

Water plays a crucial role in nearly every aspect of life on Earth. Covering more than 70% of the Earth's surface, water stands as a fundamental natural resource essential for all living organisms. It has a significant influence on various environmental processes and profoundly impacts the destiny of life on our planet. If the water resources of Earth are classified based on their utility, then nearly 97% of the water resources are in the form of Saltwater having very limited utilities such as transportation, the release of heat, fishery, etc. (Kamble & Jadhav, 2011). However, these waters are unsuitable for consumption due to their very high salt content. Out of the remaining 3% of freshwater, the majority is either trapped in polar ice caps or exists as groundwater with limited accessibility. The surface freshwater that is readily available for human use constitutes only a small fraction of the total water resources, around 0.33%, meeting most of the human freshwater needs. Nevertheless, unregulated exploitation of these resources - such as lakes, ponds, rivers, and streams - leads to their rapid deterioration (Tailor & Mankodi, 2013).

1.1 Aquatic Ecosystem:

The term ecosystem was first proposed in 1935 by the British Ecologist Sir Arthur G. Tansley (Tansley, 1935). "Living (biotic) organisms and their non-living environment are inseparably interrelated and interact with each other" or "Any unit that includes all the organisms in a given area interacting with the physical environment so that a flow of energy leads to clearly defined biotic structures and cycling of materials between living and non-living components called ecological system or ecosystem" (Odum, 2005). There are two different ecosystems which are, (1) Aquatic ecosystem and (2) Terrestrial ecosystem. There are three types of aquatic ecosystem: (1) Marine ecosystem, (2) Freshwater ecosystem and (3) Estuarine ecosystem.

1.2 Freshwater Ecosystem:

A fundamental process in the regulation of aquatic ecosystem is the cycling of nutrients between autotrophs, heterotrophs and detritivores. The freshwater macrophyte communities of lotic ecosystems range from macrophyte assemblages of springs, rivulets, creeks, brooks, and rivers in headwater streams to those in larger rivers (with relatively slow flow rates and depths). Lotic ecosystems are characterized by regular flowing water with waterfalls. Ponds, lakes, wetlands, dams, bogs, swamps, reservoirs, and pools constitute lentic ecosystems generally in Plate 1. They vary considerably in physical, chemical, and biological characteristics. Besides the natural lakes, man is building up artificial lakes usually called reservoirs, Dams, or

impoundments all over the world, including areas with no natural lakes. While not exactly borne of catastrophe, manmade lakes are probably also transitory in the geological sense and if they are properly managed, they can serve society in several ways. Depending upon the circumstances it can be a priceless blessing or a curse. (Brahmbhatt, 2006).

