Assessment of fish species and migratory aquatic birds' biodiversity in Yamuna river (Haryana)

BY

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CERTIFICATE – I

This is to certify that this thesis entitled "**Assessment of fish species and migratory aquatic birds' biodiversity in Yamuna river (Haryana)"** was submitted for the degree of Master of Fisheries Science in the subject of **Fisheries Resource Management** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Mr. Shri Ram Yadav** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of the investigation have been fully acknowledged.

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This is to certify that this thesis entitled "**Assessment of fish species and migratory aquatic birds' biodiversity in Yamuna river (Haryana)**" was submitted by **Mr. Shri Ram Yadav** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, in partial fulfillment of the requirements for the degree of Master of Fisheries Science in the subject of **Fisheries Resource Management** has been approved by the Student‟s Advisory Committee after an oral examination on the same.

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ABBREVIATIONS

%	-	Percentage
/	-	Per
Fig.	-	Figure
i.e.	-	ideast (that is)
ml	-	Millilitre
Km	-	Kilometres
cm	-	Centimetre
L	-	liter
mm	-	Millimetre
µm	-	Micrometre
Viz.	-	Vi delicat (namely)
C.D.	-	Critical difference
C.R.D.	-	Completely randomized design
e.g.	-	Example gratia; for example
et al.	-	*Et al*ibei
ANOVA	-	Analysis of Variance
ha	-	Hactare
sp.	-	Species
No.	-	Number
H’	-	Diversity index
Ind.	-	Individual
org.	-	Oraganism

CHAPTER-I

INTRODUCTION

Biological diversity has many forms, from the smallest molecules to the most complex ecosystems—the creation of populations, communities, ecosystems, and biomes by individual creatures' levels and the ecosystem. Said, biodiversity is the total number of species. The diversity of fish needs to be taken more seriously as a worldwide resource that needs to be catalogued, used, and most importantly, maintained. To take the required actions for the conservation of threatened or vulnerable species, the study of biodiversity aids in a better understanding of an area's habitat, ecology, and zoogeography as well as an assessment and evaluation of the state of its flora and fauna. We can learn about a region's land and water resources thanks to the rapidly changing biosphere scenario around the globe, and in particular, thanks to some of its more established parts. One requirement for managing fisheries resources effectively and preserving certain significant threatened fish species in the field of water resources is a thorough knowledge of the fish fauna and its diversity

Fish make up about half of all vertebrates on the planet. There are 32,900 species of fish among the 64,000 vertebrates (Froese & Pauly 2014). In India, there are 2500 different fish species,out of them 930 dwell in freshwater and 1570 live in the sea (Kar *et al*., 2004). In the Indian Subcontinent, 742 freshwater species are classified into 233 genera, 64 families, and 16 orders (Jayram, 1999). Central India's diverse water resources, such as streams, rivers, reservoirs, subterranean aquatic ecosystems, traditional lakes, and domestic ponds, are home to a diverse range of freshwater fish. India is the world's second-largest fish producer, behind China, and the world's second-largest aquaculture producer (FAO, 2014).

This sector in India accounts for around 5% of global fish production. During 2017-18, overall fish production was 12.59 million tonnes, with the inland sector contributing 8.90 million metric tonnes. Comparing 2016-17 to 2017-18, the average increase in fish production was 10.14 per cent (11.43 million metric tonnes). *Catla catla, Labeo rohita,* and *Cirrhinus marigla*, Indian big carps, dominate the fishing wealth from Indian reservoirs (Shenoy & Rajpathak, 2021). The variety and variability of flora, fauna, and microbes in an environment can be defined as biodiversity. Fish account for half of all vertebrate species on the planet. They can be found in practically every type of aquatic environment. Over exploitation of biological resources to feed a growing human population is so evident, especially in densely populated third-world nations, that most resources, whether terrestrial or aquatic, have

exhibited symptoms of diversity loss, which is a severe problem for all living things (Rathore *et al.,* 2017).

Mishra & Moza (2007) reported the increasing presence of exotic fishes *C. carpio* and *O. niloticus* in the Yamuna river, gradually establishing themselves as a breeding population and displacing Indian major carps. Reduced discharge alters the micro and macro habitat characteristics, favouring the increase of non-indigenous species, according to observations in other nations' rivers.

The Ganga basin, in general, and the Yamuna basin in particular, have a substantial proportion of the population concentrated in large urban centres, the majority of which lack sewerage and those that do lack enough capacity to treat domestic wastewaters (Vass *et al*., 2011). As a result, massive amounts of untreated or partially treated sewage, industrial effluents and agrochemical pollutants are released into the Yamuna river in the metropolitan areas (CPCB, 2005).

Biodiversity refers to the genetic and biological diversity of populations, species, communities, and ecosystems (Hiddik *et al*., 2008). Biodiversity impacts the ability to live systems to adjust to environmental changes and is necessary for ecosystems to provide goods and services. As a result, it is the most important but underappreciated resource, and comprehending it is critical for the world's survival. Protecting biodiversity in all ecosystems is necessary for the stabilization of ecological systems and the protection of environmental quality, as well as for understanding the intrinsic value of all species on the planet (whether for agriculture, fisheries, forestry systems, or evolutionary processes) (Ehrlich & Wilson, 1991).

Freshwater habitats are the richest and most diversified on the planet among all ecosystems (Revenga & Mock, 2000). They make up only 0.01 per cent of the world's water, cover only 0.8 per cent of the planet's surface, yet provide nearly 3% of the world's net primary production (Alexander, 1999). Freshwater, however, is home to 6% of all species and more than 10% of all animal species, including 25% of all vertebrates and 40% of all fishes (Balian *et al*., 2008). Furthermore, freshwater environments are home to 40% of the world's known fish species (Daily, 1997).

Anza marsh and the Gorgan Bay are two of the most important wetlands and provide good feeding and roosting habitat to many fish-eating birds, these shallow wetlands (Scott 1995, Behrouzirad, 1997). Fish-eating birds play a vital part in the natural world (Doorbon, 1984). Between 18-25 fish species were detected in the diets of Common Kingfishers on different types of water bodies in this study (Slapy Reservoir, Blanice River and trout

streams). The diet included fish from all parts of the water body: subsurface (European Chub, Bleak and Dace), mid-water (European Perch, Roach, Stone Moroko *Pseudorasbora parva* and Brown Trout), and benthic (European Perch, Roach, Stone Moroko *Pseudorasbora parva* and Brown Trout) and benthic (European Perch, Roach, Stone Moroko Pseu (Gudgeon, Bullhead and Stone Loach). Even if benthic species are abundant in the water body, the Common Kingfisher neglects them in various parts of Europe (Vilches *et al.,* 2012).

Crayfish are another form of prey included in the Kingfisher's diet (Cramp, 1990). The Great Cormorant, accounts for quantitatively 0.16 per cent of the diet (Cech, 2012). Common Kingfishers have been diving for vegetation or, more significantly, willow leaves swept away by the stream (Cramp, 1990). Individual Common Kingfishers, on the other hand, may occasionally switch to non-fish prey. It was observed that a Common Kingfisher feeding on larvae of the Common Spadefoot Toad Pelobates fuscus in a pond on a forest edge in Alsace France (Cech, 2012).

In several European coastal regions and significant freshwater bodies, the great cormorant (*Phalacrocorax carbo sinensis*) has grown in abundance in recent decades (Punt *et al.,* 2009; Vetemaa *et al.,* 2010). Although it is unclear whether this increase in cormorant abundance harms the abundance of fishery-relevant species, it has sparked a debate between fishery managers and bird conservationists (Vetemaa *et al.,* 2010). Cormorants eat a variety of fish species and can be classified as opportunistic feeders (Johnsgard, 1993; Lindell, 1997). (Leopold *et al.,* 1998). Seasonal variations in their nutrition have been observed, which have been linked to breeding status and fish availability (Cech *et al.,* 2008; Gwiazda & Amirowicz, 2010).

Photosynthetic, primary producers, and zooplankton are examples of heterotrophic, primary, or secondary consumers. The availability of fish food species determines the productivity of a lake's ecosystem. Hence limnobiology is crucial. Natural freshwater lakes with significant scientific and economic importance abound in India.

So, keeping the above facts in view, the present investigation was carried out with the following objectives:

1. To study the fish diversity in the selected sites of Yamuna river
2. To study the diversity of migratory aquatic birds and their nature of damage in the selected sites at Yamuna river

CHAPTER - II

REVIEW OF LITERATURE

After China, India is the world's second-largest fish-producing and aquaculture nation. The total fish production in 2019-20 was around 14.16 million metric tonnes (MMT), with the inland sector contributing 10.43 MMT and the marine sector contributing 3.72 MMT. With yearly export earnings of Rs. 46,662.85 crores, the fishing sector contributes around 1.24 per cent to the national GDP and 7.28 per cent to the agricultural GDP (Handbook of Fisheries Statistics, 2020). Inland and marine resources make up the country's fisheries resources. Rivers and canals (3.8 lakh km), reservoirs (27.03 lakh ha), brackish water (9.65 lakh ha), derelict water bodies/oxbow lakes (3.48 lakh ha), ponds and tanks (24.7 lakh ha) are examples of inland resources. In comparison, coastline (8118 km), exclusive economic zone (2.02 million sq km), continental shelf (0.53 million sq km), and landing centres (1548) are examples of marine resources (Handbook of Fisheries Statistics, 2020).

2.1 Fish diversity

Joshi & Pandey (2015) reported that the Yamuna River, also known as 'Jamuna', is northern India's main tributary of the Ganga. It begins at the Yamunotri Glacier, at the height of 6,387 metres on the south western slopes of the Banderpooch peaks in Uttarakhand's uppermost region of the lower Himalayas, and flows for 1,376 kilometres (855 miles), draining 366,223 square kilometres (141,399 square miles), or 40.2 per cent of the Ganga Basin. Before arriving in Delhi, it passed through numerous states, including Uttarakhand, Haryana, and Uttar Pradesh and later on, it joined its tributaries.

Kumar & Asthana (1993) found 116 species of fish in Rajasthan, belonging to nine orders, 23 families, and 58 genera. Rathore *et al.* (2017) investigated the fish biodiversity and fisheries potential of the Udaisagar reservoir in Rajasthan. In the current study, 31 species spanning nine families were identified, with 12 species mainly contributing to the commercial fisheries of this reservoir. During the study period, Indian major carps (IMCs) dominated the catch, accounting for 90 per cent of all landings from this reservoir. Minor carps and catfishes, in addition to Indian big carps, were reported to be 8.84 and 0.9 per cent, respectively. *C. catla* (70%) dominated the groups of Indian major carps, followed by *L. rohita* (25%) and *C. mrigala* (20%). The bulk of the 31 species in the Udaisagar reservoir is significant food fishes, although only 12 species make up the reservoir's commercial catch (Rathore *et al.*, 2017).

There are 41 species of fish in Sagar Lake, belonging to 25 genera and 13 families. When the current data is compared to prior data on ichthyofaunal diversity in Sagar Lake,

which was collected less than a decade ago, the ichthyofaunal variety of this lake has decreased dramatically. The most common species in the lake are *Puntius ticto*, *Puntius conchonius* and *Puntius sophore* (Tiwari, 2006).

It was reported that the fish and phytoplankton biodiversity of the *Pichhola* Lake in Udaipur (Rajasthan) concerning primary productivity, and found that a total of 20 fish species belonging to seven families. Only 11 fish species, namely Catla, Mrigala, Rohu, Kharpata, Sarsi, Puthi, Chal, Pabda, Lanchi, Singhi, and Channa, contributed to the reservoir's commercial catch (Bhatt *et al*. 2018).

Nyanti *et al.* (2012) investigated the composition and diversity of fish and crustacean fauna in the Lutong River, Sarawak, and the length-weight connection of the most often collected fish species. The study region yielded 33 fish and crustacean species, divided into 28 genera and 23 families. Ambassidae accounted for 39% of the total number of individuals caught, with Penaeidae accounting for 15%, Portunidae for 10%, Mugilidae for 8%, Megalopidae for 6%, Scatophagidae for 4%, and Centropomidae for 3%.

Kathiresan & Rajendiran (2002) investigated fisheries resources and economic gain in three mangrove sites along India's southeast coast. According to their findings, there were 102 fin fish species in the Pichavaram mangroves and 86 fin fish species in the Vellar estuary. At the Ariyankuppam estuary in the Pondicherry region, they found 72 fin fish.

Govindasamy (2011) looked at the diversity of 193 plant species, 397 fish species, 259 crab species, 256 mollusc species, 450 insects, over 250 mammalian species, and other plants and animals around the world. In the context of global warming, mangroves play a critical role in preventing simultaneous sea level rise, coastal erosion, and long-term community stability, as well as having a high potential for medical benefits.

Fishes abound among the macrofauna of the Pondicherry mangroves, with 39 species belonging to 24 families and seven orders. The order Perciformes accounts for 77% of these fish. *Chanos chanos, Arius jella*, *Atule mate*, *Oreochromis mossambica, Terapon jarbua, and Gerrus filamentosus* are the most common fish species. Mullet, milkfish, and tilapia are taken in the high sections of the Murungapakkam and Thengaithittu rivers. Fishes abound among the macrofauna of the Pondicherry mangroves, with 39 species belonging to 24 families and seven orders. The order Perciformes accounts for 77% of these fish. *Chanos chanos*, *Arius jella, Atule mate, Oreochromis mossambica, Terapon jarbua, and Gerrus filamentosus* are the most common fish species. Mullet, Milkfish and Tilapia are taken in the high sections of the Murungapakkam and Thengaithittu rivers. *Caranx sp., G .filamentosus and Kathala axillaries* are mostly found at the mouth while species like *Lutjanus argentimaculatus*, *Siganus*

canaliculatus, and Siganus javus are mangrove-specific fishes caught near submerged branches (Kumar & Kumar, 2011).

Sreekantha & Ramachandra (2005) reported 43 species from the Sharavathi River. The Koyana River discovered 58 species from 16 families and 35 genera. The Karanja Reservoir revealed that most fish recorded were extensively spread across North Karnataka's streams, rivers, and reservoirs, with Cyprinid fishes being the most prominent category. All three landings yielded many Indian Major Carp, including *C. catla, L. rohita,* and *C. mrigal.*

Bairwa *et al*. (2019) found 32 species in the Udaipur lakes, spanning nine groups. The Cyprinidae family was responsible for most of the commercial fisheries in this reservoir, and *C. catla* was the most common IMC, followed by *L. rohita* and *C. mrigala*. The lake must be conserved for a few species observed in small numbers during the study period.

Devi *et al*. (2017) recorded the diversity of fish species at Loktak Lake in Manipur, India and analysed fish fauna as quantitatively and qualitatively. The physicochemical characteristics of water have also been investigated.

The thirty-two freshwater fish species from six different orders were reported by Naik *et al.* (2013), and the data revealed that the order Cypriniformes had the most fish species (16), followed by Siluriformes (9) and Perciformes (3). The orders Clupiformes, Symbranciformes, and Osteoglassiformes each had only one species documented from the Upper Mullamari Reservoir's three sampling centres.

The 64 freshwater fish species arereported from Karanja Reservoir located in the northern part of Karnataka between 17°22′30″ N latitude and 76°59′0″ E longitude .and divided into 37 genera, 16 families, and five orders. With 31 fish species, the order Cypriniformes was the most common, followed by Siluriformes and Perciformes, Osteoglossiformes and Synbranchiformes. Even though 64 species, the Cyprinidae family was the most prominent with 27 fish species, followed by the Bagridae with nine fish species. Because of geographical and hydrological factors, the distribution of fish species is highly variable. Three fish landing centres recorded fish species' density, quantity, and dispersion. Species like *L. kontius* (Hamilton, 1822*), Osteobrama cotio* (Hamilton, 1822), *Gagata cenio* (Hamilton, 1822), *Glossogobius giuris* (Hamilton, 1822*), Cirrhinus reba (Hamilton*, 1822), *Garra gotyla (Gray, 1830), Silonia silonda (Hamilton, 1822*), At the landing centre, fish species *Gagata cenio, Glossogobius giuris, and Osteobrama cotio* were discovered by Naik *et al*. (2013).

2.2 Diversity of migratory aquatic birds.

According to Ali & Ripley (1968), by the end of August, Common Teal, Northern Shoveller, Northern Pintail, and Gadwall had arrived in India, with the influx continuing until November. Regarding departure during a particular winter season, Mallards leave in February for their original home, which they only arrived in December. In March, most birds flew away (Gadwall, Greylag Goose, Spot-billed Duck, Common Pochard, Tufted Pochard, Red-crested Pochard and Rudy Shelduck).

