ASSESSMENT OF THE EFFICIENCY OF 5TH (20 KM) HILSA SHAD (*TENUALOSA ILISHA*) SANCTUARY OF THE PADMA RIVER (BANGLADESH) FOR SUSTAINABLE POLICY FORMULATION AND CONSERVATION MANAGEMENT

Md. Monjurul HASAN * [(c.a)], *Md. Anisur RAHMAN* *, *Md. Mehedi Hasan PRAMANIK* *, *Flura* *, *Rumana YASMIN* * and *Yahia MAHMUD* **

* Bangladesh Fisheries Research Institute, Riverine Station, Chandpur, Bangladesh, BD-3602, mhshihab.hasan@gmail.com, ORCID: 0000-0002-3178-0666, (corr. auth.), anisur2002@yahoo.com, ORCID: 0009-0008-8151-1748, mehedibfri@gmail.com, ORCID: 0000-0002-8753-0690, flura_bfri@yahoo.com, ORCID: 0009-0004-7813-1614, rumana.biva@gmail.com, ORCID: 0000-0002-0725-1625.
** Bangladesh Fisheries Research Institute, Headquarter, Mymensingh, Bangladesh, BD-2201, yahiamahmud@yahoo.com, ORCID: 0009-0009-7621-3794.

DOI: 10.2478/trser-2023-0023

KEYWORDS: Hilsa, sanctuary, *Tenualosa ilisha*, Padma River, Bangladesh.

ABSTRACT

The studied area is the single largest fishery in Bangladesh. The present work was conducted at two points of the Padma River (Sureshwar and Tarabunia) from July 2019 to June 2021 to monitor the efficiency of the 5th Hilsa sanctuary. Proportion of spent rate, length frequency, larvae and Jatka abundance, CPUE of larvae, the length-weight relationship of Jatka, plankton composition, and physico-chemical parameters of water were assessed and found adequate in the Hilsa sanctuary.

RÉSUMÉ: Évaluation de l’efficacité du 5ème sanctuaire (20 km) d’alose hilsa (*Tenualosa ilisha*) de la rivière Padma, Bangladesh pour la formulation de politiques durables et la gestion de la conservation.

La zone êtudiée est la plus grande pêcherie du Bangladesh. Les présents travaux ont été menés en deux points de la rivière Padma (Sureshwar et Tarabunia) de juillet 2019 à juin 2021 pour contrôler l’efficacité du 5ème sanctuaire de Hilsa. Le pourcentage de taux d’épuisement, la fréquence de longueur, l’abondance des larves et du Jatka, la CPUE des larves, la relation longueur-poids du Jatka, la composition du plancton et les paramètres physico-chimiques de l’eau ont été évalués et jugés satisfaisants dans le sanctuaire de Hilsa.

REZUMAT: Evaluarea eficacității celui de-l cincilea (20 km) sanctuar pentru *Tenualosa ilisha* de pe râul Padma (Bangladesh) pentru formularea politicilor durabile și managementului conservativ.

Zona studiată este cea mai mare zonă de pescuit din Bangladesh. Studiul de față a fost efectuat în două puncte ale râului Padma (Sureshwar și Tarabunia) din iulie 2019 până în iunie 2021 pentru a monitoriza eficiența celui de-al 5-lea sanctuar pentru Hilsa. Procentul de consum, frecvența lungimii, abundența larvelor și Jatka, CPUE a larvelor, relația lungime-greutate a Jatka, compoziția planctonului și parametrii fizico-chimici ai apei au fost evaluate și considerate satisfăcătoare în sanctuarul Hilsa.

INTRODUCTION

Human activities have had a significant negative impact on aquatic ecosystems, jeopardizing their fragile balance and biodiversity (Rasiga et al., 1999; Onciu and Radu, 2006; Paltenea et al., 2008; Gumpinger and Scheder, 2008; Soolutayo, 2012; Kulkarni Balasaheb et al., 2017; Adom, 2018; Tsybulskiy et al, 2023). Pollution from a variety of sources, including industrial discharge, agricultural runoff, and urban trash, introduces hazardous compounds into bodies of water, including heavy metals, pesticides, and plastics (Zubcov et al., 2008; Astratinei and Varduca, 2008; Iepure and Selescu, 2009; Bashir, 2020; Öktener and Bănăduc, 2023). All these contaminants disturb aquatic food chains, injure aquatic animals, and reduce water quality, resulting in eutrophication, hypoxia, and algal blooms (Clarkson, 1995; Smith et al., 1999; González et al., 2021). Overfishing, which is driven by commercial demands and unsustainable practices, depletes fish populations while disrupting the structure and function of marine ecosystems (Pauly et al., 2002; Bardey, 2020). Habitat loss due to dredging, coastal development, deforestation, etc., exacerbates the reduction of aquatic biodiversity (Halpern et al., 2008). The cumulative consequences of these human-induced stresses endanger the health and resilience of aquatic ecosystems, compromising the supply of critical ecological services on which human societies rely (MEA, 2005; Bănăduc et al., 2022; Boeraș et al., 2024). It is vital to develop holistic management approaches and enact strong rules to prevent these harmful impacts and support the sustainable stewardship of aquatic resources for present and future generations.

Rivers and stream ecosystems are critical for biodiversity and delivering essential ecosystem services (Constanza et al., 2011; Alan Yeakley et al., 2016; Vári et al., 2022). Conservation activities focused at safeguarding these freshwater habitats are critical for preserving their ecological integrity and ensuring sustainable water resource management. According to Waters (1996), good river ecosystems not only support various aquatic species, but also help to purify water, regulate floods, and move sediment. Furthermore, the preservation of riparian vegetation along riverbanks is critical for stream bank stabilization, erosion prevention, and riparian terrestrial wildlife habitat (Naiman et al., 1993; Curtean-Bănăduc et al., 2014). Effective conservation techniques, such as habitat restoration, pollution management, and sustainable water use practices, are critical for maintaining the health and resilience of river and stream ecosystems (Vörösmarty et al., 2010). By following these steps, we can protect rivers and streams' biodiversity and ecological functioning for short and long term.

The Padma River is a natural, free-flowing river. This river is one of the major rivers of Bangladesh., located in the north-western part of this country. It is 120 km long and about four to six km wide. The shape of the river has changed significantly over the last 30-35 years. A satellite image of a river change at a NASA site (NASA Earth Observatory) shows that the river changed from a relatively thin straight line to a braided shape. Recently, it has become straight up again. It is formed at the confluence of the Ganga and Jamuna rivers in India. It later merged with the Meghna River in Bangladesh and ended in the Bay of Bengal. Thousands of people besides farmers and fishermen depend on this river. The common perception of general people is that the character of the Padma River is aggressive in terms of its impact on the riparian communities. Due to the wild nature of the river, countless farms, property, and homes have been destroyed and countless lives lost in recent decades, a high number of people have been displaced in other safer areas. This Padma River is famous too for its Hilsa Shad (or Rupali Hilsa), with a highly economic and ecologic importance (Gragnani and Michele 2021).

Following the formulation of The Hilsa Fisheries Management Action Plan (HFMAP) by Bangladesh Fisheries Research Institute (BFRI), four sanctuaries and four breeding grounds were established in 2002-2003. Subsequently, two new nursery grounds (5th and 6th) were implemented by the Department of Fisheries under the supervision of BFRI.