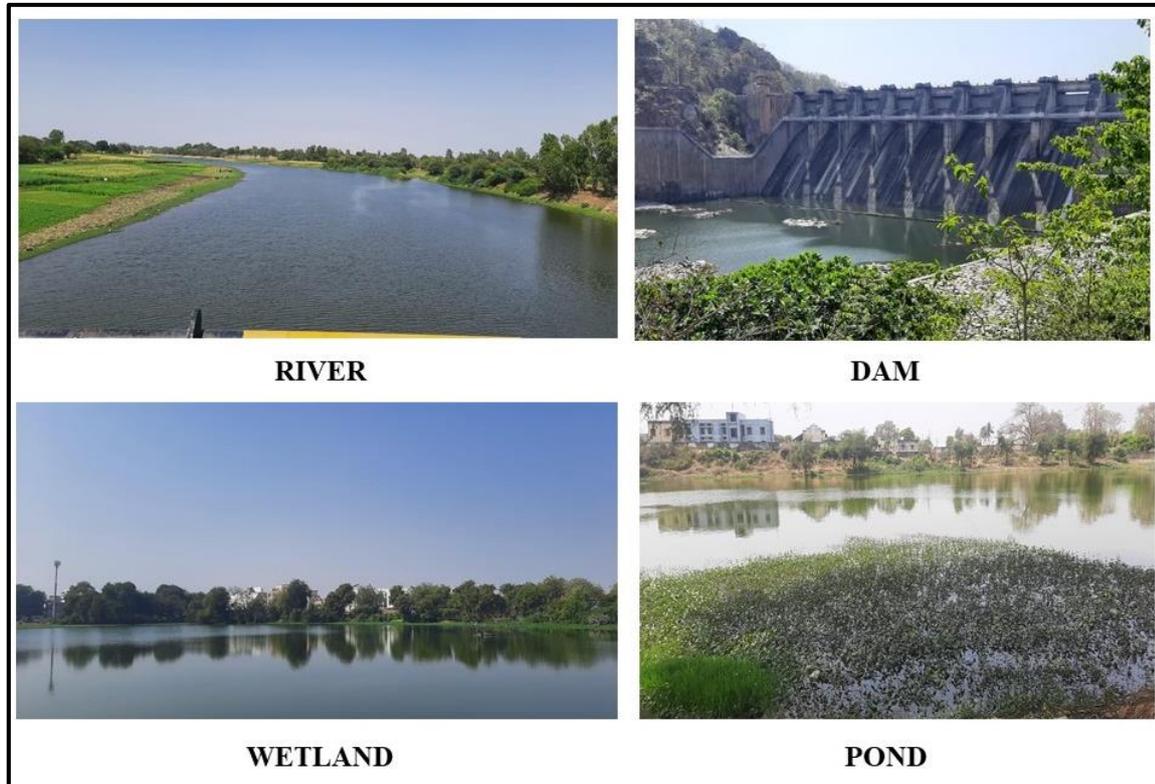


Plate 1: Showing Freshwater Ecosystems

1.3 Rivers and Streams:

These are collections of clean, moving water. The water flows into another body of water, such as a lake, sea, or ocean, either year-round or periodically through a natural channel. Compared to lakes or ponds, rivers and streams typically have higher oxygen concentrations and are home to a variety of creatures that have evolved to the following water.

1.4 Wetlands:

Wetlands are habitats that are primarily water-associated, and include marshes, swamps, ponds and others. This also comprises of lakes, reservation and ponds as well. They serve as ecotones — interfaces between areas where things are quite different — and so have features of aquatic and terrestrial (land-dwelling) ecosystems. These habitats support diverse flora and fauna and are highly productive ecosystems kin to the tropical rainforest in terrestrial ecosystems (Ramachandra et.al; 2005)

1.5 Ponds:

Ponds are smaller bodies of still water located in natural hollows, such as limestone sinks, or that result from the building of dams, either by humans or beavers. Ponds exist in most regions and can be seasonal or year-round.

1.6 Lakes:

A lake is a large body of water surrounded by land that is fed by rivers, springs, or local precipitation. A lake's structure has a considerable impact on its biological, chemical, and physical characteristics. Lakes are classed as oligotrophic or eutrophic based on a range of characteristics, including their formation and chemical or biological conditions. Oligotrophic lakes have limited production and are dominated by cold-water bottom fish like lake trout. Eutrophic lakes are shallower, more productive, and dominated by warm-water species like bass. Natural mechanisms of lake development most typically involve glacial, volcanic, and tectonic forces, whereas man-made lakes are generated by reservoirs or excavation of basins.

Lakes are simply described as bodies of water that fill depressions on the land surface. There is no common definition of 'lakes'. The International Glossary of Hydrology defines a lake as a "inland body of water of significant size." (UNESCO and WMO 1992)". One of the most elaborated definitions of lakes has been provided by Kuusisto (1985) as "a depression or a group of depressions partly or filled by water, all parts of the water body have the same surface, excluding temporary variability, caused by wind or ice, the ratio between in-flow and volume is small enough to let most of the suspended, inflowing material to form Bottom sediments and the surface area exceeds a given minimum value."