Prajapati & Dharaiya (2014) investigated the bird and macrofauna diversity in the mangrove ecosystem of Jakhau Creek, (Gulf of Kachchh), India. They discovered a total of 65 bird species belonging to 17 groups. Migratory birds made up 49 per cent of all documented bird species. Polychaetes (30 per cent), crustaceans (30 per cent), gastropods (26 per cent), bivalves (7 per cent), and fish (7 per cent) were among the 27 macroinvertebrate species discovered (7 per cent). The research shows that the mangrove environment of Jakhau Creek can be an excellent feeding place for migratory birds. Still, it will take numerous conservation techniques and management of coastal shipping and other human activities.

Kumar & Kumara (2011) studied the avifaunal diversity of the mangrove ecosystem (Kundapura, Udupi district) Karnataka, India. They revealed that the habitat attracted 32 bird species belonging to 19 groups, including residential, residential migrants, and migratory birds, aquatic birds, waders, and others. Pre-monsoon, monsoon and post-monsoon seasons had the highest number of egrets, common mynas, open-billed storks, black-headed ibis, and crows. Cormorants, pond herons, tiny herons, and night herons were among the other permanent occupants.

Pawar (2011) studied the species diversity of birds in the mangroves of Uran (Raigad), Navi Mumbai, Maharashtra, India's west coast, and found 56 species from 11 orders, 29 families, and 46 genera in the mangroves of Uran. Passeriformes accounted for 33.93 per cent of the recorded species, Ciconiiformes for 26.79 per cent, Charadriiformes for 8.93 per cent, Anseriformes for 7.14 per cent, Coraciiformes and Falconiformes for 5.36 per cent each, Columbiformes and Gruiformes for 3.57 per cent, and Cuculiformes, Pelecaniformes, and Psittaciform. The order Passeriformes, dominates the avifauna in Uran mangroves, with 11 families, followed by the order Ciconiiformes with five families. There are 33 permanent residents, 20 seasonal guests, and three occasional visitors among the species diversity. There are 33 permanent residents, 20 seasonal guests, and three occasional visitors among the species diversity. The biological conditions in Uran's mangroves currently sustain a reasonable density of birds, although contamination of the Uran shoreline cannot be

disregarded due to intensive industrialization and urbanization. As a result, the data reported in this research can be used as a baseline.

From the Hathnikund Barrage in Haryana's Yamunanagar area, Gupta & Kaushik (2011) discovered 47 species of wetland birds divided into nine orders and 13 families. Twenty-six kinds of winter migratory birds visit this Yamuna barrage every year during the winter season. On the other hand, Gupta *et al.* (2012) found 70 species of wetland birds from rural ponds in the Panipat district, which is close to the Yamuna River. Compared to the Yamuna River, it appears that migrating birds visiting Haryana prefer traditional ponds. According to current research, Ferruginous Pochard, Black-headed Gull, Greater Scaup, River Tern, and Pallas Gull are the birds unique to the River Yamuna. Some famous wetland occupants are Little Cormorants, Median Cormorants, Pond Herons, Night Herons, Black-winged Stilts, Common Moorhens, Bronze-winged Jacana, Red-wattled Lapwing, big Egrets and Median Egrets, Lesser Pied Kingfisher, White-breasted Kingfisher, and Large Pied Wagtail. Mallard, Northern Pintail, Northern Shoveller, Red-crested Pochard, Common Pochard, Tufted Pochard, Bar-headed Goose, Greylag Goose, Brahminy Shelduck, Gadwall, and Eurasian Wigeon are among the most popular winter migratory species. The stream was devoid of Ruff, Common Greenshank, Pallas Gull, Painted Stork, Open-billed Stork, White-necked Stork, Eurasian Spoonbill, Black-tailed Godwit, Wood Sandpiper, Little Stint, Common Redshank, Spotted Redshank, Pied Avocet, Eurasian Spoonbill, Black-tailed Godwit, Wood Sandpiper, Wood Sandpiper.

Gupta *et al*. (2012) reported the most famous birds in the Yamuna River. There are 60 wetland birds divided into eight orders and fourteen families. A closer look at the birds indicated that 35 species were winter migratory, 11 were local migratory, and 11 were resident. Charadriiformes (18 species), Anseriformes (16 species), and Ciconiiformes (12 species) are the most common orders. The Orders Podicipediformes (Little Grebe) and Coraciiformes (Coraciiformes) have the least diversity of marsh birds (Lesser Pied Kingfisher, White-breasted Kingfisher). The Anatidae family has the most avian diversity (16 species), followed by the Ardeidae family (8 species). The Podicipedidae family has the least diversity (Little Grebe).

Gupta *et al.* (2010) reported that the winter migratory birds are seen in rural Haryana ponds every winter. Out of the forty-six species observed during the study period in Northern Haryana, eighteen wetland birds were: Northern Shoveller, Northern Pintail, Common Teal, Spot-billed Duck, Mallard, Garganey, Eurasian Wigeon, Common Pochard, Tufted Pochard, Red-Crested Pochard, Bar-Headed Goose, Graylag Goose, Gadwall, Common Coot, Pheasant-tailed Jacana Winter migratory birds arrive in September and stay until December,

as evidenced by the fact that they arrive in September. However, the most significant number of species each year comes in October and November.

Gupta & Kaushik (2010) reported that 58 species of wetland birds might be found in Haryana's rural ponds, belonging to ten orders and 17 families. Charadriiformes (17 species) are the most common order, followed by Anseriformes (13 species) and Ciconiiformes (08 species). Falconiformes (one species) and Apodiformes (one species) have the least diversity, followed by Podicipediformes (2 species) and Coraciiformes (two species). Winter migratory birds made up 28.49 per cent of the 58 species of wetland birds recorded in Yamunanagar district village ponds. In comparison, resident birds made up 18.21 per cent, local migratory birds made up 10.17 per cent, and summer migratory birds made up 2.3 per cent.

Kumar *et al.* (2005) counted 109 residents, but the status of eight species is unknown. At Kalesar National Park in Haryana's Yamunanagar area, Kalsi (1998) documented 161 bird species. From rural village ponds in Haryana's Karnal District, Gupta *et al.* (2009) reported 72 species of Wetland Birds belonging to 10 Orders and 19 Families. There are 37 species of winter migratory birds, 13 species of local migratory birds, and 20 species of resident birds.

2.3 Plankton diversity

Victor Hensen, a German physicist, created the term "plankton" (1887). Plankton is derived from the Greek word plankton, meaning "wanderer" or "drifter." These invertebrates rely on the mercy of water for mobility. Plankton is a type of plankton widely used to assess the state of the ecosystem. Based on nutrition, phytoplankton and autotrophic plankton are the two types of plankton, (i) Phytoplankton; (ii) Zooplankton.

Anthropogenic impact on dryland lakes is varied in nature and extent. Lake water's chemical and biological features are immediately affected by salinization, water diversion, catchment activities, and pollution (Downing *et al.*, 1999; Williams, 2000). Human activities have had a significant impact on tropical lakes, which have not only affected the water quality but also the aesthetic values (Wade, 1999). Saxena & Shrivastava (2001) investigated primary phytoplankton production in a sewage-fed fish culture lake. The phytoplankton dynamics and physical-chemical characteristics of a shallow lake were studied by Kangalou *et al.* (2001). Akbulut & Yalidiz (2001) observed Lake Mogan's distribution and planktonic algae (Ankara). They also attended the distribution and planktonic algae except for Bacillarophyta of lake Mogan (Ankara).

Phytoplanktonic composition in Jananpura pond near Bhadravathi town, Karnataka, was investigated by Kiran *et al.* (2002*),* and primary productivity of two freshwater bodies of Gulbarga, India was ascertained by Sedamkar & Angadi (2002).

Jain *et al.* (2018) studied the physiochemical properties and plankton diversity of Alaknanda river, Uttrakhand, and recorded the seasonal changes. They found that the Alaknanda River's current have abundant phytoplankton.

2.4 Physicochemical parameters of water

Kumar *et al.* (2018) reported that the untreated industrial and household waste discharged into Hindon River deteriorates the water quality. Samples collected from five locations along the Hindon River between Muzaffarnagar and Meerut revealed the seasonal changes in water quality. The physiochemical parameters like pH, Electrical conductivity (EC), Nitrate, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness (TH), Total Alkalinity (TA), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO) (NO3 -) were found over the BIS standard (IS 10500) limit and that the pre-monsoon season was when water quality decreased significantly compared to monsoon and post-monsoon seasons. Therefore, on the bases, it was assumed that none of the sampling sites along the Hindon River's water supply is suitable for irrigation, fish farming, or drinking.

Tiwari *et al*.(2016) investigated the water samples from the Ganga River at Kanpur, Allahabad, and Varanasi locations. The values for pH, TDS, EC, sulphate, phosphate, nitrate, BOD, and COD were found at their lowest values at the Allahabad location. While alkalinity and total hardness had their lowest values at the Kanpur site, chloride and dissolved oxygen were also detected at the lowest levels. Although the Ganga, some tolerant fish species, like the exotic *C. carpio* and *O. niloticus*, may inhabit river waters. All the species in very hardy conditions concerning poor water quality parameters. Thus they (alien species) have powerfully invaded degraded systems in India and worldwide aquatic ecosystems.

CHAPTER -III

MATERIALS AND METHODS

The present study was carried out from September 2021 to April 2022 to investigate the fish species and migratory aquatic bird's biodiversity in Yamuna river (Haryana)

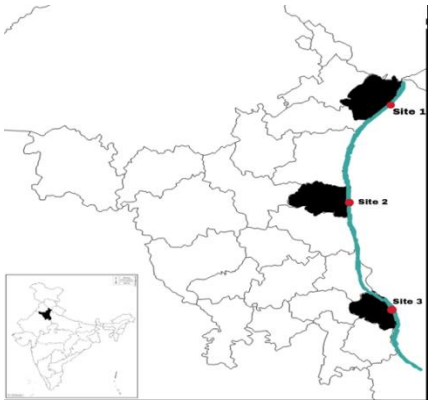
3.1 Climate of Haryana

Haryana is found in northwest India. The zone experience is highly regarded in summer and markedly cold in winter, and in between are the pleasant months of spring. The most rainfall is 216 cms; therefore, the minimum rainfall ranges from twenty-five to thirty-eight cms.

3.2 Study Area

In Haryana, the Yamuna riverine area is studied in three districts (Yamunanagar, Panipat, and Faridabad). The Yamuna river is between **28° 55' 42.8664'' N** North latitude and **77° 5'29.3712'' E**'East longitudes. The Average depth of the river in Haryana is 3m. The total length of the river in Haryana is 305km.

Geography &topography of Yamuna river	
Longitude	77° 5' 29.3712" E
Latitude	28° 55' 42.8664" N
Average rainfall	536.5 mm
Maximum depth (Zm)	3m
Water spread area	366,220 sq km
District(s) covered	Yamunanagar,Panipat and Faridabad



(Plate: 1 Studied sites of Yamuna river)
Sites 1:Yamunanagar, Sites 2: Panipat,
Sites 3: Faridabad (Source: www.Googlemaps.com)

3.3 Sampling sites

In the present research, three fixed sampling sites were selected for the collection of fish in the landing centre of the Yamuna river at (Yamunanagar, Panipat and Faridabad) and named Sampling Site I, Site II, and Site III.

The sample were collected from landing centre or river at different location.

- The site I was situated in the Yamuna riverine area of Yamunanagar, and the samples were collected from different location A, B, C, and D at river bank.
- Site II– It was situated in the Yamuna riverinr area of the Panipat, and the samples were collected from different location A, B, C, and D at river bank.
- Site III– The samples were collected from Faridabad landing centre and near Yamuna River.

3.4 Sample collection

The information on piscine diversity and composition was collected through experimental fishing conducted at the selected sites using cast nets (1.5 m diameter and 2.0 × 2.0 mm mesh), gill nets (10-40 mm) and drag nets (different mesh sizes and lengths), fishes caught by the local fishers and market survey at fish landing sites along the river banks. The samples were collected twice a month.

Sr No.	District(s)	Sampling Site	Location
1.	Yamuna Nagar	A	30.123, 77.298
2.		B	30.114, 77.290
3.		C	30.111, 77.279
4.		D	30.111, 77.274
5.	Panipat	A	29.383, 77.153
6.		B	29.377, 77.149
7.		C	29.348, 77.125
8.		D	29.345, 77.120
9.	Faridabad	A	28.368, 77.295
10.		B	27.964, 77.530

3.4.1 Collection and preservation.

Fishes were collected at regular intervals from the Yamuna river at Yamunanagar, Panipat, and Faridabad in the landing centre of Haryana. The fishes were photographed with the help of a digital camera at the sampling sites. The specimen of each species was preserved in 8 per cent formalin solution and brought to the laboratory. After recording the data, the rest of the specimens were released back into the water bodies.

The morphometric characters of the collected fishes were identified with the help of standard keys and monographs (Jayaram, 1999) . Morphometric characters include Total length, Head length, Preorbital Distance, Postorbital distance, Interorbital Distance, Length of the dorsal fin, Length of the anal fin, Distance between pectoral and pelvic fin, Distance between pelvic and anal fin etc. Meristic counts like Dorsal fin rays, Pectoral fin rays, Pelvic fin rays, Anal fin rays, caudal-fin rays, and lateral line scales.

3.5 Identification

The collected fishes were identified with the help of standard keys and monographs (Heda 2009; Jayaram, 1999; Peterson 2011; Smith 2019).

3.5.1 Species Diversity Index (d)

a) Fish biodiversity was analyzed from the collected samples.
Species Diversity Index (d) = d Fish species diversity was determined using the Shannon and Weaver Diversity Index method (Shannon and Weaver, 1963).

Species Diversity Index (d) = d
$d = - \sum (ni/N) \log 2\ ni/N$
d = Species diversity
ni = Number of individuals of ith species.
N = Total number of individuals in the sample

3.6 Diversity of migratory aquatic birds :

a) The diversity of migratory aquatic birds was be studied at Yamuna River; weekly visits were conducted in the morning and later in the evening hours using the line transect method (Gaston 1975; Sales & Berkmuller 1988) and point count method (Altman 1974) during the study period.

b) Birds were photographed and subsequently identified using standard reference books (Ali & Raphley 1968; Grimmet *et al*. 1998), and data were recorded

c) Classification of the observed bird species (residential, abundances and IUCN conservational status) was recorded (Manakandan & Pittie 2001).

d) Standard biodiversity indices like Simpson's Index (D) = $1 - \Sigma\ n(n-1)/ N(N-1)$ where n is the Number of individuals of one species N = the total Number of all individuals, Simpson's Index of Diversity: 1-D, Shannon-Weiner Diversity Index (H') = $- \sum$ Pi ln Pi where Pi = n / N where n = Number of individuals of one species, N = total Number of all individuals in the sample & ln = logarithm to base e and Margalef Richness Index (DMg) = $(n- 1)/\ln N$ where n= total Number of specie, N = total Number of individuals in the

sample, ln =natural logarithm were applied to calculate the species diversity, evenness and richness (Simpson, 1949; Shannon-Weaver, 1963; Margalef, 1958 respectively).

3.6.1 Materials

Materials used during the study period were: the digital camera and binoculars.

3.6.1.1 Survey Periodicity

The birds' detailed account was recorded, either residing or migratory several visits have been made in different regions of the study area. All the spots (Yamuna river Yamunanagar, Panipat, Faridabad) selected for the study have been visited periodically as far as possible. The times of visits were 06:00 o clock to 09:00 o clock in the morning and 15:30 o clock to 18:00 o clock in the evening as far as possible.

Recording for observations

The methods adopted for the survey were:-

a) Line Transect Method (Gaston, 1975; Sales &Berkmuller, 1988)

b) Point Count Method (Altman, 1974)

Plate2 :Estimation of total alkalinity content in water

Plate3 :Estimation of total hardness content in water

Plate 4: Measuring pH of water body

Plate 5-a: Measuring of temperature of water body

Plate 5-b: Examination of plankton diversity

A point was randomly selected at the study site. About 100 meters of the area was covered on both sides of the point chosen horizontally, and 50 meters of the area was also covered in the vertical direction to study the diversity of bird species. The recordings were taken in the form of photographs and written notes to get the exact information about birds' diversity. The camera used for this purpose is a Nikon Coolpix P900 having 83X zoom and 16.0 megapixels clarity.

The birds were cross-checked and identified with the help of various books like “The Handbook of Birds of India and Pakistan” by Ali and Ripley (1968); “Guide to the Birds of the Indian Subcontinent” by a Grimmet *et al.* (1998) and “The Book of Indian Birds” by Ali (2002).

