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Effects of Water's Physico-Chemical Characteristics on the Presence of Fish Helminth Parasites

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ABSTRACT
Fish plays a significant role in human nutrition. Fish is widely consumed by the people of Bihar as a reliable food source. Fish parasites are a frequent and natural occurrence. Helminths are among the parasites that are known to negatively impact their hosts, and some of them are also well-known for having the ability to spread to humans. There aren't many studies on helminths in fish from this area, though. Among eukaryotes, parasitism is one of the most prevalent lifestyle patterns. Only until a parasite causes illness and occasionally results in the mass death of its host does its presence become apparent. Parasites exhibit a range of body shapes and life cycles and are classified into several phylogenetically separate taxa. There are parasites on all free-living organisms, and the number of parasitic species surpasses that of free-living species. Therefore, in terms of the quantity and variety of species that exist, parasites greatly contribute to biodiversity. These parasites' intricate life cycles provide them as good indicators of a wide range of biological characteristics of their hosts, including nutrition, migration, recruitment, population distinctness, and phylogeny. Depending on the species, size, and overall health of the host, a different number of parasites might cause injury to a fish. Numerous parasite species have a degree of host specificity and can infect one or a small number of host species. The purpose of this study was to investigate the spectrum of helminth parasites in a few selected freshwater fish species. To ascertain the variety, frequency, strength, and seasonal fluctuations of the parasites, a thorough examination of fish-borne helminths was conducted.

Key words : Fish, human nutrition, Helminths, freshwater

INTRODUCTION

For most people on the planet, fish is essential to both the economic and food security. It is the most reasonably priced animal protein that the underprivileged may obtain, and it is also a low-fat, high-protein diet. Fisheries and aquaculture provide a living for almost 250 million people, either directly or indirectly. When it comes to ornamental fish, it's also a recreational and pet fish. The last several decades have seen a lot of growth and expansion in the fishing and aquaculture industries, which has brought attention to the issues that parasites bring and their significance for fish health, productivity, behavior modification, and cleanliness. Globally, fish infections with parasites are quite widespread and damage the hosts' mechanical, physical, and reproductive systems. The majority of fish are heavily infected with parasites, which reduces their nutritional value and may even be fatal. Furthermore, some zoonotic helminth infections can only infect fish and subsequently spread to humans. Helminths inflict microscopic lesions on the lining of the host's tissues, which can restrict immunological function as a defense against host immunity. This raises the possibility of secondary microbial infection. Because parasite infection of fish causes significant economic losses, either directly or indirectly, it poses a serious threat to aquaculture in tropical and subtropical regions. In addition to the economic damage, there is also a health risk to people. Human zoonotic infections are caused by numerous major helminths and are contracted from fish by eating raw or partially cooked fish.

Accurate identification is essential to comprehending the biology, variety, and epidemiology of a parasite. As scientific expertise grows, so does the necessity for precise organism identification and naming. One of the reasons for the crisis of new infectious diseases is thought to be the absence of thorough taxonomic explanations of parasites. The combination of biosystematics and phylogenetic studies improves our knowledge of the life cycle, dynamics of transmission, and prognostic framework. For the previous 250 years, taxonomic research has been conducted using an organism's morphological characteristics. While

morphological identification is undoubtedly the most basic and direct method of identifying an organism, many people with comparable physical characteristics may have completely distinct genetic makeups (Friedheim, 2016). This is where the identification process becomes crucial with the molecular method.

The molecular approach to systematics has become increasingly popular with advances in genetic and evolutionary studies. Molecular techniques, such DNA-based PCR methods, have shown promise in distinguishing closely related helminth parasites and identifying parasites up to the species level. To address taxonomic concerns and distinguish closely related parasitic species, the nuclear ribosomal internal transcribed spacer 2(rDNA-ITS2), 18S, and mitochondrial gene cytochrome coxidase subunit 1 (mtCO1) have all been widely utilized in this context. These genes have become the go-to source for information on taxonomy, population genetics, species identification, and the evolutionary relationships of different helminth parasite species, such as trematode, nematode, and cestode, due to their rapid rate of evolution. The ability to infer ITS2's secondary structure from primary sequence data is another benefit of employing it; it is known to yield additional information that can be helpful in distinguishing closely related species. Plants, fungi, and parasitic groups such as cestodes and trematodes have all been effectively distinguished using this method. Therefore, the generally recognized way for identifying parasites is the integrated strategy that combines both morphological and molecular research.

