Pol. J. Environ. Stud. Vol. 31, No. 6 (2022), 5549-5561
DOI: *10.15244/pjoes/152167* ONLINE PUBLICATION DATE: 2022-10-03

Original Research

Distribution of Fish Species in Relation to Water Quality Conditions in Bengawan Solo River, Central Java, Indonesia

Siti Nurul Aida[1], Agus Djoko Utomo[1], Dian Pamularsih Anggraeni[1], Yoga Candra Ditya[1], Tuah Nanda M. Wulandari[1], Muhammad Ali[1], Christopher Marlowe A. Caipang[2], Indra Suharman[3]*

[1]Research Center for Conservation of Marine and Inland Water Resources, National Research and Innovation Agency, Cibinong 16911, Indonesia
[2]Department of Biology, College of Liberal Arts, Sciences, and Education, University of San Agustin, Iloilo City 5000, Philippines
[3]Department of Aquaculture, Faculty of Fisheries and Marine Sciences, Universitas Riau, Pekanbaru-Riau 28292, Indonesia

Received: 8 April 2022
Accepted: 16 July 2022

Abstract

Bengawan Solo River is heavily modified into reservoirs and dams. Starting from Karanganyar to Sragen District, mass fish deaths happen up to 3-4 times a year due to organic matter pollution. The research was conducted to determine water quality during the rainy season (April 2020) and the dry season (August 2020). Samplings were carried out in three zones: the upstream zone (I) in Sukoharjo District, Central Java; the middle zone (II) in the Solo City, Karanganyar, and Sragen District, Central Java; and the downstream zone (III) in Ngawi and Bojonegoro District, East Java. Results showed that the waters of Bengawan Solo in zone I were not affected by waste. After reaching zone II, there was a heavy pollution effect. In zone III, the water quality has returned to normal levels (recovery). The fish species in zone I were dominated by exotic fish such as Nila (*Oreochromis niloticus*) and Jambal Sius (*Pangasianodon hypothalamus*). The fish species in zone II was dominated by Sapu sapu (*Pterygoplichthys pardalis*). In zone III were dominated by native fish species such as Jendil (*Pangasius polyuranodon*), Seren (*Cyclocheilichthys enoplos*), Bendol (*Barbichthys laevis*), Wader (*Rasbora* spp.), Keting (*Barbonymus gonionotus*), Daringan (*Mystus microcanthus*), and Tagih (*Hemibagrus nemurus*).

Keywords: water quality, pollution, fish distribution, recovering, river

*e-mail: indra70s@yahoo.com

Introduction

Bengawan Solo River is the longest river on the island of Java, reaching 600 km, crossing the provinces of Central Java and East Java with a drainage area of 16,000 km^2 [1, 2]. This river has an important role in agriculture, fisheries and tourism. This river system has been heavily modified into reservoirs and dams, and along the river basin, there are many industries and human settlements. Human disturbance impacts the spatial heterogeneity of fish species [3].

The construction of water conservation facilities and dams in aquatic ecosystems can eliminate fish habitats and breeding grounds, resulting in fragmentation that damages the migration processes of fish species. Construction can also change water temperature, discharge, and runoff processes, which adversely affect the growth and reproduction of aquatic organisms [4, 5]. Likewise in China, rivers have undergone changes due to the construction of agriculture, dams and hydropower which have had a significant impact on species migration between different river habitats [6].

The population density of the river basin will more or less affect the environmental conditions of the river because about 15.2 million people live in the River Basin Unit (RBU) of Bengawan Solo. Disposal of waste by the community into the river will cause contamination of organic matter in the waters. There are many industries around Solo City including textiles, alcohol, tanning cowhide, and food manufacturing. Wastes from these industries that are disposed of into rivers must be treated first so as not to pollute the river system [7-11].

In Bengawan Solo river starting from the Karanganyar District to Sragen District, there are occurrences of mass fish kills otherwise known as "*pladu*" in the local dialect. In one month "*pladu*" occurs 3-4 times, and the local people are aware that "*pladu*" is caused by wastes from the upstream, especially from the alcohol industry in Karanganyar District. Fish live in water media so changes in the aquatic environment will have a direct impact on fish life [12, 13].

Unlike previous research where studies done at specific sections of the river, the present study conducted samplings during the dry and rainy seasons, and was carried out from upstream to downstream sections of the river. For example, there were 9 fish species found in Lamongan District, 1 gastropoda and 1 shrimp [14]. A study in the tributary of Solo River, Madiun District, obtained 6 fish species, indicating low fish diversity [15]. While studies in Gajah Mungkur Reservoir, Wonogiri District, showed that the diversity of fish species at the Gajah Mungkur Reservoir outlet was higher than the inlet [16]. There were also fish diversity studies at Bendung Colo Sukoharjo [17].

The study aimed to determine the effect of water quality on the distribution of fish along Bengawan Solo river from the upstream, middle stream, and downstream. The research results are expected to provide information on how to manage fish resources in Bengawan Solo River Basin.

Materials and Methods

Time and Location of Research

Samplings were done to represent the rainy and dry seasons from April to August 2020. The research was carried out in three zones. The upstream zone (zone I) in Sukoharjo District, Central Java: is an area that is not much affected by industrial areas. The middle zone (zone II) is Solo City, Karanganyar District, and Sragen District, Central Java: is an area that has several industries, including the textile industry in Solo City and the alcohol industry in Karanganyar District. Downstream Zone (zone III) in Ngawi, Bojonegoro, and Lamongan District, East Java: is an area that is located far from an industrial area, and the influence of industrial waste from zone II has been reduced and disappeared. (Fig. 1).

Water Quality Parameters and Analysis Methods

The different water quality parameters that were monitored *in situ* included: oxygen, pH, transparency, conductivity, and carbon dioxide. On the other hand, total dissolved solids (TDS), and P–total were carried out in the laboratory. Water quality analyses were done following the procedures described by APHA [18] (Table 1).

Distribution of Fish Species

To determine the distribution of fish species from upstream to downstream, fish samples were taken in each zone. The upstream zone (zone I) is in Wonogiri and Sukoharjo District, Central Java Province. The middle zone (zone II) is in Solo City, Karanganyar District, and Sragen District, Central Java Province. Downstream zone (zone III) is in Ngawi District, Bojonegoro District, and Lamongan District, East Java. Data and information on the distribution of fish species are taken from the records of the fishers's catch and interviews with fishers in each zone from various kinds of fishing gear. Recording of catch data with the help of local fishers who were selected as enumerators. Determining the enumerator based on several considerations is having experience as a fisherman for at least 5 years, using a variety of fishing gears, and being willing to work together to record.

Fish samples were placed in a plastic bag and labeled (location, date, fishing gear, name of fish/species). Formalin solution was added as a preservative, then transported to the laboratory. Fish were identified based on [19, 20]. The data were analyzed descriptively