1.7 Classification of Lakes in India:

In India, there is no particular classification of lakes, although lakes are commonly identified based on the following criteria: Geographical locations include Himalayan lakes, peninsular lakes, and coastal lakes. Limnological criteria include freshwater lakes and brackish water lakes, among others. Beels and Jheels are examples of ephemeral lakes in the Ganga-Bramputra basin. Functional criteria such as lakes for irrigation, water supply and hydrology etc. (Chaudhary, 2014)

India is blessed with vast biodiversity and has a remarkable number of freshwater resources that serve as a platform for the survival of various indigenous freshwater fishes. Additionally, coastal areas (marines) serve as the main source of income and livelihood for an

enormous fishing population of the country. The Indian sub-continent hosts three large rivers, the Ganga, Brahmaputra and Godavari. All these three rivers have high sediment yield; the Ganga and Brahmaputra are essentially Himalayan drainages with high sediment production in active tectonic settings whereas high sediment yield of the Godavari despite its cratonic setting is a reflection of tropical weathering of Deccan Basalts and therefore higher sediment production (Tandon and Sinha, 2022). Some Chenab, Parbati and Basapa basins data have been published (Kulkarni et al., 2007; Kulkarni, 2010).

There are more than 100 reservoirs located in various parts of country according to the present or existing literature on limnology and fisheries of Indian reservoirs. An assessment of environment-mediated production functions of reservoirs has been attempted. The selection of the species for stocking in reservoir fisheries is followed by the country's reservoirs norms by fisheries management. For decades, Indian lakes have been stocked with Indo-Gangetic carps, and the impact has been measured in terms of fish output and indigenous faunistic diversity. Different ways of exploitation, as well as the types of vessels and gear used in various reservoirs throughout the country, are discussed. Reservoir fisheries resources and their exploitation are discussed separately for each state, along with a few case studies outlining water quality, biotic communities, boats and gear, and fisheries management strategies used. The status of reservoir fisheries in the States has been reviewed and the factors responsible for the slow rate of development identified (FAO, 1995).

Reservoirs are classified generally as small (<1 000 ha), medium (1 000 to 5 000 ha) and large (> 5 000 ha), especially in the records of the Government of India (Sarma, 1990, Srivastava et al., 1985). The small reservoir has a higher estimated average fish yield per hectare (49.9 kg/ha), followed by the medium reservoir (12.3 kg/ha) and the bigger reservoir (11.43 kg/ha). The average reservoir production across the country is 20 kg ha⁻¹. The reservoir produces 93650 tons and has a potential of 245134 tons. Fish output can be increased by about 50% in small reservoirs, 16.39% in medium reservoirs, and 22.85% in bigger reservoirs, resulting in an average total fish potential increase of about 38%. Stocking larger fingerlings and providing formulated feed can achieve an average production of 500kg ha⁻¹ (Sugunan and FAO, 1995). There is no system in place to severely and effectively control human-caused contamination of these water resources, hence decreasing their utility for future consumption.

The metropolitan cities of India are under the pressure of water scarcity (Chennakrishnan et al., 2008). Many of the ponds and lakes of developing countries are

polluted to a level where their redevelopment is not possible and ultimately these water bodies are lost forever (Tailor & Mankodi, 2013). Aquaculture is the fastest-growing food-producing sector in the world (FAO, 2005). India has a long tradition of aquaculture from time immemorial as a sustenance activity and is presently a leader in the world after China, contributing to about 4.2% of the total global production in 2004 (FAO, 2006). Aquaculture technologies have undergone considerable advancement in the last three decades mainly because of the stagnation of fish supply from the capture fisheries sector. Aquaculture is one of the most rapidly growing areas in the field of food production and fishes can be used for supplementing the protein demands of our expanding population. We are at the threshold of “Green Revolution” and “Blue Revolution” fisheries can be a boon to developing countries. In many cases, it has been calculated that the cost of fish production is cheaper than the production of protein from any other sources (Nair, 2013).

In Gujarat, inland fisheries are distributed in about 1085 perennial village ponds with an aggregate area of 9500 ha; 1192 km of major river stretches; 7 major irrigation reservoirs in an area of 144358 ha; 28 medium irrigation reservoirs in an area of 57748 ha; and 676 minor irrigation tanks, with on areas of 84124 ha. Besides these, there is a vast coastal saline marshy land (of about 3.76 lakhs ha) suitable for developing brackish water fishponds (Brahmbhatt, 2006). In the central Gujarat region, the two major rivers are the Mahi and Narmada which are the mothers of the inland resources for the nearby districts.