3.7 Plankton estimation

3.7.1 Collection and Preservation.

Plankton samples were collected by filtering 50L of water through a plankton net of mesh size 50µm with demarcating collecting tube. These samples were collected in 100 ml

plastic bottles, and concentrated samples were then made up to a standard volume of 50ml with distilled water. Samples were preserved with 4% buffered formalin.

The study area (Yamuna river)
↓
Sample collected by plankton net (Mesh size 50 µm)
↓
Sample collected in 100 ml plastic bottles
↓
Sample preserved with 4% formalin (On the spot)
↓
After 24-hour sample observed in the microscope

Flow chart of Plankton collection method

3.7.1.2 Identification

The Number of plankton to genus levels was studied and identified using the keys from Ward and Whipple (1959), Needham and Needham (1962), and APHA (1998).

3.7.1.3 Quantification

Plankton's abundance was expressed as organism per litre. The microorganisms were counted in a Sedgwick rafter cell, and 1.0 ml of the concentrated sample was transferred to the cell cavity. Planktons were allowed to settle, and ten randomly selected fields of the chamber were counted under the microscope and calculated L-1 as follows.

Total No. of Planktons: L-1 (PxCx100)/L

Where,

P = Number of plankton counted in ten fields

C = Volume of final concentrate of the sample (ml)

L = volume of the water sample filter

Total phytoplankton: L –(PpxCx100)/ L

Where,

Pp = The Number of phytoplankton counted in ten fields

C = Volume of final concentrate of the sample (ml)

L = The volume of water sample filtered

Total Zooplankton: L-1= (P_zx C x 100) / C

Where,

Pz = The Number of Zooplankton counted in ten fields

C = Volume of final concentrate of the sample (ml)

L = The volume of water sample filtered

Species Diversity Index (d) The diversity of phytoplankton and Zooplankton was determined using the Shannon and Weaver Diversity Index method (Shannon and Weaver, 1963; Washington, 1984).

$d = - \sum (ni/N) \log 2\ ni/N$

d = Species diversity

ni = Number of individuals of ith species.

N = Total Number of individuals in the sample

3.7.1.3 Phytoplankton Species Diversity Index

To determine the species diversity index of total phytoplankton:

The species diversity index of each species was calculated. The species diversity index of phytoplankton was calculated by taking the sum of the species diversity index (each phytoplankton species).**dp = ∑dip**

Where

dp = Phytoplankton Species Diversity Index

dip = Species diversity index of each species of phytoplankton

Zooplankton Species Diversity Index

For the determination of the Species diversity index of total Zooplankton, the species diversity index of each species was calculated. The species diversity index of Zooplankton was calculated by taking the sum of the species diversity index of each species of Zooplankton.

dz = ∑diz

Where

dz = Zooplankton Species Diversity Index

diz = Species diversity index of each species of Zooplankton

3.8 Physico-chemical parameters of water

For the monitoring of water quality parameters, water samples were collected from three sampling sites between 9 am to 12 noon as such the water temperature, dissolved

oxygen (DO), pH and hardness were analysed at sampling sites. Where as the analysis of TDS, total hardness and total alkalinity in laboratory. The protocol use followed for the analysis of selected water parameters was below:

3.8.1 Temperature

Water temperature was recorded with the help of an electric thermometer (AQUASOL DIGITAL pen-type thermometer) on the field with an accuracy of $\pm 0.1^0$C

3.8.2 Dissolved oxygen (DO)

The dissolved oxygen content of the water was determined by Winkler's titrimetric method as described by APHA (1995). Briefly, the procedure is described as follows:

Water samples were collected carefully in 100 ml glass stoppered sampling bottles within the water body to exclude air bubbles. 1.0 ml each of manganese sulphate and alkaline iodide reagents was added usinga 1ml pipette immersed in the bottle's bottom, and the pipette was slowly drawn out after addition.The stopper was replaced, and the bottle was inverted 3-4 times for thorough mixing. The resultant flocculent was dissolved by solution and then transferred to an Erlenmeyer flask, and 0.025 N $Na_2S_2O_3$ solution was added drop by till the colour turned pale straw.1ml starch solution was added, and titration continued to reach the endpoint,i.e.disappearanceof the colour.

Dissolved oxygen (mg/l) = quantity of 0.025N $Na_2S_2O_3$ used (in ml) x 4

3.8.3 Hydrogen–ion concentration

The pH of water samples was measured with the help of a digital pH meter (AQUASOL DIGITAL pen-type pH meter) on the field.

3.8.4 Total Dissolve Solids (TDS)

The value of TDS was measured with the help of a portable TDS/conductivity meter (Microprocessor COND-TDS-SAL Meter LT-51), and the value was expressed as mg/l.

3.8.5 Total alkalinity

The total alkalinity of water was estimated using the titration method using phenolphthalein and methyl orange indicators. Both carbonate and bicarbonate alkalinities were measured following the standard method (APHA, 1995).

3.8.5.1 Phenolphalein alkalinity

About 5-6 drops of phenolphthalein indicator solution were added to 50ml of the water sample. If the sample remained colourless, phenolphthalein alkalinity was absent. The

appearance of pink colour indicated the presence of phenolphthalein alkalinity. The sample was titrated with 0.02N H_2SO_4 solutions to a colourless endpoint.

Calculation:

Phenolphthalein alkalinity was calculated by using the following expression.

Phenolphthalein alkalinity ($CaCO_3$ mg/l) = (AxNx50000)/ Volume of water sample (ml)

Where,

A= ml. 0.02 N H_2SO_4 used for titration

N = normality of acid (H_2SO_4)

3.8.5.2 Methyl orange alkalinity

About 5-6 drops of methyl orange indicator solution were added to the 50ml sample. The sample was titrated with standard 0.02 N sulphuric acids until the colour of yellow to faint orange was developed.

Calculation: Methyl orange alkalinity as (mg/$CaCO_3$)= (BxNx50000) /Volume of water sample (ml)

Where,

B= ml. Titrant used for a sample to develop pink colour

N= normality of acid (H_2SO_4)

Total alkalinity (mg/l) = (phenolphthalein alkalinity + methyl orange alkalinity)

3.8.6 Total hardness

The total hardness of water was estimated by titration method using EriochromeBlack- T- indicator. Total hardness was measured following the standard methods (APHA, 1995). About 1-2 ml of ammonia buffer solution was added to a 50ml water sample in a conical flask. Then add a pinch of Eriochrome black-T-indicator. The colour of the water sample turned wine red. Titrate against EDTA solution until blue colour appears. The amount of EDTA was noted to be used during titration.

Calculation:

Total Hardness in mg/l = [ml of EDTA used/ Volume of Sample (50ml)] x 1000

CHAPTER- IV

RESULTS

The results of the present investigation titled **"Assessment of fish species and migratory aquatic birds' biodiversity in Yamuna river (Haryana)"**are given in this chapter. The results of fish diversity in the Yamuna river and migratory aquatic birds are shown in19 tables, 9 figures and 142 photographs.

(i) To study the fish diversity in the selected sites of Yamuna river

A total of sixty-four (64) fish species have been recorded from 3 sites (Yamunanagar, Panipat and Faridabad) which belong to 9 orders, 15 families and 64 species. The maximum number of species was recorded from 3 sites during November 2021, which was 56 species from Yamunanagar, 52 from Panipat and 27 from Faridabad. The minimum number of species reported was 44 from Yamunanagar (in February), 42 from Panipat (in October) and four from Faridabad (in April). Most dominating order was Cypriniformes followed by Siluriformes, Anabentiformes and Synbranchiformes. *C. carpio, L. rohita, Ompak bimaculatus and Parambassis ranga* were recorded from Yamunanagar, and *L. rohita* was the only species recorded during all months. *Puntius sophore, P. chola,* and *Pethia ticto* were the species recorded from the most dominating family Cyprinidae from Faridabad.

Table 4.1 :**Order and family-wise distribution of recorded fish species at selected sites**

S.No	Order	Family	*Species*	Common Name	Fin formula
1.	Cypriniformes	Cyprinidae	*Barilius barna*	Boroli	D. 9 (2/7); P. 14-15; V. 9; A. 12-14 (2-3/10-11); C. 19
2.			*Labeo catla*	Katla	D-18(3/15),P-19,V-9,A-8(3/5),C-19,LL-40-43
3.			*Chagunius chagunio*	*Chagunio*	D. 11(3/8); P_1. 15; P_2. 9; A. 8 (3/5)
4.			*Cirrhinus mrigala*	Mrigal	D. 16; P1. 17; P2. 9; A. 8
5.			*Cirrhinus reba*	Rewah/Bata	D. 32-39/74-90; A. 3/75-88; P. 23
6.			*Cyprinus carpio*	Common carp	D. 3-4/18-20, P_1: 1/15, P_2: 1/8, A. 3-5
7.			*Esomus danricus*	Meese	D. 8 (2/6); P1. 11-13 (1/10-12); P2. 7 (1/6); A. 7-8 (2-3/5)
8.			*Hypopthalmicthys molitrix*	Silver carp	D 3/7; P_1 1/17; P_2 1/7; A 2-3/12-14
9.			*Labeo bata*	Bata	D. 17-18 (3/14-15); P_1. 16-18; P_2. 9 (1/8); A. 7(2/5)
10.			*Labeo rohita*	Rohita	D. 15-16 (3/12-13); P_1. 16-17; P_2. 9; A. 7(2/5)
11.			*Labeo gonius*	Kuri	D. 16-17 (3/13-14); P_1. 15-16;

					P_2. 9(1/8); A. 7(2/5)
12.			*Labeo calbasu*	Kalisasu	D. 17-18 (3/14-15); P_1. 16-18; P_2. 9 (1/8); A. 7(2/5).
13.			*Puntius sarana*	Olive barb /Sar puti	D. 3/8; A. 3/5; P. 15; V. 19
14.			*Oxygaster bacaila*	Large razorbelly minnow	D. 10(2/8); P_1. 12-13; P_2. 9; A. 14-15(2/12-13)
15.			*Osteobramacotio cotio*	Hafo	D. 10 (2/8); P_1. 15; P_2; 9-10; A. 33-36 (3/30-33)
16.			*Crossocheilus latius*	Kala bata	D. 10-11 (2-3/8); P. 14-16; P. 9; A. 7 (2/5)
17.			*Garra annandalei*	Annandale garra/ Stone roller	D. 9 (2/7); P_1. 15; P_2. 9; A. 7 (2/5) (Rahman, 1989 and 2005)
18.			*Garra gotylagotyla*	Ngamusseng um	D. 10 (2/8); P_1. 15; P_2. 9; A. 7 (2/5)
19.			*Puntius sophore*	Phabounga	D. 11 (3/8); P_1. 15; P_2. 9 (1/8); A. 8 (3/8).
20.			*Pethiacon chonius*	Puthi	D. 11 (3/8); P_1. 13-15; P_2. 9 (1/8); A. 7-8 (2-3/5)
21.			*Pethia ticto*	Chenaputhi	- D iii-iv 8; P 13-15; V i 8; A ii-iii 5.
22.			*Puntius chola*	Chola puti	D. 10-11 (2-3/8); P_1. 15; P_2. 9; A. 7-8 (2-3/5)
23.			*Systomus sarana*	olive barb	D. 3/8; A. 3/5; P. 15; V. 19
24.			*Puntius chelynoides*	Kendai	D. 3/8, P_1.15, P_2. 1/8. A. 3/5
25.			*Schizothoraxricha rdsonii*	Ngaka/ Common snowtrout	D iii 8; A iii 5; P i 15-16; V i 9
26.			*Salmo phasiabacaila*	Chelakani	D. 10(2/8); P_1. 12-13; P_2. 9; A. 14-15(2/12-13)
27.			*Salmo phasiaphulo*	Finescalleraz orbellymino w	-D1. 8; P1. 11-13; P2.7-8; A. 15; C. 16
28.			*Amblypharyngodo n mola*	molacarplet	D. 9 (2/7); P_1. 15; P_2. 9; A. 7 (2/5)
29.			*Cabdio morar*	*Cabdiomorar*	D. 2/8-9; P1. 14-15; P2. 8; A. 2-3/8-9
30.			*Aspidoparia jaya*	Jaya	D. 2/7; P_1. 14-15; P_2. 8; A. 2 / 7
31.			*Rasbora daniconius*	Dohnikona/ Slender rasbora	D. 9 (2/7); P1. 14-15; P2. 9; A. 7 (2/5)
32.			*Barilius bendelisis*	Bilcha	D. 9(2/7); P. 13-15; V. 9; A. 9-10(2-3/8); C. 18
33.			*Barilius vagra*	Gheur/ Glar	D. 9 (2/7); P. 16; V. 9; A. 13-15 (2-3/11-12); C. 19
34.		Botiidae	*Botia lohachata*	Reticulate loach	D. 9-10; P_1. 14; P_2. 8; A. 5-6
35.			*Botia dario*	Bengal loach	D. 11-13 (2-3/9-10); P_1. 14; P_2. 8; A. 7-8 (2/5-6)
36.		Engraulidae	*Setipinna phasa*	Phasa	D i 14-15; A iii 66-78; P i 14; V i 6

37.	Anabantiformes	Channidae	*Channa gachua*	Boga	D. 32-37; A. 21-23; P. 15; V. 6; C. 12
38.			*Channa marulius*	Hall/Gajal	D. 49-55; P_1. 17-19; P_2. 6; A. 28-35
39.			*Channa punctatus*	Gorissa	D. 29-32; P1. 15-18; P2. 6; A. 20-22
40.		Anabantidae	*Anabas testudineus*	Climbing perch	26-28 (XVI-XVIII 1-2/7-10) P1. 13-15 (1-2/11-14) P2
41.	Siluriformes	Clariidae	*Clarias batrachus*	Magur	D. 64-70; P1. 1/9-10; P2. 6. A. 45-52
42.		Heteropneustidae	*Heteropneustes fossilis*	Singee	D. 6-7; P1. 1/6-7; P2. 6; A. 62-70
43.		Siluridae	*Wallago attu*	Barali/Poil	D. 5; P_1.1/13-14; P_2. 10; A. 85-89.
44.		Bagridae	*Rita rita*	Rita	D. 11/6; P1. 1/10; P2. 8; A. 11-13
45.		Siluridae	*Ompok bimaculatus*	Butter Catfish	D. 4; P_1.12-15(1/11-14); P_2. 8; A. 66-73.
46.		Notopteridae	*Mystus tengara*	Tengaramystus	D. I/7; P1. I/8; P2.6; A. 10-139
47.		Ailiidae	*Ailia coila*	Kajuli	D. 0; P1. 1/14; P2. 6; A. 67-75.
48.			*Ailiichthys punctata*	Jamuna ailia	D. 0; P I/12; A 70-90; C. 17
49.			*Clupisoma garua*	GaruaBachcha	D.l/6; A 3/28; P. 1/11; V. 1/5; C. 17-20.
50.		Schilbeidae	*Eutropiichthys vacha*	Basa	D. 1/7; P1. 1/13-14; P2. 6; A. 3-4/46-48
51.			*Eutropiichthys murius*	Muribacha	D. I/7; P1. 1/13; P2. 6; A. 3/35-37
52.			*Neotropius atherinoides*	Indian potasi	D. 1/5-6; P1. 1/7; P2. 6; A. 33-40
53.			*Silonia silondia*	Silond catfish	D1 I/7; D2 0; P I/11-13; V 6; A 40-46 (4-36/42)
54.	Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	Bami	D. XXXVII-XXXVIII/78-84, P_1. 25-26, A. III/77-85
55.		Notopteridae	*Notopterus chitala*	Featherback	D. 9; P1. 15-16; P2. 6; A. 115-120
56.			*Notopterus notopterus*	Bronze featherback	D. 7-8; P1. 15-17; P2. 5-6; A. 99-104.
57.			*Mystus seenghala*	Seenghala	D. I/7; P_1.I/9; P_2.I/5; A.11-12
58.	Anguilliformes	Anguillidae	*Anguilla bengalensis*	Mottled eel	D. 250-305; P. 18; A. 210-250; C. 10-12
59.	Clupeiformes	Pristigasteridae	*Ilisha megaloptera*	Indian ilisha	D. 2-3/12-14; P1. 13-15; P2. 7; A. 2-3/36-39.
60.		Clupeidae	*Gudusia chapra*	Karati	D. 14-15 (3/11-12); P1. 13 (1/12); P2. 7; A. 23-25 (2/21-23)
61.			*Gonialosa manmina*	Ganges river gizzard shad	D. 3/12-13; P_1. 14-15; P_2. 8; A. 24-25

62.	Ovalentaria	Ambassidae	*Chanda nama*	Chanda	D_1. VIII, D_2. I/16-17, P_1. 12-13, P_2. I/5, A. III/16-17
63.	Perciformes		*Parambassis ranga*	Indian X-ray fish	D_1. VI, D_2. I/13-15, P_1. 10-11, P_2. I/5, A. III/15-16
64.			*Parambassis lala*	Highfin glassy perchlet	D VII/I P_1 I/13 P_2 I/5 A. III/13

The recorded 64 fish species belonged to 8 orders and 19 families. The checklist of fish species and their orders and families is given in Table 4.1.