Understanding which freshwater fish are infected with various helminth parasites can yield valuable insights into the epidemiological index, which indicates the prevalence of the parasites, marketability of the fish, and the status of human infection sources. For the purpose of advanced disease management, a comprehensive inventory of parasites peculiar to a certain ecosystem is essential. Therefore, a thorough survey must be conducted to ascertain the species composition of the fish helminth parasite spectrum as well as the prevalence, intensity, and seasonal fluctuation in the occurrence of various helminth parasites.

The Indo-Burma Biodiversity Hotspot includes the state of Bihar, which is one of the global diversity hotspots. This relatively small geographic area offers a vast variety of woods and wildlife, as well as a wide range of climates from temperate to tropical. More than 200 indigenous species, representing 84 genera, 31 families, and 11 orders—of which 15 are listed as endangered—are protected by its four main river basins, which boast significant pisces diversity. According to Haokip, there are four river basins: the Yu river basin in the east, the Barak river basin in the west, the Bihar river basin in the center, and the Lanye river basin in the west. Additionally, 19,200 tonnes of fish are produced there year. Despite the state's abundance of fish kinds, there is a limited range of helminth parasites that have been examined in these species. Regarding fish helminth infections in this area, very little is known.

Fish pique the curiosity of humans for a variety of reasons. In addition to providing sustenance for millions of people worldwide and recreational opportunities for anglers, they are also used commercially as raw materials and animal feed. Out of the over 20,000 species known to exist globally, 2200 fish species are identified as belonging to India. A diverse environment that includes cold water (4.53%), fresh water (30.43%), estuary water (9.12%), and marine waters (55.92%) is home to a multitude of fish species found in India (Das and John, 1991).India has a vast inland water resource that includes 171334 km of rivers and canals, 2.02 m ha of reservoirs, 2.855 m ha of area under tanks and ponds, 0.788 m ha of oxbow lakes and abandoned waters, and 1.422 m ha of brackish water.

Among eukaryotes, parasitism is one of the most prevalent lifestyles. Every aquatic community needs parasites as a necessary component. After a significant development, their presence becomes apparent, spreading illness and occasionally even resulting in the mass death of infected hosts. These occurrences frequently occur in conjunction with biotic or abiotic environmental changes. Because they are members of numerous, phylogenetically diverse taxa, parasites exhibit a diversity of life cycles and morphologies. Parasites are present in almost all types of free-living organisms. It's possible that there are more parasitic species than free-living

ones. As a result, only in terms of the quantity and diversity of species that exist, parasites greatly contribute to biodiversity.

Two types of parasites can be distinguished based on their site of occurrence: endoparasites, which are enclosed in a host's internal organs or cavities, and ectoparasites, which reside on the exterior surface of the host, such as the skin or gills. Most marine and freshwater fishes have internal parasite worms of one form or another, such as trematodes, tapeworms, round or thread worms, and hornheaded worms. Based on size, parasites can be separated into two categories: macroparasites and microparasites. The protozoans, myxozoans, bacteria, fungus, and viruses are examples of microparasites. Protozoa and Myxozoa are the only microparasites typically included in surveys. Larger multicellular creatures, mostly helminthes and arthropods, are known as macroparasites. Monogenea, Trematoda, Cestoda, Nematoda, and Acanthocephala are examples of helminths. The Copepoda are the primary arthropod parasites of freshwater vertebrates.