Mahi River is a significant west-flowing interstate river in India that drains into the Gulf of Khambhat. The basin is limited by the Aravalli hills to the north and north-west, the ridge that separates it from the Chambal Basin to the east, the Vindhyas to the south, and the Gulf of Khambhat to the west. The basin has a maximum width of around 250 kilometers. The Mahi River starts on the northern slope of the Vindhyas at latitude 22o35' N and longitude 74o58'E, near the village of Sardarpur in Madhya Pradesh's Dhar district, at an elevation of 500m above mean sea level. It spans 583 kilometers and passes across Madhya Pradesh, Rajasthan, and Gujarat. The total drainage area of Mahi is 34,842 square kilometers. The Mahi River rises in Madhya Pradesh's Vindhyachal Hills and flows into the Gulf of Khambhat. Its overall length is 583 kilometers, and the catchment area is 34842 square kilometers. Bhadar is a right bank tributary, whereas Panam, Kun, and Goma are left bank tributaries to the Mahi River.

The Kadana dam on the Mahi River is about 25 kilometers away. The catchment area is 25520 square kilometers. The Wanakbori weir is located 102 kilometers up the Mahi River and has a catchment area of 30665 square kilometers. The Bhadar dam, located 19 kilometers away on the Bhadar River, has a catchment area of 407 square kilometers. Hadaf and Koliyari are two sub-tributaries of the Panam River. Panam Dam is located on the Panam River in Panam at a distance of 83 kilometers and has a catchment area of 2312 square kilometers. Kabutri and Wankadi are sub-tributaries of the Hadaf River. Hadaf Dam is located on the Hadaf River and covers a catchment area of 508 square kilometers. Umari Dam is located on the Hadaf River at a distance of 13 kilometers and has a catchment area of 73 square kilometers. Karad Dam is located 13 kilometers down the Karad River and has a catchment area of 130 square kilometers. Goma Dam is located 120 kilometers away on the Goma River and has a catchment area of 175 square kilometers.

Narmada River originates from Vindhya hills, Madhya Pradesh and meets to bay of Khambhat. It measures 1312 kilometers in length and has a catchment area of 97410 square kilometers. Orsang is a right bank tributary, and Karjan is a left bank tributary of the Narmada River. Narmada dam is located at 1200 km. distance having 88000 sq.km. catchment area. Sukhi, Ani, Unch, and Heran are sub-tributaries of the Orsang River. Jojawa Dam is located on the Orsang River at a distance of 96 kilometers and has an 870 square kilometer catchment. Karjan Dam is located on the Karjan River at 54 kilometers and has a catchment area of 1404 square kilometers. Based on these possibilities, the study region was chosen, which primarily encompassed the area between the Mahi and Narmada rivers.

In the mid-nineteenth century, teleosts were named and identified as the largest group of ray-finned fishes (Müller, 1846). By the mid-twentieth century, it was clear that teleost was a distinct group (Greenwood et al., 1996), however, identifying the major lineages and delineating their phylogenetic relationships remained the challenge (Arratia 1996, Patterson & Rosen 1977, Rosen 1973, Dornburg & Near, 2021). Teleosts can be grouped into five major categories: The Osteoglossomorpha (Including arowanas, elephant fishes, and Mooneye), Elopomorpha (e.g., tarpons, bonefishes, and eels), Ostariophysi (e.g., catfishes, piranhas, and minnows), Clupeiformes (e.g., shads and anchovies), and Euteleostei (all remaining teleosts). Ostariophysi's main groups are Gonorynchiformes, which have fewer species like milkfish and beaked sandfishes, and Otophysi, which includes most species (Dornburg & Near, 2021).