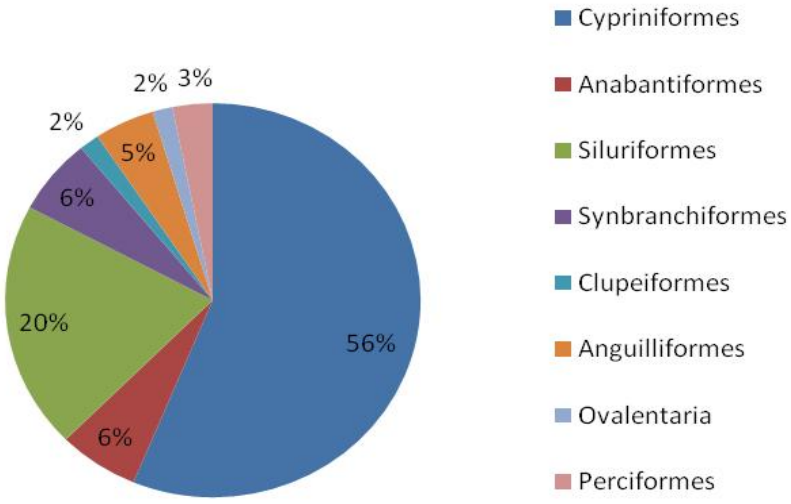


Figure 4.1: Order-wise distribution of observed fish species

The order Cypriniformes was dominant, containing 56 per cent of fish species, followed by the order Siluriformes, 20 per cent. Orders Synbranchiformes and Ananbantiformes comprise six per cent of fish species, while Clupeiformes and Perciformes had only five per cent of the total reported fish species. The rest of the orders had less species diversity, only two or three per cent.

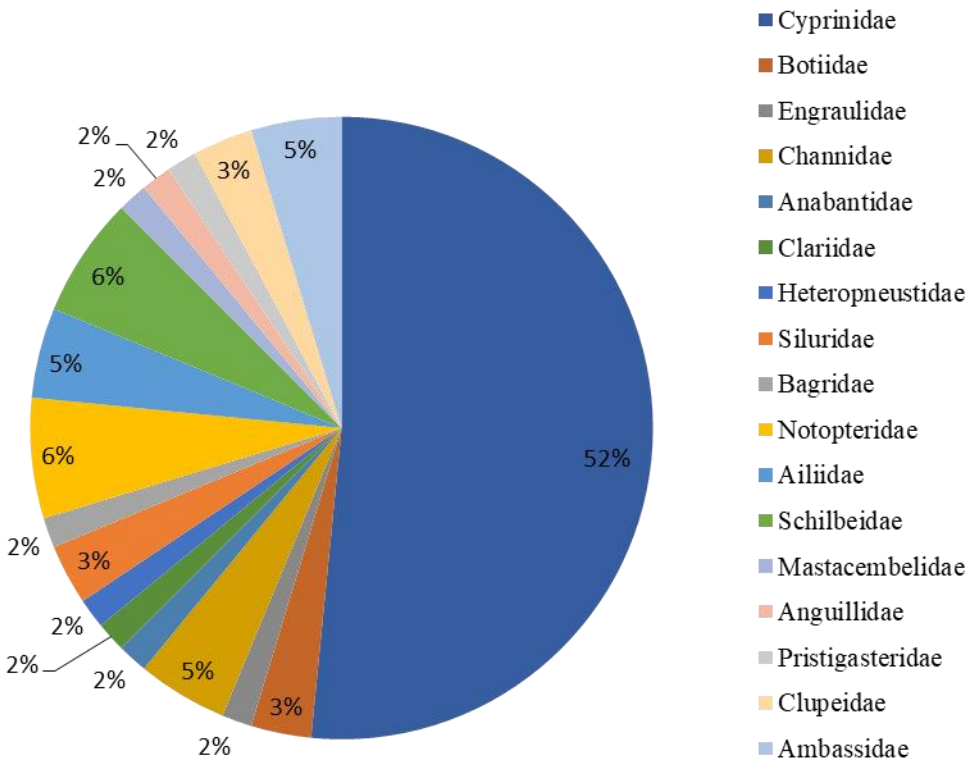


Figure 4.2: Family-wise distribution of observed fish species

The family Cyprinidae was found to be dominant, containing 52 per cent of fish species, followed by the family Sciaenidae (six per cent), family Notoptendae (six per cent) and Channidae comprise (six per cent) of fish species. At the same time, Channidae, Heteropneustidae and Culpeidae had only five per cent (each) of the total reported fish species. The rest of the families had a low amount of species diversity, having only two per cent.

Table 4.2: Distribution of fish species at the riverine area of Yamuna River in Yamunanagar

Sr No.	Order	Genus/Species	Duration of study							
			Sep. 2021	Oct 2021	Nov. 2021	Dec. 2021	Jan 2022	Feb. 2022	Mar. 2022	Apr. 2022
1	Cypriniformes	*Barilius barna*	+	-	+	+	+	+	+	-
2		*Catla catla*	+	+	+	+	+	+	-	+
3		*Chagunius chagunio*	+	+	+	-	-	+	+	+
4		*Cirrhinus mrigala*	+	+	+	+	-	-	+	+
5		*Cirrhinus reba*	+	-	-	+	+	+	+	+
6		*Cyprinus carpio*	+	+	+	+	+	+	+	+
7		*Esomus danricus*	-	-	+	+	-	+	+	-

8		*Hypopthalmicthys molitrix*	-	+	+	+	+	+	+	+
9		*Labeo bata*	-	+	+	+	+	+	+	-
10		*Labeo rohita*	+	+	+	+	+	+	+	+
11		*Labeo gonius*	+	+	+	-	-	+	+	+
12		*Labeo calbasu*	+	+	+	+	-	+	+	+
13		*Puntius sarana*	-	+	+	-	+	+	+	+
14		*Oxygaster bacaila*	-	-	+	+	+	-	-	+
15		*Osteobramacotio cotio*	-	+	+	+	-	+	+	+
16		*Crossocheiluslatius*	+	+	+	-	+	-	-	+
17		*Garraannandalei*	+	+	+	+	+	+	+	-
18		*Garragotylagotyla*	+	+	+	-	-	+	+	+
19		*Puntius sophore*	+	-	+	+	+	-	-	+
20		*Pethiaconchonius*	+	+	+	+	+	+	-	-
21		*Pethiaticto*	-	-	+	+	-	+	+	+
22		*Puntius chola*	+	+	+	+	+	+	+	-
23		*Systomus sarana*	+	-	+	+	+	-	+	+
24	Cypriniformes	*Puntius chelynoides*	-	+	+	-	-	+	+	+
25		*Schizothorax richardsonii*	-	+	+	+	-	+		+
26		*Salmophasia bacaila*	+	-	+	+	+	+	-	+
27		*Salmo phasiaphulo*	+	+	+	-	+	+	+	-
28		*Amblypharyngodon mola*	-	+	+	-	+	+	+	+
29		*Cabdio morar*	-	+	+	+	+	-	-	+
30		*Aspidoparia jaya*	+	+	+	+	-	+	+	+
31		*Rasbora daniconius*	-	+	-	+	+	+	+	+
32		*Barilius bendelisis*	+	+	+	+	-	-	+	+
33		*Barilius vagra*	+	+	+	+	+	+	-	-
34		*Botialohachata*	+	+	-	-	+	+	+	+
35		*Botia Dario*	+	+	+	+	+	+	-	+
36		*Setipinnaphasa*	+	+	-	+	+	+	-	+
37	Anabantiform es	*Channa gachua*	+	+	-	+	-	-	+	+
38		*Channa marulius*	+	-	+	+	+	-	+	+
39		*Channa punctatus*	+	+	+	+	+	+	+	+
40		*Anabas testudineus*	+	+	+	+	+	-	-	+
41	Siluriformes	*Clarias batrachus*	+	+	+	+	+	-	+	-
42		*Heteropneustes fossilis*	+	+	+	-	-	+	+	+
43		*Wallago attu*	+	+	+	+	+	-	-	+
44		*Rita rita*	+	+	+	+	-	-	+	+
45		*Ompok bimaculatus*	+	+	+	+	+	+	+	+
46		*Mystus tengara*	-	+	+	-	-	+	+	+
47		*Ailia coila*	+	+	+	+	-	-	+	+
48		*Ailiichthys punctata*	-	-	+	-	+	+	+	-
49		*Clupisoma garua*	+	+	-	-	+	+	+	-
50		*Eutropiichthys vacha*	+	+	+	-	+	-	+	+

51		*Eutropiichthys murius*	-	+	+	+	+	+	+	+
52		*Neotropius atherinoides*	-	+	-	+	+	+	+	+
53		*Silonia silondia*	+	+	+	+	+	+	-	+
54		*Mastacembelus armatus*	-	+	+	+	+	+	-	+
55	Synbranchiformes	*Notopterus chitala*	-	+	-	+	+	-	-	+
56		*Notopterus notopterus*	+	+	+	+	+	+	+	-
57		*Mystus seenghala*	+	+	+	-	+	-	+	+
58	Anguilliformes	*Anguilla bengalensis*	-	-	+	-	+	-	+	+
59	Clupeiformes	*Ilisha megaloptera*	+	+	+	+	+	-	+	+
60		*Gudusiachapra*	+	+	+	+	-	+	+	+
61		*Gonialosa manmina*	+	+	+	+	+	-	-	+
62	Ovalentaria	*Chanda nama*	+	+	+	+	+	+	+	+
63	Perciformes	*Parambassis ranga*	+	+	+	+	+	+	+	+
64		*Parambassis lala*	-	+	+	+	+	+	+	-

A total of sixty-four fish species were reported during the study in the Yamunanagar riverine system. The maximum fish species reported belongs to the order Cypriniformes (36 species), followed by the order Siluriformes (14 species).

Table 4.3: Distribution of fish species at the riverine area of Yamuna River in Panipat

	Order	**Genus/Species**	**Duration of study**							
			Sep. 2021	**Oct. 2021**	**Nov. 2021**	**Dec. 2021**	**Jan. 2022**	**Feb. 2022**	**Mar. 2022**	**Apr. 2022**
1.	Cypriniformes	*Barilius barna*	+	+	+	+	+	+	+	-
2.		*Catla catla*	+	+	+	+	+	+	-	+
3.		*Chagunius chagunio*	-	+	+	+	-	+	+	-
4.		*Cirrhinus mrigala*	+	+	-	+	-	-	+	+
5.		*Cirrhinus reba*	+	+	-	+	+	+	-	-
6.		*Cyprinus carpio*	+	+	-	+	+	+	+	+
7.		*Esomus danricus*	+	-	+	+	-	+	+	-
8.		*Hypopthalmicthys molitrix*	-	+	+	+	+	-	+	+
9.		*Labeobata*	+	+	+	-	-	+	+	-
10		*Labeo rohita*	+	+	+	+	+	+	+	+
11.		*Labeo gonius*	+	-	+	-	-	+	+	+
12.		*Labeo calbasu*	+	+	+	+	-	+	+	+
13.		*Puntius sarana*	-	+	+	-	+	+	+	+
14.		*Oxygaster bacaila*	-	-	+	+	+	+	-	+
15		*Osteobramacotio cotio*	+	+	+	+	-	+	+	+
16.		*Crossocheilus latius*	+	+	+	+	+	-	-	+
17.		*Garra annandalei*	+	+	-	+	+	+	+	-
18.		*Garra gotylagotyla*	-	+	+	-	-	+	+	+

19.		*Puntius sophore*	+	-	+	+	+	-	+	+
20.		*Pethia conchonius*	+	-	+	+	+	+	+	-
21.		*Pethia ticto*	-	-	+	+	+	+	+	-
22.		*Puntius chola*	+	-	+	+	+	+	+	-
23.		*Systomus sarana*	+	-	+	+	+	-	+	+
24.		*Puntius chelynoides*	-	+	+	+	-	+	+	+
25.		*Schizothora xrichardsonii*	+	+	+	+	-	+	-	+
26.		*Salmophasia bacaila*	+	-	+	-	+	+	-	+
27.		*Salmophasia phulo*	+	-	+	-	+	+	+	-
28.		*Amblypharyngodon mola*	-	+	+	+	+	+	+	+
29.		*Cabdio morar*	+	+	+	-	+	-	+	+
30.		*Aspidoparia jaya*	+	+	-	+	-	+	+	+
31.		*Rasbora daniconius*	-	+	-	+	+	-	+	+
32.		*Barilius bendelisis*	+	-	+	+	+	-	+	-
33.		*Barilius vagra*	+	-	+	+	+	+	-	-
34.		*Botia lohachata*	+	+	-	+	+	+	+	+
35.		*Botia Dario*	+	+	-	+	+	+	-	+
36.		*Setipinna phasa*	-	+	-	+	+	+	-	+
37.	Anabantiformes	*Channa gachua*	+	+	-	+	+	-	+	+
38.		*Channa marulius*	+	-	+	+	+	+	+	+
39.		*Channa punctatus*	+	+	+	+	+	+	+	+
40.		*Anabas testudineus*	+	+	-	+	+	-	-	+
41.	Siluriformes	*Clarias batrachus*	+	+	+	+	+	-	+	-
42.		*Heteropneustes fossilis*	+	+	+	-	-	+	-	+
43.		*Wallago attu*	+	+	+	+	+	+	-	+
44		*Rita rita*	-	+	+	-	+	+	+	+
45.		*Ompok bimaculatus*	-	-	+	+	+	+	-	+
46.		*Mystus tengara*	-	+	+	+	-	+	+	+
47.		*Ailia coila*	-	+	+	+	-	-	+	+
48.		*Ailiichthys punctata*	+	-	+	-	+	-	+	+
49.		*Clupisoma garua*	+	+	+	-	+	+	+	-
50.		*Eutropiichthys vacha*	+	-	+	-	+	-	+	+
51.		*Eutropiichthys murius*	-	+	+	+	-	+	+	+
52.		*Neotropius atherinoides*	-	+	-	+	+	+	-	+
53.		*Silonia silondia*	+	-	+	+	+	+	-	+
54.		*Mastacembelus armatus*	+	+	+	-	+	+	-	+
55.	Synbranchiformes	*Notopterus chitala*	-	-	+	+	+	-	-	+
56.		*Notopterus notopterus*	+	-	+	+	+	+	+	-
57.		*Mystus seenghala*	+	-	+	-	+	-	+	+
58.	Anguilliformes	*Anguilla bengalensis*	-	+	+	+	-	-	+	+
59.	Clupeiformes	*Ilisha megaloptera*	+	+	+	+	+	-	+	+

60.		*Gudusia chapra*	+	-	+	+	-	+	+	+
61.		*Gonialosa manmina*	-	+	+	+	+	-	-	+
62.	Ovalentaria	*Chanda nama*	+	+	+	+	+	+	-	+
63.	Perciformes	*Parambassis ranga*	+	-	+	+	+	+	+	+
64.		*Parambassis lala*	-	+	+	-	+	+	+	-

A total of sixty-four fish species were reported during the study at the Panipat riverine system. The maximum fish species reported belongs to the order Cypriniformes (36 species), followed by Siluriformes (14 species).

