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RESEARCH TRENDS IN AQUACULTURE AND FISHERIES

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PREFACE

In the ever-evolving world of aquaculture and fisheries, where science meets the shimmering waters, this book serves as a compass guiding us through the currents of cutting-edge research. As we cast our nets into the sea of knowledge, we find a wealth of discoveries, innovations, and trends that shape the future of sustainable aquatic practices.

From the bustling activity of aquaculture farms to the serene depths of fisheries research, the chapters within this tome unravel the intricacies of aquatic ecosystems and the dynamic interplay between human endeavors and the underwater world. We explore the latest methodologies, technological advancements, and breakthroughs that redefine the landscape of aquaculture and fisheries science.

This compilation is a testament to the collaborative efforts of brilliant minds dedicated to unraveling the mysteries of marine life. As we flip through these pages, we navigate through a mosaic of studies, each contributing a brushstroke to the canvas of our understanding. The interdisciplinary nature of the research showcased here mirrors the complex web of relationships that sustain aquatic ecosystems.

In the spirit of curiosity, let us delve into the depths of these research trends, recognizing that the pursuit of knowledge is a journey without a final destination. Instead, it is an ongoing exploration, a continuous voyage into the uncharted territories of aquaculture and fisheries. So, fellow adventurers, fasten your intellectual seatbelts as we embark on this enlightening expedition through the currents of progress and innovation in the realm of aquatic research.

Editors

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FUNCTIONALITY OF SYNBIOTICS ON THE RESISTANCE CAPACITY OF SHRIMP AGAINST WHITE SPOT SYNDROME VIRUS (WSSV)

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Abstract:

Aquaculture has become a vital contributor to the global food production sector, effectively meeting the rising demand for protein sources fit for human consumption. The vannamei shrimp, *Penaeus vannamei* commonly known as white legged shrimp or pacific shrimp is the native breed of the Pacific coast of Mexico and Central and South America. It is greyish- white in color. White Spot Syndrome Virus (WSSV) emerges as a pervasive and lethal menace to vannamei shrimp farming worldwide, and thus far, no cure has been found. This project ventures into the innovative solutions to tackle WSSV while simultaneously enhancing shrimp health. By combining *Arthrospira fusiformis* and *Lactobacillus acidophilus* beneficial microorganisms and growth-promoting substances. Probiotics are live microorganisms that when administered in adequate amounts, confer health benefits on the host. These beneficial bacteria inhibit the growth of harmful pathogens, including WSSV by competitive exclusion and the production of antimicrobial compounds. Prebiotics are non-digestible compounds that selectively stimulate the growth and activity of beneficial microorganisms in the gut. This synergy between probiotics and prebiotics is essential for establishing a stable and beneficial microbial community within the shrimp's digestive system. It is estimated that viruses account for roughly 60% of shrimp production losses, with bacterial infections contributing another 20%, leaving the remaining percentage allocated to fungal and parasitic ailments. Among these threats, White Spot Disease (WSD), induced by WSSV, looms as the gravest peril, causing mortality rates of up to 80–100% within a matter of days, resulting in substantial financial losses. The highly contagious nature of WSSV has established it as one of the most widespread and relentless adversaries in the shrimp farming sector. In response to these multifaceted challenges, we delve into the utilization of synbiotics, which can be administered orally, through water, or as feed additives. Our primary focus lies in enriching shrimp feed with synbiotics. We seek to simultaneously boost the shrimp immune system, health, enhance growth, elevate productivity, and enhance sustainability while mitigating the catastrophic consequences of WSSV. This project signifies a pivotal stride toward a future in aquaculture that is more resilient and sustainable.

Keywords: Synbiotic, WSD (White Spot Disease), WSSV (White Spot Syndrome Virus), Probiotic, *Lactobacillus acidophilus*, Prebiotic, *Arthrospira fusiformis*, Immune system boosting.