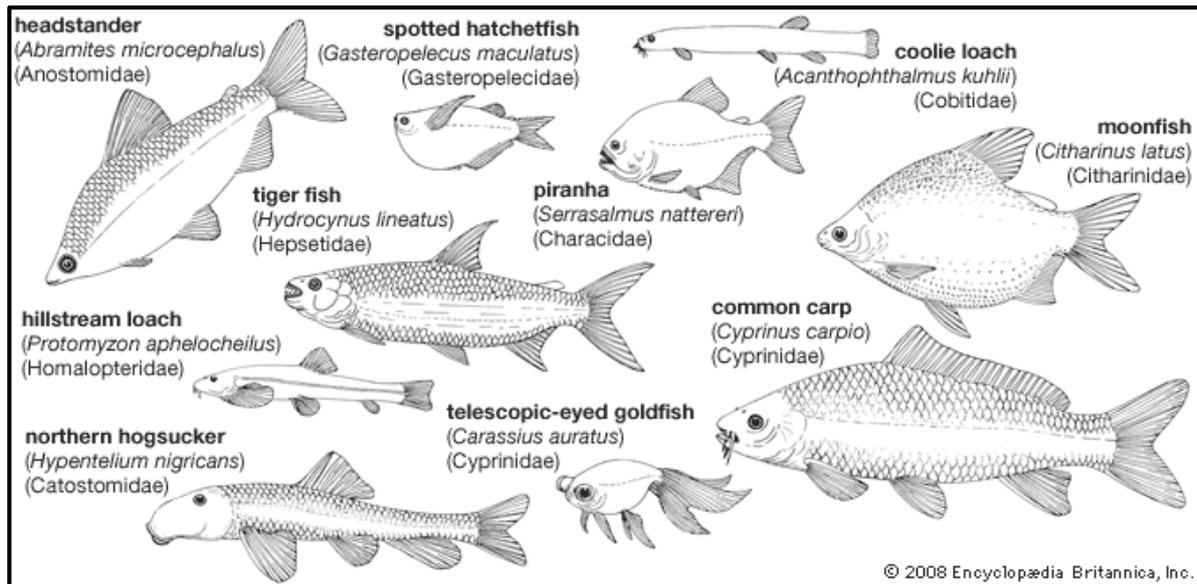


Fig. 1. Represents the group Ostariophysi

The superorder Ostariophysi comprises most freshwater fishes found worldwide including bony fishes. Some known representatives of this group are carps, suckers, minnows, piranhas, electric eels, and countless catfishes. According to Fricke *et al.*, (2021b) and Nelson *et al.*, (2016), the Ostariophysi group contains a minimum of 11,280 teleost species, comprising more than 60% of total freshwater fishes. Otophysan species are classified among the Cypriniformes (Carp, minnows, and loaches), Characiformes (Tetra, piranhas), Cithariniformes (Citharinids and distichodontids) Siluriformes (catfishes), and Gymnotiformes (Neotropical knife fishes and electric eels) (Nelson G., 2006; Dornburg & Near, 2021). Evidence for monophyly of ostariophysans and Otophysan was established early in the phylogenetic study of teleosts (Fink & Fink 1981, Greenwood *et al.* 1966, Rosen *et al.*, 1970, Fink *et al.*, 1996). However, molecular phylogenetic analyses have realigned the delimitation and interrelationships of major ostariophysan clades and resolved the phylogenetic placement of this important lineage within Teleostean (Dornburg and Near, 2021).

The Indian contribution to the global fish community is approximately 3500 species, of which 2500 have been recorded. The Indian species account for around 8.9% of all known fish species worldwide (Jayaram, 1999; Kar *et al.*, 2003). In terms of biological resources, India is one of the 17 mega biodiversity hotspots, accounting for 60-70% of total worldwide biodiversity and ranking third in total fish output, accounting for 11.72% of total global fish biodiversity. Fish diversity and distribution have been intensively examined in the Kerala region of the Western Ghats (Vijaylaxmi *et al.*, 2010). There are 930 freshwater species in India, out of a total of 2500. In an annual report by the Zoological Survey of India, Devi and

Indra (2012) identified 667 species classified into 12 orders, 35 families, and 149 genera (Mankodi, 2018). The study on the Anjanapura reservoir in Karnataka found 25 species of fish belonging to four orders and nine families. 14 fish species belong to the Cyprinidae family, three to the Siluridae family, and one each to the Bagridae, Claridae, Heteropneustidae, Ambassidae, Gobiidae, Channidae, Mastacembelidae, and Notopteridae (Bhakta et al., 2019).