Table4.4: Distribution of fish species at the riverine area of Yamuna River in Faridabad

Sr No	**Order**	**Genus/Species**	**Duration of study**							
			Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr
			2021	2021	2021	2021	2022	2022	2022	2022
1.	Cypriniformes	*Barilius barna*	-	-	-	-	-	-	-	-
2.		*Labeo catla*	-	-	-	-	-	-	-	-
3.		*Chagunius chagunio*	-	-	-	-	-	-	-	-
4.		*Cirrhinus mrigala*	-	-	-	-	-	-	-	-
5.		*Cirrhinus reba*	-	-	-	-	-	-	-	-
6.		*Cyprinus carpio*	-	-	-	-	-	-	-	-
7.		*Esomus danricus*	-	-	-	-	-	-	--	-
8.		*Hypopthalmicthys molitrix*	-	-	-	-	-	-	-	-
9.		*Labeo bata*	-	-	-	-	-	-	-	-
10.		*Labeo rohita*	-	-	-	-	-	-	-	-
11.		*Labeo gonius*	-	-	-	-	-	-	-	-
12.		*Labeo calbasu*	-	-	-	-	-	-	-	-
13.		*Puntius sarana*	-	-	-	-	-	-	-	-
14.		*Oxygaster bacaila*	-	-	-	-	-	-	-	-
15.		*Setipinna phasa*	-	-	--	-	-	-	-	-
16.		*Osteobramacotio cotio*	-	-	-	-	-	-	-	-
17.		*Crossocheilus latius*	-	-	-	-	-	-	--	-
18.		*Garra annandalei*	-	-	-	-	-	-	-	-
19.		*Garra gotylagotyla*	-	-	-	-	-	-	-	-
20.		*Puntius sophore*	+	+	-	+	-	-	-	-
21.		*Pethia conchonius*	-	-	-	-	-	-	-	-
22.		*Pethia ticto*	+	+	+	-	-	-	-	-
23.		*Puntius chola*	-	-	+	+	--	-	-	-
24.		*Systomus sarana*	-	-	-	-	-	-	-	-
25.		*Puntius chelynoides*	-	-	-	-	-	-	-	-

26.		*Schizothorax richardsonii*	-	-	-	-	-	-	-	-
27.		*Salmophasia bacaila*	-	-	-	-	-	-	-	-
28.		*Salmophasiaphulo*	-	-	-	-	-	-	--	-
29.		*Amblypharyngodon mola*	-	-	-	-	-	-	-	-
30.		*Cabdio morar*	-	-	-	-	-	-	-	-
31.		*Aspidoparia jaya*	-	-	-	-	-	-	-	-
32.		*Rasbora daniconius*	-	-	-	-	-	-	-	-
33.		*Barilius bendelisis*	-	-	-	-	-	-	-	-
34.		*Barilius vagra*	-	-	-	-	-	-	-	-
35.		*Botia lohachata*	-	-	-	-	-	-	-	-
36.		*Botia dario*	-	-	-	-	-	-	-	-
37.	Anabantiformes	*Anabas testudineus*	+	+	+	-	-	-	-	-
38.		*Channa gachua*	+	-	+	-	-	-	-	-
39.		*Channa marulius*	+	+	-	+	-	-	+	+
40.		*Channa punctatus*	-	-	+	+	-	-	-	-
41.	Siluriformes	*Clarias batrachus*	+	+	+	+	+	+	-	+
42.		*Heteropneustes fossilis*	+	+	+	-	+	+	-	+
43.		*Wallago attu*	+	+	+	+	+	-	+	-
44.		*Rita rita*	+	+	+					
45.		*Ompok bimaculatus*	+	-	+	-	-	+	-	-
46.		*Mystus tengara*	+	+	+	-	-	-	+	-
47.		*Mystus seenghala*	-	+	+	+	-	+	-	-
48.		*Ailia coila*	-	-	+	-	-	+	-	-
49.		*Ailiichthys punctata*	+	+	+	-	-	-	-	+
50.		*Clupisoma garua*	+	-	+	+	-	-	-	-
51.		*Eutropiichthys vacha*	-	+	+	-	-	-	-	-
52.		*Eutropiichthys murius*	-	+	+	-	-	-	-	-
53.		*Neotropius atherinoides*	+	+	+	-	+	+	-	-
54.		*Silonia silondia*	+	-	+	-	-	-	-	-
55.	Synbranchiformes	*Mastacembelus armatus*	-	-	+	-	-	-	-	-
56.		*Notopterus chitala*	+	-	+	-	-	--	-	-
57.		*Notopterus notopterus*	+	-	+	+	-	-	-	-
58.	Anguilliformes	*Anguilla bengalensis*	+	-	+	-	-	-	-	-
59.	Clupeiformes	*Ilisha megaloptera*	+	+	-	-	-	-	-	-
60.		*Gudusia chapra*	-	+	+	+	+	-	-	-
61.		*Gonialosa manmina*	-	+	+	-	-	-	-	-

62.	Ovalentaria	*Chanda nama*	+	+	-	+	-	-	-	-
63.	Perciformes	*Parambassis ranga*	+	-	+	-	-	-	-	-
64.		*Parambassis lala*	-	+	+	+	-	+	-	-

A total of sixty-four fish species were reported during the study in the Yamunanagar riverine system. The maximum fish species reported belongs to the order Siluriformes (14 species). In comparison, only three species were reported from order Cypriniformes, compared to the Yamunanagar and Panipat areas.

Table 4.5: Shannon-Weaver Diversity Index (Fish diversity) of study areas (segmentwise)

Month	Yamunanagar	Panipat	Faridabad
September 2021	2.0356	1.8183	1.6590
October 2021	**2.0921**	2.0174	1.1413
November 2021	1.8829	1.9064	1.5806
December 2021	1.9020	1.9153	**1.6731**
January 2022	2.0845	2.0343	0.5004
February 2022	1.6461	1.7795	0.4101
March 2022	1.9173	1.6604	1.0397
April 2022	2.0446	**2.1817**	1.0397

In Yamunanagar, maximum species diversity was recorded in October 2021. In Panipat, maximum species diversity was recorded in April 2022. While in Faridabad maximum diversity was recorded in December 2021.

Plate 6:*Labeo rohita*

Plate 7:*Labeo catla*

Plate 8*:Cirrhinus mrigala*

Plate 9*:Clarias batrachus*

Plate 10*:Anabas testudineus*

Plate 11*:Chagunius chagunio*

Plate12*:Cirrhinus reba*

Plate 13*:Esomus danricus*

Plate 14:*Labeo bata*

Plate 15:*Labeo gonius*

Plate 16*:Puntius sarana*

Plate 17*:Oxygaster bacail*

Plate 18*: Crossocheilus latius*

Plate 19*:Garra gotylagotyla*

Plate 20*:Puntius sophore*

Plate 21*:Pethia conchonius*

Plate 22*:Pethia ticto*

Plate 23*:Puntius chola*

Plate 24*:Systomus sarana*

Plate 25*:Schizothorax richardsonii*

Plate 26*:Salmophasia bacaila*

Plate 27*:Amblypharyngodon mola*

Plate 28*:Cabdio morar*

Plate 29*:Aspidoparia jaya*

Plate 30*:Rasbora daniconius*

Plate 31*:Barilius bendelisis*

Plate 32*:Barilius vagra*

Plate 33*:Botia Dario*

Plate 34*:Channa marulius*

Plate 35*:Heteropneustes fossilis*

Plate 36*:Ompok bimaculatus*

Plate 37*:Mystus tengara*

Plate 38*:Ailia coila*

Plate 39*:Clupisoma garua*

Plate 34:*Eutropiichthys vacha*

Plate 41*:Neotropius atherinoides*

Plate 42*:Silonia silondia*

Plate 43*:Mastacembelusa rmatus*

Plate 44*:Notopterus chitala*

Plate 45*:Notopterus notopterus*

Plate 46:*Anguilla bengalensis* Plate 47:*Ilisha megaloptera*

Plates 6-47: Fishes reported in the study area

(ii)To study the diversity of migratory aquatic birds at the selected sites in Yamunanagar riverine area

Table 4.6: List of identified bird species in the selected sites

S.No.	Order	Family	Common Name	Residential status	Abundance status
1.	Podicipediformes	Podicipedidae	Little Grebe	R	Common
2.	Pelecaniformes	Phalacrocoracidae	Little Cormorant	R	Very common
3.			Indian Shag	LM	Very common
4.			Great Cormorant	LM	Less common
5.	Ciconiiformes	Ardeidae	Little Egret	LM	Common
6.			Grey Heron	WM	Rare
7.			Purple Heron	LM	Rare
8.			Large Egret	LM	Lees common
9.			Median Egret	LM	Very common
10.			Cattle Egret	R	Very common
11.			Indian Pond-Heron	R	Very common
12.			Black-crowned Night Heron	LM	Rare
13.		Ciconiidae	Painted stork	LM	Rare
14.			White-necked Stork	LM	Rare
15.			Asian Openbill Stork	LM	Rare
16.		Threskiornithidae	Eurasian Spoonbill	WM	Less common
17.	Anseriformes	Anatidae	Greylag Goose	WM	Common
18.			Bar-headed Goose	WM	Common
19.			Brahminy Shelduck	WM	Common
20.			Mallard	WM	Very common
21.			Eurasian Wigeon	WM	Common
22.			Spot-billed Duck	WM	Very common
23.			Northern Shovelle	WM	Very common
24.			Northern Pintail	WM	Very common
25.			Garganey	WM	Less common
26.			Common Teal	WM	Very common
27.			Common Pochard	WM	Very common
28.			Red-crested Pochard	WM	Common
29.			Ferruginous Pochard	WM	Common
30.			Greater Scaup	WM	Common
31.			Tufted Pochard	WM	Common
32.			White-breasted Waterhen	R	Very common
33.			Purple Moorhen	R	Common

34.	Gruiformes	Rallidae	Common Moorhen	R	Very common
35.			Common Coot	WM	Very common
36.		Jacanidae	Bronze-winged Jacana	R	Rare
37.		Charadriidae	Little Ringed Plover	WM	Common
38.			Red-wattled Lapwing	R	Very common
39.			White-tailed Lapwing	WM	Rare
40.			River Lapwing	R	Common
41.	Charadriiformes	Scolopacidae	Spotted Redshank	WM	Very common
42.			Common Redshank	WM	Very common
43.			Ruff	WM	Common
44.			Little Stint	WM	Very common
45.			Black tailed Godwit	WM	Common
46.			Common Sandpiper	WM	Very common
47.			Common Greenshank	WM	Very common
48.			Wood Sandpiper	WM	Very common
49.		Recurvirostridae	Black-winged Stilt	R	Very common
50.			Pied Avocet	WM	Less common
51.		Laridae	River Tern	R	Common
52.			Black-headed Gull	WM	Common
53.			Pallas's Gull	WM	Common
54.	Coraciiformes	Alcedinidae	Lesser Pied Kingfisher	R	Less common
55.			White-breasted Kingfisher	R	Very common
56.	Passeriformes	Motacilidae	White Wagtail	WM	Very common
57.			Large Pied Wagtail	R	Less common
58.			Citrine Wagtail	WM	Common
59.			Yellow Wagtail	WM	Common

R. Resident WM. Winter migratory LM. Local migratory

A total of fifty nine-birds species were reported during the study near the Yamuna riverine area of selected sites. The maximum bird species reported belongs to the order followed byAnseriformes15 species.

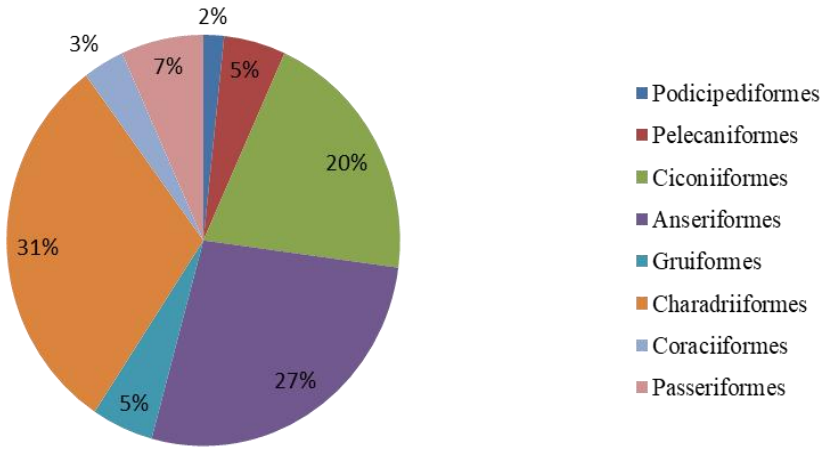


Figure 4.3: Order-wise distribution of observed birds' species

The Order Anseriformes were dominant (containing 15 species), followed by the Order Charadriiformes (containing 13 species) and Order Gruiformes (containing 09 species). At the same time, others had only a few bird species.

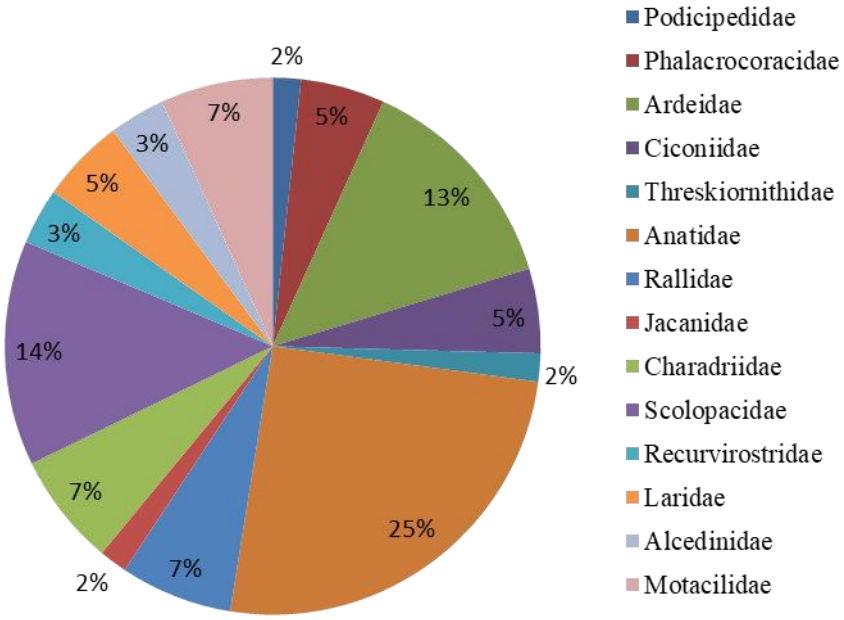


Figure 4.4: Family-wise distribution of observed birds' species

Anatidae was dominant, containing 25 per cent of bird species, followed by Scolopacidae, 14 per cent family Ardeidae, 13 per cent and Charadriidae, Rallidae, and Motacilidae with 7 per cent of birds species. At the same time, Phalacrocoracide, Ciconiidae and Laridae had only five per cent of the total reported bird species. The rest of the families had a low amount of species diversity, having only two and three per cent.

Tables 4.7: Comparative population dynamics of bird species

S.No.	Particulars	Segment 1	Segment 2	Segment 3	Total
1.	No. of Species	48	41	44	59
2.	No. of Families	13	11	13	14
3.	No. of Orders	8	7	8	8

Fifty-nine bird species belonging to 14 families and eight orders have been recorded from Yamuna riverine area in Haryana at selected study sites. Segment one was found in 48 species, segment two 41 species and segment three found in species 44

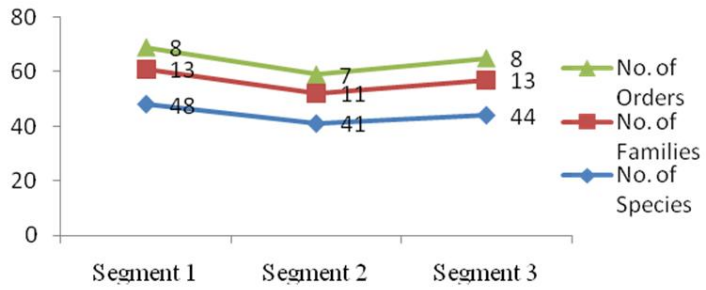


Figure 4.5: Comparative population of bird species, families and orders wise

It was found that, No. of species were maximum in a segment-first (Yamunanagar area) that was 48 species, followed by 44 species in segment three (Faridabad area) and 41 in segment two (Panipat area).

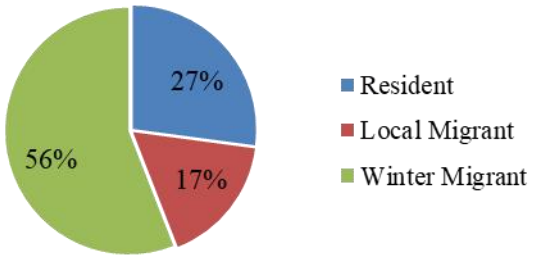


Figure 4.6: Residential status of observed bird species

Out of 59 bird species, 33 species (56 %) were winter migrants, 16 species (27 %) were residents, and ten species (17 %) were local migrants.

