/aiep.51.63339

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ACTA ICHTHYOLOGICA ET PISCATORIA

Evaluating the size at sexual maturity for 20 fish species (Actinopterygii) in wetland (Gajner *Beel*) ecosystem, north-western Bangladesh through multi-model approach: A key for sound management

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http://zoobank.org/0CEF77D6-DDAB-4BCF-89B0-E50AF451CF87

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Academic editor: Rodolfo Reyes Jr. ♦ **Received** 4 July 2020 ♦ **Accepted** 8 December 2020 ♦ **Published** 31 March 2021

Citation: Hasan MdR, Hossain MdY, Mawa Z, Tanjin S, Rahman MdA, Sarkar UK, Ohtomi J (2021) Evaluating the size at sexual maturity for 20 fish species (Actinopterygii) in wetland (Gajner *Beel*) ecosystem, north-western Bangladesh through multi-model approach: A key for sound management. Acta Ichthyologica et Piscatoria 51(1): 29–36. https://doi.org/10.3897/aiep.51.63339

Abstract

Effective fisheries management depend on having an exact assessment of biological parameters, including growth parameters, reproduction, size at sexual maturity (L_m), and stock assessment. The purpose of this research was to estimate the size at sexual maturity (L_m) for 20 fish species belongs to 14 families from a wetland (Gajner Beel) ecosystem in the north-western (NW) Bangladesh through multi-models such as length (L_{max}) based empirical model, gonadosomatic index (GSI)-based model, and logistic model using commercial catches from January to December 2018. Also, we assessed the L_m in other water-bodies worldwide. Specimens' total length (TL) was noted up to 0.1 cm using measuring board body weight (BW) and gonad weight (GW) weighed by digital electronic balance with 0.01 g accuracy. To assess the L_m, maximum body length (L_{max}) based empirical model; the relation between TL (total length in cm) vs. GSI (gonadosomatic index in %); and a logistic model were considered. The minimum L_m was 4.64, 3.90, and 4.15 cm for *Chanda nama* Hamilton, 1822 and the maximum was 25.33, 24.50, and 24.70 cm for *Channa striata* (Bloch, 1793) through L_{max}, GSI, and logistic-based models, respectively. From these three models, the minimum mean L_m was 4.23 cm for *C. nama* and the maximum was 24.84 cm for *C. striata*. The L_m with 50.0% species was in 8.80 cm TL. We also calculated the L_m from different bodies of water based on L_{max}. This study was generated data of 17 new L_m among 20 species, which are globally absent. Therefore, the study will help develop sustainable management strategies, conservation through the implementation of mesh size based on the size at sexual maturity (L_m).

Keywords

Bangladesh, logistic models, fish species, size at first sexual maturity, Gajner Beel

Introduction

In Bangladesh, fishes are the most affluent organisms, which secure livelihood, contribute food, generate employment, and are used to develop the nation's economy (Hamilton 1971; Godfray et al. 2010; Costello et al. 2012; FAO 2012). The fisheries sector plays a key role in the national economy, contributing 3.50% to the GDP (Gross Domestic Product) of the country and 25.71% in agricultural GDP (DoF 2019). A large variety of aquatic animals

is found in the inland, estuarine, and marine waters of Bangladesh (Rahman 1989).

Bangladesh is fortunate to have vast aquatic resources and rich fish genetic diversity. It has a lot of inland water bodies that host 267 freshwater fish species. Biodiversity of fishes is very essential for nutrition and livelihoods for the rural people in Bangladesh (Thilsted 2013). Fishes, which spend their life in freshwater, (rivers and lakes), where the salinity is below 1.05‰ are considered freshwater fishes. Fishes require a range of physiological modification to live in the freshwater environment (Rohalin et al. 2019).

A land, which is inundated by water, annually or seasonally, permanently or temporarily that is called a wetland (Keddy 2010). Water purification, processing of carbon and other nutrients, maintenance of shorelines, water storage, and assistance of animals and plants are the important functions of a wetland (Butler 2010). Marsh, swamp, pen, and bog are the main types of wetlands (Keddy 2010). The wetlands can be freshwater, brackish, or saltwater (Ramsar Conservation 1971). The Pantanal in South America, the Amazon River basin, the West Siberian Plain (Fraser and Keddy 2005), and the Sundarbans in the Ganges–Brahmaputra delta (Giri et al. 2007) are the largest wetlands on the Earth. Rivers and streams, *Hoars*, *Baors*, Beels, lakes and marshes, reservoirs, ponds, cultivated fields flooded by water, and estuarine systems are considered wetlands in Bangladesh (See Table 1). The freshwater wetlands are Haors, Baors, Beels, and Jheels. The man-made wetlands are dighis, lakes, ponds, and borrow pits (Banglapedia 2004).