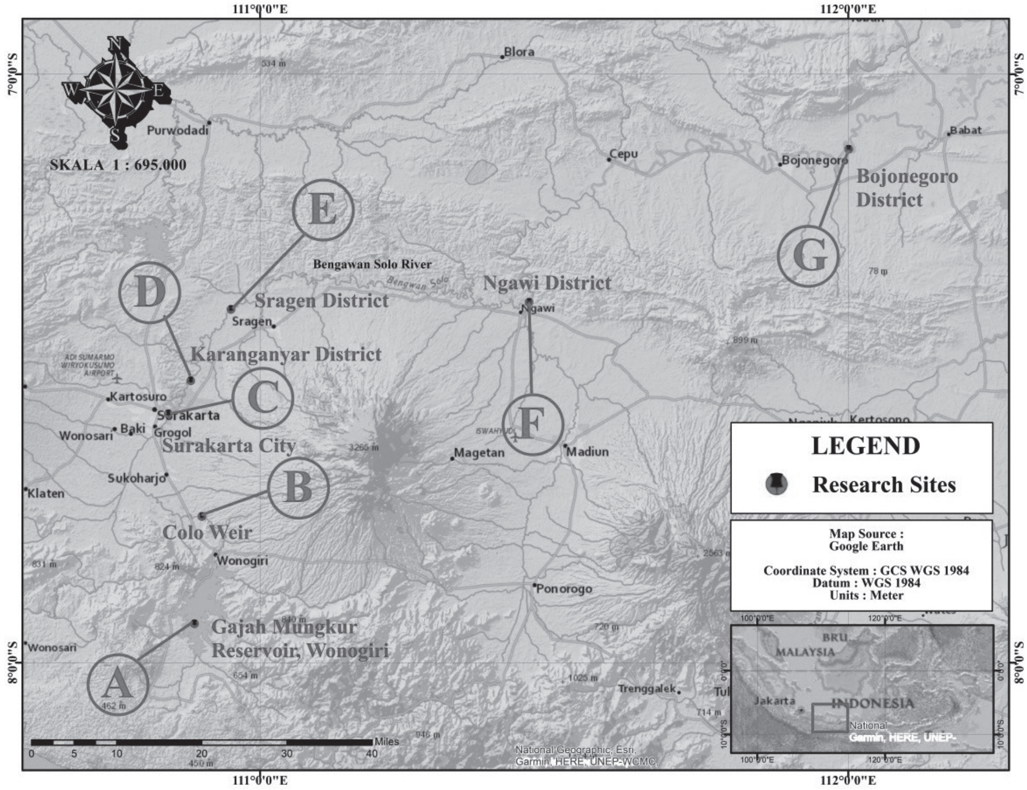

Fig. 1. Map of research station

Note:

Upstream zone (zone I): This zone is an area that is not much affected by industrial areas.

A. Gajah Mungkur Reservoir, Wonogiri District; there is no industry, but many floating cages.

B. Bendung Colo Village, Sukoharjo District research station; there is no industry

Middle Stream zone (zone II): This zone is an area that has several industries

C. Kampung Sewu Village, Solo City research station; there is a textile industry.

D. Bison Village, Karanganyar District research station; there is an alcohol industry.

E. Tenggak Village, Sragen District Research Station, there is no industry but near Bison Village (which are many industries).

Down Stream zone (Zone III): The zone is an area that is located far from an industrial area, and the influence of industrial waste from zone II has been reduced and disappeared.

F. Ngawi Purba Village, Ngawi District research station. It's estimated that the effect of industrial waste from zone II has been reduced.

G. Kabalan Village, Bojonegoro District Research Station. It's estimated that the effect of industrial waste from zone II has disappeared.

Table 1. Parameters and analysis methods.

Parameters	Unit	Methods and equipment
1. Transparency	cm	*In situ*. Sechi disk
2. Conductivity	µS/cm	*In situ*. SCT meter
3. Carbon dioxide	mg/L	*In situ*, Winkler methods, titrimetry with NaOH as a titrant
4. Dissolved oxygen	mg/L	*In situ*, metode Winkler, titrimetry with thiosulfate solution as a titrant.
5. Total phosphorus	mg/L	Metode Vanadate molybdate, Spectrophotometric

Source: APHA [14].

through data tabulation and fish distribution was based on zoning. Analysis of the relationship between fish catch production and water quality parameters was done using regression analysis: Y = a + b.X; where: "*Y*" is the production of fish catch (kg) and "*X*" is the water quality parameter.

Results and Discussion

Water Quality

The water quality during the rainy season (Table 2) was relatively better than during the dry season (Table 3). Water quality in the upstream zone (zone I) of Sukaharjo District was relatively better, with indications that oxygen levels are still relatively high at 5.63 mg/L during the rainy season and 6.75 mg/L during the dry season. In the middle zone, there was a decrease in water quality, especially during the dry season. In Kampung Sewu Village, Solo City, oxygen levels during the rainy season were 5 mg/L and during the dry season at 3.44 mg/L. In Bison Village, Karanganyar District oxygen content during the rainy season was 2.43 mg/L, and during the dry season was 0.65 mg/L. In Tenggak Village, Sragen District, the oxygen level during the rainy season was 3.74 mg/L and 0.98 mg/L during the dry season. In the downstream zone (zone III) the water quality recovered better, in Ngawi Purba Village, Ngawi District, oxygen levels during the rainy season were 5.67 mg/L and during the dry season 4.5 mg/L. In Kanor Village, Bojonegoro District during the rainy season oxygen content was 7.78 mg/L, and during dry season 5.63 mg/L.

Dissolved oxygen content at each study location during the dry season was worse than during the rainy season. This is because during the dry season the volume of water is small, so that the pollution becomes more concentrated. Increased human activities around the waters cause environmental degradation and decrease in water quality that can threaten biodiversity, especially vertebrate groups such as freshwater fish [21]. Inland waters (river) are more concentrated, especially in the dry season [4, 22].

Organic matter pollution in the waters will reduce dissolved oxygen so that oxygen levels are low [8, 21, 23, 24]. Upstream zone (zone I) is located in Bendung Colo Sukoharjo District. Around the location, there are no industries that affect the water quality in Bengawan Solo River, waters the water quality is relatively good, the oxygen content ranges from 5.68 to 6.75 mg/L. The flow from the outlet of the Gajah Mungkur Reservoir that enters Bengawan Solo when it reaches the waters of the Bendungan Colo is of good quality with oxygen levels each of 4.12-9.98 mg/L and 4.20-11.64 mg/L, pH = 7.5-8.0 and 6.0-7.5 Adjie, et al. [25]. Although Gajah Mungkur Reservoir has floating net cages for fish culture, the amount does not exceed the water carrying capacity of Gajah Mungkur Wonogiri Reservoir [26]. In addition, the condition of the aquatic environment can still support the process of self-purification.

The water quality in the middle zone (zone II) has become poor due to the presence of many industries in the middle zone. These factories dump their industrial waste directly into the waters without proper treatment, these industrial wastes contain chemical residues that are harmful to the environment [9, 27, 28]. At the location of Kampung Sewu, Solo City (zone II) the oxygen level between the dry and rainy seasons ranges from 3.44-5 mg/L. Solo City has a textile industry that has a channel for disposing of waste to Bengawan Solo River. According to State University of Surakarta (UNS) in [29], reports that Bengawan Solo River in Solo City and its surroundings were contaminated by Cd (Cadmium) and Cr (Chromium). Fish bio-accumulated heavy metals Cd and Cr through various organs such as the liver, muscle, skin, gastric gills, and intestine [30-32]. High concentrations of heavy metals in water can affect the interaction of fish with the aquatic environment [33, 34]. However, pollution by heavy metals does not directly cause mass mortality of fish, but the combined factors of toxins and low dissolved oxygen are the cause of the mass death of fish [35-39].

In Bison Village, Karanganyar District, zone II, the water quality is worse, where the oxygen content between the dry and rainy seasons was 0.65-2.43 mg/L. At this location, there is an alcohol production industry, which channels its waste directly to Bengawan Solo River. Organic waste produced (distillery wastewater) by alcohol production factories can cause a decrease

Table 2. Water Quality in Bengawan Solo River during the Rainy Season, April 2020.

Parameters	Zone I	Zone II			Zone III	
	Bendung Colo, Sukoharjo	Kampung Sewu, Solo	Bison, Karanganyar	Tenggak Sragen	Ngawi Purba, Ngawi	Kanor, Bojonegoro
O_2 (mg/L)	5.68	5	2.43	3.74	5.67	7.78
CO_2 (mg/L)	0.06	0.5	2.64	2.5	0.8	0.52
Conductivity (µS)	159	336	522	438	407	318
TDS (mg/L)	103	218	339	285	264	207
Transparency (cm)	40	20	20	25	50	50
Total phosphor (mg/L)	0.363	0.472	0.688	0.521	0.260	0.246
S :	07° 45’4”	07° 34’ 37”	07° 31’16”	07° 23’ 58”	07° 22’ 28”	07° 45’4”
E :	110° 54’06”	110° 50‘ 38”	110° 52’ 56”	110° 57‘ 03”	111° 21’ 30”	111° 54’06”

Table 3. Water Quality in Bengawan Solo River during the Dry Season, August 2020.