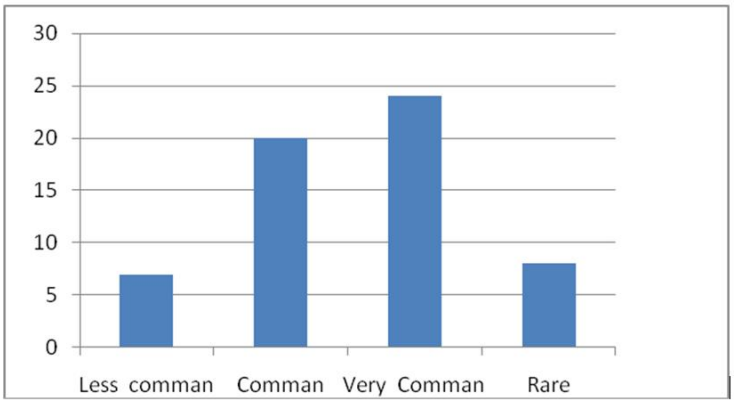


Figure4.7: Abundance status observed bird species

Out of 59 reported species, 24 were very common,20 were common, 08 were rare, and 07 were less common in the study area.

Table 4.8:IUCN Status of the observed bird species during the study			
Sr.No.	Common Name	Scintific Name	IUCN Status
1.	Little Grebe	*Tachybaptausr ufficollis*	LC
2.	Little Cormorant	*Phalacrocorax niger*	LC
3.	Indian Shag	*Phalacrocorax fuscicollis*	LC
4.	Great Cormorant	*Phalacrocorax carbo*	LC
5.	Little Egret	*Egretta garzetta*	LC
6.	Grey Heron	*Ardea cinerea*	LC
7.	Purple Heron	*Ardea purpurea*	LC
8.	Large Egret	*Casmerodius albus*	LC
9.	Median Egret	*Aredea intermedia*	LC
10.	Cattle Egret	*Bubulcus ibis*	LC
11.	Indian Pond-Heron	*Ardeola grayii*	LC
12.	Black-crowned Night Heron	*Nycticorax nycticorax*	LC
13.	Painted stork	*Mycteria leucocephala*	NT
14.	White-necked Stork	*Ciconia episcopus*	NT
15.	Asian Openbill Stork	*Anastomus oscitans*	LC
16.	Eurasian Spoonbill	*Platalea leucorodia*	NT
17.	Greylag Goose	*Anser anser*	LC
18.	Bar-headed Goose	*Anser indicus*	LC
19.	Brahminy Shelduck	*Tadorna ferruginea*	LC
20.	Mallard	*Anas platyrhynchos*	LC
21.	Eurasian Wigeon	*Anas penelope*	LC
22.	Spot-billed Duck	*Anas poecilorhyncha*	LC
23.	Northern Shovelle	*Anas clypeata*	LC
24.	Northern Pintail	*Anas acuta*	LC
25.	Garganey	*Anas querquedula*	LC
26.	Common Teal	*Anas crecca*	LC
27.	Common Pochard	*Aythya ferina*	VR
28.	Red-crested Pochard	*Rhodonessa rufina*	LC
29.	Ferruginous Pochard	*Aythya nyroca*	CE
30.	Greater Scaup	*Aythya marila*	LC
31.	Tufted Pochard	*Aythya fuligula*	LC
32.	White-breasted Waterhen	*Amaurornis phoenicurus*	LC
33.	Purple Moorhen	*Porphyrio porphyrio*	LC
34.	Common Moorhen	*Gallinulachloropus*	LC
35.	Common Coot	*Fulica atra*	LC
36.	Bronze-winged Jacana	*Metopidius indicus*	LC
37.	Little Ringed Plover	*Charadrius dubius*	LC
38.	Red-wattled Lapwing	*Vanellus indicus*	LC
39.	White-tailed Lapwing	*Vanellus leucurus*	LC
40.	River Lapwing	*Vanellus duvaucelii*	NT
41.	Spotted Redshank	*Tringae rythropus*	LC
42.	Common Redshank	*Tringa totanus*	LC
43.	Ruff	*Philomachus pugnax*	LC
44.	Little Stint	*Calidris minuta*	LC
45.	Black tailed Godwit	*Limosa limosa*	NT
46.	Common Sandpiper	*Actitis hypoleucos*	LC
47.	Common Greenshank	*Tringa nebularia*	LC
48.	Wood Sandpiper	*Tringa glareola*	LC
49.	Black-winged Stilt	*Himantopus himantopus*	LC
50.	Pied Avocet	*Recurivirostra avosetta*	LC
51.	River Tern	*Sterna aurantia*	VUL
52.	Black-headed Gull	*Larus ridibundus*	LC
53.	Pallas's Gull	*Larus ichthyaetus*	LC
54.	Lesser Pied Kingfisher	*Ceryle rudis*	LC
55.	White-breasted Kingfisher	*Halcyon smyenensis*	CE
56.	White Wagtail	*Motacilla alba*	LC
57.	Large Pied Wagtail	*Motacilla maderaspatensis*	LC
58.	Citrine Wagtail	*Motacilla citreola*	LC
59.	Yellow Wagtail	*Motacilla flava*	LC
LC: Least Concern NT: Near Threatened VR: Vulnerable CE: Critically Endangered			

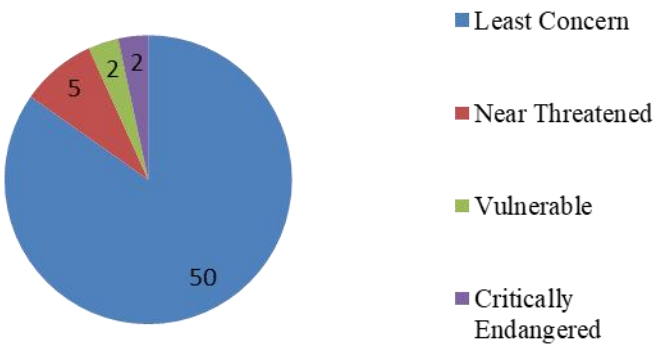


Figure 4.8: IUCN status of observed bird species

Among the eight orders represented during the study period, order: Anseriformes was found to be the most dominant, having 15 species, followed by Charadriiformes with 13 species.

The percentage contribution of abundance status in total birds diversity of Yamuna river was reported as Least concern 50%, Near-threatened 5%, Vulnerable 2%, Critical Endangered 2%.

Systematic classification of bird samples collected during the study was carried out based on global conservation status provided by the International Union for Conservation of Nature (IUCN) and Residential, and abundance status systematically arranged bird species under different genera with their local names in Yamuna river.

Table 4.9: Segment-wise distribution of observed bird species

Sr.No.	Common name	Segment 1 (Yamunanagar area)	Segment 2 (Panipat area)	Segment 3 (Faridabad area)
1.	Little Grebe	+	-	+
2.	Little Cormorant	+	+	+
3.	Indian Shag	+	+	+
4.	Great Cormorant	+	-	-
5.	Little Egret	+	+	+
6.	Grey Heron	+	-	+
7.	Purple Heron	-	-	+
8.	Large Egret	+	+	+
9.	Median Egret	+	-	+
10.	Cattle Egret	+	+	+
11.	Indian Pond-Heron	+	+	+
12.	Black-crowned Night Heron	-	+	+
13.	Painted stork	+	-	-
14.	White-necked Stork	+	-	+
15.	Asian Openbill Stork	-	+	+
16.	Eurasian Spoonbill	-	-	+
17.	Greylag Goose	+	+	+
18.	Bar-headed Goose	+	+	+
19.	Brahminy Shelduck	-	+	-

20.	Mallard	+	+	+
21.	Eurasian Wigeon	+	-	-
22.	Spot-billed Duck	+	+	+
23.	Northern Shovelle	+	+	+
24.	Northern Pintail	+	+	+
25.	Garganey	-	-	+
26.	Common Teal	+	+	+
27.	Common Pochard	+	+	+
28.	Red-crested Pochard	+	+	-
29.	Ferruginous Pochard	+	+	-
30.	Greater Scaup	+	-	-
31.	Tufted Pochard	+	+	+
32.	White-breasted Waterhen	+	+	+
33.	Purple Moorhen	+	+	-
34.	Common Moorhen	+	+	+
35.	Common Coot	+	+	+
36.	Bronze-winged Jacana	+	-	-
37.	Little Ringed Plover	-	-	+
38.	Red-wattled Lapwing	+	+	+
39.	White-tailed Lapwing	+	+	-
40.	River Lapwing	+	-	-
41.	Spotted Redshank	+	+	+
42.	Common Redshank	+	+	+
43.	Ruff	-	+	+
44.	Little Stint	+	+	+
45.	Black tailed Godwit	-	+	-
46.	Common Sandpiper	+	+	+
47.	Common Greenshank	+	+	+
48.	Wood Sandpiper	+	+	+
49.	Black-winged Stilt	+	+	+
50.	Pied Avocet	-	-	+
51.	River Tern	+	+	-
52.	Black-headed Gull	-	-	+
53.	Pallas's Gull	+	+	-
54.	Lesser Pied Kingfisher	+	-	+
55.	White-breasted Kingfisher	+	+	+
56.	White Wagtail	+	+	+
57.	Large Pied Wagtail	+	-	-
58.	Citrine Wagtail	+	+	+
59.	Yellow Wagtail	+	+	+

Table 4.10: Diversity Indices for each segment

S.No.	Diversity Index	Segment 1	Segment 2	Segment 3
1.	Simpson Index	0.1143	0.1414	0.0739
2.	Simpson Index of Diversity	0.8857	0.8586	**0.9266**
3.	Shannon weaver Index	**2.2735**	2.0671	2.2658
4.	Marglef Richness Index	3.0998	2.6928	**3.1712**

Different diversity indexes were calculated for the three segments of the study area. It was found that species diversity was maximum in segment 3. Species richness was maximum in segment three, and species evenness was maximum in segment 1

Plate 48: Black winged stilt

Plate 49: Citrine wagtail

Plate 50:Common teal

Plate 51: Eurasian spoonbill

Plate 52: Grey heron

Plate 53: Greylag goose

Plate 54: Indian pond heron

Plate 55:Indian spot billed

Plate 56: Little egret

Plate 57: Little grebe

Plate 58: Median egret

Plate 59: Northern pintail

Plate 60: Northern shoveler

Plate 61: Painted stork

Plate 62: Purple moorhen

Plate 63: White-breasted kingfisher

Plate 64: White breasted

Plate 65: Red wattled lapwing

Plate 66: Common redshank

Plate 67:White necked stork

Plate 68: Indian shag

Plate 69: Little cormorant

Plate 70: Common sandpiper

Plate 71: Great cormorant

Plate 72: White wagtail

Plate 73: Cattle erget

Plate 74: Common moorhen

Plate 75: Common coot

Plate 76: Purple Heron

Plate 77: Large Egret

Plate 78: Cattle Egret

Plate 79: Black-crowned Night Heron

Plate80: Asian Openbill Stork

Plate 81: Bar-headed Goose

Plate 82: Brahminy Shelduck

Plate 83: Mallard

Plate 84: Eurasian Wigeon

Plate 85:Garganey

Plate 86: Common Pochard

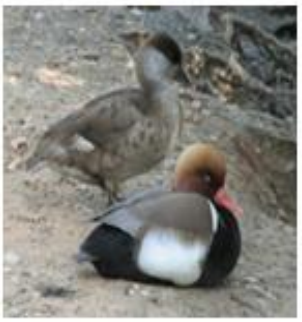


Plate 87: Red-crested Pochard

Plate 88: Ferruginous Pochard

Plate 89: Greater Scaup

Plate 90: Tufted Pochard

Plate 91: Bronze-winged Jacana

Plate 92: Little Ringed Plover

Plate 93: River Lapwing

Plate 94: Spotted Redshank

Plate 95: Ruff

Plate 96: Little Stint

Plate 97: Black tailed Godwit

Plate 98: Common Greenshank

Plate 99: Wood Sandpiper

Plate 100: Pied Avocet

Plate 102: R*iver* Tern

Plate 103: Pallas's Gull

Plate 104: Lesser Pied Kingfisher

Plate 105: White-breasted Kingfisher

Plate 106: Large Pied Wagtail

Plate 107:Yellow Wagtail

Plates 48-107: Birds reported in the study area

(iii) To study the plankton diversity in the selected sites of Yamuna river

4.1 Phytoplankton diversity

Phytoplankton is an autotrophic component that occupies the lowest level of the aquatic food chain, providing all of the ecological activities required for aquatic life. Phytoplankton is responsible for producing a large portion of the oxygen in the atmosphere. Phytoplankton differs significantly from Cyanobacteria to diatoms and green algae., Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae are the essential algae group of phytoplankton

During the study period, planktons were collected from three distinct places in the Yamuna river in Yamunanagar, Panipat, and Faridabad district in Haryana. The qualitative analysis of these four samples in one site revealed that there are 17 genera of phytoplankton in total, belonging to four major groups, (i) Bacillariophyceae (consisting of 3 genera), (ii) Chlorophyceae (consisting of 10 genera), (iii) Euglenophyceae (consisting two genera), (iv) Cyanophyceae (consisting three genera).

Table 4.11: Phytoplankton diversity in Yamuna riverine area at study sites			
Group	**Study sites**		
	Yamunanagar area	**Faridabad area**	**Panipat area**
Bacilliriophyceae	*Navicula sp*	*Syendra sp*	*Syendrasp*
	Syendra sp	*Cyclotella sp*	-
	Cyclotella sp	-	-
Cyanophyceae	*Anabaena sp*	*Aphanizomenon sp*	*Anabaena sp*
	Microcystis sp	-	*Microcystis sp*
Chlorophyce	*Chlorella sp*	*Coleastrum sp*	*Chlorella sp*
	Closterium sp	*Oocystis sp*	*Closterium sp*
	Coleastrum sp	*Protococcus sp*	-
	Oocystis sp	*Akinstrodesmus sp*	*Oocystis sp*
	Protococcus sp	*Pedistrum sp*	-
	-	*Anacystis sp*	*Akinstrodesmus sp*
	Pedistrum sp	*Akinstrodesmus sp*	*Pedistrum sp*
	Anacystis sp	*Desodesmus sp*	*Anacystis sp*
	Akinstrodesmus sp	-	*Akinstrodesmus sp*
	-	-	*Scenedesmus sp*
	Desodesmus sp	-	-
Euglinophyceae	*Euglena sp*	*Euglena sp*	-
	Phacus sp	-	-

4.2 Zooplankton diversity

Zooplankton plays an essential role, serving as a bio-indicator, and it is a very suitable tool for understanding the contamination status of water. Water properties are essential in the growth and abundance of Zooplankton.

Zooplankton is cosmopolitan and inhabits all freshwater habitats worldwide, including polluted industrial waters and municipal waste. Zooplankton forms crucial links in the food chain, in the food web, in energy flows and in the circulation of matter, thus playing a significant ecological role in all functional aspects of the aquatic ecosystem system.

Table 4.12: Zooplankton diversity in Yamuna riverine area at study sites			
Group	**Study sites**		
	Yamunanagar area	**Faridabad area**	**Panipat area**
Protozoa	*Paramisium sp*	*Paramisium sp*	*Arcella sp*
	Arcella sp	*Arcella sp*	
Copepoda	*Macrocyclops albidis*	*Cyclops stretnum*	*Eucyclops sp*
	Phyllodiaptomus sp		*Macrocyclops albidis*
	Mesocyclops sp	*Macrocyclops albidis*	*Mesocyclops sp*
	Diaptomus sp	*Mesocyclops sp*	-
	Naupilus larvae	*Hapacticoid copepods*	*Diaptomus sp*
	Cyclops sutifer	*Naupilus larvae*	*Naupilus larvae*
	-	*Diacyclopsthemsi*	*Diacyclopsthemsi*
	-	*Cyclops sutifer*	*Cyclops sutifer*
Cladocera	*Daphnia pulicaria*	*Daphnia Pulicaria*	*Daphnia catwba*
	Daphnia carinata	*Daphnia carinata*	*Daphnia carinata*
	Daphnia manga	*Daphnia longispina*	*Daphnia longispina*
	Daphnia laevis	*Daphnia manga*	*Daphnia manga*
		Daphnia laevis	*Daphnia laevis*
	Daphnia similis	*Daphnia similis*	*Daphnia similis*
	Daphnia mendotae	*Diaphno somasarsi*	*Ceriodaphnia corunta*
	Diaphnosoma sarsi	*Diaphno soma branchyrus*	*Moina micrura*
	Diaphnosoma branchyrus	*Ceriodaphnia corunta*	*Moina macrocopa*
	Moina micrura	*Moina micrura*	*Daphnia pulex*
	Moina macrocopa	*Moina macrocopa*	
	Daphnia pulex	*Daphnia pulex*	
		Moina macrocopa	
Rotifera	*Branchinous pictilis*	*Branchinous roundiformis*	*Asplencha pariodonta*
	Branchinous roundiformis	*Branchinous variabilis*	-
	Asplenc haherrikki	*Asplenc haherrikki*	-
	Asplencha pariodonta	*Asplencha pariodonta*	-

A total of 30 genera belong to four classes i) Protozoa, ii) Copepoda, iii) Cladocera and iv) Rotifers. Copepoda included ten genera, Cladocera included 13 genera, Rotifers included 05 genera and Protozoa represented by two genera only.