Introduction:

Shrimp aquaculture

The 1970s saw the beginning of the lucrative practice of shrimp aquaculture, or farming, which is currently prevalent beyond the tropical world. About 1.2 million hectares (three million acres) of shrimp ponds currently exist on the land of Thailand, Indonesia, China, India, and other Asian countries. Approximately 200 thousand hectares of shoreline in the western part of the globe have undergone a similar transformation. In Ecuador, there are at least 130,000 hectares of shrimp reservoirs, a sight that is uncommon in the United States, where less than 1,000 hectares are used for the practice. This type of fish and seafood is nearly solely served on plates in the United States, Europe, or Japan. Raising shrimp, like many other forms of aquaculture, was hailed as the "blue revolution" over twenty-five years ago because it seemed to provide a method to lessen the strain that poaching brought on in native populations. With 10 kilos of marine life regularly captured for each kilogram of the shrimp eliminated from the sea, aquaculture of shrimp also claimed to reduce the tremendous collateral damage that trawling for these organisms did to other aquatic organisms. Regretfully, neither of these advantages has completely shown up to date. Furthermore, shrimp farming's performance over the previous 20 years makes abundantly evident that aquaculture frequently brings with it a unique set of environmental concerns [1].

Like other businesses, shrimp aquaculture is always in need of novel approaches to boost output yield. Biotechnology and microbiology, together with contemporary technology, are valuable resources that have the potential to provide both more and better-quality products. Aquaculture often relies heavily on nutrition and innovative farming techniques, and many farmers and manufacturers of both shrimp and fish feed frequently add different additives to a balanced feed formula to improve growth [2]. The development of shrimp farming has primarily occurred in tropical and subtropical coastal lowlands because of the ideal environment and abundance of space. Approximately 850,000 metric tons of whole shrimp were generated by shrimp farmers worldwide in 1998; the Asian region produced the most (72%), next to Latin America. Shrimp aquaculture is unquestionably exerting a positive socioeconomic impact, and the sector's global expansion has been greatly aided by its high likelihood of success and ability to generate foreign exchange. Nonetheless, there are countless instances where production declines and ecosystem repercussions worldwide because of inadequate organization, leadership, and laws [3].

Vannamei shrimp

The white shrimp of the Pacific One of the most significant aquaculture shrimps globally, Litopenaeus vannamei has a broad spectrum of salt tolerance, quick growth, and other traits appropriate for large-scale aquaculture. Shrimp are sensitive to a wide range of environmental factors, including temperature, salinity, dissolved oxygen (DO), pH, and contaminants including sulfide, ammonia, and nitrite [8].

Approximately 52% of the world's penaeid shrimp production comes from Litopenaeus vannamei, one of the major farmed penaeid shrimp species. It is found naturally along Central and South America's Pacific coasts. L. vannamei was brought to China in 1988. With years of real-world expertise under its belt, its farmed yield now accounts for over 60% of China's overall shrimp harvest. The shrimp-culture sector has suffered significant financial losses as a result of the rapid growth of L. vannamei culture, epidemics of diseases brought on by the taura syndrome virus (TSV), infectious hypodermal and hematopoietic necrosis virus (INSNV), and other pathogens. The most common and deadly viral disease affecting penaeid shrimps, WSSV, costs the global shrimp farming business billions of dollars in losses annually. To combat WSSV, several strategies are employed, including removing the infection's source, blocking its channels of dissemination, managing the condition of the water, and strengthening shrimps' resilience to sickness. Nevertheless, WSS remains the most significant illness affecting penaeid shrimps, resulting in almost 100% fatalities, and the afore mentioned approaches are insufficiently efficient in managing WSS occurrences and predominance [4].

White spot disease

It has been documented that over 20 different viruses can infect marine shrimp. Many have not been linked to any disease-related symptoms, and some have only been seen through electron microscopy and are not well characterized. Major viruses infecting marine shrimp are White spot syndrome virus, yellow head virus, Gill-associated virus, Taura syndrome virus, Infectious myonecrosis virus, Infectious hypoderma and hematopoietic necrosis virus [19]. In this WSSV is major infected virus due lack of immune**.** WSSV was originally assigned to the subfamily *Nudibaculoviridae* of the family *Baculoviridae* since it was a non-occluded baculovirus. It was, nevertheless, regrouped into the *Whispoviridae* family. Subsequently, WSSV was accepted into the *Nimaviridae* family, a novel family that has only one species, WSSV, and one genus, Whispovirus. The WSSV is big, enveloping, rod-shaped to elliptical morphologically. The virion, which has an extension resembling a tail, was estimated to be 80–120 9 250380 nm in size. The thickness of the viral envelope is 6-7 nm, and occasionally ∼12 nm. The exterior of the envelope is covered in many tadpole-shaped spines that help them connect to host cells. The spike measures 5 to 6 inches in length. The spike head has an outer diameter of 4-5 nm [7].