Fish are extremely resistant to illness and parasites, although they can contract helminth parasites when exposed to certain unfavorable conditions, such as improper care, inappropriate diet, low oxygen levels, extreme temperatures, or other stressors. For certain nematode species, fish act as definitive hosts, whereas for others, they act as intermediate or reservoir hosts for the larval stages. In terms of species, the latter group is by far more numerous than the former, but in terms of individual numbers, the former group might actually be more abundant (Margolis, 1970). Animal parasites of all kinds infest nearly all fish to varying degrees; some of these parasites cause severe discomfort or injury, while others seem to be harmless. The fact that some fish species can carry parasites that directly harm humans is a drawback of man's interaction with fish that is significant in some regions. Although some parasites can be spread to humans by marine fish, these parasites are usually only a problem in locations where freshwater fish is consumed uncooked or with little preparation. Evolutionary biologists choose to study parasites because their host, or habitat, is easier to define in space and time than the external environment. It's common knowledge that parasites provide excellent biological models for studies of ecosystems. Compared to free-living animals, it is simpler to identify their ecological niches. By using a host phylogeny, it is also feasible to investigate how their surroundings have changed throughout time. Fish with helminth infections lose nutritional value and may die in large numbers. Particularly in fish farming and culture, when occasionally the entire pond population is destroyed, the significance of fish parasites as a factor leading to fish mortality should not be undervalued. This results in the loss of potential food and financial loss for the culturist. In fish hatcheries, nematodes and cestodes are crucial components. Fish that are infested with parasites typically have stunted growth rates.

The phylum Nematoda is made up of nematodes, threadworms, and roundworms. Nematodes continue to be the primary gastrointestinal parasites of livestock animals, causing lower productivity and significant financial losses in companies that depend on animal products. The life cycle of a nematode can be extremely simple or complex. A class of parasites known as monogeneans (flukes) are best described as flatworms. "Monogenea" refers to the simple life cycle and implies "born once." Fish kept in captivity and occasionally those in the wild can die from severe diseases. They cannot tolerate desiccation, so they are obligatory parasites of aquatic and semi-aquatic species. Most of the known monogeneans have fish as their primary host.

Another type of flatworms is made up of flukes and digeneans, originally known as digenetic trematodes. Flukes are called "di-genetic," or "two births," because they reproduce both as adults and again as larvae. They infect numerous animals, including people, with dangerous and deadly diseases.

A sizable class of flatworms, or platyhelminths, are called tapeworms, or cestodes. The lengthy sequence of body segments that resemble a tape measure is where the common name originates. They are always interesting because they can stunt fish growth and interfere with their ability to reproduce, and some of them can be harmful to people when they are still in their embryonic phases.

In the animal kingdom, thorny-headed worms, or Acanthocephala, are a tiny phylum. "Acanthocephala" translates to "thorny headed." All acanthocephalans are intestinal parasites that live permanently in the majority

of vertebrates, including humans. Renal endoparasites are obligate chelonians. The adults reside in the gnathostome definitive hosts' intestines. The presoma of adult acanthocephalans anchors its body to the intestinal wall of its ultimate hosts. Furthermore, the trunk functions as an organ of attachment in certain animals. Although they have the potential to be highly harmful and potentially control their permanent host populations, acanthocephalans are less significant in terms of public health. There is a free-living egg stage that is eliminated by the definitive host's excrement, which must be consumed by an intermediate arthropod host (insect, crustacean, or myriapod) that is climate-dependent.

Fish parasitology research mostly consists of life history studies, descriptions of new species, and sporadic listings of pleuronectid parasites as a component of larger marine fish parasite surveys. Few studies have been done that take the ecological elements of host-parasite relationships into account. The age or size of fish hosts has an effect on the metazoan parasite infection intensity in fish populations. When many size classes are combined, the positive association usually persists, albeit the rise occasionally ends beyond a particular host age or size. Compared to younger fish, older fish have had more time to accumulate parasites. Due to their bigger size, which allows them to eat more parasitized food and provide a larger contact area for skin-attaching parasites, they also have higher infection rates. This is because they provide more internal and exterior space for parasite establishment.

Numerous ecological studies have examined the connections between species richness and ecosystem function, particularly those that have significance for conservation ecology. Because fish parasite groups have close relationships to both the host and aquatic habitats, they may be able to provide valuable insights into ecosystem conditions. Their frequent usage as bio-indicators of environmental stress, particularly in relation to pollution, is a result. In the wild, environmental and host factors affect the prevalence or abundance of parasites. Moreover, numerous research have examined how the seasons affect the dynamics of parasite populations in continental climates. The primary determinant impacting the structure of parasite communities, particularly for species of ectoparasites found in temperate and tropical regions, was shown to be host size. Additionally, comparative studies demonstrate that the richness of ectoparasite species increases with the size of the host body.