The survey was conducted from BFRI, Riverine Station, Chandpur to assess the previously identified Fifth Hilsa Nursery Ground. That is 20 km wide from the confluence of Meghna, Padma, and Dakatia River to the Sureshwar area. The physico-chemical parameters of water, plankton observations, Jatka CPUE, length-frequency percentage, Jatka length-weight relationship have been studied; juvenile Hilsa is locally called Jatka.

After analysing the collected data from the study area (for two consecutive years), the previously identified nursery grounds were re-evaluated.

This study will serve as crucial documentation to formulate policy for the sustainable conservation of Hilsa fishery resources in the Padma River through sustainable management adoption.

MATERIAL AND METHODS

Study sites and duration

Two sites were selected for conducting the study: a) Tarabunia and b) Sureswar. The study was conducted from July 2019 to June 2021 (Figs. 1-3).

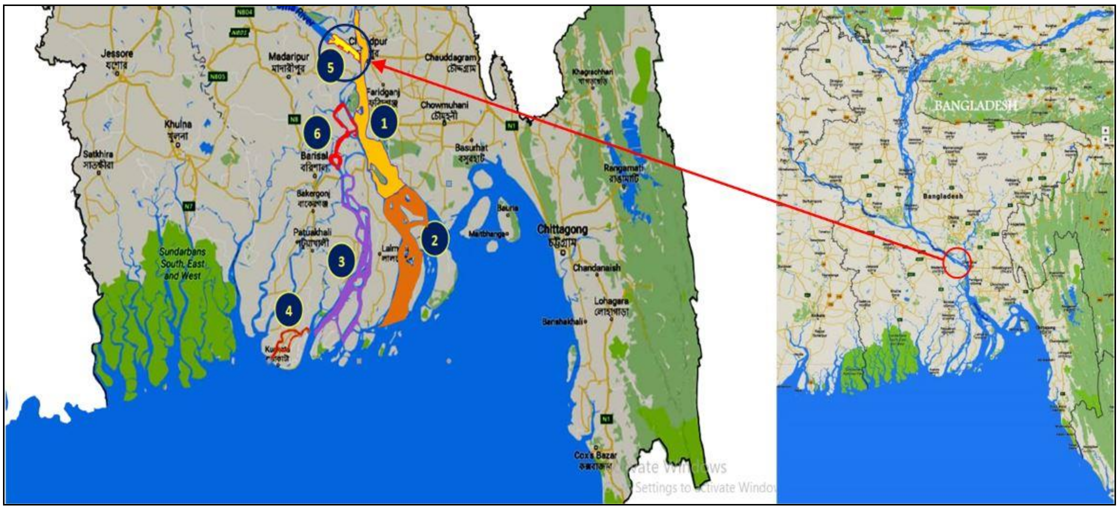

Figure 1: Nursey Grounds
(5^{th} Hilsa Sanctuary, 20 km)
of Padma River.

Figure 2: The studied area detail.

Figure 3: Field work in the study area.

A) Physico-chemical parameters of water

Chemical parameters such as DO, CO_2, pH, Total Alkalinity, Total Hardness, TDS, and Conductivity, as well as physical factors such as air temperature, water temperature and transparency, were monitored directly in each sampling station. HACH (Model FF2, USA) water test kit was used to determine both physical and chemical characteristics.

B) Plankton

During the study, plankton samples were collected from the sampling station via 50-micron plankton net following the standard drop count method. Considering the qualitative and quantitative aspects, one ml concentrated plankton samples were placed in Sedgwick-Rafter counting cells and observed under an electronic microscope (Amscope binocular biological microscope). Ward and Whipple (1959) and Prescott (1962) were used to identifying plankton.

C) Jatka observation

i) CPUE of Jatka: CPUE of Jatka Hilsa were collected by BFRI Experimental Net from the sanctuary and estimated by calculating the amount of Jatka (kg per 100 m net per hour). All the Jatka Hilsa were treated in accordance with the the BFRI rules ethics committee.

ii) Length frequency and percentage: Length frequency data were collected from sampling station. The total length of Hilsa larvae and Jatka was measured by measuring scale and total body weight was taken with an electric digital balance for each fish after the specimens were dried on blotting paper.

iii) Length-weight relationship of Jatka: The relationship between the total length (TL) and total body weight (BW) of fish was estimated by using the following parabolic equation: $BW = aTL^b$; where TW = Body weight of fish in (g); TL = Total length of fish in (cm); a = Proportionality constant (intercept); b = An exponent indicating isometric growth when equal to 3, regression coefficient (slope). The association degree between TL and BW was calculated by the determination coefficient (r^2). Value of theexponent 'b' provides information on fish growth. When $b = 3$, the increase in weight is isometric, otherwise it is allometric (positive allometric if $b > 3$, negative allometric if $b < 3$).

Data analysis

Data was analysed using Microsoft Excel 2010, with representations in pie charts and line diagrams. Additionally, calculations for the length-weight relationship were conducted.

RESULTS AND DISCUSSION

A) Physico-chemical parameters of water. Much work has already been done in Bangladesh to check the river-based physico-chemical parameters. However, relatively little work has been done on the big rivers like Padma, Meghna, and Jamuna. Even less noticeable in the case of the river Padma.

The air and water temperatures varied at both Padma sampling sites, being lower from December to January. Sureswar exhibited higher levels of dissolved oxygen (DO), pH, and transparency compared to the Tarabunia site. Free carbon dioxide showed minor fluctuations in both locations throughout the year. Total alkalinity and total hardness were nearly identical in both sites (Fig. 4).

B) Plankton identification and composition. The present study revealed that among the 13 phytoplanktonic groups studied, Bacillariophyceae was found to be highest (21%) followed by Cyanophyceae (18%), Chlorophyceae (16%), and Zygnematophyceae (11%), Dinophyceae (7%), Euglenophyceae and Coscinodiscophyceae (5%), Trebouxiophyceae and Mediohyceae (4%), Xanthophyceae, Ulvophyceae and Chrysophyceae (2%). Among the four zooplanktonic groups studied, Rotifera shared the highest percentage (37%) followed by Copepoda (36%) and Cladocera (27%) (Tabs. 1 and 2) (Figs. 5-7).