The White Spot Syndrome Virus (WSSV) is a highly transmissible virus that has spread globally and is detrimental to the shrimp trade. The impact of WSSV on shrimp acclimated to low (5 practical salinity units [psu]) or high (40 psu) salinity regimes has been the subject of a few research. In this study, we examined the physiological reactions of juvenile Litopenaeus vannamei treated with WSSV that had been raised in salinities of 5, 15, 28, 34, and 54 psu [5]. The pathogen causing white spot disease (WSD) in shrimp and numerous other crustaceans is called the white spot syndrome virus (WSSV). In normal culture circumstances, this highly transmissible virus can cause entire mortality within 3–10 days of an epidemic. Since the WSD outbreak was first documented in China and Taiwan in 1991 and 1992, it has resulted in enormous losses for farms worldwide. In terms of managing the disease, most existing assessments on WSSV place a strong emphasis on cutting-edge genetic research and biosecurity precautions. Some innovative solutions are currently being developed for WSD control, including greenhouse, polyculture, biofloc, and restricted water interchange [6].

Since the disease's introduction, the total projected economic damage to the shrimp industry worldwide has been estimated to be between $8 and $15 billion. Every year, the economic losses had been rising by USD 1 billion. According to several writers, the yearly financial losses brought on by WSSV have historically been estimated to be around 10% of the world's shrimp harvest [7].

White spot syndrome virus

An underestimation of their quantity, marine viruses were regarded as environmentally irrelevant until the late 1980s. Nevertheless, later research found that millions of virus-like particles could exist in every milliliter of seawater. Viruses are now recognized as some of the most prevalent "lifeforms" in the oceans, contributing significantly to geochemical cycles and serving as a storehouse for the highest genetic diversity on the planet. Even though a sizable number of viral outbreaks happen in the oceans daily, little is known about the environment's reservoirs for most of these viruses or their routes of transmission and spread. White spot syndrome virus (WSSV), a highly virulent and quickly multiplying shrimp infectious agent, is one of the more dangerous deadly viruses that affect Penaeid shrimp and has become one of the most common and pervasive worldwide. After being discovered for the first time in Taiwan in 1992, it eventually reached Japan and nearly every Asian nation. When WSSV was initially identified at a South Texas shrimp farm in 1995, it was hypothesized that an Asian consignment of frozen bait shrimp was most likely the source of the virus's arrival to the Americas. The route for the spread of the virus is arguably the most important step in the dynamics of the infection. Viruses can spread in two ways: vertically (when a virus is given from an infected female parent to her F1 progeny) and horizontally (when they are spread among members of the same generation through personal contact or inadvertently by consumption of contaminated organisms). Yet, reports have indicated that WSSV can spread by the consumption of infected tissue, direct contact with virus particles in water on body surfaces or injecting of a small amount of contaminated tissue that is cell-free. White spots (0.5–3.0 mm in diameter) on the the outer shell, body parts, and inside the epidermis may appear quickly in shrimp contaminated with WSSV. These spots are not thought to be an accurate marker for an early diagnosis of this illness because they vary from person to person and because some germs, excessive alkalinity, and stress can cause similar spots. Feeling drained, an abrupt decrease in food intake, red coloring of the body and appendages, and a loose cuticle are other symptoms of WSSV [9].