Climate variables can impact the prevalence, intensity, and geographical distribution of helminths by directly affecting free-living larval stages and indirectly influencing mostly invertebrate hosts, but also vertebrate hosts, depending on the life-cycle pattern of each helminth species. A particular type of mollusk serves as the first intermediate host in the heterogeneous life cycle of trematodes. Cestodes have life cycles that are less affected by the weather.

The degree of host specificity and the extent to which this reflects host relationships varies significantly amongst parasites. Furthermore, the interaction between the parasite and its host may also be influenced by other variables like the host's age, diet, habitat, and migration patterns. On the other hand, closely related host species with dissimilar dietary requirements could display significantly diverse parasite faunas. The availability of their host may also have an impact on the diversity of parasites. Therefore, in a given location, the variety of the free-living fauna is correlated with the parasite abundance. The food choices of hosts and habitat heterogeneity appear to be significant factors influencing the composition of helminth communities in teleosts. This has previously been discussed broadly through a comparison of various host species. However, more accurate information regarding the effects of the trophic niche on the structure of the helminth community should be provided by intraspecific comparisons utilizing distinct ecotypes of the host species that coexist in the same water supply.

The most significant aspect of a community may be its species richness, but this does not account for all aspects of diversity. Other aspects of parasitism, such as parasite abundance—which can be quantified as the number or biomass of parasites per host—as well as the average taxonomic distance between parasite species in an

assemblage have been proposed as substitutes for species richness in the measurement of diversity in parasite communities.

In parasitology, the observational scale is also crucial. An infrapopulation is the parasite population within a single host, whereas a component population is the parasite population within a host population. The suprapopulation in an ecosystem is made up of all the parasites of a certain species. Every parasite identified makes up an infracommunity within a single host, and a component community within a host population. An ecosystem's compound community is made up of all the parasites present in it. Diversity studies are a useful instrument for ecological analysis. It considers not only the total number of species found in a community but also each species' relative abundance. Several indices can be computed to learn about the species balance within an assemblage or community. The ability to discern important patterns in a community, such as its basic structure (governed by dominance or competition), the degree of succession, the impact of extreme events, or population density, depends on the equability and dominance levels of the species. Leong and Holmes state that the quantity and variety of related hosts in a given habitat, as well as the size of individual hosts and host populations, all influence the richness and diversity of fish parasite communities. The unique feeding habits of hosts, the availability of intermediate and final hosts, the distribution of depths, and host migrations all affect the diversity of parasites. The availability of their host may also have an impact on the diversity of parasites. Therefore, in a given location, the variety of the free-living fauna is correlated with the parasite abundance.

Similar to host range, host specificity is the number of host species that a particular parasite species uses (Lymbery, 1989). It is important to keep in mind that specificity diminishes as host range grows because the two variables are inversely connected. These ideas are based on relative terms; parasite species that belong to a single genus or family can be referred to be specialists. Many parasites have varying degrees of host specificity, which can be impacted by morphological, physiological, and ecological variables.

Studies on parasites are becoming more and more important in fisheries biology because parasites can act as natural identifiers for fish stock identification. Since its inception, the study of parasite evolution and life cycles has been an academic pursuit in the field of parasitology. It is an essential adjunct to the pathology and management of the major tropical diseases that affect humans and their cattle. The variety of parasites found in warm tropical regions of the planet, along with the horrifying degrees of debilitation and suffering they inflict, are, in fact, the most remarkable aspects of parasitology. Additionally, parasites can be used as biological markers of the prey species and their origin to study the diet of fish species. While stomach analysis might offer comprehensive details about the current trophic relationship at the moment of sampling, parasitological research allows for the inference of past tropic interactions, which integrates short-term variability in the food web to highlight broader relationships. Because the various phases of helminths' life cycles are transferred through the marine food web until they find their permanent host, helminths are especially helpful for these kinds of investigations.

Nonetheless, the multidisciplinary significance of parasitology cannot be overstated. Parasitologists are studying the nature of their interest, namely parasites and parasitism, at all levels of organization, from populational and macrological to micrological and biochemical levels, as is the case in an expanding number of biological scientific fields.