Gajner Beel is situated at Sujanagar, Pabna in north-western (NW) Bangladesh. This Beel is used as an imperative feeding and spawning ground by many freshwater fish species. Near about 0.5 million people of surrounding villages of this Beel are directly or indirectly reliant on this wetland for their livelihood (Mazid et al. 2005; Hasan et al. 2020).

Table 1. Types and area of wetlands in Bangladesh.

Types	Wetland	Area [km²]
Open waters	Rivers	7497
	Estuaries and mangrove swamps	6102
	Beels and haors	1142
	Inundable floodplains	54 866
	Kaptai Lake	688
Closed water	Ponds	1469
	Baors (Oxbow Lakes)	55
	Brackish-water farms	1080
	Total	72 899

Effective fisheries management depends on having an exact assessment of biological parameters, including growth parameters, reproduction, size at sexual maturity (L_m), and stock assessment (Tracey et al. 2007). The L_m in fish species is a fundamental requirement to find out the reasons on behalf of modifications of the length of maturity (Templeman 1987). Subsequently, it is habitually castoff as a sign of least-acceptable capture dimensions (Lucifora et al. 1999).

Scanning of the literature shows non-availability of species-specific data on size at sexual maturity (L_m) of these 20 species except *Channa striata* (Bloch, 1793) (see Herre 1924; Makmur et al. 2003), *Gudusia chapra* (Hamilton, 1822) (see Hossain et al. 2010), and *Puntius sophore* (Hamilton, 1822) (see Hossain et al. 2012a) from the Gajner Beel, Bangladesh. The objective of our research is to estimate the L_m for 20 species from the Gajner Beel in Bangladesh that will be helpful for the management strategies of these species in Gajner Beel in Bangladesh and adjacent aquatic ecosystems.