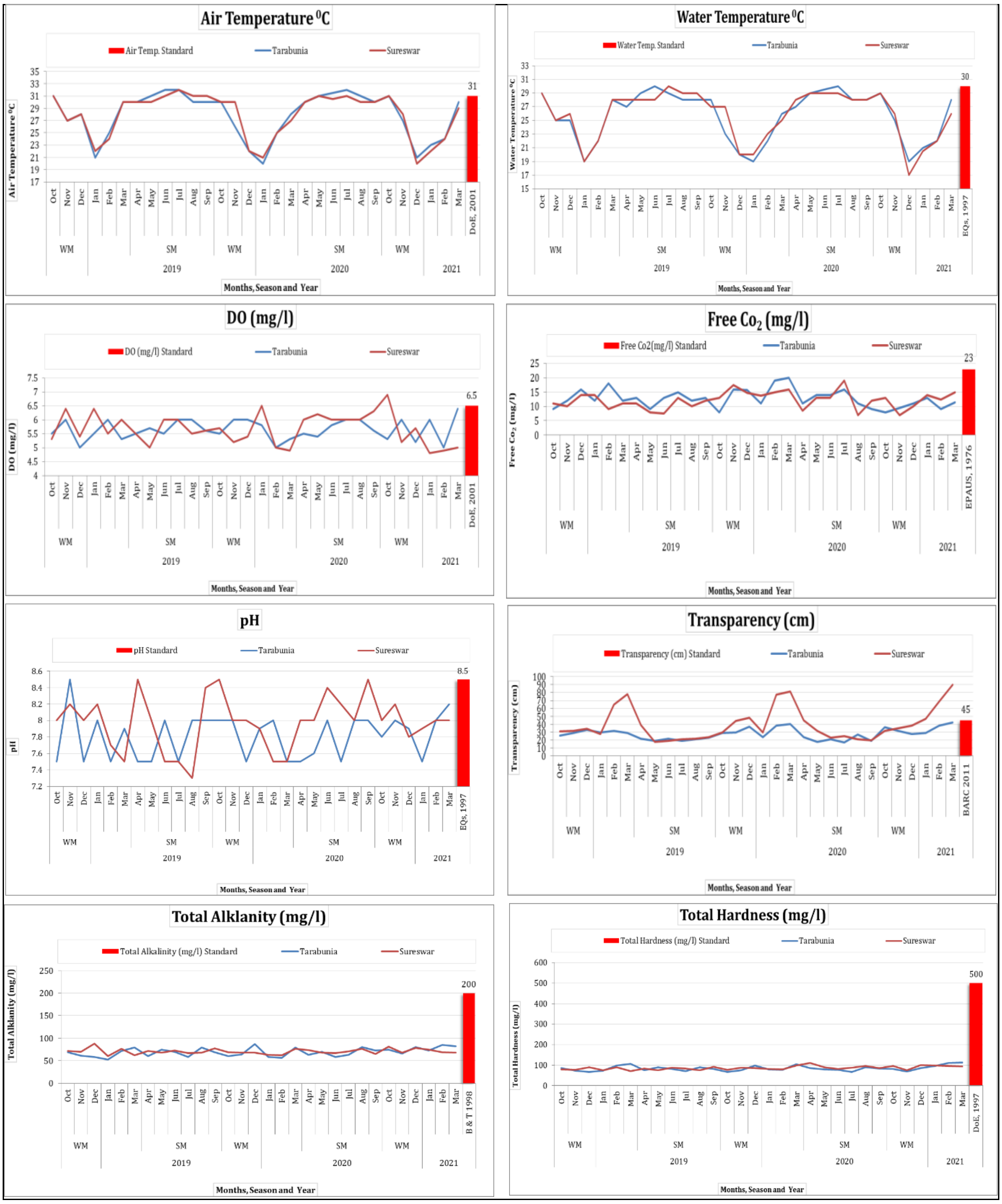

Figure 4: Average water quality parameters of Padma River (2018 to 2021). Eight Parameters (Air Temperature, Water Temperature, Dissolved Oxygen, Carbon Dioxide, pH, Transparency, Total Alkalinity, and Total Hardness) are showing the changes (location and season-wise). Bangladesh standard is highlighted with red bar and data labels. WM = Winter Monsoon, SM = Summer Monsoon (Banglapedia, 2022; National Geographic Society; Eurekalert Organization, 2002).

Table 1: Phytoplankton of Padma River.

Serial number	Phytoplankton group	Species name
1.	Bacillariophyceae	*Amphora* sp., *Asterionella* sp., *Bacillaria* sp., *Cyclotella* sp., *Diatoma* sp., *Fragillaria* sp., *Gomphonema* sp., *Navicula* sp., *Nitzschia* sp., *Striatella* sp., *Synedra* sp., *Tabellaria* sp.
2.	Cyanophyceae	*Anabaena* sp., *Aphanocapsa* sp., *Arthrospira* sp., *Gomphosphaeria* sp., *Merismopedia* sp., *Microcystis* sp., *Nostoc* sp., *Oscillatoria* sp., *Polycystis* sp.
3.	Chlorophyceae	*Ankistrodesmus* sp., *Coelastrum* sp., *Coelastrum* sp., *Microspora* sp., *Pediastrum* sp., *Scenedesmus* sp., *Selenestrum* sp., *Tetraedron* sp., *Volvox* sp.
4.	Chrysophyceae	*Uroglena* sp.
5.	Conjugatophyceae	*Spirogyra* sp., *Staurastrum* sp.
6.	Coscinodiscophyceae	*Coscinodiscus* sp., *Melosira* sp., *Triceratium* sp.
7.	Dinophyceae	*Ceratium* sp., *Dinophysis* sp., *Peridinium* sp., *Prorocentrum* sp.
8.	Euglenophyceae	*Phacus sp.*, *Euglena* sp., *Trachelomonas* sp.
9.	Mediophyceae	*Skeletonema* sp., *Thalassiosira* sp.
10.	Trebouxiophyceae	*Actinastrum* sp., *Oocystis* sp.
11.	Ulvophyceae	*Ulothrix* sp.
12.	Xanthophyceae	*Tribonema* sp.
13.	Zygnematophyceae	*Closterium* sp., *Cosmarium* sp., *Muogeotia* sp., *Spirogyra* sp., *Staurastrum* sp., *Zygnema* sp.

Table 2: Zooplankton of Padma River.

Serial number	Zooplankton group	Species name
1.	Rotifera	*Asplanchna* sp., *Brachionus* sp., *Filinia* sp., *Keratella* sp.
2.	Cladocera	*Bosmina* sp., *Daphnia* sp., *Moina* sp.
3.	Copepoda	*Cyclops* sp., *Diaptomus* sp., *Naupleus* sp.,*Mesocyclops* sp.

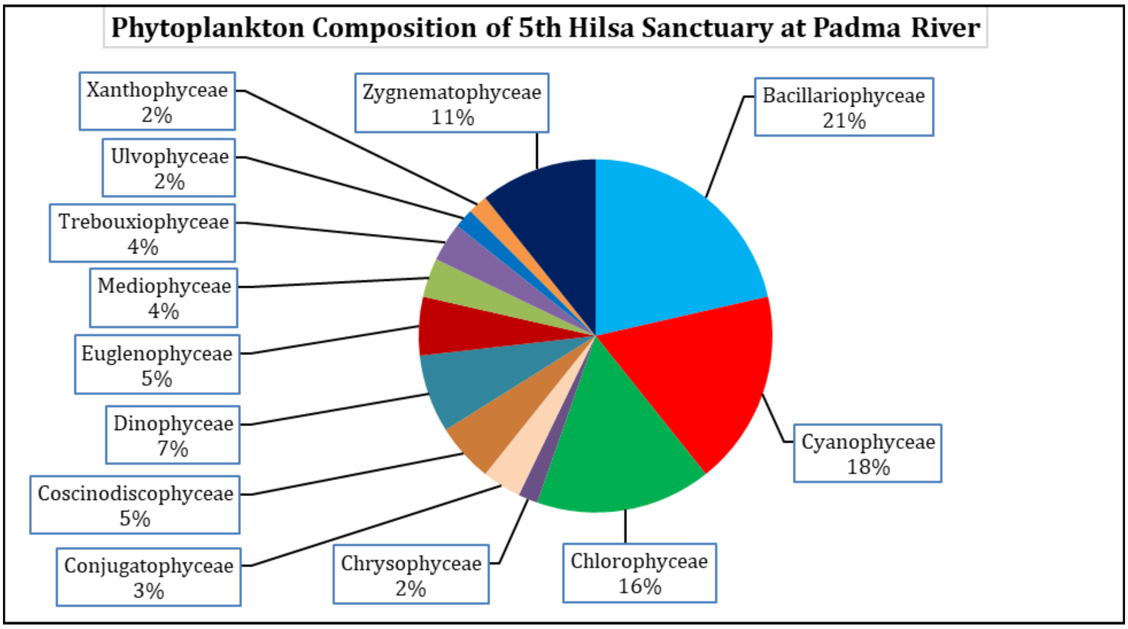

Figure 5.