Only 35% of the host species under consideration for this review 50% of support WSSV proliferation because of spontaneous infections. The remaining 15% are WSSV hosts that have been found by paired individually species dissemination studies conducted in a lab setting. In these studies, consuming or injecting WSSV-infected shrimp was the most popular method of WSSV transmission. The path by which WSSV spreads between species. In a lab setting, WSSV can proliferate via cohabitation, water, cannibalism, and the trophic food chain. If the transmission takes place in the wild or in a shrimp pond, the significance of each route may differ. Furthermore, the aggressiveness of the relevant virus strain, the proportion of vulnerable hosts, the state of each host's defenses, the initially administered viral dose, and environmental biotic and abiotic factors all affect how widely a virus spreads. The spread of WSSV from non-farmed animals to farmed crustaceans. The fact that WSSV is present in animals that originate from various geographical locations indicates how common WSSV is there. The dilemma is whether WSSV infection spreads from ponds filled with shrimp to wild animals or the other way around. Spreading of WSSV in aquatic environments. Many species can serve as hosts or vectors in complicated aquatic circumstances, but not all these species are equally prone to the virus or its propagation [10].

White spot syndrome virus control measures

Owing to the damage that white spot syndrome virus (WSSV) has brought to shrimp crops worldwide, several disease management strategies have been implemented. There will be a quick rundown of the most recent developments in the key tactics used to manage WSSV infection. Strict hygiene regulations on shrimp farms have led to comparatively positive outcomes, but it is important to remember that there is now no medication available to stop the disease's unchecked recurrence and travel [9].

1. Shrimp antiWSSV immune response

They lack a genuine adaptive immune system; crustaceans must rely on their innate immune response to identify and eliminate foreign substances. Hemocytes are a crucial component of the defense strategy that crustaceans use to fend off infections because they trigger blood coagulation, a process that stops invasive microbes from spreading throughout the body. Hemocyanin has been shown to have antiviral action against WSSV as a crucial innate immune response because it can postpone infection and prevent the virus from replicating [9].

2. Environmental control of WSSV

It would be foolish to encourage farmers to use this expensive method of managing WSD until the physiological effects of cultivating penaeids at elevated temperatures are well understood. Furthermore, although temperature changes may not totally prevent or cure WSD, they may help to mitigate its effects because WSSV has a wider thermal tolerance window than shrimp. Severe infection levels are quickly attained at salinities between 0 and 40 psu, suggesting that changing salinity by itself won't be enough to stop WSSV outbreaks. Shrimp have improved immunological parameters, greater resistance to infection, and increased energy availability at salinities of 25 psu (isoosmotic), because of reduced demands for constant oxygen regulation and stress reactions. The immune systems of shrimp may have been worn down after many periods of acclimatization to inadequate salinities (and salty tolerance) at the time of the WSSV challenge, hence the results of immune function investigations must be cautiously assessed while considering the methodology that was used. Maintaining DO is crucial to minimizing the effects of disease epidemics and/or reducing their frequency. Farmers are interested about tracking pond dissolved oxygen levels because, in hypoxic environments, feed consumption and development rate are reduced, and penaeid shrimp are believed to be more disease-prone due to a reduction in the phagocytic activity of hemoglobin. A pH that deviates from the ideal range causes a higher likelihood of WSD outbreaks. Increased toxicity from ammonia is caused by elevated pH, and continuous exposure can cause excessive calcium deposition in areas beneath the exoskeleton, which can lead to incorrect WSD diagnoses in shrimp cultivation [18]. Incompatible and ambiguous data can occasionally be created from many sources, as is common in aquaculture. Thus, high water temperatures were blamed for large fatalities during a 1998 WSSV epizootic episode that occurred in China. Because of the cold water, shrimp farmers on the coast saw a marked rise in the severity of WSSV. Serious WSSV epizootics are generally shown to be less likely to occur throughout warm seasons, and it has been suggested that pond temperature-raising management techniques could present an intriguing chance to control this illness [9].

3. Herbal treatments against WSSV

Both curative and preventive approaches can be used to control infections caused by viruses. In this regard, natural products that can boost immunity and stave off viruses in order are becoming more and more popular. Strong antiviral activity has been documented for many traditional medicinal herbs, and some of these have already been used to treat animals (including shrimp) sick with viruses [9].