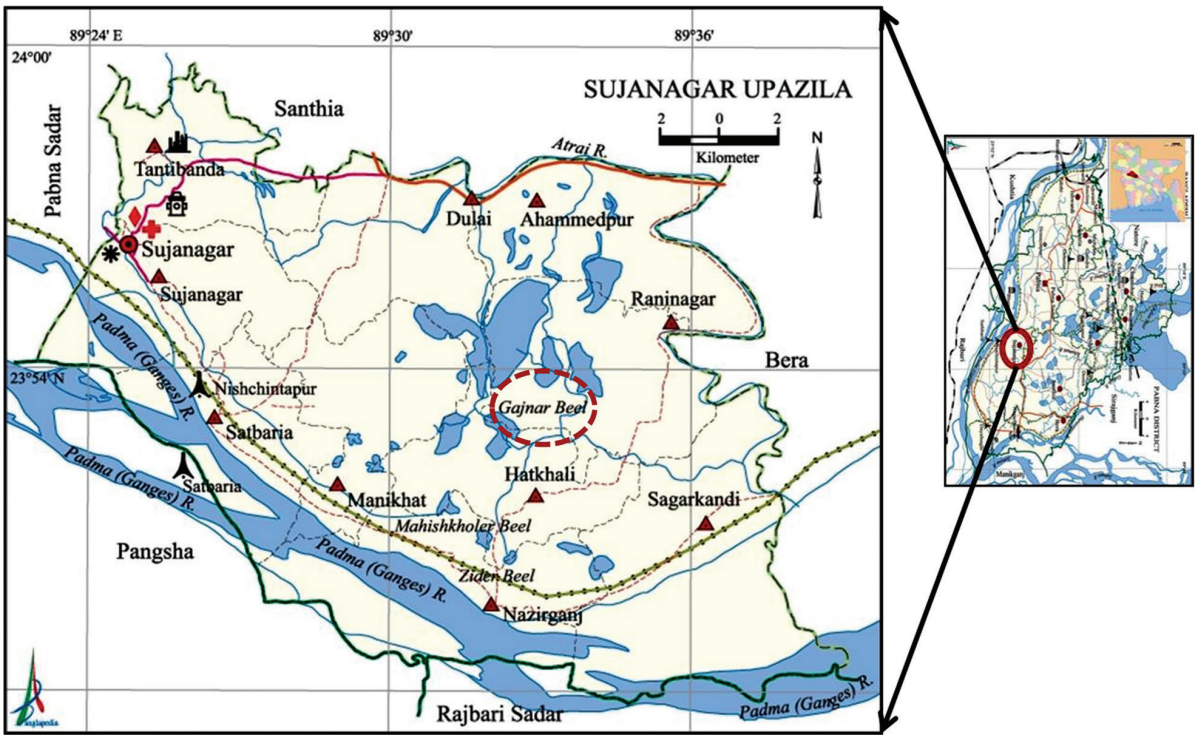

Figure 1. Sampling sites in a wetland ecosystem (Gajner Beel) (indicated by red circle), northwestern Bangladesh.

Materials and methods

The presently reported study was conducted in Gajner Beel (23°55′N, 89°33′E), which is located at Sujanagar, Pabna, NW Bangladesh (Fig. 1). Sampling was done from January to December 2018. Fishes were caught by several types of net (gill nets, long seine) and then preserved in 10% formalin for the further process. Species identification was done by observation of morphometric characters and reviews the various pieces of literature. Each individual was measured by measuring board (0.1 cm) and weighed by digital weight balance (0.01 g). After dissection the fishes, gonads have been removed and weighed. Sexing was determined under the microscopic view, and then only female specimens were used for this analysis. The gonadosomatic index was estimated based on Nikolsky (1963)

$$GSI\ (\%) = GW/BW*100$$

where, GW referred to the gonad weight (g) and BW were body weight (g). The length of 50% maturity (50% L_m) of the 20 fish species was estimated using three models, which were shown in Table 2.

Table 2. Size at sexual maturity of 20 fish species was calculated by these three models.

Model name	Equations	Reference
Empirical model	$\log(L_m) = -0.1189 + 0.9157 * \log(L_{max})$	Binohlan and Froese 2009
GSI based model	L_m = TL vs. GSI	Hossain et al. 2010
Logistic model	$PMI = 100/[1 + \exp\{-f(TL_m - TL_{50})\}]$	King 2007

Analysis of L_{50}, a logistic curve following King (2007) was applied for the data by plotting the percentage of mature individuals (PMI) against TL class. TL = total length (cm), GSI = Gonadosomatic index (%) and L_m = Size at sexual maturity.

Results

Altogether 3040 specimens of 20 fish species were considered in the presently reported study and a list of fish species is given in Table 3. The minimum length was 2.40 cm in TL for *C. nama* and the maximum length was 46.00 cm for *C. striata*. The estimated minimum L_m was 4.64, 3.90, and 4.15 cm for *C. nama* and the maximum was 25.33, 24.50, and 24.70 cm for *C. striata* through L_{max}, TL vs. GSI, and logistic-based models, respectively, and the mean value was 10.04 cm for the 20 species of Gajner Beel, Bangladesh. The maximum length, minimum length, and L_m with 95% CL are given in Table 4. We also calculated the L_m from the different water bodies (Table 5) based on L_{max} which are collected from the previous works on these species by previous workers. As an example of TL vs. GSI and logistic models and figures are presented in Fig. 2. L_m shows that 50% of mature fishes are below 8.80 cm, so the selection of this net-mesh size would protect half the adults in the Gajner Beel ecosystem. On the other hand, 80% of mature fishes are below 12.10 cm, so such a larger, more-conservative mesh size might play a vital role for sustainable fish production in wetland ecosystems (Fig. 3).

Table 3. List of total 20 fish species in a wetland ecosystem (Gajner *Beel*), NW Bangladesh.