MORPHOLOGICAL OBSERVATION ON HELMINTH PARASITES

Freshwater fish make up 25% of all vertebrate species, making fish a varied group of vertebrates that make up almost half of all vertebrates in the world. In fish, parasites and microbial infections are both frequent occurrences, with a larger prevalence of parasitic infections than microbiological infections. The helminths are a type of parasite that are known to negatively impact their hosts, and some of them are also recognized for their capacity to spread to other animals. The four main classes of helminth parasites are Trematoda, Cestoda, Nematoda, and Acanthocephala. Class Trematoda is thought to include the greatest number of species with zoonotic potential. Food-borne trematodiases are prevalent in Asian nations and are spread to humans through

aquatic goods. These illnesses are regarded as neglected tropical diseases despite their rising prevalence and varied effects on public health.

Evidence suggests that parasite infections in fish that require a lot of nutrition might affect the way the host forages, changing the preferences of the prey and the rate at which food is consumed. Numerous writers have examined the presence of helminth parasites in freshwater fishes and its consequences (pathogenicity, immunological response, behavioral alterations, etc.); however, there is a lack of agreement regarding the taxonomy of many helminths. Many biologists have come to understand the value of taxonomy and systematics as a result of technological advancements. These fields rely on the basic concepts of combining different kinds of data to create classifications that reflect the natural history of living things. Precise classification of the parasites is essential, not only from a taxonomic perspective but also because they offer a framework for studying every element of the biology of the parasites. Reports from various regions of the world have examined the taxonomy of helminth parasite fauna.

A fundamental function for systematics exists in all fields of biology. Recognizing the ongoing importance of systematics is crucial in today's technology-driven research environment. The fundamental principle of systematics is to mix various data kinds to create classifications that reflect the natural history of living organisms. In the study of parasitology, precise classification systems are essential because they allow for the identification of parasite species and strains as well as the creation of a framework for the biological study of parasites.

Parasites exhibit a range of life histories and body shapes and are classified into several phylogenetically distinct taxa coined the term "Helminths" to describe parasitic worms. Later, in 1756, Nicholls released a brief report on "Worms in animal bodies." All worms were categorized by Zeder into four classes: "Acanthocephalan," "Hookworms," "Roundworms," and "Sucking worms" (i.e., Trematoda, Cestoda, and Bladder worm).

Researchers Bhalerao and Chandler have examined fish helminth parasites. The fauna of British India, which includes Ceylon and Myanmar, was described. In Akhmerov conducted research on fish parasites in Alaska. Investigated the zoogeography of USSR marine fish parasites. conducted research on fish biology and parasitology in 1961. In 1961, Yamaguti documented 300 different species of nematodes from fish, spanning over 40 taxa and 17 families. Pakistani marine fish nematode checklist was published.

Out of the more than 20,000 species recorded worldwide, fishes are one of the most diverse groups of vertebrates, with about 2200 species reported from India. They are found in practically all aquatic environments and provide millions of people worldwide with a significant and consistent supply of animal protein. The four groups of helminth parasites that typically infect fish are Trematodes, Cestodes, Nematodes, and Acanthocephalans. In Southeast Asia and the Far East, where freshwater fish is a common source of protein for many people, fish-borne helminthic diseases (trematodiases, cestodiases, and nematodiases) are highly significant. Fish are thought to harbor thousands of different helminth parasite species, many of which can pose a serious threat to their hosts' reproduction and health, making them easy targets for predators and resulting in significant losses for fish-based businesses. Numerous researchers have examined the anatomy, ecology, behavior, life cycle, and histology of various organs infected by helminth parasites, among other features of fish parasites in various parts of the world. In order to ascertain the species composition, identify helminth parasites, and, if applicable, distinguish parasites with zoonotic potential, the current experiment was conducted on a few edible fish.