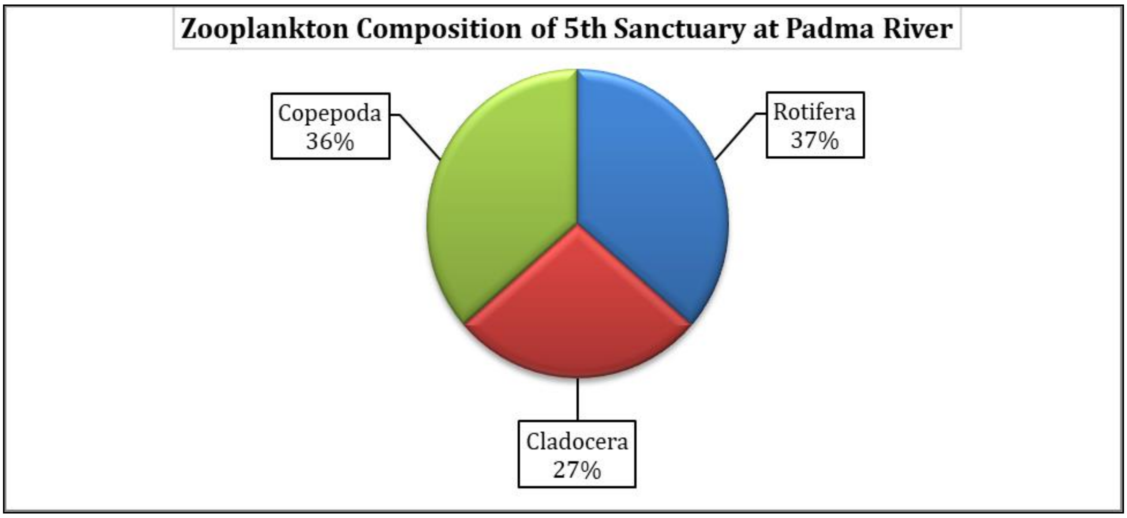

Figure 6.

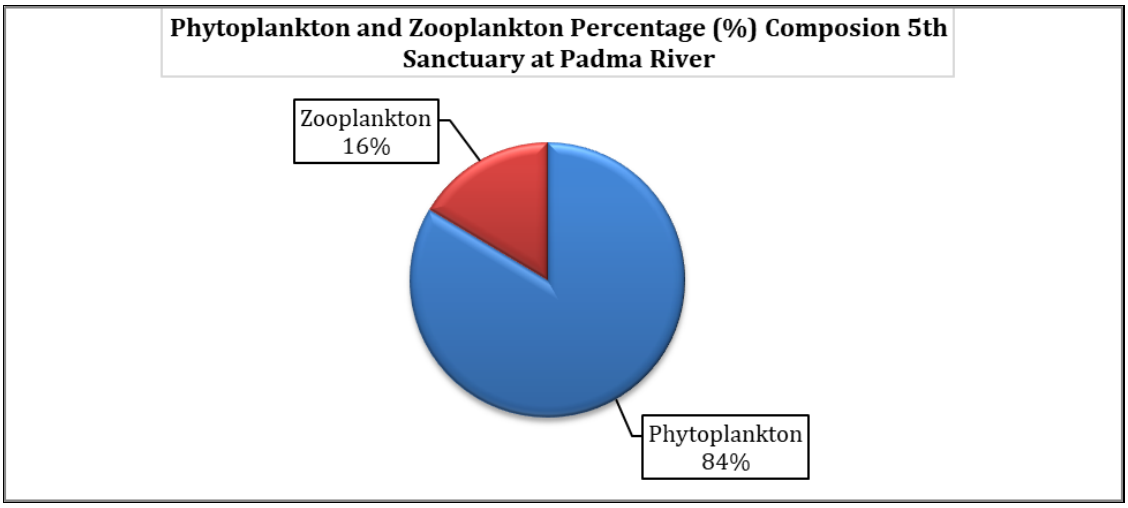

Figure 7.

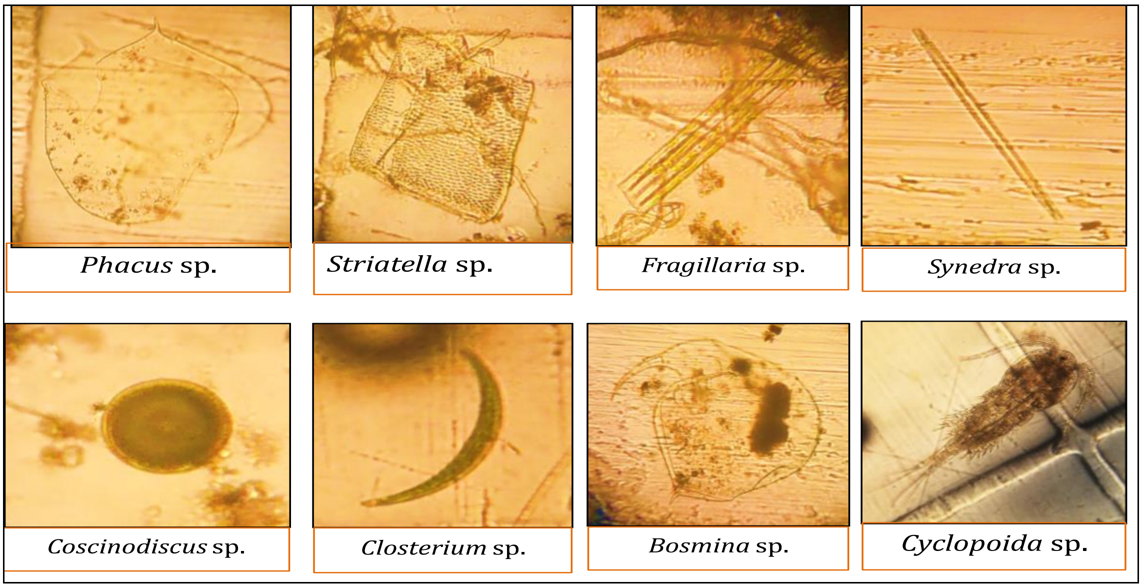

Figure 8: Pictorial view of identified Zooplankton and Phytoplankton species from 5th (20 km) Hilsa Sanctuary of Lower Padma River.

C) Jatka Observation

i) CPUE and change percentage of Jatka (2019-2020-2021)

Jatka's CPUE (kg/hour/100 m net) at the 5th Sanctuary is set to be 4.2 kg in 2019, 4.5 kg in 2020, and 4.8 kg in 2021. Jatka's CPUE has gradually increased. Compared to 2019, the CPUE of Jatka in Padma River has increased by 6.14 percent in 2020 and 11.9 percent in 2021 (Fig. 9).