Sl. No	Family	Scientific name	Common name
01	Ambassidae	*Chanda nama*	Chanda
02	Anabantidae	*Anabas testudineus*	Koi
03	Bagridae	*Mystus cavasius*	Gulsa
04		*Mystus tengara*	Tengra
05	Belonidae	*Xenentodon cancila*	Kakila
06	Channidae	*Channa orientalis*	Cheng
07		*Channa punctata*	Taki
08		*Channa striata*	Shol
09	Clupeidae	*Gudusia chapra*	Chapila
10	Cobitidae	*Lepidocephalichthys guntea*	Gutum
11	Cyprinidae	*Amblypharyngodon mola*	Moa
12		*Puntius sophore*	Jat punti
13		*Salmostoma bacaila*	Chela
14	Gobiidae	*Glossogobius giuris*	Bele
15	Heteropneustidae	*Heteropneustes fossilis*	Shingi
16	Mastacembelidae	*Macrognathus aculeatus*	Shal baim
17		*Macrognathus pancalus*	Guchi
18	Nandidae	*Nandus nandus*	Bheda
19	Osphronemidae	*Trichogaster fasciata*	Kholisa
20	Siluridae	*Ompok pabo*	Pabda

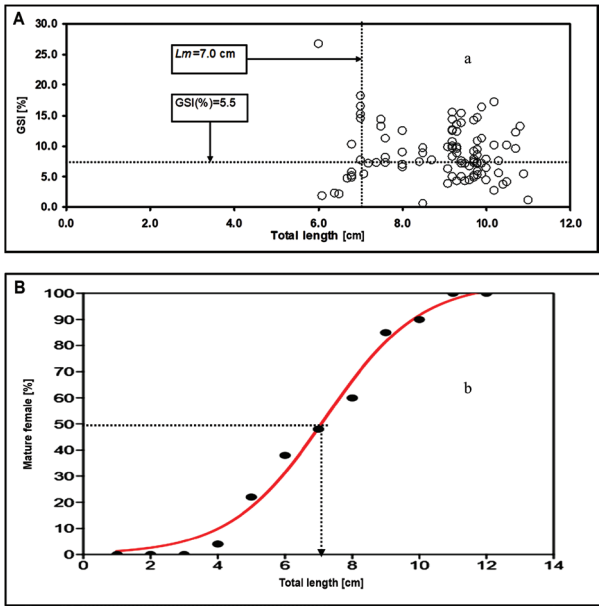

Figure 2. An example figure of size at sexual maturity which produced by TL vs. GSI (**A**) and logistic model (**B**) for the 20 species in wetland ecosystem (Gajner Beel) northwestern Bangladesh.

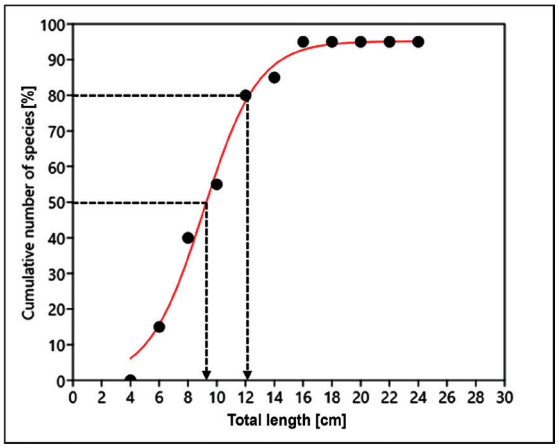

Figure 3. Relation between the maximum total length attained by a species and the number of species attaining that length in a wetland ecosystem (Gajner Beel) northwestern Bangladesh.

Table 4. Size at first sexual maturity (L_m) of 20 fish species in a wetland ecosystem (Gajner *Beel*), NW Bangladesh.