In total, 140 fish species have been identified in the Ganga. However, it has been confirmed that over 69 fish species exist in the comparatively short section of the Ganga River between Kanpur and Ballia. The investigation of the alien species' impact found a constant decrease in the capture of local fish, particularly Indian big carp and others. Risks and ecological implications of foreign fishes in the Ganga River are especially concerning considering global concerns about fish biodiversity conservation. Introduced alien fish have resulted in significant community alterations in aquaculture and other naturalized ecosystems (Atul et al., 2013). According to the Zoological Survey of India's annual report, Devi and Indra (2012), about 120 freshwater fishes may be found in Gujarat state. Gujarat is home to 96 freshwater fishes, according to authors Dholakia, 1986; Patel and Chhaya, 1980. The other main freshwater fish literature resource available is work done by Goswami and Mankodi (2010) and Gohil and Mankodi (2007) on the Nyari-II reservoir and Mahi River, where they identified fifteen and twenty-six species of fish, respectively (Mankodi, 2018). During the investigation period (July 2014 - June 2015), 85 finfish species from 65 genera, 35 families, and 12 orders were discovered within a 72-kilometer stretch of the Narmada estuary region (Bhakta et al., 2019). However, many species remain to be dealt with in terms of molecular aspects.

Freshwater fisheries are growing faster than marine fisheries (Muruganandam *et al.*, 2019). Freshwater aquaculture contributes to over 95% of the total aquaculture production. Aquaculture is the most rapidly growing area of the food production sector where 52 percent of fish for human consumption are derived (FAO, 2020a). India has showcased phenomenal growth in fisheries production rising from 0.75 MT in 1950-51 to around 12.89 MT of seafood worth Rs 46,662.85 crore during 2019-20 (Anonymous, 2020b). Fisheries and aquaculture are important in ensuring food security and providing alternative livelihoods in developing countries. With human population growth projected to exceed 10 billion people by 2050, demand for an inexpensive high-protein diet is expected to rise (World Population Prospects, 2015). Aquaculture is one of the fastest-growing food-producing sectors in the world. It offers

nutrition, food security, money, and livelihoods for millions of people, accounting for over 46% of global food fish output. In 2018, worldwide fisheries production was 179 million tons, with aquaculture production estimated to be 82.1 million tons (Anonymous, 2020a).

Aquaculture growth has so accelerated, with the majority of output earmarked for human use (FAO 2021; Opiyo et al., 2020). Technological improvements and the expansion of the aquaculture business have caused culture methods to become more intensive to produce yields sufficient to meet current demand (Rico et al., 2012). Fisheries in India is a progressively growing sector with varied resources. It has been estimated that more than 14.50 million people at the primary level are directly or indirectly dependent on this sector for their livelihood security (Mishra et al., 2017). Ponds, rivers, and ground water are utilized for both home and agricultural uses. Effective water quality maintenance requires suitable control mechanisms and constant monitoring of a wide range of quality metrics. These things have recently become a difficult chore for frequent monitoring of all the indicators, even when enough people and laboratory facilities are available.

Fish farming is a highly risky business for fish farmers mainly due to the disease problems because insidious diseases pose a major threat to fish population. The quality of life is linked with the quality of the Environment (Brahmbhatt, 2006). Fish production is often reduced due to diseases and parasites by affecting the normal physiological condition of fish and it can result in mass mortalities (Kabata, 1985). Disease has emerged as a significant barrier to the cultivation of many aquatic species. Traditional treatments, synthetic chemicals, and antibiotics have been used to control disease in the aquaculture business (Bondad-Reantaso *et al.*, 2001; Sahu *et al.*, 2008). The disease is becoming a major impediment to the cultivation of many aquatic species. Disease is a major cause of fish death, especially in young fish. They have become an important obstacle to aquaculture output and commerce, negatively impacting the country's socioeconomic situation. Fish that can reduce the effects of diseases and parasites through behavioral or biochemical means have a reproductive advantage (Sarma *et al.*, 2012).