Parameters	Zone I	ZoneIII			Zone III	
	Bendung Colo, Sukoharjo	Kampung Sewu, Solo	Bison, Karanganyar	Tenggak Sragen	Ngawi Purba, Ngawi	Kanor, Bojonegoro
O_2 (mg/L)	6.75	3.44	0.65	0.98	4.5	5.63
CO_2 (mg/L)	0,05	8.8	10.56	7.7	5.5	5.26
Counductivity (µS)	267	684	935	605	567	438
TDS (mg/L)	173	445	607	393	368	284
Transparency (cm)	45	20	10	40	50	50
Total Phosphor (mg/L)	1.36	2.97	4.83	1.98	1.11	1.11
S :	07° 45’4”	07° 34’ 37”	07° 31’16”	07° 23’ 58”	07° 22’ 28”	07° 45’4”
E :	110° 54’06”	110° 50‘ 38”	110° 52’ 56”	110° 57‘ 03”	111° 21’ 30”	111° 54’06”

in the amount of dissolved oxygen in the waters, because most of the dissolved oxygen will be used by microorganisms in the decomposition process [40-42]. Low dissolved oxygen levels are the main cause of fish mass mortality [43]. At the location of Tenggak, Sragen District (still zone II) which is located at the downstream side of Bison Karanganyar Village, the water quality was still bad because it was still influenced by the quality of water from Bison Village. Oxygen content during dry and rainy days in Tenggak Village ranged from 0.98 to 3.74 mg/L.

According to information from the local community, the waters of Tenggak Village and Cemeng Village, Sragen District experienced 3-4 times of serious pollution in a month. During this time, the water smells bad resulting in mass fish kills. This incident is called “*pladu*” in local dialect. The locals know that “*pladu*” is caused by the discharge of wastes from the alcohol production industry in Bison Village, Karanganyar District. According to Aida, et al. [29], the river between Solo City-Karanganyar District-Sragen District is polluted with indications of low oxygen, high carbon dioxide, high COD, high phenols, and high fatty oils. The content of heavy metals such as Cr, Cu, and Z in the waters in several locations has exceeded the threshold levels and was also found in the muscle tissues of Sailfin Catfish.

Poor water quality in Zone II is due to the large number of industrial areas. This proves the lack of supervision from the government, and the lack of concern for the users of the waters of the Solo River. Environmental damage is also caused because there is no synergy between the relevant stakeholders. Management of the aquatic environment is things that should be the common concern of all relevant stakeholders [44]. Good governance of natural resources by the government is very necessary because of the damage to natural resources that occurs due to lack of attention from the government, increased potential sectoral ego, and regional ego due to the use of natural resources in the watershed [45].

In Ngawi District (zone III), the position is far from the location of pollution; hence, the water quality is rather good. The oxygen content between the dry and rainy seasons was 4-5.67 mg/L. Meanwhile, the downstream location located in Kanor/Kabalan Village, Bojonegoro District, the water quality has recovered, and the oxygen content between the dry and rainy seasons was 7-8 mg/L. The oxygen content in the water that is good for aquatic organisms should be more than 4 mg/L and dissolved oxygen less than 2 mg/L can cause the death of some fish (Boyd in [46]).

Organic matter contamination will also increase gases that are toxic to fish, including carbon dioxide (CO_2) and ammonia (NH_3) [6]**.** CO_2 levels in the upstream (zone I) are still low, whereas, in zone II which is an area of pollution, the CO_2 levels are quite high, especially during the dry season (7.5-10.5 mg/L). At the downstream (zone III), which was far from the source of contamination, the CO_2 level begins to decrease by 5.63 mg/L. High levels of carbon dioxide (CO_2) in water is toxic to fish because it can inhibit the respiratory process. The carbon dioxide content should be less than 5 mg/L and a carbon dioxide content of more than 10 mg/L accompanied by low oxygen can cause the death of several types of fish. The high carbon dioxide content can be caused by the decomposition of pollutants in the waters Effendie in [47].

The total phosphorus content (TP) in Bengawan Solo River was quite high, especially in zone II which is an industrial area. Total phosphorus level was 0.472-0.688 mg/L in the rainy season and 1.98-4.83 mg/L in the dry season. According to Novotny and Olem in [48], waters with a total phosphorus content of >0.1 mg/L are eutrophic. The source of phosphorus in nature is very little, if in the waters the phosphorus content is high, it can be ascertained that it comes from human activities, including pollution from industry.

The presence of high phosphorus in the waters can stimulate the growth of phytoplankton, which can then inhibit light penetration. The density of plankton in Bengawan Solo in zone II was quite high = 800-1500 ind/L, while the diversity index was low = 1.6-1.8, there are many Cyanophyceae algae that cannot be utilized by fish, and are poisonous [49].

Water transparency at Bengawan Solo River during both the dry and rainy season and in all research locations is low, only around 10-50 cm. Transparency is influenced by suspended solids. Low transparency in Bengawan Solo River is caused by waste and sediment from the land that enter the river along with rainwater runoff. Low transparency will inhibit the intensity of sunlight entering the water, and turbidity will also inhibit the respiration of the fish, Boeufb, et al. in [47].

Distribution of Fish Species

There are approximately 38 freshwater fish species that are often caught along Bengawan Solo river (Table 4). Many introduced fish species are found in Zone I because here there is a reservoir that is often stocked with introduced fish species including Nila (*Oreochromis niloticus*) and Jambal Sius (*Pangasianodon hypophthalmus*); while the native fish species are Sogo (*Hemibagrus nemurus*) and Tawes (*Barbodes gonionotus*). The fish species that dominates in the middle zone (zone II) is Sapu sapu (*Pterygoplichthys pardalis*). In the downstream zone (zone III), many native fish are found in the Bengawan Solo river, namely Bendol (*Barbichthys laevis*), Garingan (*Mystus microcanthus*), Sepat rawa (*Trichogaster tricopterus*), and Wagal/Jendil (*Pangasius polyuranodon*), Bader (*Cyclocheilichthys enoplos*), Tagih (*Mystus mumurus*). Keting (*Barbonymus gonionotus*), Wader (*Rasbora* spp.). The diversity of fish species in the waters is strongly influenced by environmental conditions and water quality. Waters contaminated with organic matter will be dominated by Sailfin Catfish (*Pterygoplichthys pardalis*), because these fish eat organic waste [50]. This condition occurs whenever the fish habitat is disturbed, resulting in the appearance of a dominant species, which often consists of only one or several species, and the population is relatively large. Whilst in the less disturbed and relatively stable habitats, the dominant species generally consists of more than one species, and thus the population is relatively stable [51].

It is reported that there are 15 species of fish in Gajah Mungkur Reservoir, Wonogiri District Many introduced fish species found in Gajah Mungkur reservoir include Nila (*Oreochromis niloticus*), Jambal Sius (*Pangasianodon hypophthalmus*), Tawes (*Barbodes gonionotus*) (Purnomo in [25]). Nila and Tawes can grow and develop well in the Gajah Mungkur Reservoir because these fish take advantage of the ecological niches in the reservoir where there are many aquatic plants. Meanwhile, Jambal Sius can grow and develop well because there are many plankton and detritus reservoirs in the Gajah Mungkur Reservoir [7, 52].

The dominant native fish species in Zone I are Sogo (*Hemibagrus nemurus*), Lukas (*Dangila cuverii*), Nilem (*Osteochilus hasselti*). There are several native fish species that are sometimes still found, including Betutu (*Oxyeleotris marmorata*), Gabus (*Channa striata*), Karper lumut (*Osteochilus schlegeli*), Keprek abang (*Barbodes sp*). According to Purnomo, et al. in [25], the catch of Lalawak fish (*Barbodes bramoides*) in 1999 ranks sixth, whereas in the present study, these fish are rarely caught. Other reports also state that, Gengehek fish (*Mystacoleucus marginatus*) are still often caught even though the numbers are relatively small, but based on current research results these fish are not found [53].