Scientific name	*n*	Minimum length [cm]	Maximum length [cm]	Size at sexual maturity (L_m)			
				Maximum length based	GSI based	Logistic-based models	Mean
Chanda nama	196	2.40	7.20	4.64 (3.81–5.68)	3.90	4.15	4.23
Anabas testudineus	130	7.50	16.40	9.85 (7.84–12.39)	10.20	9.10	9.72
Mystus cavasius	124	5.30	16.90	10.13 (8.05–12.75)	9.80	9.70	9.88
Mystus tengara	139	4.80	12.60	7.74 (6.23–9.65)	7.00	7.10	7.28
Xenentodon cancila	118	8.50	24.00	13.96 (10.95–17.77)	12.98	13.45	13.46
Channa orientalis	152	8.10	19.00	11.27 (8.92–14.24)	12.48	11.00	11.58
Channa punctata	178	5.30	19.40	11.49 (9.09–14.53)	12.20	11.25	11.65
Channa striata	128	9.50	46.00	25.33 (19.35–32.89)	24.50	24.70	24.84
Gudusia chapra	126	4.40	14.60	7.18 (5.79–8.93)	6.90	6.95	7.00
Lepidocephalichthys guntea	117	5.00	10.30	6.44 (5.22–7.98)	6.50	6.20	6.38
Amblypharyngodon mola	193	3.90	7.80	4.99 (4.09–6.13)	4.90	4.85	4.91
Puntius sophore	191	4.20	11.00	6.83 (5.53–8.49)	7.00	6.50	6.78
Salmostoma bacaila	114	4.20	10.00	6.26 (5.09–7.76)	6.50	5.90	6.22
Glossogobius giuris	189	3.90	14.70	8.91(7.13–11.17)	8.10	8.45	8.49
Heteropneustes fossilis	180	6.30	24.10	14.02 (10.99–17.84)	12.20	13.96	13.39
Macrognathus aculeatus	115	8.70	27.00	15.55 (12.14–19.86)	16.18	15.00	15.58
Macrognathus pancalus	190	6.90	15.70	9.47 (7.55–11.89)	9.80	9.00	9.42
Nandus nandus	168	6.50	17.20	10.29 (8.18–12.96)	10.40	9.95	10.21
Trichogaster fasciata	170	3.30	9.30	5.86 (4.77–7.24)	6.00	5.00	5.62
Ompok pabo	122	4.80	17.80	10.62 (8.43–13.39)	9.85	10.20	10.22

Table 5. Calculate the size at sexual maturity based on maximum length from the different water bodies in world wide.

Species name	Sex	Habitat	L_{max} [cm]	L_m (95% CL)
Chanda nama	C	Brahmaputra River tributary, Bangladesh	6.40	4.16 (3.44–5.08)
	C	Deepor *beel*, Assam, India	7.00	4.52 (3.72–5.53)
	C	Hirakud Reservoir, India	10.10	6.32 (5.13–7.83)
	C	Brahmaputra River, Bangladesh	7.40	4.75 (3.91–5.83)
	C	Ganges River, Rajshahi, Bangladesh	7.20	4.64 (3.81–5.68)
	C		11.00	6.83 (5.53–8.49)
Anabas testudineus	C	Chi River, Thailand	16.50	9.91 (7.89–12.46)
	C	Pampanga River, Candaba, Philippines	11.70 (SL)	7.23 (5.84–9.00)
	C	Agusan Marsh, Philippines	17.00	10.18 (8.09–12.82)
	C	Tetulia River, Bangladseh	16.10	9.69 (7.72–12.18)
	C	India	25.00	14.49 (11.35–18.47)
Mystus cavasius	C	Betwa River, India	27.40	15.76 (12.30–20.14)
	C	Ganges River, Bangladesh	15.00	9.08 (7.25–11.39)
	C	Brahmaputra River tributary, Bangladesh	11.30	7.00 (5.66–7.71)
	C	Qadirabad barrage, Chenab River, Pakistan	17.80	10.62 (8.43–13.39)
	C		40.0	22.29 (17.12–28.81)
Mystus tengara	C	Brahmaputra River, Bangladesh	11.20	6.95 (5.62–8.64)
	C	Ganges River, Bangladesh	11.60	7.18 (5.79–8.93)
	C	India	18.00	10.73 (8.51–13.53)
Xenentodon cancila	C	Atrai River, Bangladesh	18.10	10.78 (8.55–13.60)
	C	Hirakud reservoir, India	18.60	11.06 (8.76–13.96)
	C	Chi River, Thailand	23.00	13.43 (10.55–17.07)
	C	India	40.00	22.29 (17.12–28.81)
Channa orientalis	C	Basantar River, India	19.60	11.60 (9.17–14.67)
	C	Gajner *beel* floodplain, Pabna, Bangladesh	18.40	10.95 (8.68–13.82)
	C		33.00	18.69 (14.47–24.02)
Channa punctata	F	Siruvani River, Tamil Nadu, India	24.40	14.18 (11.11–18.05)
	M		25.00	14.49 (11.35–18.47)
	F	Vellar River, Tamil Nadu, India	24.50	14.23 (11.15–18.12)
	M		27.90	16.03 (12.49–20.49)
	F	Cauvery River, Tamil Nadu, India	25.90	14.97 (11.70–19.10)
	M		25.40	14.71 (11.51–18.75)
	F	Tamirabrani River, Tamil Nadu, India	27.40	15.76 (12.30–20.14)
	M		26.80	15.45 (12.06–19.72)
	C	Hirakud Reservior, India	19.20	11.38 (9.01–14.38)
	C	Mathabhanga River, Bangladesh	18.90	11.22 (8.88–14.17)
	C		31.00	17.65 (13.70–22.64)
Channa striata	F	North Kerian rice agoecosystem, Malaysia	54.00	29.34 (22.27–38.28)
	M		45.20	24.93 (19.06–32.35)
	C	Agusan Marsh, Philippines	61.0	32.80 (24.78–42.96)
	C	Chi River, Thailand	51.00	277.84 (21.18–36.26)
	C	Pampanga River, Candaba, Philippines	41.40 (SL)	23.0 (17.65–29.77)