Correct early pathogen identification, as well as an understanding of pathogenic processes, are critical for disease management in aquaculture. Among the diagnostic tools available, electron microscopy (EM) and standard histology techniques continue to be the most significant for determining pathogen etiology during illness conditions. The physicochemical condition of water has been proven to have a major influence on fish health and disease development, primarily on fish resistance to pathogens and parasite fauna (Plumb *et al.*, 1973;

Hossain *et al.*, 2009). Water quality degradation is the primary cause of the proliferation of pathogenic organisms known to influence carp growth and induce illness development. As with some parasitic diseases, this disease encompasses protozoan, viral, and bacterial infections, among others (Toor *et al.*, 1983).

Protozoan illnesses are more harmful in that they cause abrupt mortality of the host fish as well as spreading and harming livestock affecting the aqua-culturists' economy. In contrast to bacterial and parasitic diseases, only a few fungal species have been identified as pathogenic to fish. Whereas parasites are most commonly found on the host fish's exterior surface, they have also been observed parasitizing in the mouth (replacing the tongues, for example, the Cymothoids: Isopods) and gill arches, generating pressure on the gill surface and so decreasing the efficiency of respiration. Although the infestation did not result in immediate death, it did interfere with the normal growth of the host fish and most likely contributed to the high levels of secondary infections (Govindan and Ravichandran *et al.*, 2016).

Death or mortality due to such diseases can account to 10-15% loss. Fish in aquaculture ponds are generally affected by diseases of parasitic, fungal, and bacterial in origin. Above all, parasitic infestations are frequently encountered; however, they are studied to a limited extent in some regions of the world. As freshwater aquaculture grows in India, it is necessary to check the cultures for infectious and parasitic illnesses. The farmers' responses revealed that they were plagued by white spot problems in their skin caused by *Ichthyophthirius spp.* Mostly in all seasons, and the worth of the fish fell as the white spots appeared. Another issue they encountered was the fish's inability to grow because of intestinal parasites. The occurrences of the pathogens were high in the summer and autumn months and low in winter months (Chanda *et al.*, 2011). Suitable preventive and control methods must be developed based on the occurrence of diseases and the economic losses they cause (Solanki *et al.*, 2016).

Contaminated aquaculture units have resulted in lower aquaculture productivity, disease outbreaks in aquaculture organisms, economic loss, human health issues, and contamination of natural water bodies such as oceans and rivers when discharges from aquaculture units are released. Vibriosis, skin ulceration, albino derma, erythroderma furunculosis, and vertical scale disease are all frequent bacterial infections in Indian ponds (Chavda, 2012). It is crucial to have accurate classification systems in the field of parasitology, not only because they provide the means of species identification and strains of parasites, but

also because they provide a framework around which a parasite's biology can be studied (Monis, 1999).

Hence, the current study focused on the number of water sheets that are suitable for aquaculture practices with their Ichthyofaunal diversity, which outnumber the total number of ponds in the study area, as well as an inventory of fish disease and parasitology.

AIM

To study the Freshwater resources of Central Gujarat with special reference to Ichthyofaunal diversity and Parasitology

OBJECTIVES

1. To study the Inland water resources of Central Gujarat.

- The freshwater bodies in the study area were surveyed to evaluate their current fisheries, aquaculture status and potential.

2. To study the Diversity of freshwater fishes along with their fishery and Aquaculture aspects.

- The diversity data was primarily contributed by Cypriniformes due to their significant role in aquaculture. Additionally, Siluriformes are also emerging with increasing potential for aquaculture development. The other species' fisheries data was also collected.

3. To prepare an inventory of fish Parasites and their management.

- The data on fish parasites and diseases was gathered to create an inventory and implement preventive measures aimed at identifying the best practices for preventing parasite infestations in fish farms and natural habitats.