At the observation station in Bendung Colo Village (Sukaharjo District), the native fish that were often found were Wader pari (*Rasbora* spp.), Tawes (*Barbodes gonionotus*), and Sogo (*Hemibagrus nemurus*). At the upstream zone (zone I) there were no Sailfin Catfish (*Pterygoplichthys pardalis*) just like in the middle zone (zone II). This is because Sailfin Catfish can adapt well in waters that are heavily polluted with organic matter such as in zone II, but in waters that are less polluted by organic matter such as in zone I Sailfin Catfish can't adapt well.

The reason for Sailfin Catfish can survive in heavily polluted water due to a gastric system modification which functions as an additional respiratory organ in the form of a labyrinth, the large vascular system that functions as a lung enables it to breathe air even in the state of hypoxia with little dissolved oxygen [54, 55]. But this condition still influenced by environmental pH. The water quality preferences for Sailfin Catfish in toxic conditions (dissolved oxygen values <3 mg/L) is neutral pH (7±1) [56, 57].

In the middle zone (zone II), there were 13 types of fish. At the observation station in Kampung Sewu Village, Solo City; there were often caught Kutuk

Table 4. Freshwater Fish Species That Are Often Caught In Bengawan Solo River.

No	Local Name	Scientific Name	Zone		
			Upstream (Zone I)	Middle Stream (Zone II)	Down Stream (Zone III)
1.	Arengan	*Labeo chrysophekadion*	–	–	+
2.	Bader/Tawes	*Barbodes gonionotus*	++++	+	++

Table 4. Continued.

3.	Bader	*Cyclocheilichthys enoplos*	–	+	+
4.	Bandeng**)	*Chanos chanos*	–	–	+
5.	Bangbangan	*Barbodes schwanefeldii*	–	+	–
6.	Belut	*Fluta alba*	+	+	+
7.	Bendol	*Barbichthys laevis*	–	–	+++
8.	Betik	*Anabas testudineus*	–	–	+
9.	Betutu	*Oxyeleotris marmorata*	+	+	+
10.	Bloso	*Callogobius hasselti*	–	–	+
11.	Garingan	*Mystus microcanthus*	–	–	+++
		Mystus nigriceps	–	–	+
12.	Jambal sius*)	*Pangasianodon hypophthalmus*	++++	–	–
13.	Jambal lokal	*Pangasius djambal*	–	–	+
14.	Karper lumut	*Osteochilus schlegeli*	+	–	–
15.	Keprek abang	*Barbodes* sp.	+	–	–
16.	Keting	*Mystus planiceps*	–	–	++
17.	Kutuk	*Channa striata*	+	+	+
18.	Lalawak	*Barbodes* sp.	+		
19.	Lele	*Clarias* spp.	+	+	+
20.	Lemper	*Notopterus notopterus*	–	–	+
21.	Lempuk	*Ompok bimaculatus*	–	–	+
22.	Lempik	*Parachela oxygastroides*	+	–	–
23.	Lingkasan/Lukas	*Dangila cuvieri*	++	–	+
24.	Lumbet	*Cryptopterus* spp.	–	–	+
25.	Mujair**)	*Oreochromis mossambicus*	–	+	++
26.	Nila*)	*Oreochromis niloticus*	++++	+	–
27.	Nilem	*Osteochilus hasselti*	+	–	–
28.	Palung	*Hampala macrolepidota*	+	–	–
29.	Sapu–sapu	*Pterygoplichthys pardalis*	–	++++	++
30.	Sepat siam	*Trichogaster pectoralis*	–	–	++
31.	Sepat rawa	*Trichogaster tricopterus*	–	–	+++
32.	Seren	*Cyclocheilichthis* sp.	–	–	+
33.	Sili	*Macrognathus aculeatus*	–	–	+
34.	Sogo/Tagih	*Mystus nemurus*	+++	+	++
35.	Urang	*Macrobrachium rosenbergii*	–	–	+
36.	Wader	*Rasbora* spp.	+	+	+
37.	Wader	*Mystacoleucus marginatus*	–	–	+
38.	Wagal/Jendil	*Pangasius polyuranodon*	–	–	+++

Note:
› The upstream zone (zone I) includes Gajah Mungkur Reservoir, Wonogiri District; Bendung Colo Village, Sukohardjo District. Central Java
› The middle zone (zone II) includes Kampung Sewu Village, Solo City; Bison Village, Karanganyar District; Tanggak Village Sragen District, Central Java
› Downstream zone (zone III) includes Ngawi District; Kabalan/Kanor Village, Bojonegoro District, East Java.
++++ = Almost every day they are caught, the yield is ≥2 Kg/day/person
+++ = Almost every day they are caught, the yield is 1-2 Kg/day/person
++ = Not every day caught, the results are 0.5-1 Kg/day/person
+ = Rarely caught, yield ≤ 0.5 Kg/day/person
* = Introduction fish species
** = Escaped fish species from the pond

fish (*Channa striata*), Lele (*Clarias* spp.), and Mujair (*Oreochromis mussambicus*). Mujair is an escaped fish from farming in ponds. Based on the sampling results from fishers at the observation station of Tenggak Village and Cemeng Village, Sragen District, the dominant fish species is Sailfin Catfish (*Pterygoplichthys pardalis*). At certain times, many fish get intoxicated due to contamination, namely Tawes (*Barbodes gonionotus*), Daringan (*Mystus nigriceps*), and Tagih (*Hemibagrus nemurus*).

Sailfin Catfish are mostly found in the middle zone (zone II) because this area is heavily polluted. This fish species lives in waters that contain a high organic matter load. Hence, Sailfin Catfish is a bioindicator of waters that are contaminated with organic matter. If the river has lots of Sailfin Catfish, is an indication that the waters are heavily polluted by organic matter [58]. Incidentally 3-4 times a month in Karanganyar District to Sragen District, many fish die massively due to waste disposal which is suspected to be from the alcohol industry in Bison Village, Karanganyar District. In this incident by the local community called "*pladu*", a lot of intoxicated fish, floating on the surface are very easy for fishers to catch with the scoop–net fishing gear. Species of fish caught during "*pladu*" are those that are sensitive to pollution such as Tawes (*Barbodes*), Nilem (*Osteochilus*), Bader (*Cyclocheilichthys*), Wader (*Mystacoleucus*), etc. There are indications that the Bengawan Solo River in Sragen Regency and its surroundings is heavily polluted, there are many Sailfin Catfish [50].

In the downstream zone (zone III) there are 33 types of fish. At the observation station of Kabalan Village, Bojonegoro District, East Java, many native fish species have important economic value, namely Wagal (*Pangasius polyuranodon*), Tawes *(Barbodes gonionotus)*, Tagih (*Hemibagrus nemurus*), Jambal (*Pangasius djambal*), Lumbet (*Cryptopterus* sp.), Lemper (*Notopterus notopterus*), Bendol (*Barbichthys laevis*), Seren (*Cyclocheilichthys* sp.), Betutu (*Oxyeleotris marmorata*), Kutuk (*Channa striata*), Sepat (*Trichogaster trichopterus*), Sili (*Macrognathus aculeatus*), Bader (*Cyclocheilichthys enoplos*), Keting (*Barbonymus gonionotus*), and Daringan (*Mystus microcanthus*). Native fish species have dominated in zone III because the water quality has recovered, large fish species such as Jambal (*Pangasianodon hypophthalmus*) and Tagih (*Hemibagrus nemurus*) are found in the deep part of the river especially during the dry season. Downstream (zone III) has the highest fish diversity compared to either the middle part of the river (zone II) or the upstream part of the river (zone I). This result was in agreement to an earlier study on fish diversity in the Brantas River, East Java, where it is said that the diversity of fish in the upstream (Karangkates Reservoir) is lower than the downstream (Surabaya River) which has a very high diversity value [59]. Bengawan Solo River's fish biodiversity is affected by the fluctuation of fish resources. According to result of research by Liu et al. [60], fish resources have a direct impact on fish biodiversity, the sustainable development of freshwater fisheries, and the health of ecological environments in the entire Yangtze River basin, China.