Table 5 continues on next page.

Table 5. cont.

Species name	Sex	Habitat	L_{max} [cm]	L_m (95% CL)
Channa striata	C	Pearl River, China	39.30	21.93 (16.86–28.34)
	C		100.00	51.58 (38.20–68.60)
Gudusia chapra	F	Lake, Mymensingh, Bangladesh	13.70 (SL)	8.36 (6.70–10.45)
	M		12.60 (SL)	7.74 (6.23–9.65)
	C	Lower Brahmaputra, India	13.80	8.41 (6.74–10.52)
	C	Betwa River, India	15.00	9.08 (7.25–11.39)
	C	Hirakud Reservoir, India	11.60	7.18 (5.79–8.93)
	C	Ganges Lower region, Bangladesh	13.40	8.19 (6.57–10.23)
	C		20.00	11.82 (9.33–14.95)
Lepidocephalichthys guntea	C	Atrai River, Bangladesh	8.70	5.51 (4.50–6.80)
	C	Ganges Lower region, Bangladesh	9.60 (SL)	6.03 (4.91–7.46)
	C		15.00	9.08 (7.25–11.39)
Amblypharyngodon mola	F	Wetlands of Dishoi and Neamatighat, Assam, India	9.00	5.69 (4.64–7.02)
	M		6.60	4.28 (3.53–5.23)
	C	Hirakud Reservoir, India	7.20	4.64 (3.81–5.68)
	F	Payra River, Bangladesh	5.80 (SL)	3.80 (3.16–4.63)
	M		5.40 (SL)	3.56 (2.97–4.33)
	C	Atrai River, Bangladesh	6.20	4.04 (3.35–4.93)
	C	Ganges River, Bangladesh	8.10	5.16 (4.23–6.35)
	F	Garjan *beel*, India	8.30	5.28 (4.32–6.50)
	M		7.60	4.73 (4.00–5.98)
	C	Ganges lower region, Bangladesh	5.9 (SL)	3.86 (3.20–4.71)
	C	Mathabhanga River, Bangladesh	7.00	4.52 (3.72–5.53)
	U	South 24 Parganas, India	8.70	5.51 (4.50–6.80)
	C	India	20.00	11.82 (9.33–14.95)
Puntius sophore	C	Ganga basin tributaries, India	18.50	11.00 (8.72–13.89)
	C	Mathabhanga River, Bangladesh	10.20	6.38 (5.18–7.90)
	C	Hirakud Reservoir, India	10.80	6.72 (5.44–8.34)
	C	Brahmaputra River basin, India	7.40 (SL)	4.75 (3.91–5.83)
	C		20.00	11.82 (9.33–14.95)
Salmostoma bacaila	C	Atrai River, Bangladesh	10.50	6.55 (5.31–8.12)
	C	Hirakud Reservoir, India	14.70	8.91 (7.13–11.17)
	C		18.00	10.73 (8.51–13.53)
Glossogobius giuris	C	Brahmaputra River, Bangladesh	9.70	6.09 (4.95–7.54)
	C	Hirakud Reservoir, India	22.50	13.16 (10.35–16.71)
	C	Hongshui River, China	17.50	10.46 (8.30–13.18)
	C	Agusan Marsh, Philippines	19.50	11.54 (9.13–14.60)
	C	Ganges lower region, Bangladesh	23.60	13.75 (14.79–17.49)
	F		22.80	13.32 (10.47–16.92)
	M		23.60	13.75 (14.79–17.49)
	C		17.90 (SL)	10.67 (8.47–13.46)
	C	Estuaries, South Africa	11.90 (SL)	7.34 (5.92–9.15)
	C		50.00 (SL)	27.34 (20.82–35.59)
Heteropneustes fossilis	C	Atrai River, Bangladesh	13.70	8.36 (6.70–10.45)
	C	Gajner *beel* floodplain, Pabna, Bangladesh	16.50	9.91 (7.89–12.46)
	C	Ganga River, India	31.00	17.65 (13.70–22.64)
	C	Gajner *beel* floodplain, Pabna, Bangladesh	26.80	15.45 (12.06–19.72)
	C		24.10	14.02 (10.99–17.84)
Macrognathus aculeatus	C	Ganges River, NW Bangladesh	23.40	13.64 (10.71–17.35)
	C	Thailand	38.00	21.27 (16.37–27.45)
Macrognathus pancalus	C	Atrai River, Bangladesh	12.60	7.74 (6.23–9.65)
	C	Mathabhanga River, Bangladesh	16.20	9.74 (7.76–12.25)
	C	Gajner *beel* floodplain, Pabna, Bangladesh	14.40	8.75 (7.00–10.95)
	C	Hirakud Reservoir, India	16.60	9.96 (7.93–12.53)
	C		18.00	10.73 (8.51–13.53)
Nandus nandus	F	Ganges River, NW Bangladesh	13.60	8.30 (6.66–10.38)
	M		12.60	7.74 (6.23–9.65)
	C	Brahmaputra River, Bangladesh	14.00	8.52 (6.83–10.67)
	C	Mathabhanga River, Bangladesh	14.20	8.63 (6.91–10.81)
	C	Gajner *beel* floodplain, Pabna, Bangladesh	14.10	8.58 (6.87–10.74)
	C		20.00	11.82 (9.33–14.95)
Trichogaster fasciata	C	Deepor *beel*, Assam, India	8.10	5.16 (4.23–6.35)
	C	Gajner *beel* floodplain, Pabna, Bangladesh	9.40	5.92 (4.82–7.32)
	C		12.50	7.68 (6.18–9.58)
Ompok pabo	C		25.00	14.49 (11.35–18.47)
	F	Feni and Gomati River, Tripura, India	19.00	11.27 (8.92–14.24)
	M		20.70	12.19 (9.62–15.45)
	C	Payra River, southern Bangladesh	22.30	13.05 (10.27–16.57)