SCANNING ELECTRON MICROSCOPY OF HELMINTHPARASITES

In the study of helminths, microscopy is being used more and more as a potent investigative tool. This has improved our understanding of the intricate life cycles and host-parasite connections. Its application in parasitology extends beyond taxonomy to include multidisciplinary research on parasites, including

epidemiology, disease control, and functional studies. Accordingly, drug efficacy and drug resistance tests have shown the value of using scanning electron microscopy to comprehend the tegumental character of parasites.
The standard way of identifying helminth parasites is through light microscopy; however, with technological advancements, SEM has also been utilized as a supplementary tool for morphological identification. In order to establish a true taxonomic status for the parasites, molecular tools that are combined with various microscopical methodologies have been employed and accepted recently. Therefore, one of the most important instruments in helminthology for the structural characterisation of helminth parasites is still SEM analysis.
Nematodes, among helminths, show little variation in their morphology at the optical level; nevertheless, scanning electron microscopy (SEM) studies have demonstrated that they have a wide range of morphological variation, effectively removing observational restrictions. In the case of nematodes, the SEM aids in a thorough understanding of the surface architecture of the head and tail regions, such as the buccal cavity, teeth, lips, cuticular ridges or ornamentations, spines, papillae, alae, vulva, bursa, and spicules; in the case of trematodes, the SEM aids in understanding the nature of segmentation in cestodes and oral suckers, acetabulum, holdfast (metacercariae), haptors, sensillary organs, etc.
Numerous publications have demonstrated the use of SEM as a supplemental tool in the taxonomy of helminths, including fish parasites. In order to complement the light microscopic study and determine the particular identity of the helminth parasites collected from edible fishes of Bihar, India, the present study used SEM to characterize the parasites. To demonstrate the differences amongst parasites in the same species, tegumental comparisons were done.

MOLECULAR CHARACTERIZATION OF HELMINTHPARASITES

An essential first step toward improving understanding and conducting more research in the field of biology is the identification of organisms. The simplest and most popular technique for identification in this situation is the morphological approach. To effectively identify an organism up to the species level, distinguish between intra-specific variation and cryptic species, an integrative approach combining morphological and molecular investigations has gained widespread acceptance. Several researchers have employed various molecular methods in their systematics, phylogeny, and diversity analyses of helminth parasites.
Understanding the phylogeny reconstruction using different genetic markers has mostly relied on molecular techniques, such as DNA-based PCR methods. Additionally, systematics using DNA sequencing to determine the taxonomic status of parasites has shown benefit from it. Using genetic markers such as mitochondrial DNA (mtDNA) and nuclear ribosomal DNA (rDNA), it is possible to distinguish between species that share similar morphology but differ genetically. This makes the process of describing new species more precise.
The multigene family known as the nuclear ribosomal DNA (rDNA) gene is organized in tandemly repeating clusters, with a set of genes inside each cluster divided by spacer sections. This gene family is extensively utilized in molecular taxonomy and phylogeny. The highly conserved internal transcribed spacer 1 (ITS1) and internal transcribed spacer 2 (ITS2) variable regions divide each eukaryotic rDNA repeat, which is composed of the external transcribed spacer (ETS), 5.8S, and 28S or large subunit (LSU), and smaller subunit (18S). Because the nuclear rDNA gene markers experience fast, coordinated evolution that supports the intra-genomic homogeneity of the repeat unit, they have been widely employed. It also contains a highly conserved area and is quite varied, even across closely related species. As a result, it has been applied to numerous phylogenetic investigations to identify and distinguish between various taxa, including parasitic helminths.
The taxonomic status and molecular phylogeny of helminth parasites, including fish parasites, have been thoroughly resolved using the rDNA ITS2. Due to the fact that they have become the go-to source for information on taxonomy, population genetics, species identification, and the evolutionary relationships of different helminth parasites. Predicting ITS2's secondary structure from primary sequence data is an additional benefit of employing it, and it is known to offer additional information that can be helpful in distinguishing

closely related species. Distinguishing between closely related species of fungi, plants, and parasitic groups like trematodes and cestodes has been accomplished with success using this method.

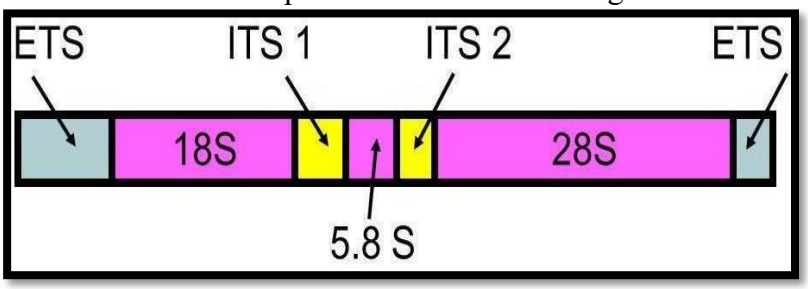

Figure 1.1. Nuclear rDNA gene arrays with the ITS1 and ITS2 spacers linked.