Fish Catch Composition

The fish catch composition of each location shows varying results because each location has different water quality and each fish species will have a different response to water quality [61]. Fish catch data from fishers in the upstream zone (zone I) on Bendung Colo Village, Sukoharjo District during the rainy season was the catch of 3.1 Kg/day/person consists of Cyprinidae 1.6 Kg, Snakehead = 0.6 Kg, Cichlids = 0.9 Kg (Table 5), while during the dry season the catch 2.14 Kg/day/person consisting of Cyprinidae 1.64 Kg, Catfish 0.39 Kg, Snakehead 0.06 Kg, Cichlids 0.05 Kg (Table 6). Fish catch composition in zone I are dominated by Cyprinidae, an indication that the water quality in zone I is still good, not much polluted.

Table 5. The Fish Catch Data in Some Location of Bengawan Solo River in Rainy Season.

Location	Catch Data of Fishes (Kg)					Total (Kg)
	Cyprinidae	Catfish	Snakehead	Cichlids	Sailfin Catfish	
1. Zone I						
•Bendung Colo	1.6	0	0.6	0.9	0	3.12
2. Zone II						
•Kampung sewu	0.8	0	0.7	0.8	2.2	4.5
•Bison	0	0	0	0	4.8	4.8
•Tenggak	0.6	0	0	0	2.6	3.2
3. Zone III						
•Ngawi	2.4	2.1	0.8	0.9	0.3	6.5
•Kanor	2.8	3.8	0	1.2	0	8

Table 6. The Fish Catch Data in Some Location of Bengawan Solo River in Dry Season.

Location	Catch Data of Fishes (Kg)					Total (Kg)
	Cyprinidae	Catfish	Snakehead	Cichlids	Sailfin Catfish	
1. Zone I						
• Bendung Colo	1.64	0.39	0.06	0.05	0	2.14
2. Zone II						
• Kampung Sewu	0.3	0	0.4	0.5	2.8	4
• Bison	0	0	0	0	4.5	4.5
• Tenggak	0.29	0	0	0	3.19	3.48
3. Zone III						
• Ngawi	1	1.5	0.3	0.7	0.15	3.65
• Kanor	1.59	3.54	0	0	0	5.13

The fish caught in the middle zone (zone II) during the rainy season in the village of Kampung Sewu, Solo City was 4.5 Kg/day/person consisting of Cyprinidae 0.8 Kg, Snakehead 0.7 Kg, Cichlids 0.8 Kg, Sailfin Catfish 2.2 Kg. The fish caught in the village of Bison, Karanganyar District was 4.8 Kg/day/person consisting of Sailfin Catfish only. The fish caught in the village of Tenggak, Sragen District was 3.2 Kg/day/person consisting of Cyprinidae 0.6 Kg, and Sailfin Catfish 2.6 Kg (Table 5). The fish caught in the middle zone (zone II) during the dry season in the village of Kampung Sewu, Solo City was 4 Kg/day/person consisting of Cyprinidae 0.3 Kg, Snakehead 0.4 Kg, Cichlids 0.5 Kg, Sailfin Catfish 2.8 Kg. The fish caught in the village of Bison, Karanganyar District was 4.5 Kg/day/person consisting of Sailfin Catfish only. The fish caught in the village of Tenggak, Sragen District is 3.48 Kg/day/person consisting of Cyprinidae 0.29 Kg, and Sailfin Catfish 3.19 Kg (Table 6). Fish catch composition in zone II are dominated by Sailfin Catfish, which is an indication that in zone I there is a lot of organic matter pollution. In accordance with the results of research by Aida et al. [49], that the catch of fish in zone II is relatively high 3-5 kg/day, but is dominated by the sweeper fish reaching 80-90%

The catch in the downstream zone (zone III) during the rainy season in Ngawi Districts was about 6.5 Kg/day/person and consisting of Cyprinidae 2.4 Kg, Catfish 2.1 Kg, Snakehead 0.8 Kg, Cichlids 0.9 Kg, and Sailfin Catfish 0.3 Kg. The fish caught in the Kanor Village, Bojonegoro District during the dry season was 8 Kg/day/person consisting of Cyprinidae 2.8 Kg, Catfish 3.8 Kg, Cichlids =1.2 Kg (Table 5). While during the dry season in Ngawi Districts was 3.65 Kg/day/person and consist of Cyprinidae 1 Kg, Catfish 1.5 Kg, Snakehead 0.3 Kg, Cichlids 0.7 Kg, and Sailfin Catfish 0.15 Kg. The fish caught in the Kanor village, Bojonegoro District during the dry season was 5.13 Kg/day/person consisting of Cyprinidae 1.59 Kg, and Catfish 3.54 Kg (Table 6). Fish catch composition in zone III are dominated by native fish, which is an indication that water quality in zone III has recovered to normal. In accordance with the results of research by Adjie and Utomo [53], that in zone III there are many native fish of the Bengawans olo river. There is even a local catfish (*Pangasius djambal*) which is a rare fish. These fish often inhabit the bottom of the river in Bojonegoro Regency. Capture fisheries in the Bengawan Solo River in zone III have an important role in the lives of local fishermen. Inland Capture Fishery if managed properly will contribute to Global Food Security [62].

The Relationship between Water Quality and Fish Catch Production

Each fish will have a different response to water quality, so fish production is strongly influenced by water quality. The relationship between fish catch data and water quality by using the regression analysis method is provided in Table 7 and Table 8. The decrease in oxygen in the water is often caused by the decomposition of waste organic matter. Waters contaminated with organic matter will cause a decrease in dissolved oxygen in the water. Dissolved oxygen in the waters is needed by fish for respiration, not all fish can live in waters with low oxygen levels. Cyprinids require a relatively high oxygen content, the higher the dissolved oxygen content in the waters, the more suitable it is for the production of Cyprinids. Likewise, the opposite happens when there is less dissolved oxygen [63-65]. The volume of catch of Cyprinids during the dry and rainy seasons had a significant positive linear relationship between catch production and oxygen content (Table 7).

During the dry and rainy seasons, Catfish, Snakehead, and Cichlids had a non-significant positive linear relationship between catch production and dissolved oxygen content (Table 7). This is because these fish can live in waters with relatively low oxygen content so that the production of catches is not very dependent on dissolved oxygen in the waters. Snakehead

Table 7. The Relationship between Fish Catch and Dissolved Oxygen Levels

Fishes	Regression Equation	R–sq	P
1. Cyprinidae	Y (Kg) = –0.183 + 0.2697 Oxygen (mg/L) *	0.88	0.006
	Y (Kg) = –0.878 + 0.3329 Oxygen (mg/L)**	0.74	0.028
2. Catfish	Y(Kg) = –0.17 + 0.300 Oksigen(mg/L)*	0.22	0.429
	Y (Kg) = –2.52 + 0.694 Oxygen (mg/L)**	0.62	0.063
3. Snakehead	Y (Kg) = 0.147 + 0.0112 Oksigen(mg/L)*	0.02	0.851
	Y (Kg) = 0.065 + 0.0121Oxygen mg/L)**	0,01	0.813
4. Cichlids	Y (Kg) = 0.230 + 0.0215 Oxygen (mg/L)*	0.02	0.841
	Y (Kg) = 0.076 + 0.0262 Oxygen (mg/L)**	0,02	0.770
5. Sailfin Catfish	Y (Kg) = 4.456 – 0.713 Oxygen (mg/L)*	0.84	0.029
	Y (Kg) = 6.58 – 0.952 Oxygen (mg/L)**	0.78	0.019

Note * = Dry season ** = Rainy season

Table 8. Relationship Between Fish Catch and Total Phosphate (TP).