FishBase: Froese and Pauly (2020).

Discussion

This study referred to the first strive to evaluate the size at sexual maturity of 20 fishes through multiple models in the Gajner Beel wetland ecosystem. The selection of permissible capture size at first maturity is broadly used and it is also used as an important tool in fisheries management (Lucifora et al. 1999; Hossain et al. 2012b) in open waters. Available information on size at sexual maturity of fishes from plots of percentage occurrence of mature females against length class can be obtained from the resulting logistic equation (King 2007). Some studies have narrated low exactness in the estimation of L_m of fishes using this logistic equation (Hossain and Ohtomi 2008; Hossain et al. 2013) but its accuracy for short life cycle organisms is addressed. Garcia (1985) also reported that using the proportion of mature females as an index of population reproduction was highly biased.

Nevertheless, the L_m was estimated by several models including brooding of eggs over time (especially for crustaceans), the appearance of the ovary and maturation stages over time (King 2007), the relative weight of gonad (TL vs. gonadosomatic index, modified gonadosomatic index, and Dobriyal index) over time (Hossain et al. 2017; Ahamed et al. 2018; Khatun et al. 2019), and histological studies (Chelemal et al. 2009; Jan and Ahmed 2019; Lucano-Ramirez et al. 2019). These methods differ with processing time, precision, accuracy, or suitability when we used these singly (De Martini and Lau 1999). To prevent this problem, we used three models (L_{max}, TL vs. GSI, and logistic-based models) and their mean value was used to calculate their size at sexual maturity.