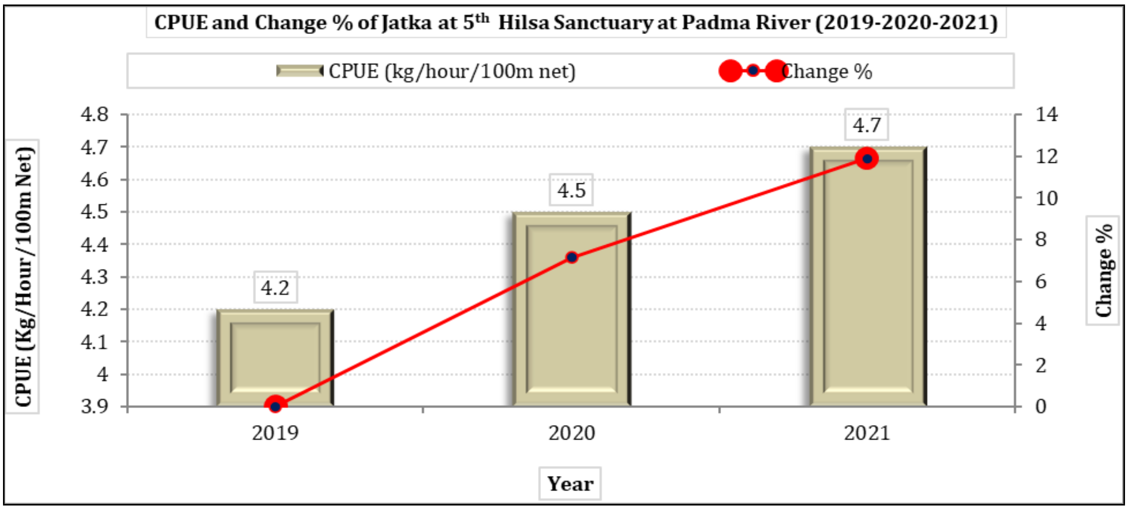

Figure 9.

ii) Length frequency percentage (%) (2019-2021)

Jatka ranged from 11 to 22 cm length sizes were found 5th Hilsa Sanctuary in 2019. In the Tarabunia Region in 2019, and 2020 numbers 214, 212 Jatka Hilsa's length frequencies have been made, respectively. Jatka, 13 cm in length size was found to be the most common size (37%) followed by 14 cm (33%), 15 cm (12.6%), and 12 cm (9%) in 2019. Length frequency percentage gradually decreased from 16 to 22 cm (1.4-0.4%). The lowest percentage of Jatka (0.4%) was recorded as 17 cm length sizes.

Jatka ranged from 11 to 18 cm length were found 5th Hilsa Sanctuary in 2020. Jatka, 12 cm in length was found to be the most common size (33%) followed by 14 cm (28%), 13 cm (24%) and 11 cm (8%) in 2020. Length frequency percentage gradually decreased from 15 to 18 cm (3-1%). The lowest percentage of Jatka (1%) was recorded as 17-18 cm length sizes.

In the case of Tarabunia, it was found that in the year 2019, the presence of 12, 13, 14, and 15 cm Jatka was higher and as a percentage, it was 9, 37, 33, and 12.5 cm respectively. In 2020, 12 (33%), 13 (24%), and 14 cm (28%). In these two years 2019-20, it is seen that the presence and abundance of 12 to 15 cm Jatka were more in Tarabunia (Fig. 10).

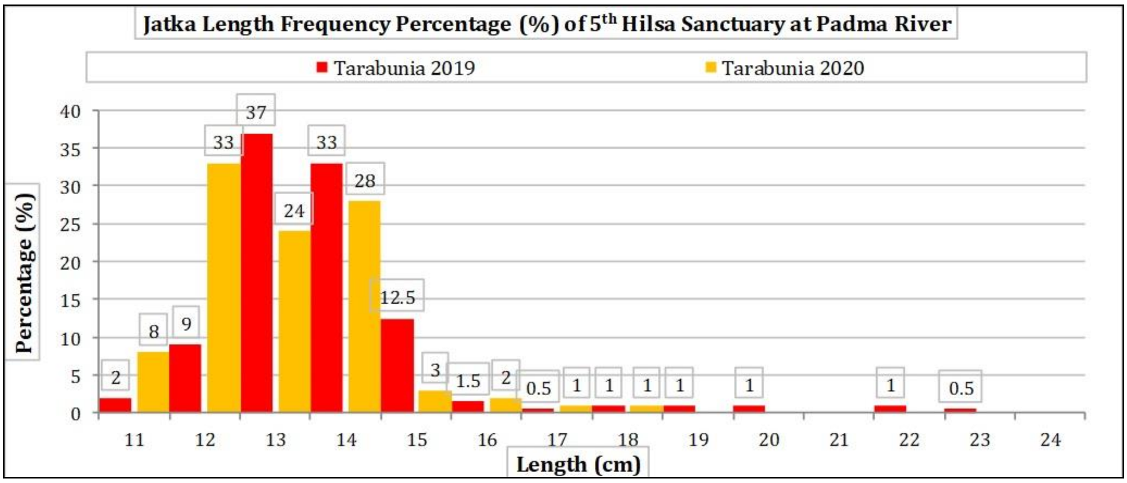

Figure 10.

iii) Length-weight relationship of Jatka

In this study, the length-weight relationship of Jatka in the Hilsa Sanctuary has been established. The maximum length of Jatka was recorded as 23 cm approximately. The value of 'b' greater than 3.0 indicates positive allometric growth. In the current study, the value of 'b' was calculated as 2.88, which indicates the bad condition of Jatka in the Padma River in 2019 (Fig. 11). The value of 'b' was calculated as 3.07, which indicates the good condition of Jatka in the Padma River in 2020 (Fig. 12). In the current study, the value of 'b' was calculated as 2.83, which indicates the bad condition of Jatka in the Padma River in 2021 (Fig. 13).

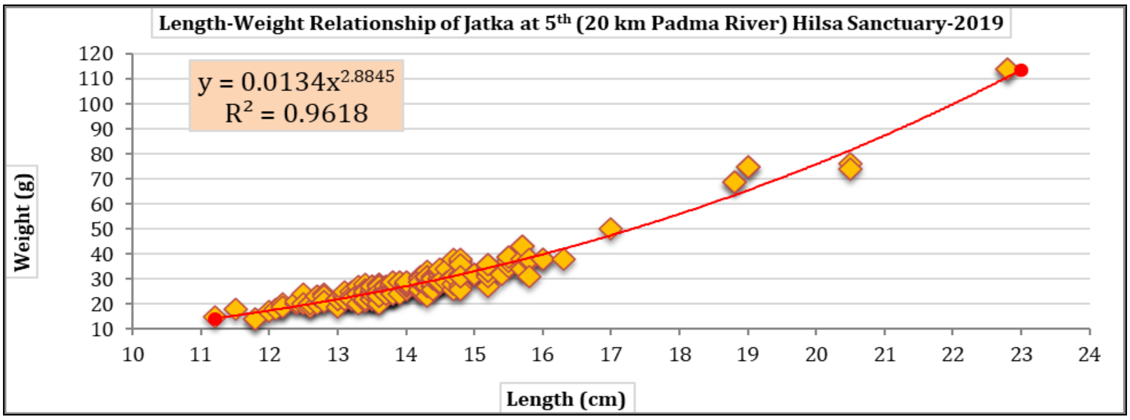

Figure 11.