Fishes	Regression Equation	R–sq	P
1. Cyprinidae	Y (Kg) = 1.836 – 0.408 Tp (Mg/L)*	0.80	0.041
	Y (Kg) = 4.171 – 6.520 Tp (Mg/L)**	0.93	0.002
2. Catfish	Y (Kg) = 2.43 – 0.590 Tp (Mg/L)*	0.41	0.247
	Y (Kg) = 4.02 – 7.14 Tp (Mg/L) **	0.56	0.086
3. Snakehead	Y (Kg) = 0.291 – 0.0393 Tp (Mg/L)*	0.12	0.646
	Y (Kg) = 0.753 – 0.95 Tp (Mg/L)**	0.17	0.415
4. Cichlids	Y (Kg) = 0.567 – 0.099 Tp (Mg/L)*	0.25	0.502
	Y (Kg) = 1.762 – 2.655 Tp (Mg/L)**	0.78	0.019
5. Sailfin Catfish	Y (Kg) = –1.350 + 1.251 Tp (Mg/L)*	0.97	0.013
	Y (Kg) = –2.981 + 10.90 Tp (Mg/L)**	0.93	0.002

Note: * = Dry season, ** = Rainy season

fish (*Channa strata*) and catfish (*Clarias melanoderma*) can live in swamp waters with low oxygen levels because these fish have additional respiratory organs, i.e., labyrinth organs [48].

The catch volume of Sailfin Catfish during the dry and rainy seasons, showed a significant negative linear relationship between catch production and dissolved oxygen (Table 7). The higher the oxygen does not cause the production of the catch to decrease, on the contrary, this is because Sailfin Catfish can take oxygen from the air, so the low oxygen levels in the waters do not cause problems for Sailfin Catfish. Sailfin Catfish can grow well in waters that are heavily polluted with organic matter as food, the more organic pollution materials the more Sailfin Catfish, although organic matter will cause the oxygen content in the waters to below [58].

There are very few sources of phosphorus in nature, if in the waters the phosphorus content is high, it can be ascertained that it comes from human activities, including organic phosphorus from fish farming residues in floating net cages. Cyprinidae have a significant negative linear relationship between catch production and TP, both during the dry and rainy seasons (Table 8). Cyprinidae is a type of fish that is sensitive to pollution so the increase in phosphorus will get a response for low catch production. The increase in nitrogen and phosphorus in the water causes the growth of algae. It can even become an algae bloom. The proportion of Cyanophyceae can increase along with the increase in nutrients. The presence of Cyanophyceae in the waters is an indication of organic matter pollution, and is a poisonous algae [61, 66].

Catfish and Snakehead have a non-significant negative linear relationship between catch production and TP content (Table 8). This is because these fish can live in waters that contain relatively large amounts of organic matter or little, can live in the highlands that are low in phosphorus, and in the lowlands where there is a lot of phosphorus so that the production of catches is not greatly affected by phosphorus.

The production of Cichlids in the Bengawan Solo River during the rainy season has a significant negative linear relationship with the phosphorus content in the river, the higher the phosphorus in the river, the lower the catch production (Table 8). Cichlids are sensitive to phosphorus content which comes from organic waste. Meanwhile, during the dry season, the production of Cichlids has an insignificant linear relationship with phosphorus. This is because, during the dry season, the production of catches in rivers is not only affected by phosphorus but also production sources such as rice fields and reservoirs have dried up. During the rainy season there was a significant relationship between catch and TP, and this could be caused by the influx of Tilapia from rice fields due to overflowing waters [50]. Sailfin Catfish has a significant positive linear relationship between catch production and phosphorus (Table 8).

The higher the phosphorus content in the river, the higher the catch production. This is because the Sailfin Catfish can grow well in waters that are polluted with organic matter as the main food. The more organic matter in the water, the more sailfin catfish; on the other hand, the less organic matter, the less the catch production. Sailfin Catfish are rarely found in clear, unpolluted waters, so the presence of Sailfin Catfish can be used as a bio–indicator of waters that have been polluted by organic matter. This observation is the same as previous research which stated that there are several types of fish that can live in waters polluted by industrial waste, one of which is the Sailfin Catfish (*Pterygoplichthys pardalis*). This fish can survive and breed successfully in polluted locations because of its good adaptability and is also caused by physiological, behavioral, or genetic factors of the fish [54, 55, 58]

Water pollution has a negative impact on the survival and reproduction of fish resources, so it is necessary to build a sewage treatment plant to maintain the quality of the surrounding waters by reducing pollution from non-point sources, and strengthening monitoring and management of water quality in line. with environmental ecology [67-69]. The problem of decreasing fish resources can be overcome by using the method of enhancement and releasing fish into the waters. This method can help increasing the overall population and support successful breeding. The use of this method has resulted in increasing in fish species stock in the Lijiang River to one million each year [70].

Conclusions

The zone I (upstream zone) of Bengawan Solo River located in the village of Bendung Colo, Sukoharjo District, central Java is not polluted; and the fish species are dominated by both exotic namely, Tilapia (*Oreochromis niloticus*), Jambal Sius (*Pangasianodon hypophthalmus*) and native fish species, namely Sogo (*Hemibagrus nemurus*) and Tawes (*Barbodes gonionotus*).

At zone II (middle zone) in the village of Kampung Sewu, Solo City; Bison village, Karanganyar District; Tenggak village, Sragen District, Central Java; there were indications of heavy pollution with organic matter; and the fish species are dominated by Sailfin Catfish (*Pterygoplichthys pardalis*).

At zone III (downstream zone), the water quality has recovered; and the fish species are dominated by native fish species such as Wagal (*Pangasius polyuranodon*), Tawes *(Barbodes gonionotus)*, Tagih (*Hemibagrus nemurus*), Lumbet (*Cryptopterus* sp.), Bendol (*Barbichthys laevis*), Seren (*Cyclocheilichthys* sp.), Kutuk (*Channa striata*), Sepat (*Trichogaster trichopterus*), Bader (*Cyclocheilichthys enoplos*), Keting (*Barbonymus gonionotus*), Daringan (*Mystus microcanthus*).

Acknowledgments

The author would like to thank: Research Institute for Inland Fisheries and Fisheries Extension Palembang who have funded research activities; research team colleagues who have helped a lot during the conduct of the research and the fishers as enumerators who helped in recording the data on fish catch.

Conflict of Interest

The authors declare no conflict of interest.

References

1. MINISTRY OF PUBLIC WORKS. JDIH Ministry of PUPR-Regulation of the Minister of Public Works and Public Housing Number 04/PRT/M/2015 Water r of the Bengawan Solo river. (in Indonesian). Diretorate General of Highways. **2015** [In Indonesia].
2. UTOMO A.D., WIBOWO A., SUHAIMI R.A., ATMINARSO D., BAUMGARTNER, L.J. Challenges balancing fisheries resource management and river development in Indonesia. Marine and Freshwater Research. **70** (9), 1201. **2019**.
3. SHUKLA R., BHAT, A. Morphological divergences and ecological correlates among wild populations of zebrafish (*Danio rerio*). Environmental Biology of Fishes. **100** (3), 251, **2017**.
4. ARTHINGTON A.H., DULVY N.K., GLADSTONE W., WINFIELD I.J. Fish conservation in freshwater and marine realms: status, threats and management. Aquat. Conserv. **26** (5), 838, **2016**.
5. YANG J., YAN D., YANG Q., GONG S., SHI Z., QIU Q., HUANG S., ZHOU S., HU M. Fish species composition, distribution and community structure in the Fuhe River