Table 4.13: Simpson's Diversity Index of Phytoplankton and Zooplankton in all the Segments				
S.No.	Diversity Index	Yamunanagar	Panipat	Faridabad
1	Phytoplanktons	**0.3416**	0.4393	0.5272
2	Zooplanktons	**0.1936**	**0.1938**	**0.2047**

The diversity of phytoplankton was maximum in a segment first Yamunanagar (value of Simpson's index is lower than 0.3416). The diversity of Zooplankton was maximum in a segment first and almost equal to the segment second Panipat.

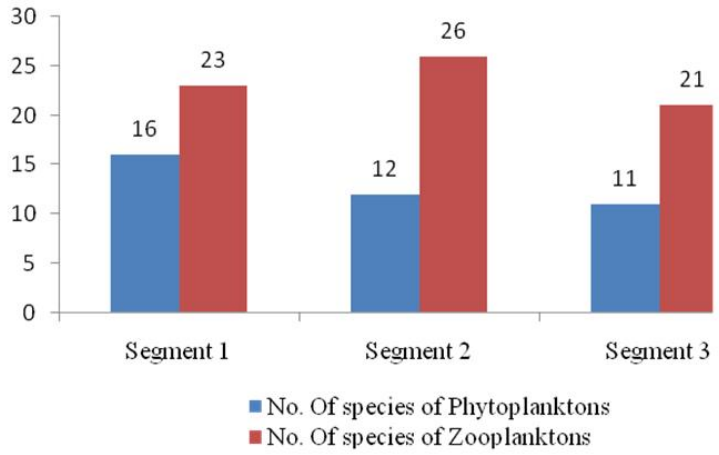


Figure 4.9 : Phytoplankton and zooplankton species in different segments

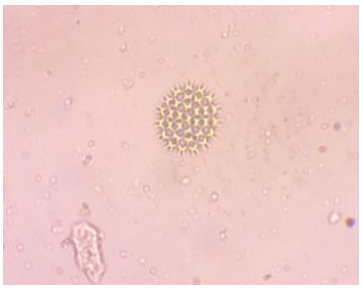


Plate108:*Pedistrum sp.*

Plate109:*Desodesmussp*

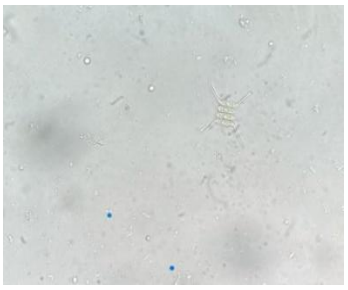


Plate110:*Scendesmus sp.*

Plate111: *Closterium sp.*

Plate112: *Chlorella sp.*

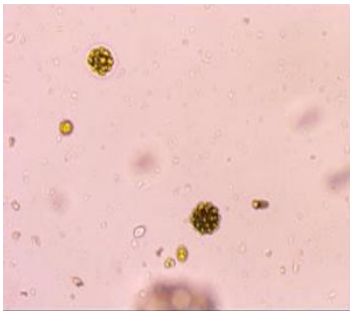


Plate113:*Eudorina sp.*

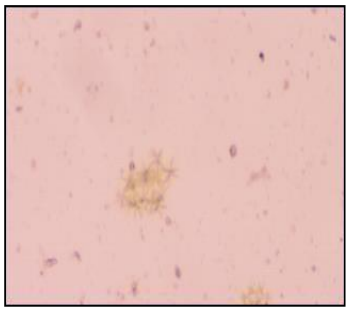


Plate*114:Ankistrodesmus sp.*

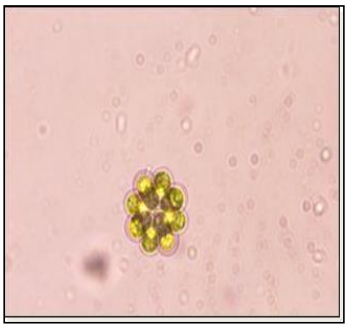


Plate115:*Coleastrum sp.*

Plate*116:Protococcus sp.*

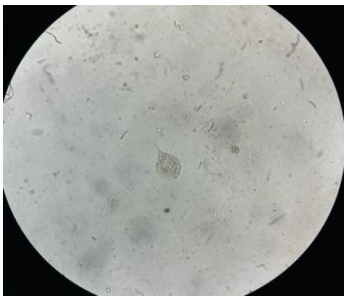


Plate117:*Phacus sp.*

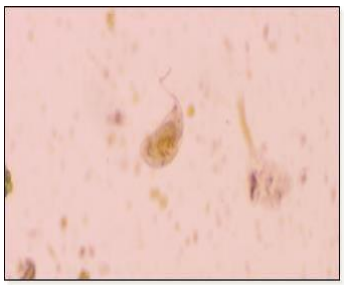


Plate118: *Euglena sp.*

Plate119:*Syndera sp.*

Plate120*:Navicula sp.*

Plate121:*Microsystis sp*

Plate122:*Aphanizomenon sp*

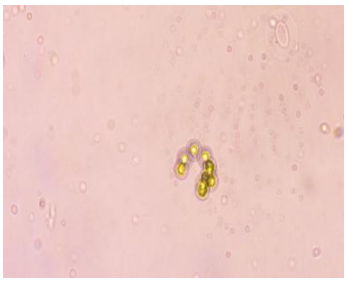


Plate123: *Anabaena sp.*

Plate124: *Daphnia catawba*

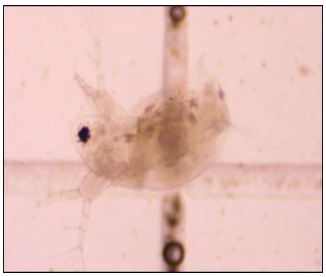


Plate125: *Daphnia manga*

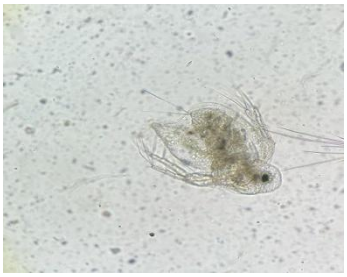


Plate126: *Daphnia mendotae*

Plate127: *Daphnia longispina*

Plate128:*Moina macrocopa*

Plate129:*Moina micrura*

Plate*130:Ceriodaphnia cornuta*

Plate131:*Diaphanosoma branchhyrum*

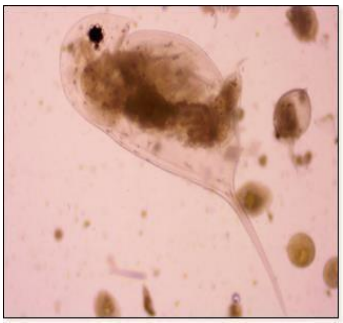


Plate132: Daphnia similis

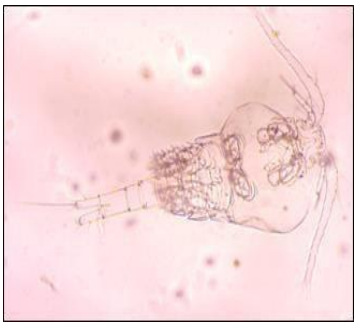


Plate133: *Cyclops stretnum*

Plate134: *Cyclops scutifer*

Plate135:*Eucyclops sp.*

Plate*136:Naupilus larva*

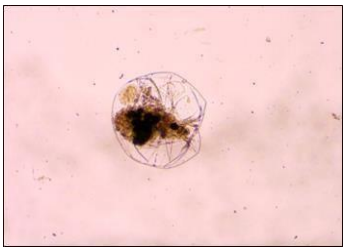
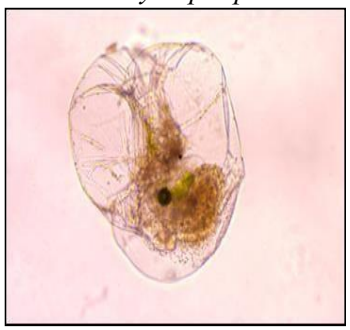


Plate137:*Asplanchus herriki*



Plat*138:* *Asplanchus pariodonta*

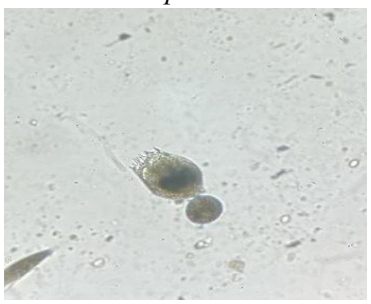


Plate139:*Branchinous roundiformis*

Plate*140:Branchinous calciflorus*

Plate141: *Paramecium sp.*

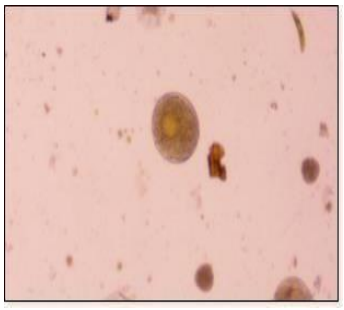


Plate142:*Arcella sp.*

Plates 108-142: Phytoplanktons and Zooplanktons reported in the study area

(iv) To study the physicochemical parameters of water at the selected sites of the Yamuna river

The study of the Yamuna river (Haryana) was undertaken from September 2021 to April 2022 to investigate the various changes in different water quality parameters of water in the river.

Water temperature

The temperature has a direct effect on the important factors, viz. growth. Oxygen demand, food requirement and conversion efficiency (Ayyappan *et al*., 2011) and all biological activities like ingestive variation, reproduction, movement and distribution are also greatly influenced by water temperature (Rath, 2018). Moreover, the temperature is a primary determining factor of biodiversity in any water body.

In the present investigation, the maximum water temperature was recorded in different sites Yamunanagarat (20.68±0.05), Panipat (20.43±0.14) and Faridabad (21.33±0.13) in April 2022. The minimum temperature was recorded during January 2022 (winter). That condition was observed due to low water levels during summer and natural climatic changes like minimum atmospheric temperature during winter and high summers.

Table4.14: Water temperature of Yamuna River water at different study sites

	Water temperature (°C)							
Studied Sites	**Sept. (2021)**	**Oct. (2021)**	**Nov. (2021)**	**Dec. (2021)**	**Jan. (2022)**	**Feb. (2022)**	**Mar. (2022)**	**Apr. (2022)**
Yamunanagar	19.80± 0.11	16.95± 0.07	15.40± 0.07	11.73± 0.25	8.38± 0.08	10.43± 0.06	14.30± 0.09	**20.68± 0.05**
Panipat	19.80± 0.31	18.05± 0.09	15.90± 0.17	11.95± 0.33	8.50± 0.18	10.43± 0.06	14.13± 0.11	**20.43± 0.14**
Faridabad	21.25± 0.10	20.63± 0.55	17.25± 0.10	13.95± 0.07	9.88± 0.09	11.23± 0.09	15.68± 0.09	**21.33± 0.13**
CD (p=0.05)	0.64	1.04	0.39	0.79	0.40	0.23	0.31	0.36

Hydrogen–ion concentration (pH)

In the present investigation, the pH value recorded from Yamunanagar was a maximum of 8.03±0.11 (in January), in Panipat 7.38±0.11 (in February), and in Faridabad 6.98±0.11 (in February).

Table 4.15: pH of Yamuna River water at different study sites								
pH								
Studied Sites	**Sept. (2021)**	**Oct. (2021)**	**Nov. (2021)**	**Dec. (2021)**	**Jan. (2022)**	**Feb. (2022)**	**Mar. (2022)**	**Apr. (2022)**
Yamunanagar	7.03±0.05	7.50±0.08	7.40±0.06	7.88±0.05	**8.03±0.11**	7.58±0.15	7.68±0.06	7.08±0.15
Panipat	6.95±0.03	7.13±0.15	7.15±0.10	7.08±0.13	7.13±0.06	**7.38±0.11**	6.85±0.07	6.80±0.07
Faridabad	6.85±0.07	6.50±0.08	6.53±0.08	6.33±0.17	6.00±0.11	**6.98±0.11**	6.83±0.09	6.33±0.13
CD (p=0.05)	NS	0.35	0.25	0.40	0.31	0.41	0.23	0.39

Dissolved Oxygen (DO)

The dissolved oxygen in water is one of the most crucial parameters or factors of any aquatic ecosystem that decides its life. The level of dissolved oxygen in any natural water body viz. River depends on their physical, chemical and biological activities. It plays a vital role in the life of aquatic life. Oxygen from the atmosphere and the process of photosynthesis by aquatic plants are the primary sources of dissolving oxygen in the water.

In Yamunanagar, DO value ranges from 5.53±1.74 - 8.10±0.07. In Panipat, it was 3.63±0.08 – 4.80±0.4, while, in Faridabad, it was found to be the least among the recorded values, 1.33± 0.06 – 2.33± 0.09.

Table 4.16: Dissolved oxygen (DO) of Yamuna River water at different study sites								
Dissolved oxygen (DO) mgL^{-1}								
Studied Sites	**Sept. (2021)**	**Oct. (2021)**	**Nov. (2021)**	**Dec. (2021)**	**Jan. (2022)**	**Feb. (2022)**	**Mar. (2022)**	**Apr. (2022)**
Yamunanagar	**8.10±0.07**	7.90±0.07	**5.53±1.74**	6.58±0.15	6.68±0.10	6.40±0.11	6.53±0.09	7.20±0.13
Panipat	4.58±0.05	3.90±0.07	**4.80±0.11**	4.68±0.14	**3.63±0.08**	4.40±0.16	4.63±0.10	3.88±0.17
Faridabad	2.30±0.08	**2.33±0.09**	2.23±0.11	1.68±0.09	1.68±0.06	1.85±0.24	1.70±0.18	**1.33±0.06**
CD (p=0.05)	0.22	0.25	NS	0.41	0.27	0.57	0.42	0.42

Total Alkalinity (TA):

Water's total alkalinity is the capacity to neutralize a strong acid. Alkalinity in natural water bodies is mainly due to carbonates and bicarbonates ions in water. Still, other ions, such as phosphates, nitrates, silicates, etc., also contribute to the total alkalinity recorded. In the present investigation, it was observed at maximum in Yamunanagar at 172.00±1.63 mg/l, Panipat at 194.00±2.16 mg/l and Faridabad, it was maximum (351.75±11.89 mg/l) among the recorded values of total alkalinity.

Table 4.17: Total Alkalinity of Yamuna river at different study sites

Total Alkalinity (TA) mgL^{-1}								
Studied Sites	**Sept. (2021)**	**Oct. (2021)**	**Nov. (2021)**	**Dec. (2021)**	**Jan. (2022)**	**Feb. (2022)**	**Mar. (2022)**	**Apr. (2022)**
Yamunanagar	83.25± 0.48	103.25± 0.63	95.50± 0.96	139.75± 0.63	163.25± 1.38	124.75± 1.11	170.25± 0.63	**172.00 ±1.63**
Panipat	167.50± 2.33	169.50± 0.96	193.75± 2.53	147.00± 3.11	174.00± 2.94	158.00±2. 86	177.00± 2.04	**194.00 ±2.16**
Faridabad	216.50± 2.33	219.75± 5.48	**351.75± 11.89**	289.75± 6.49	311.50± 10.48	175.50±25 .39	330.50± 14.41	274.50 ±7.89
CD (p=0.05)	6.23	10.49	22.8	13.52*	20.55	NS	27.29	15.63

Total Hardness:

Both temporary and permanent hardness were observed in freshwater bodies. The first is caused by soluble calcium and magnesium bicarbonates and is caused by soluble calcium and magnesium carbonates and salts of organic acids.

Table 4.18: Total Hardness of Yamuna river water at different study sites

Total Hardness (TH) mgL^{-1}								
Studied Sites	**Sept. (2021)**	**Oct. (2021)**	**Nov. (2021)**	**Dec. (2021)**	**Jan. (2022)**	**Feb. (2022)**	**Mar. (2022)**	**Apr. (2022)**
Yamunanagar	121.75± 1.93	146.25± 3.75	140.50± 2.26	146.75± 2.18	125.50± 2.87	169.75± 3.09	**209.50± 4.21**	182.75±1.44
Panipat	133.50± 0.96	268.75± 2.69	268.75± 2.69	242.50± 2.10	127.00± 2.52	259.50± 3.78	**291.00± 1.92**	275.50±2.66
Faridabad	186.00± 3.19	203.00± 2.35	203.00± 2.35	169.50± 9.74	186.25± 8.69	218.50± 12.09	**279.25± 6.29**	247.00±11.90
CD (p=0.05)	7.21	9.70	7.91	19.11	17.78	24.43	14.63	22.9

During the present investigation, the value of total hardness was recorded at maximum values in March, 209.50±4.21 mg/l (in Yamunanagar), 291.00±1.92 mg/l (in Panipat) and 279.25±6.29 mg/l (in Faridabad). The sudden fluctuation in the value of total hardness in march month in maximum value.