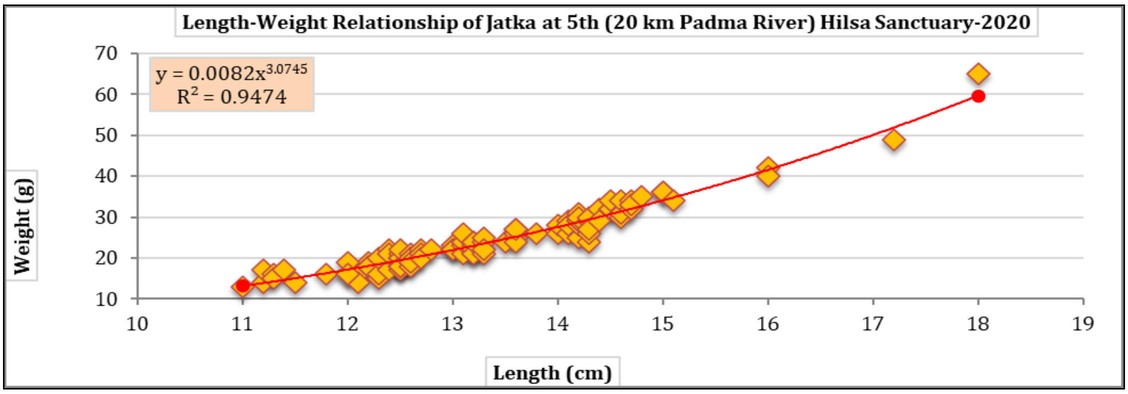

Figure 12.

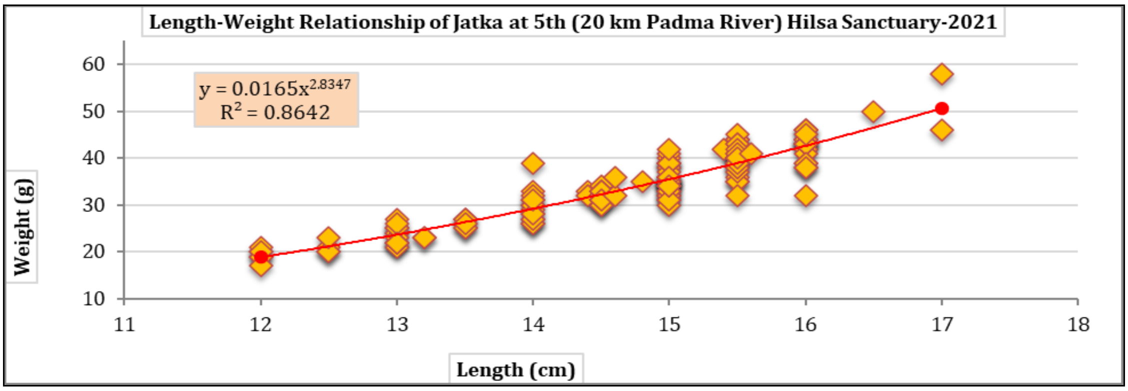

Figure 13.

The physico-chemical properties of the water studied in the Padma River were more or less the same by the standards of Bangladesh. According to DoE (2001) and EQS (1997), air and water temperatures at all sites were within the standard range. DoE standards in all site areas were within the allowed limits (DoE, 2001). CO_2 values were recorded lower than the standard (EQS, 1997). Transparency, hardness, and alkalinity were also within reasonable limits, including the pH value (Rahman, 1992; DoE, 1997; EQS, 1997). The recorded values of various physical and chemical parameters of the Padma River were within the standard values of the rivers in Bangladesh. This is conducive to the normal physiological life of river aquatic life. According to Rahman (2018), in 2015 (September to December), the air and water temperatures in the Sureshwar area of Meghna River were 22.1-32°C and 21.5-31.5°C, the pH and dissolved oxygen ranges were 7.3-7.7 and 5.2-5.8 mg/l, CO_2 was 17.4-19.6 mg/l and total hardness and alkalinity ranges were 58-75 mg/l and 72.5-89.3 mg/l respectively.

At the same time, air and water temperatures in the Tarabunia area of the Meghna River were 22-32.5°C and 21.7-31.2°C, the pH and dissolved oxygen ranges were 7.4-7.8 and 5.1-5.9 mg/l, CO_2 was 17.3-18.4 mg/l and total hardness and alkalinity ranges were 60-80 mg/land 74-84 mg/l respectively. The values of all the parameters mentioned in the above reference match the results obtained in this study. In the case of temperature, one-and-a-half limits were exceeded, but all other standards were within the approved standard of Bangladesh River water as directed by (EQS, 1991; EQS, 1997; ESR ,1997; DoE, 1997; DoE, 2001).

According to (JICA, 1992), during the month of February-May, Chlorophyceae (in the case of phytoplankton) and Brachionidae (in the case of zooplankton) were dominant in the Rajshahi Region of the Padma River. According to (Ahmed and Alfasane, 2004), Munshiganj in the upper reaches of the Padma River was dominant by phytoplankton’s group: Chloropyceae (10 species and 38.46%), and Bacillariophyceae (9 species and 34.61%) in 2002. According to (Rahman and Huda, 2012), in the case of phytoplankton in Manikganj of Padma river in 2010-2011, Bacillariophyceae (10 species, average value 3,3421 ind/100 l) was dominant. In the case of zooplankton, Rotifera (10 species, average value 348.6 ind/100 l) was dominant. Flura et al. (2016) has reported that the Mawa, Godagari, and Pakshi areas of the Padma River were dominated by Chlorophyceae (25 and 50%) (Phytoplankton group) and Rotifera (8 and 45%) (Zooplankton group) in 2014. NATP 2 (2018) reported that Munshiganj in the upper reaches of the river Padma was dominated by Chlorophyceae (25) (Phytoplankton group) and Rotifera (8) zooplankton (Zooplankton groups) in 2016. The period from 2002 to 2011 shows that in the upper reaches of the river Padma, in Munshiganj, in Manikganj, Bacillariophyceae is the dominant group for phytoplankton. In the case of zooplankton, Rotifera is singularly dominant. Again, it is seen that in the period from 2014 to 2017, Chlorophyceae is the dominant group in the case of phytoplankton in the upper reaches of the river Padma, in Munshiganj, and Mawa, Godagari, Pakshi region. In the case of zooplankton, the Rotifera alone are dominant. Bacillariophyceae (21%) also dominate in the present study, and in the case of zooplankton, Rotifera (36%) was dominant. The proportion of plankton was phytoplankton 84 and zooplankton 16%.

According to (Rahman et al., 2017), the CPUE of Jatka in the Meghna River from 2002 to 2016 was 0.94 to 3.25 kg respectively. Although it declined slightly in 2006 and 2007, Jatka has steadily increased. The current study shows that in 2019-2021, the CPUE is 4.2-4.7 kg. That means that the environment for Jatka growth in the Padma River is in the best condition.

Not much works has been done about the length frequency percentage rate of Jatka. According to Rahman et al. (2017), 15-20 cm size Jatka was found in the Meghna River from 0.39 to 2.11%, 21-25 cm size Jatka has been found in Meghna River from 1 to 17.27%. In the present study, in 2019, 11 cm size Jatka (2%), 12 cm (9%), 13 cm (36%), 14 cm (33%), 15 cm (12.7%), 18 cm (1.4%) and 22 cm (1%) were found in Padma River, and in 2020, 11 cm size Jatka (8%), 12 cm (33%), 13 cm (24%), 14 cm (28%), 15 cm (3%), 16 cm (2%) and 18 cm (1%) were found in Padma River.

In the case of Jatka, not much has been done about the length-weight relationship. Haldar and Rahman (1998) reported that the value of Jatka (2-18 cm) 'b' in the Chandpur, Bhola, Kuakata-Barisal region was 3.41. Amin et al. (2000) reported that the 'b' value of 365 Jatka Hilsa in the Meghna River (3.50-15.50 cm in length) was 3.09. In the present study, the 'b' value of 205 Jatka Hilsa in 2020 was 3.06 (positive allometric). According to Narejo et al. (2008), the 'b' values of male Hilsa are 3.03 and 3.61 in the length-weight relationship of 10.1-50 cm fish of 260 Jatka Hilsa in Indus River of Pakistan; the value of 'b' of female Hilsa is 3.06 and 3.63 cm in length. The river environment, fish food, breeding, the life cycle can be more or less the quality of the variety. In the present study, all the values of 'b' were allometric positive.