Basin, Jiangxi Province, China. Global Ecology and Conservation. 27, **2021**.
6. LIU X.J., AO X.F., NING Z.T., HU X.Y., WU X.P., OUYANG S. Diversity of fish species in suichuan river and shushui river and conservation value, China.Environ. Biol. Fish. **100** (5), 493, **2017**.
7. BUCKE D. Aquatic pollution: Effects on the health of fish and shellfish. Parasitology. **106**, S25. **1993**.
8. AMOATEY P., BAAWAIN M.S. Effects of pollution on freshwater aquatic organisms. Water Environment Research. **91** (10), 1272. **2019**.
9. QUADRA G.R., ROLAND F., BARROS N., MALM O., LINO A.S., AZEVEDO G.M., CAMPOS J.M.S. Far-reaching cytogenotoxic effects of mine waste from the Fundão dam disaster in Brazil. Chemosphere. **215**, 753, **2019**.
10. BASSEM S.M. Water pollution and aquatic biodiversity. Biodiversity International Journal Review. **4** (1), 10. **2020**.
11. ANAWAR H.M., CHOWDHURY R. Remediation of Polluted River Water by Biological, Chemical, Ecological and Engineering Processes. Sustainability. **12** (17), 7017, **2020**.
12. SCHWARZENBACH R.P., EGLI T., HOFSTETTER T.B., VON GUNTEN U., WEHRLI B. Global water Pollution and Human Health. Annual Review of Environment and Resources. **35**, 109, **2010**.
13. UTOMO A.D., RIDHO M.R., SALEH E., PUTRANTO D.D.A. Pollution in The Bengawan Solo River Between Solo and Sragen, Central Java. Bawal Widya Capture Fisheries Research. **3** (1), 25, **2010** [In Indonesia].
14. AKYUNIN Q. Composition of Fish Caught in Bengawan Solo, Downstream, Lamongan District, East Java. University of Brawijaya. **2016** [In Indonesia].
15. BUWONO N.R., FARIEDAH F., ANESTYANINGRUM R.E. Fish Community in Jerowan River Madiun District. Journal of Aquaculture and Fish Health. **6** (2), 81, **2019** [In Indonesia].
16. SRIWIDODO D.W.E., BUDIHARJO A., SUGIHARTO. Diversity of Fish Species on The Inlet And Outlet Area of Gajah Mungkur Reservoir Wonogiri. Bioteknologi. **10** (2), 43, **2013** [In Indonesia].
17. CAHYONO R.N., BUDIHARJO A., SUGIYARTO S. Diversity and Kinship of Cyprinidae Family Fish In The Sukoharjo Colo Dam Ecosystem of Central Java. EnviroScienteae. **14** (2), 137, **2018** [In Indonesia].
18. APHA (American Public Health Association). Standard Methods for the Examination of Water and Wastewater. APHA. 1134, **1981**.
19. KOTTELAT M., WITTEN T. Freshwater biodiversity in Asia with special reference to fish. World Bank Technical Paper. Washington DC: The World Bank. **1996**.
20. WEBER M., DE BEAUFORT L. The fishes of the Indo–Australian Archipelago. Leiden: E.J. Brill Ltd. **1911**.
21. GONG D., GAO X., NTAKIRUTIMANA T., GUO J., LI K. Water Quality Status along the Liangtan River and Control Planning Alternatives for Pollution Reduction. Polish Journal of Environmental Studies. **22** (4), 1061, **2013**.
22. ISLAM M.S., UDDIN M.K., TAREQ S.M., SHAMMI M., KAMAL A.K.I., SUGANO T., KURASAKI M., SAITO T., TANAKA S., KURAMITZ H. Alteration of Water Pollution Level with the Seasonal Changes in Mean Daily Discharge in Three Main Rivers around Dhaka City, Bangladesh. Environments. **2**, 280, **2015**.
23. BAYRAM A., KANKAL M. Artificial Neural Network Modeling of Dissolved Oxygen Concentrations in a Turkish Watershed. **24**, 4, 1507, **2015**.
24. LE MOIGNE F.A.C., CISTERNAS-NOVOA C., PIONTEK J., MAßMIG M., ENGEL A. On the effect of low oxygen concentrations on bacterial degradation of sinking particles. Sci Rep. **7**, 16722, **2017**.
25. ADJIE S., UTOMO A.D., MUFLIKHAH N., KRISMONO. A. Study of Polluton and Biology of Catfish (*Pangasiidae*) in Bengawan Solo River. Technical reports on Reasearch Institute for Inland Fishries, Palembang. 23, **2005** [In Indonesia].
26. UTOMO A.D. Carrying Capacity Estimation for Fish Culture of Floating Net Cages in Gajah Mungkur Reservoir. Dissertation, Sriwijaya University, Palembang, Indonesia. **2013** [In Indonesia].
27. UNESCO. The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. Paris, UNESCO. **2017**.
28. ALI H., E. KHAN. Environmental chemistry in the twenty- first century, Environmental Chemistry Letters. **15**, 2, 329, **2017**.
29. AIDA SN., UTOMO A.D., MAKRI, WARO B. Fish Stock Assessment and Fissheries Potential in Bengawa Solo River, Centre Java. Technical Report, Research Institute for Inland Fisheries, Palembang. **2019** [In Indonesia].
30. IBEMENUGA K.N. Bioaccumulation and toxic effects of some heavy metals in freshwater fishes. Anim. Res. Int. **10**, 3, 1792, **2013**.
31. SHAKIR H.A., QAZI J.I., CHAUDHRY A.S., ALI S. Metal accumulation patterns in livers of major carps from anthropogenically affected segment of the river Ravi, Pakistan.Int. J. Adv. Res. Biol.Sci. **1**, 261, **2014**.
32. QAZI M.A., AZMAT H., KHAN N., KHAN N.I., UMAR F., HAMID Z., GUL R., KHALID M., FATIMA M., MALIK A., BANO S., KHALID F., NAZIR S., MUGHAL M.I., BAIG B. Findings on Trends of Chromium and Lead Bioaccumulation in Cirrhina mrigala in the Water and Sediments of River Ravi. Pol. J. Environ. Stud. **31**, 2, 1285, **2022**.
33. AKINBORO A., MOHAMED K.B., ASMAWI M.Z., SULAIMAN S.F., SOFIMAN O.A. Antioxidants in aqueous extract of Myristicafragrans (Houtt.) suppress mitosis and cyclophosphamide-induced chromosomal aberrations in Allium cepa L. cells. J. Zhejiang Univ. Sci. B. **12,** 11, 915, **2011**.
34. RAJPUT S., KAUR T., ARORA S., KAUR R. Heavy Metal Concentration and Mutagenic Assessment of Pond Water Samples: a Case Study from India. Pol. J. Environ. Stud. **2**, 1, 789, **2020**.
35. ZHAO X.M., YAO L.A., MA Q.L., ZHOU G.J., WANG L., FANG Q.L., XU Z.C. Distribution and ecological risk assessment of cadmium in water and sediment in Longjiang River, China: Implication on water quality management after pollution accident. Chemosphere, **194**, 107, **2018**.
36. DANIS B., WANTIER P., FLAMMANG R., PERNET PH., CHAMBOST-MANCIET Y., COTEUR G., WARNAU M., DUBOIS P.H. Bioaccumulation and effects of PCBs and heavy metals in sea stars (*Asterias rubens*, L.) from the North Sea: a small scale perspective, Sci. Tot. Environ. **356**, 275, **2006**.
37. JAKIMSKA A., KONIECZKA P., SKÓRA K., NAMIEŚNIK J. Bioaccumulation of Metals in Tissues of Marine Animals, Part I: the Role and Impact of Heavy Metals on Organisms. Pol. J. Environ. Stud. **20**, 5, 1117, **2011**.