4. Vaccination against WSSV

The scientific literature concerning the immune system of crustaceans is abundant. It is widely accepted that crustaceans, as most invertebrates, lack a true adaptive immune response system and its defense against pathogens relies on various innate immune mechanisms, including both cellular and humoral responses. Thus, the development of a vaccine against WSSV, or other shrimp pathogens, has been severely impeded by such lack of memory-type immunity and by the lack of a comprehensive knowledge about the etiology of the disease. However, the presence of a quasi-immune response against WSSV was detected in the shrimp *P. japonicus*. Survivors of a WSSV outbreak were re-challenged after 4 months of the devastating event [9]. The feed served as an oral booster "vaccination" for the shrimp. The regular basal diet was combined with the "vaccine" and fed to the shrimp at prearranged frequencies. A booster "vaccination" was administered throughout the meal on a periodic basis (every 15 days). After following the preceding instructions, the "vaccine" was made and added to the daily ration at a dose of 200 μg shrimp−1 (Amar and Faisan Jr., 2011). The amount of protein of the deactivated antiviral inoculum with a known titer (106.7 LD50 ml−1) was determined. After being immersed in PBS and sprayed onto a commercial feed (1-day ration calculated based on shrimp size), the "vaccine" was permitted to absorb into the pellet and breathed dry. The pellets were then spray-coated with cod liver oil, let to air dry, and then sealed in [17].

Probiotics in shrimp aquaculture

The term "probiotics," which refers to bacteria that have positive effects on both people and animals, comes from the Greek meaning "for life." The interpretation of probiotics has changed over the years. The purview of the phrase was expanded upon extended to incorporate tissue substances that promoted the growth of microbes. Probiotics as "a live microbial feed supplement that beneficially affects the host animal by improving its intestinal microbial balance." As a result, the word probiotics was utilized to signify "living organisms and compounds that support gastrointestinal microbiological homeostasis" [2]. The variety of probiotics that have been approved for use in aquaculture is far greater than those of conventional agriculture. Numerous probiotics have been shown to be both feasible and effective for use with aquatic animals. examined in several research, but the most well-documented are presumably yeast organisms, Bacillus species, and lactic acid bacteria. In addition, some Probiotic dietary supplements, whether single-species or multispecies, are accessible internationally for use in aquaculture activities [15]. Probiotics can be effectively protected throughout preparation, manufacture, storage, and after intake by microencapsulating them. Probiotics are frequently kept in cold storage to maintain the isolates' survival. The items' durability over the course of the product's storage period was guaranteed by the application of dehydration procedures. After four months of storage, the microencapsulation of pseudoalteromonas piscicida probiotics utilizing the technique of freeze-drying successfully maintained the vitality at 91% [11].

Prebiotics in shrimp aquaculture

An alternate strategy for influencing endogenous bacteria to enhance health is the use of prebiotics. Prebiotics try to activate rather than introduce beneficial bacteria through diet. favorable native microbe populations that were chosen. A probiotic is characterized as a dietary element that is not digested and has positive effects on the by deliberately promoting the development and/or activity of microorganisms that promote health and can benefit the host organism. Prebiotics are mostly made up of oligosaccharides that encourage the formation of healthy bacteria in higher animals' digestive tracts. Throughout the previous ten years, numerous compounds have been the subject of been studied in relation to prebiotics. Anything edible that arrives to the colon (such as some peptides, nondigestible polysaccharides, and proteins and certain lipids) is a potential prebiotic. But still, most of the research has concentrated on indigestible carbohydrates, primarily oligosaccharides [15]. There are rudimentary classification criteria for prebiotics. Prebiotics must be able to do the following things: (i) resist stomach acid and gastrointestinal enzymes; (ii) not absorb in the proximal portion of the digestive system; (iii) be fermentable by gut bacteria; and (iv) specifically promote the growth of the targeted beneficial microbes. Not to mention, (v) the modifications in the composition of the gut microbiota should successfully cause physiological alterations that are beneficial to the host's health. Since prebiotics predominantly sustain the community of microbes within the organism rather than the host themselves, nutritional sufficiency for the host is nevertheless a prerequisite for the prebiotics to reach their maximum potential. Interestingly, shrimps' negative reactions to soybeans, such as lowered immunity, decreased feed efficiency, and sluggish growth rate, can be effectively alleviated by adding 2–4 g of prebiotics FOS to every kilogram of soybean-substituted fish meal that they consume. Even with the list of health advantages, prebiotics' effects aren't always reliably demonstrated in every study. For example, the survival and growth rate of L. vannamei were not significantly affected by the 42-day prescription of short-chain fructooligosaccharides (scFOS) or the 62-day treatment of inulin addition [11].