CONCLUSIONS

The survey was conducted from BFRI, Riverine Station, Chandpur to re-evaluate and to monitor the efficiency of the previously identified nursery grounds. Research has been conducted on physico-chemical parameters of water, plankton observation, Jatka CPUE, length-frequency percentage, Jatka length-weight relationship. The results of all the above-mentioned topics were satisfactory; the functioning of the nursery ground remained stable.

It may be mentioned here that after the formulation of the Hilsa Fisheries Management Action Plan by BFRI, four sanctuary and four breeding grounds were set up in the light of necessary recommendations (HFMAP, 2002). Later, two new nursery grounds (5th and 6th) were implemented by the Department of Fisheries under the supervision of BFRI. Therefore, the results of this research project will undoubtedly serve as important evidence and reference for future research, policy, strategy, and implementation for Hilsa fish conservation.

Recommendations: i) Effective research needs to be continued to keep the Jatka and Brood Hilsa conservation management in all Hilsa-friendly rivers of Bangladesh; ii) Proper measures should be taken to protect the fishery resources from river salinity; iii) Timely action should be taken in the context of climate change; iv) The new nursery grounds of Hilsa needs to be identified through further investigation; v) Above all, necessary and timely steps should be taken to maintain the productivity of the nursery ground.

ACKNOWLEDGEMENTS

The research was supported by the Strengthening of Hilsa Research in Chandpur Project (BFRI/RS/3-2021). The authors are thankful to the concerned staff of BFRI, Riverine Station Chandpur for their cordial support.

REFERENCES

1. Adom D., 2018 – The human impact and the aquatic biodiversity of lake Bosomtwe: rennaisance of the cultural traditions of Abono (Ghana)? *Transylvanian Review of Systematical and Ecological Research, 20*, 1, 87-110.
2. Ashfaque A. and Almujaddade A., 2004 – Ecological studies of the river Padma at Mawa Ghat Munshiganj II, Primary productivity, phytoplankton standing crops and diversity, *Pakistan Journal of Biological Sciences*, 7, 1870-1875, DOI: 10.3923/pjbs.2004.1870.1875.
3. Alan Yeakley J., Ervin D., Chang H., Granek E. F., Dujon V., Shandas V. and Brown D., 2016 – Ecosystem services of streams and rivers, *River science: research and management for the 21st century*, 335-352.
4. Amin S. N., Rahman M. A., Haldar G. C., Nahar S., Dewan S. and Mazid M. A., 2000 – Population dynamics of jatka (juvenile hilsa) in the Meghna River, Bangladesh, *Asian Fisheries Science*, 13, 4, 383-390.
5. APHA (American Public Health Association), 1995 – Standard methods for the examination of water and wastewater, 14th Edit, American Public Health Association, 1015 Eighteenth Street, N. W. Washington, D. C., 2036.
6. Millenium Ecosystem Assessment, 2005 – *Ecosystems and human well-being*, 5, 563, Island Press, Washington D. C.
7. Astratinei V. and Varduca I., 2008 – Effect of metal pollution on aquatic microorganisms: a case study in mining areas (Romania), *Transylvanian Review of Systematical and Ecological Research*, 6, 109.
8. Bănăduc D., Simić V., Cianfaglione K., Barinova S., Afanasyev S., Öktener A., McCall G., Simić S. and Curtean-Bănăduc A., 2022 – Freshwater as a sustainable resource and generator of secondary resources in the 21st century: Stressors, threats, risks, management and protection strategies, and conservation approaches, *International Journal of Environmental Research and Public Health*, 19, 24, 16570.
9. Banglapedia, 2022 – Monsoon (Bangla and English), The National Encyclopaedia of Bangladesh, https://bn.banglapedia.org/index.php/.
10. Bardey D. J., 2019 – Overfishing: pressure on our oceans, *Research in Agriculture Livestock and Fisheries*, 6, 3, 397-404.
11. Bashir I., Lone F. A., Bhat R. A., Mir S. A., Dar Z. A., Dar S. A., 2020 – Concerns and threats of contamination on aquatic ecosystems, Bioremediation and biotechnology: sustainable approaches to pollution degradation, 1-26.
12. Boeraș I., Burcea A., Bănăduc D., Florea D. I., Curtean-Bănăduc A., 2024 – Lotic ecosystem sediment microbial communities' resilience to the impact of wastewater effluents in a polluted European hotspot – Mureș Basin (Transylvania, Romania), *Water*, 16, 3, 402, https://doi.org/10.3390/w16030402.
13. Clarkson T. W., 1995 – Environmental contaminants in the food chain, *The American Journal of Clinical Nutrition*, 61, 3, 682S-686S, DOI: 10.1093/ajcn/61.3.682s.
14. Costanza R., Kubiszewski I., Ervin D., Bluffstone R., Boyd J., Brown D., Chang H., Dujon V., Granek E., Polasky S. and Shandas V., 2011 – Valuing ecological systems and services, *F1000 biology reports*, 3, DOI: 10.3410/B3-14.
15. Curtean-Bănăduc A., Schneider-Binder E. and Bănăduc D., 2014 – The importance of the riverine ligneous vegetation for the Danube Basin lotic ecosystems, in Cianfaglione K. (ed.), L'importanza degli Alberi e del Bosco, Cultura, scienza e coscienza del territorio, Temi Ed., Trento, Italia, ISBN: 978-88-973772-63-9, I-II, 187-210.
16. DoE (Department of Environment), 2001 – The general overview of pollution status of river of Bangladesh, Government of the People's Republic of Bangladesh, Ministry of Environment and Forest, Department of Environment, Dhaka, Bangladesh.