38. LA V.T., COOKE S.J. Advancing the science and practice of fish kill investigations.Rev. Fish. Sci. Aquac. **19**, 21, **2011**.
39. PETRIKI O., PATSIA A., VAFEIADOU A., TEKIDIS I., MICHALOPOULOU P., SAMARTZI S., MALLINIS D., BOBORI D.C. Tracking theCauses of a Mass Fish Kill at a Mediterranean River within a Protected Area. Water. **13**, 989, **2021**.
40. MIKUCKA W., ZIELIŃSKA M. Distillery Stillage: Characteristics, Treatment, and Valorization. Appl Biochem Biotechnol. **192**, 770, **2020**.
41. EFFENDI H., ROMANTO, WARDIATNO, Y. Water quality status of Ciambulawung River, Banten Province, based on pollution indeks and NSF-WQI. Procedia Environmental Sciences. **24**, 228, **2015**.
42. HANDOKO M., SUTRISNO A.J. Spatialand Temporal Analysis of Dissolved Oxygen (DO) And Biological Oxygen Demand (BOD) Concentrations In Rawa Pening Lake, Semarang Regency. Geography Journal Gea, **21** (1), 58, **2021**.
43. MISHRA P., NAIK S., BABU P.V., PRADHAN U., BEGUM M., KAVIARASAN T., VASHI A., BANDYOPADHYAY D., EZHILARASAN P., PANDA U.S., MURTHY M.V.R. Algal bloom, hypoxia, and mass fish kill events in the backwaters ofPuducherry, Southeast coast of India. Oceanologia. 1-8, **2022**.
44. DITYA Y.C., MUTHMAINNAH D., WIADNYANA N.N., MAKMUR S., KABAN S., RAIS A.H., HIDAYAH T., ANGGRAENI D.P., ANTONI R., DWIRASTINA M., KOESHENDRAJANA S. Assessing the Ecosystem Approach to Fisheries Management in Indonesian Inland Fisheries. Pol. J. Environ. Stud. **31** (3), 1, **2022**.
45. KOESHENDRAJANA S. Strategy for Managing Inland Waters Resources for Sustainable Fisheries Development, Research Professor Inauguration Speech, Jakarta, **2014** [In Indonesian].
46. AIDA SN., UTOMO A.D. Carrying Capacity Estimation for Fish Culture of Floating Net Cages in Pondok Reservoir, Ngawi East Java. Bawal. **10** (3), 197, **2018** [In Inddonesia].
47. AIDA SN., UTOMO A.D. Assessment Of Water Quality For Fisheries In Rawa Pening Centre of Java. Bawal. **8** (3), 173, **2016** [In Indonesia].
48. UTOMO A.D., AIDA S.N., HIDAYAH T. Optimization of Fisheries Management In Gegas Lake Musi Rawas Regency South Sumatera. Indonesian Fishery Policy Journal. **12** (1), 1, **2020** [In Indonesia].
49. AIDA S.N., RIDHO R., SALEH E., UTOMO A.D., NURHAYATI. Distribution of phytoplankton based on the water quality at Bengawan Solo River, Central Java" International Journal of the Bioflux Society (AACL Bioflux). **15** (2), **2022**.
50. UTOMO A.D., ADJIE S., MUFLIKAH N., WIBOWO A. Fish Diversity And Water Quality In Bengawan Solo. Indonesian Fisheries Research Journal. **12** (2), **2006** [In Indonesia].
51. LIN X.Z., LI D.M., LIU H.Z., LIN H.S., YANG S.R., FAN H.J., WEN R.S. Fish species diversity and its seasonal variations in the Chaozhou section of Hanjiang River, Guangdong Province. Biods. **24** (02), 185, **2016**.
52. AIDA S.N., UTOMO A.D. Striped catfish (*Pangasianodon hypophthalmus*) (Sauvage, 1878) movement and growth in Gajah Mungkur reservoir, Central Java. Indonesian Fisheries Research Journal. **21** (1), **2015** [In Indonesia].
53. ADJIE S., UTOMO A.D. The Catch of Several Types of Fishing Equipment in the Bengawan Solo River. BAWAL. **3** (1), 33, **2017** [In Indonesian].
54. DA CRUZ A.L., DA SILVA H.R., LUNDSTEDT L.M., SCHWANTES A.R., MORAES G., KLEIN W., FERNANDES M.N. Air-breathing behavior and physiological responses to hypoxia and air exposure in the air-breathing loricariid fish, Pterygoplichthys anisitsi. Fish Physiology and Biochemistry. **39** (2), 243, **2013**.
55. HUSSAN A., CHOUDHURY T.G., DAS A., GITA S. Suckermouth Sailfin Catfishes: A future threat to aquatic ecosystems of India. Aquaculture Times. **2** (6), 20, **2016**.
56. EVANS D.H. Freshwater fish gill ion transport: August Krogh to morpholinos and microprobes. Acta physiologica (Oxford, England). **202** (3), 349, **2011**.
57. NICO L.G., BUTT P.L., JOHNSTON G.R., JELKS H.L., KAIL M., WALSH S.J. Discovery of South American suckermouth armoredcatfish (Loricariidae, *Pterygoplichthys* spp.) in the Santa Fe Riverdrainage, Suwannee Riser Basin, USA. BioInvasions Records. **1**, 3, 179, **2012**.
58. AIDA S.N., RIDHO R., SALEH E., UTOMO A.D., NURHAYATI. Estimation of Growth Parameter on Sailfin Catfish (*Pterygoplichthys pardalis*) in Bengawan Solo River, Central Java Province. IOP Conference Series: Earth and Environmental Science, **695** (1), 10. **2021**.
59. HAYATI A. Water quality and fish diversity in the Brantas River, East Java, Indonesia. Journal of Biological Researches, **22** (2), 43. **2017**.
60. LIU F., LIN P.C., LI M.Z., GAO X., WANG C.L., LIU H.Z., 2019. Situations and conservation strategies of fish resources in the Yangtze River Basin. Acta Hydrobiol. Sin. 1-13, **2019**.
61. ASTUTI LP, SUGIANTI Y., WARSA A., SENTOSA A.A. Water Quality and Eutrophication in Jatiluhur Reservoir, West Java, Indonesia. Pol. J. Environ. Stud. **31** (2), **2022**.
62. YOUN S.J., TAYLOR W.W., LYNCH A.J., COWX I.G., DOUGLAS BEARD T., BARTLEY D., WU F. Inland Capture Fishery Contributions to Global Food Security and Threats to Their Future. Global Food Security, **3** (3-4), 142, **2014**.
63. AIDA S.N., UTOMO A.D. Europic Level Of Kedung Ombo Reservoir In Central Java, Indonesia. BAWAL Widya Fisheries Research Journal. **4** (1), **2012**.
64. MAMUN S.M., FOCKEN U., BECKER K. A respirometer system to measure critical and recovery oxygen tensions of fish under simulated diurnal fluctuations in dissolved oxygen. Aquaculture International, **21** (1), 31. **2013**.
65. SETYANINGRUN D., AGUSTINA L. Water Quality Analysis In Bengawan Solo River Bojonegoro Regency. Samakia: Journal of Fisheries Science. **11** (1), 1, **2020** [In Indonesia].
66. YANG Z.Y., YANG H.B. Water quality evaluation and cause analysis of typical lakes and reservoirs in Fuhe River Basin. J. Heilongjiang Hydra Sci. Technol. **43** (01), 201, **2015**.
67. HU M.L., XI H.B., HUA Q., ZHANG J.M., ZHOU, H.M., GE, G., AI, Z.M., 2014. Preliminary investigations on fish resources of yihuang Mergus squamatus nature reserve in jiangxi province. Nanchang U: Nat. Sci. **38** (05), 502, **2014**.
68. XIAO J.C., LUO D.G., WANG Z.Z. Soil erosion simulation in fuhe basin based on SWAT model. Res. Soil Water Conserv. **20** (01), 14, **2013**.
69. JIANG Y.Y., GAN Z.M., FU L. Analysis and control of water environment problems in Fu River Basin of Fuzhou City Jiang Guangdong. Chem. Ind. 46 (24), 87, **2019**.
70. WU Z.Q., HUANG L.L., Fish Biodiversity and its Relationship with Environment in Lijiang River. Science Press, Bejing. **2017**.