Among the 20 fishes, *C. nama* was the smallest and *C. striata* the largest in TL. Information on L_m was available only for three species (*Channa striata*, *Gudusia chapra*, and *Puntius sophore*) in FishBase (Froese and Pauly 2020). In our study L_m (mean L_m) was 24.84 cm for *C. striata* whereas Makmur et al. (2003) recorded 15.40 and 18.00 cm in the Musi River, south Sumatera, and 25.00 cm was found in Indonesia (Herre 1924). For the *G. chapra* L_m was 7.00 cm in this study. Hossain et al. (2010) narrated 8.00 cm in the Ganges River. We found 6.78 cm L_m for *P. sophore*. Halls et al. (1999), Halls (2005), and Hossain et al. (2012a) reported that L_m was 6.10, 4.50, and 5.00 for the *P. sophore* in the Talimnagar sluicegate, Lohajang River, and Padma River, respectively. The L_m of fish specimens might differ due to several factors like feeding rate, sex and gonadal development, behavior, season, the flow of water, populations density, water temperature, and food (Hossain et al. 2006, 2012a, b; Tarkan et al. 2006; Muchlisin et al. 2010). Most importantly it was the first attempt on L_m for 20 species in Gajner Beel wetland ecosystem so it can be used as baseline information for the future studies and essential for the selection of the permissible mesh size of nets which will be helpful for the sustainable management strategies of these 20 fish species from Gajner Beel in Bangladesh and contiguous ecosystems. Optimum catchable length (L_{opt}) is the length where the biomass of an unexploited cohort would be maximum (Froese et al. 2016). We also observed the L_{opt} which is essential for the management of these 20 fish species (Table 6).

Table 6. Optimum catchable length (L_{opt}) of 20 fish species in a wetland ecosystem (Gajner *Beel*), NW Bangladesh.

Scientific name	*n*	Minimum length [cm]	Maximum length [cm]	Optimum catchable length of individuals (L_{opt})
Chanda nama	196	2.40	7.20	4.80
Anabas testudineus	130	7.50	16.40	10.93
Mystus cavasius	124	5.30	16.90	11.27
Mystus tengara	139	4.80	12.60	8.40
Xenentodon cancila	118	8.50	24.00	16.00
Channa orientalis	152	8.10	19.00	12.67
Channa punctata	178	5.30	19.40	12.93
Channa striata	128	9.50	46.00	30.67
Gudusia chapra	126	4.40	14.60	9.73
Lepidocephalichthys guntea	117	5.00	10.30	6.87
Amblypharyngodon mola	193	3.90	7.80	5.20
Puntius sophore	191	4.20	11.00	7.33
Salmostoma bacaila	114	4.20	10.00	6.67
Glossogobius giuris	189	3.90	14.70	9.80
Heteropneustes fossilis	180	6.30	24.10	16.07
Macrognathus aculeatus	115	8.70	27.00	18.00
Macrognathus pancalus	190	6.90	15.70	10.47
Nandus nandus	168	6.50	17.20	11.47
Trichogaster fasciata	170	3.30	9.30	6.20
Ompok pabo	122	4.80	17.80	11.87

Fish diversity of Gajner Beel wetland ecosystem is declining at a faster rate because of many factors; damage of habitat, aquatic pollution, fishing pressure, natural disaster, extreme floodplain siltation, and reclamation of wetland (Dudgeon 1992; Hossain et al. 2014; Rahman et al. 2016). Therefore, to conserve the wild stock of wetlands, more population surveys and stock assessments are urgently needed. Identification of the causative factors for declining of the species, the establishment of suitable sanctuaries, conservation of habitats, and protection of adult species during the spawning – and/ or peak spawning season is highly recommended. Besides this, the mesh size of harvesting nets based on size at sexual maturity should be confirmed throughout the year for sustainable conservation and management. Furthermore, public awareness is most important for the conservation of this species.

The presently reported study concludes that around 50.0% of species were sexually matured in 8.80 cm TL. So, we strongly suggest that ≤ 8.80 cm TL fishes cannot be recommended for harvesting. As a result, at least 50% of species survive in the wetland ecosystem.

Acknowledgments

We are very much thankful to the Bangladesh Agriculture Research Council, NATP-2, ID: 484 for the financial support to complete this research.

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