Because the gene is highly conserved, studies on nuclear 18S rDNA (also known as the small subunit, or SSU) have also been conducted. It has been applied to resolve parasite connections beyond the family level and reconstruct phylogenetic branches at different taxonomic taxa. Due to its widespread distribution and fluctuating rate of evolution throughout the molecule, 18S has been thoroughly investigated to offer priceless data for phylogenetic analysis and species identification among eukaryotes, including fish parasite.

Since the mtDNA mutates more quickly than the nuclear genome, it is a valuable tool for evaluating genetic and evolutionary links because it can ensure that sufficient nucleotide variation is acquired for comparing organisms that are closely related. Furthermore, the very low rate of substitution of mitochondrial protein allows amino acid changes to accumulate gradually, providing information on the genetic distances of related species. Because it is the most basic and conserved of the mtDNA genes, mitochondrial cytochrome oxidase subunit 1 (mtCO1) has been widely employed in molecular taxonomy and phylogenetics of different helminths, including fish parasites.

In the current study, helminth parasites that could not be recognized to species level using light microscopy were characterized and supplemented using morphology-based identification using nuclear and mitochondrial DNA gene markers.

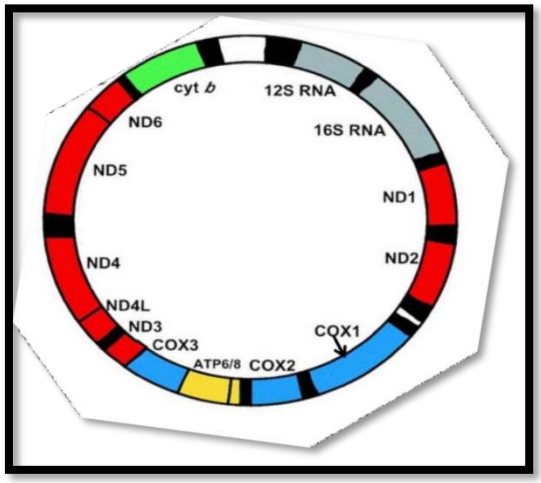

Figure 1.2: Cytochrome C Oxidase Subunit 1 (CO1) in Mitochondrial DNA

Due to the increasing demand for fish flesh due to its nutritional content, aquaculture is one of the fastest expanding industries in the food business and plays a significant part in the economy. However, the safety risks associated with eating fish because of the parasites still exist. In addition to causing harm to their hosts, parasite infections can also alter the physiology, behavior, nutrition, and cause injuries. Furthermore, the extreme weakness brought on by these diseases may give rise to deadly secondary infections.

The helminth community study is regarded as one of the crucial elements in host ecology studies since alterations in its composition can serve as both an indicator of the environment and a reflection of

environmental disturbances. Changes in the host environment, such as seasonal variations in temperature, humidity, and rainfall, have an impact on the population dynamics of parasites. Understanding these effects can help with the management of parasite-caused diseases as well as other health-related issues. Moreover, hosts are greatly impacted by parasites. Their research on the life cycle and transmission pattern is beneficial to epidemiology. Additionally, according to Marcogliese, they may serve as markers of host biology, environmental stress, food webs, and biodiversity.

CONCLUSION

Temperature is one of the key determinants of seasonality since it directly affects the parasite's ability to develop into free-living stages or within its host. Numerous fish hosts have shown variations in the distribution of acanthocephalans with seasonal changes. The seasonal variations in the incidence and quantity of other helminth parasites, such as digenetic trematodes, are also associated with cercarial emergence and a rise in water temperature. Many authors from around the world have studied the seasonal variation of helminth parasites, including important parasites for public health in fish, and various factors influence their existence. Several authors have reported on a seasonal analysis of several helminth parasite infections in fishes in India.

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