Synbiotics

Synbiotics are vitamin and mineral supplements that combine probiotics and prebiotics to enhance their individual therapeutic benefits. The term "synbiotics" refers to this type of synergistic effect. The beneficial effects that arise from combining two dietary components or supplements typically fall into one of three categories: strengthening, synergy, or additive behavior. When the two substances are employed jointly, their combined effect corresponds to the sum of the effects they have separately. This is known as an additive impact. When the combined effect of the two substances is noticeably higher than the total of the consequences of each substance taken separately, this is referred to as mutually beneficial. By specifically encouraging growth and/or triggering the metabolic process of one or a small number of health-promoting microbial organisms synbiotics improve the ability to survive and implantation of live microbial dietary supplements in the gastrointestinal tract, thereby enhancing the organism's "welfare." Prebiotics are only effective in the large intestine of human beings, whereas probiotics are mostly active in the small intestine; therefore, combining the two may have a beneficial effect [15].

The primary goals of employing synbiotics are to accelerate growth and enhance the health of the host. Synbiotic use in aquaculture has produced encouraging results. Synbiotic use in the aquaculture industry has been linked to several positive outcomes, including improved growth success, immunological stimulation, gastrointestinal microbial balance, biological control agents, as well as oversight of the quality of the water. Some of the characteristics of synbiotics include competition with pathogens, adhesion and resistance to infectious agents, and the capacity to supply digestive enzymes, metabolic products, the breakdown of food, and assimilation. Commercial synbiotics including Biogen, Pronifer, Biomin, Mycofix, Bacterins, and Grobiotic are a few that are utilized in the aquaculture sector. Positive outcomes from using synbiotics in aquaculture include increased the fermentation process and short-chain fatty acid (SCFA) creation, lowering the bowel's pH to prevent the growth of specific pathogenic bacteria, and promoting the improvement of the lactic acid bacteria and bifidobacterial [16]. Even though probiotics and prebiotics have been the subject of numerous studies assessing their effectiveness in fish, simultaneous usage of both supplements (synbiotics) has drawn very little interest to date, and the statistics that are currently available are yet limited. Thus, the purpose of this review is to gather, initially, current information on synbiotic application in aquaculture fish, emphasizing the principal outcomes so far shown [15].