17. DoE (Department of Environment), 1997 – Environment conservation rules, E. C. R. – schedule 3, standards for water, Department of Environment of Bangladesh, https://www.elaw.org/system/files/Bangladesh, Environmental Conservation Rules.
18. ECR., 1997 – The Environment Conservation Rules, Government of the People's Republic of Bangladesh, Ministry of Environment and Forest, Government of Bangladesh. https://www.elaw. org/ system/files/Bangladesh, Environmental Conservation Rules.
19. EQS (Environmental Quality Standard), 1997 – Government of the People's Republic of Bangladesh, Ministry of Environment and Forest, Department of Environment, Gazette, registered. DA-1, Dhaka, Bangladesh.
20. EQS., 1991 – Environmental quality standards for Bangladesh, Department of Environment, Government of the People's Republic of Bangladesh, 43.
21. Eurekalert Organization., 2002 – Ocean temperatures affect intensity of the South Asian monsoon and rainfall, News Release, 6-Nov-2002.NASA/Goddard Space Flight Center, https://www.eurekalert.org/news-releases/519226.
22. Flura Alam M. A., Hossain M. R. A., Rubel A. K. M. S. A., Tanu M. B. and Khan M. H., 2016 – Assessment of physicochemical conditions and plankton populations of the river Padma, Bangladesh, *Asian Australasian Journal of Bioscience and Biotechnology*, 1, 1, 86-94.
23. González R., Durante C., Arcagni M., Juncos R., Seco Pon J., Crespo E. and Narvarte M., 2021 – Effects of pollution in aquatic food chains, *Anthropogenic Pollution of Aquatic Ecosystems*, 61-89, https://doi.org/10.1007/978-3-030-75602-4_4.
24. Gragnani M. and Evangelista M., 2021 – Introduction to Geographical Indications (GIs) and the benefits of the Lisbon System, Lisbon Webinar Series, https://www.wipo.int/edocs/mdocs/mdocs/en/wipo_webinar_lisbon_2021_1/wipo_webinar_lisbon_2021_1_presentation.pdf.
25. Gumpinger C. and Scheder C., 2008 – Decline of biodiversity as a result of various human impacts related to river regulation-exemplified by several small river catchments (Austria), *Transylvanian Review of Systematical and Ecological Research*, 6, 141.
26. Haldar G. C. and Rahman M. A., 1998 – Ecology of Hilsa, Tenualosa ilisha (Hamilton), in Proceedings of BFRI/ACIAR/CSIRO Workshop on Hilsa Fisheries Research in Bangladesh held on 3-4 March 1998 at Bangladesh Agricultural Research Council, Dhaka, Bangladesh, Mazid M. A. and Blaber S. J. M. (eds), Bangladesh Fisheries Research Institute, BFRI proceedings series no. 6, 11-19.
27. Halpern B. S., Walbridge S., Selkoe K. A., Kappel C. V., Micheli F., d'Agrosa C., Bruno J. F., Casey K. S., Ebert C., Fox H. E. and Fujita R., 2008 – A global map of human impact on marine ecosystems, *Science*, 319, 5865, 948-952.
28. Hilsa Fisheries Management Action Plan for Bangladesh (HFMAP), 2002 – Fourth Fisheries Project, World Bank, Report no. 38.10 September.
29. Iepure S. and Selescu L., 2009 – Relationship between heavy metals and hyporheic invertebrate community structure in the middle basin of the Arieș River (Transylvania, Romania), *Transylvanian Review of Systematical and Ecological Research*, 7, 125-148.
30. JICA, 1992 – Ecology, 14, EPA-2, Draft Final Report, Government of the People's Republic of Bangladesh, Flood Action Plan, https://openjicareport.jica.go.jp/pdf/11044849_04.pdf.
31. Balasaheb K., Atul B., Ashok J. and Rahul K., 2017 – Present status of intertidal biodiversity in and around Mumbai (West Coast of India), *Transylvanian Review of Systematical and Ecological Research*, 19, 1, 61-70.
32. Naiman R. J., Decamps H. and Pollock M., 1993 – The role of riparian corridors in maintaining regional biodiversity, *Ecological applications*, 3, 2, 209-212.
33. Narejo N. T., Lashari P. K. and Jafri S. I. H., 2008 – Morphometric and meristic differences between two types of Palla, Tenualosa ilisha (Hamilton) from river Indus, Pakistan, *Pakistan Journal of Zoology*, 40, 1.

34. NASA earth Observatory, World of Change: Padma River, https://earthobservatory.nasa.gov/world-of-change/PadmaRiver.
35. National Geographic Society, Monsoon, Resource Library, Encyclopedic Entry, https://www.nationalgeographic.org/encyclopedia/monsoon/print/.
36. NATP 2. 2018 – Study of the climate change impact on fisheries resources and fisher`s especially women and children in selected climate hotspot zone of Bangladesh, PIU, National Agricultural Technology Program, Phase II Project (NATP-2), Bangladesh Agricultural Research Council (BARC), New Airport Road, Farmgate, Dhaka, 1215, Bangladesh.
37. Öktener A. and Bănăduc D., 2023 – Ecological interdependence of pollution, fish parasites, and fish in freshwater ecosystems of Turkey, *Water*, 15, 7, 1385, DOI: 10.3390/w15071385.
38. Onciu T. M. and Radu A., 2006 – Retezat Mountains (Romania) glacial lakes zooplankton biodiversity, *Transylvanian Review of Systematical and Ecological Research*, 3, 49.
39. Paltenea E., Viforeanu A., Bulgaru C. and Jecu E., 2008 – Swamps biodiversity of the White Nile (Sudan), *Transylvanian Review of Systematical and Ecological Research*, 6, 81.
40. Pauly D., Christensen V., Guénette S., Pitcher T. J., Sumaila U. R., Walters C. J., Watson R. and Zeller D., 2002 – Towards sustainability in world fisheries, *Nature*, 418, 6898, 689-695.
41. Prescott G. W., 1962 – Algae of the Western Great Lakes area, Revised, Brown W. M. C. (ed.) 135 South Locust Street, Dubuque, Lowa, 977.
42. Rahman M. A. and Huda M. E., 2012 – Study of the seasonal variations in physicochemical and biological aspects of the Padma River at Paturia Ghat, Manikganj, *Jahangirnagar University Environmental Bulletin*, 1, 55-66.
43. Rahman M. S., 1992 – Water Quality Management in Aquaculture, Bangladesh, Brac Prokashona, 84.
44. Rahman M. A., Pramanik M. M. H., Hasan M. M. and Mahmud Y., 2018 – Physicochemical properties and plankton abundance in sanctuary and non sanctuary areas in the river Meghna, Bangladesh, *Asian-Australasian Journal of Food Safety and Security*, 2, 2, 79-85.
45. Rahman M. A., Pramanik M. M. H., Flura, Ahmed T., Hasan M. M., Khan M. H. and Mahmud Y., 2017 – Impact assessment of twenty-two days fishing ban in the major spawning grounds of Tenualosa ilisha (Hamilton, 1822) on its spawning success in Bangladesh, *Journal of Aquaculture Research and Development*, 8, 6, 1-12.
46. Rasiga A., Momeu L., Péterfi Ş. and Kozma A., 1999 – Biodiversity of algae of the upper and middle course of the Olt River, *Transylvanian Review of Systematical and Ecological Research*, 31-48.
47. Smith V. H., Tilman G. D. and Nekola J. C., 1999 – Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems, *Environmental pollution*, 100, 1-3, 179-196.
48. Soolutayo V., 2012 – Effects of human activities on the biodiversity of a tropical man made lake (Esinminrin Dam), *Transylvanian Review of Systematical and Ecological Research*, 14, 175-186.
49. Tsybulskiy O., Trylis V., Hupalo O. and Savytskiy O., 2023 – Biological diversity of Sula River (Ukraine) under different hydrological conditions, *Transylvanian Review of Systematical and Ecological Research*, 25, 2, 65-76.
50. Vári Á., Podschun S. A., Erős T., Hein T., Pataki B., Iojă I. ., Adamescu C. M., Gerhardt A., Gruber T., Dedić A. and Ćirić M., 2022 – Freshwater systems and ecosystem services: challenges and chances for cross-fertilization of disciplines, Ambio, 51, 1, 135-151, DOI: 10.1007/s13280-021-01556-4.
51. Vörösmarty C. J., McIntyre P. B., Gessner M. O., Dudgeon D., Prusevich A., Green P., Glidden S., Bunn S. E., Sullivan C. A., Liermann C. R. and, Davies P. M., 2010 – Global threats to human water security and river biodiversity, *Nature*, 467, 7315, 555-561.
52. Ward H. B. and Whipple G. C., 1959 – Freshwater Biology, John Willey and Sons. Inc. New York, London, 2, 12-48.

53. Zubcov N., Zubcov E. and Schlenk D., 2008 – The dynamics of metals in fish from Nistru and Prut rivers (Moldova), *Transylvanian Review of Systematical and Ecological Research*, 6, 51.