Table 4.19: Co-relation in between water quality parameter

	Water temperature	**pH**	**Dissolve Oxygen (DO)**	**Total Alkalinity**	**Total Hardness**
Water temperature	1				
pH	-0.351**	1			
Dissolve Oxygen (DO)	-0.058	0.731**	1		
Total Alkalinity	0.031	-0.601**	-0.776**	1	
Total Hardness	0.136	-0.264*	-0.408**	0.268	1

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

There is negative correlation in between the water, temperature, pH, dissolved oxygen and total alkalinity. While, there is a positive correlation in between pH and dissolved oxygen. Similarly, the correlation in between total alkalinity and total hardness shows positive correlation.

There is direct correlaton in between PH and temperature,and inverssaly correlation in between pH and Dissolve Oxygen ,or tota total alkalinity and total hardness direct correlation.

CHAPTER-V

DISCUSSION

5.1 To study the fish diversity in the selected sites of Yamuna river

In the present study, a total of 64 fish species have been recorded from 3 sites (Yamunanagar, Panipat, and Faridabad districts of Haryana) which belong to the order Cypriniformes (36 species), followed by the order Siluriformes (14 species), Anabantiformes (4species), Synbranchiformes (3 species), Clupeiformes (3species), Anguilliformes (1species), Perciformes (2species), Ovalentaria (1 species). The present study reveals the same pattern of dominance as previously reported by Joshi *et al*. (2016) from the river Yamuna. They reported 112 species belonging to 10 orders, 29 families and 73 genera.

Lakra *et al*. (2010) studied the fish diversity, habitat ecology, and management issues of a tropical river in India's Ganga basin. They reported that 63 fish species, representing 20 families and 45 genera, were collected from five sampling stations distributed along the upstream, midstream, and lower streams. Joshi *et al*. (2022) reported similar patterns of species composition in several river systems and found 58 fish species, representing seven orders, 20 families, and 40 genera.

Anthropogenic activities and the associated water pollution, deposition of heavy metals, eutrophication, damming, disruption of hydrology, and introduction of exotic species have been reported as threats to the Ganga river's fauna and vegetation (Tripathi *et al*., 2017).

The same anthropogenic activity has an impact on the current inquiry as well. At Allahabad, 89 different fish species from the Ganga river were reported by (Tripathi *et al*., 2017). The annual data analysis on fish landings revealed that *C. carpio*, *O. niloticus*, and the various group made up most of the estimated yearly catch. When it comes to Indian major carps, *C. mrigala* contributed the most. Current work was assumed to study the 64 species from the Yamuna river. Annual data on fish landing showed that the estimated yearly catch was dominated by *L. rohita* and *A. testudineus*.

5.2 To study the diversity of migratory aquatic birds' and their nature of damage in the selected sites at Yamuna river

Fifty-nine species belong to 8 orders, 14 families and 40 genera. The most dominant order was Anseriformes with 15 species, Charadriiformes with 13 species and Ciconiiformes

with 12 species. The most dominant family were Anatidae having 15 species, followed by the family Ardeidae (8 species) and Scolopacidae (7 species). During the study period, prevalent species reported were Indian shag, cattle egret, Indian pond heron, common teal and wood sandskipper. Common species were little egret, graylag goose, greater scaup, purple moorhen, and ruff.

Gupta *et al*. (2012) reported that similar patterns Ruff, purple moorhen, and greater scaup, were major Wetland birds observed in the Haryana districts of Palwal, Faridabad, and Okhla along the River Yamuna. There was 60 species total, divided into eight orders and 14 families. Sixty wetland birds were observed, of which 35 were winter migrants, 11 were local migrants, and 11 were resident species. A total of 59 species from 8 orders, 14 families, and 40 genera are included in the current investigation, of which 34 are winter migratory, ten are local migratory, and 15 are resident. The same pattern of species composition was also seen.

Kaushik & Gupta (2013) studied the diversity of migratory wetland birds in Uttarakhand's Asan barrage and 60 species of marsh birds belonging to 6 orders and 13 families. The Shelduck (*Tadorna ferruginea*), Common Coot (*Fulica atra*), Red-crested Pochard (*Rhodones sarufina*), Common Pochard (*Aythya ferina*), and Mallard (*Anas platyrhynchos*) were the main birds. The Brahminy shelduck (*T. ferruginea*), Red-crested Pochard (*R. rufina*), Common Pochard (*A. ferina*), Mallard (*A. platyrhynchos*), and Common Coot (*Fulica atra*) were the most dominant birds in the current study.

About 13% of the world's bird species are found on the Indian subcontinent, a natural indicator of a healthy ecology. At the Haiderpur wetland (Hastinapur wildlife sanctuary), located along the Ganga River in Uttar Pradesh, research by Joshi *et al*. (2021) found 66 different species of water birds from 15 other families. According to IUCN records, the Haiderpur wetland area is home to four waterbird species that are vulnerable (Common Pochard, Black-headed ibis, Sarus crane, and Indian skimmer), six near-threatened species (River Lapwing, Northern lapwing, River tern, Painted stork, Woollynecked Stork, and Black-tailed Godwit), and one species that is endangered (Black-bellied Tern).

In the present investigation, 02 Vulnerable (River Tern and common pochard), 05 near threaten (Painted stork, White-necked stork, Eurasian spoonbill, River lapwing, Black tailed Godwit), and 02 Critical Endangered (*Ferruginous pochard*, White-breasted Kingfisher) were reported.

During the present investigation, out of 59 reported bird species, 24 species were found to be very common, 20 species were common, 07 species were less common, and Six species were found rare. Puri &Virani (2016) found eighty-six species of water birds and land

birds, 45% of species were reported very common, 5% were rare, 19% were common, and 16% were uncommon.

5.3 To study the plankton diversity in the selected sites of the Yamuna river

During the study period, planktons were collected from three distinct places in the Yamuna river (Yamunanagar, Panipat, and Faridabad). The qualitative analysis of water samples was observed and revealed that 17 genera of phytoplankton in total belonged to four major groups, i.e. Bacillariophyceae (3 genera), Chlorophyceae (10 genera), Cyanophyceae (2 genera).

A total of 30 genera belong to different classes (Copepoda, Cladocera, Rotifera, and Protozoa). Copepoda included (ten genera), Cladocera included (thirteen genera), Rotifers (five genera) and Protozoa (two genera).

Kumar & Khare (2015) investigated the plankton diversity and its seasonal change in density in the Yamuna river at Kalpi, district Jalaun, Uttar Pradesh. Thirty-five species of phytoplankton were discovered, with 25 taxa represented, including Bacillariophyceae (5 species), Euglenophyceae (7 species), and Chlorophyceae (15 species), and Euglenophyceae (12 species).

Thirty-one genera in the five groups Bacillariophyceae, Chlorophyceae, Myxophyceae, Euglenophyceae, and Xanthophyceae, as well as a total of 21 species of phytoplankton in the three significant categories Bacillariophyceae, Chlorophyceae, and Cyanophyceae, were observed and catalogued by Kumar *et al*. (2020).

In the present investigation, 17 species belong to four major groups, i.e. Bacillariophyceae (3 genera), represented by *Navicula, Syndera*, and *Cyclotella*. Chlorophyceae (11 genera) represented by *Chlorella, Coleastrum, Pediastrum, Oocysits, Ankistrodesmus, Closterium, Scenedesmus, Desmodesmus, Protoccocus, Eudorina* and *Chlamydomonas*. Euglenophyceae (2 genera) represented by *Euglena, Phacus* and Cyanophyceae (3 genera) represented by *Anabaena, Microcystis*, and *Aphanizomenon* were reported. The result was similar with different species compositions was different. The Chlorophyceae group was the most dominating group, which dominated the rest of the phytoplankton population.

Sarwade & Kamble (2014) conducted a quantitative study of plankton in several locations along the River Krishna in the Sangli district and reported 53 phytoplankton species in five categories (Cyanophyceae, Bacillariophyceae, Chlorophyceae, Hydrocharitaceae, and Desmidiceae). With 22 species, the Chlorophyceae subfamily dominated them all.

The present investigation followed the same pattern as Chlorophyceae predominated among all species (Cladocera, Rotifera, Protozoa, Nematoda, Aostraca, Schizopyrenida).

5.4 To study the Physicochemical parameters of water, the selected sites of the Yamuna river

Water parameter

The water quality parameters were recorded in the present investigation from different sites (Yamunanagar, Panipat, and Faridabad). The temperature of river water range from 8.38±0.08 –21.33±0.13 °C, pH range from 6.00±0.11 - 8.03±0.11, DO from 1.68±0.06 – 8.10±0.007mg/l, total alkalinity from 83.25±0.48 – 351.75±11.89mg/l and total hardness 121.75±1.93 – 279.25±6.29mg/l.

Temperature

The Physical, chemical and bacteriological study of water from rivers of Uttarakhand by Kumar *et al*. (2010) recorded temperatures ranging from 7.8 - 28°C. The present investigation recorded the water temperature in Yamunanagar from 8.38±0.08 – 20.68±0.05°C, Panipat at 8.50±0.18 – 20.43±0.14°C and Faridabad at 9.88±0.09 – 21.33±0.13°C in different time of study period. That condition was observed due to low water levels during summer and natural climatic changes like low atmospheric temperature during winter and high summers.

pH

The pH value in Yamunanagar water was 6.85±0.07 – 7.38±0.11, and in Faridabad, it was 6.00±0.11 – 6.89±0.11. A similar report was studied by Gupta *et al*. (2013). The study revealed that the pH values of the Yamuna river at Agra were between 7.3 and 7.7.

Dissolve oxygen (DO)

In the present investigation, the DO recorded in the Yamuna river during the study was registered at 5.53mg/l in the Yamunanagar area ranges 5.53±1.74 – 8.10±0.07mg/l, in the Panipat area, 3.63±0.08 – 4.80±0.11mg/l and in the Faridabad area it was recorded 1.33±0.06 – 2.33±0.09mg/l. Recorded DO was maximum during winter and minimum during the summer. Similar patterns were also observed by Singh & Verma (2016) in the river Ganga

Total Alkalinity (TA)

Total Alkalinity is the measure of the capacity of water to neutralize the acids—alkalinity increases as the number of dissolved carbonates (CO_3) and bicarbonates (HCO_3).

Alkalinity levels varied from 175 mg/l to 310 mg/l in the Yamuna River (Gupta *et al*., 2013). In the present investigation (TA) was maximum during April in Yamunanagar (172.00±1.63mg/l), in April, Panipat maximum (194.00±2.16 mg/l) and in November site 3 Faridabad maximum (351.75±11.89 mg/l).

Total hardness

In a study was by Kumar *et al*. (2010). the Physical, chemical and bacteriological examination of water from rivers of Uttarakhand recorded the total hardness from 42 - 194 mg/L. All samples showed a permissible limit except samples of Haridwar. During the present investigation, maximum total hardness was recorded at Yamunanagar ranging from 121.75±1.93 – 209.50+±4.21mg/l in March, and at Panipat ranges from 127.00±2.58 – 291.00±1.92mg/l in March and at Faridabad ranges from 169.50±9.74 – 2789.25±6.25mg/l in March. The sudden fluctuation in the value of total hardness in march month in maximum value.

CHAPTER–VI

SUMMARY AND CONCLUSION

The results of the present study 'Assessment of fish species and migratory aquatic birds' biodiversity in Yamuna river (Haryana)'are summarized below:

- In the present study, 64 fish species have been recorded from the Yamuna riverine area, which belongs to seventeen families of nine orders.
- Cypriniformes order and Cyprinidae family were found to be the most dominant.
- Indian major carp, along with exotic carps and *Wallago attu*, contribute a significant portion of the fish catch of the Yamuna river in the studied sites.
- Fifty-nine bird species belonging to 14 families and eight orders have been recorded from the Yamuna riverine area at selected locations of Haryana.
- The Order Anseriformes was dominant, containing 15 per cent of bird species, followed by the Order Anseriformes, 13 per cent of Order Ciconiiformes, 12 species and Gruiformes, nine bird species.
- The family Anatidae was found to be dominant, containing 15 bird species, followed by the family Ardeidae (8 species) and Scolopacidae (7 species).
- Out of 59 bird species, 33 species were winter migrants, 16 species were residents, and ten species were local migrants.
- The twenty-four bird species were very common; 20 were common, 08 were rare, and 07 were less common in the study area, and out of total bird species, 50% were found to be Least concern (LC).
- Out of the 17 genera of phytoplankton, belonging to four major groups (i) Bacillariophyceae, (ii) Chlorophyceae, (iii) Euglenophyceae, (iv) Cyanophyceae
- Out of 30 genera of zooplankton population, ten genera belonged to (Copepoda), five genera (Rotifera), thirteen genera belonged to (Cladocera), and two genera belonged to (Protozoa).
- The Dissolved oxygen level was recorded in the Yamunanagar area range 5.53± 1.74 – 8.10±0.07 mg/l, in the Panipat area at 3.63±0.08 – 4.80±0.11 mg/l and the Faridabad area it was recorded 1.33±0.06 – 2.33+0.09 mg/l. Recorded DO was maximum during winter and minimum during the summer. Similar patterns were also observed by Singh & Verma (2016) in the river Ganga
- The present study gives enlightening information on fish bio-diversity and assists in understanding the water nature of the Yamuna river. Fish –biodiversity is an

indicator of ecosystem health, conservation status and human food resources. The fish biodiversity of the Yamuna river was poor, indicating its water quality. There is a need of the hour to conserve the vulnerable and endangered fauna of the Yamuna river through suitable conservation strategies.

- The physicochemical water quality parameters of the Yamuna river exhibited that the water quality of Yamuna river is polluted due to industrial discharge and wastes from agriculture, surface runoff and human activity. So, Yamuna river water is unsuitable for drinking and needs to be improved for various human uses. From the above point of view, it could be concluded that the water of the Yamuna river needs to be treated before its use for drinking and should be improved for aquatic fauna by checking pollution and discharging treated domestic and industrial discharges.

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ABSTRACT

Title of Thesis	**:**	**Assessment of fish species and migratory aquatic birds'biodiversity in Yamuna river (Haryana)**
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Total number of pages in thesis	**:**	65 +v
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Keywords: Plankton diversity, fish species, migratory aquatic birds biodiversity.

The study was conducted to assess the fish diversity and migratory aquatic birds in the Yamuna river at selected sites. The fish and migratory aquatic birds were monitored from September 2021 to April 2022. The 64 fish species belonging to seven orders and 17 families and 59 bird species belonging to eight orders and fourteen families were recorded in the present investigation. Cypriniformes order and Cyprinidae family were found to be the most dominant. Indian major carp, along with exotic carps and *Wallago attu*, contribute a significant portion of the fish catch of the Yamuna river in the studied sites.

The Order Charadriiformes was dominant, containing 31 per cent of bird species. The family Anatidae was found to be dominant, including 25 per cent of bird species. Out of 59 bird species, 33 species were winter migrants, 16 species were residents, and ten species were local migrants. The twenty-four bird species were very common; 20 were common, eight were rare, and seven were less common in the study area, and out of total bird species, 50% were found to be Least concern (LC).

The 17 genera of phytoplankton belonging to four major groups were recorded. Out of 19 genera of zooplankton population, nine genera belonged to (Copepoda), two genera (Rotifera), four genera (Cladocera), and two genera (Protozoa) recorded.

The physicochemical water quality parameters during the present investigation were recorded at the poorest level in April in the Faridabad riverine system.

The present study gives enlightening information on fish bio-diversity and assists in understanding the water nature of the Yamuna river. Fish –biodiversity is an indicator of ecosystem health, conservation status and human food resources. The fish biodiversity of the Yamuna river was poor, indicating its water quality. There is a need of the hour to conserve the vulnerable and endangered fauna of the Yamuna river through suitable conservation strategies.

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I also undertake that, a patent, if any, arising out of the research work conducted during the programme shall be filed by me only with due permission of the competent authority of Chaudhary Charan Singh Haryana Agricultural University Hisar.

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