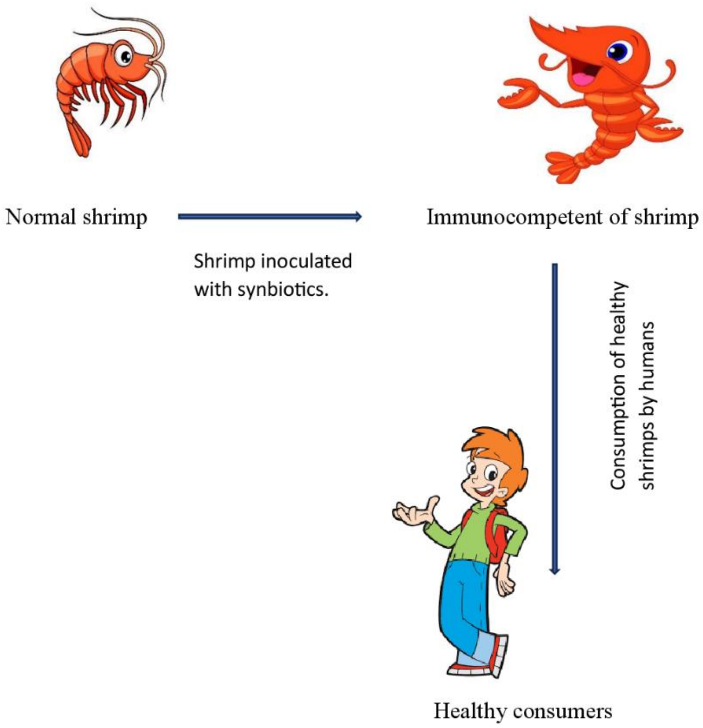

Figure 1: Shrimp feed inoculation

1. Promotion of growth and survival

Additionally, it is well known that synbiotics produce the essential digestive enzymes that enhance the host's digestion and better FCR reported elevation in the level of digestive enzymes by synbiotic supplementation. In the shrimp's gut, the use of probiotics for synbiotic preparation caused the generation and release of digesting enzymes. The levels of intestinal proteases and leu-aminopeptidase, which are crucial for the digestion of protein, are raised by synbiotics. Supplementing with probiotic bacteria mostly causes an increase in bloodstream activities such naphthol-AS-BI-phosphohydrolase, β-galactosidase, and N-acetyl-β-glycosaminidases. To fully comprehend the impact of prebiotics as a synbiotic component on the functions of digestive enzymes, more research is necessary. There is a need for natural alternatives synbiotics as dietary supplements to improve competitive exclusion of pathogens from the system and to enhance the immune parameters of shrimp without affecting its health, given the gradual increase in the demand and preference for healthy and hygienic shrimp worldwide. Nonetheless, a thorough comprehension of these immunostimulants is required to attain the best possible protection. According to studies carried out in the last few years, pro-, pre-, and synbiotics may be a preferable option to antibiotics and comparable products for attaining security while preserving ecological equilibrium and raising shrimp production. By including these nutrients in shrimp feed, disease incidence can be considerably reduced while enzymatic activity, utilization of feed, development and survival of cultured shrimp can all be increased [13].

2. Immunomodulatory effect of synbiotics

Probiotics and prebiotics work together to produce the effects of synbiotics in shrimp. Probiotics help maintain a healthy microbial balance by introducing advantageous microorganisms into the shrimp's digestive tract. These good bacteria are fed by prebiotics, which increases their productivity and multiplication. In the cultivation of shrimp, synbiotics pair up to promote better digestion, nutrient absorption, and general gut health. The study's parameters included clinical signs, total hemocyte count (THC), respiratory burst (RB), phenoloxydase (PO), immune-related gene manifestation (ProPO), lipopolysaccharide, and β-1.3-glucan-binding proteins (LGBP)), post-infection death rates, and the total number of plates surveillance of gastrointestinal bacterial cell populations [12]. Better growth, heightened immunological responses, and disease resistance are the outcomes of including synbiotics in the diet. Shrimp larvae that are bioencapsulated with synbiotics from the organism Artemia species grow to their ideal size and nutritional content. Synbiotics can be microencapsulated to aid in the growth and survival of probiotic bacteria as well as the development of gut microflora [13]. Shrimps have created a robust innate immune system to protect themselves from harmful illnesses while lacking adaptive immunity. Their first line of defense against infections is a strong exoskeleton. It supports several immunological-related physiological processes and is composed of proteins, carbohydrates, and calcium carbonate. Antibiotics throughout the. Pathogens are able to enter the shrimps' hemocoel after evading this first barrier of defense. The several hemocytes that comprise the hemocoel are the main cells in charge of protecting the shrimp's interior from outside threats. When immunostimulants reach the shrimp hemocoel, they are recognized as foreign material. PAMPs are recognized by shrimp hemocyte PRPs during immunostimulus. Upon identifying a particular pattern, a series comprises the processes of phagocytosis, pigmentation, and formation of a pathogen-hostile environment. Such Studies reveal that shrimps' safeguards remain intact. Compelled to continue even if their immune parameters go back to their pre-stimulant levels, which facilitates pathogen removal [14]. Among their many health advantages, synbiotics have a remarkable effect on shrimp immune systems. Hemocytes proliferation, PO, PA, LSZ, RB, SOD, and NOS activity may indicate the impact of synbiotics on immunological function. The results of the trial showed that synbiotic additives had immunomodulatory effects when THC improves by about 2.8 times while PO and PA activity increases by 4.6 and 4.7 times, correspondingly. Another trial that found that shrimp treated with synbiotics had higher levels of PO and THC than shrimp in other categories of treatment lends more credence to this conclusion. Specific immunological genes, including proPO, LGBP, SP, PE, and IL, showed dramatically enhanced expression at the level of the genome. Another thing to think about should be the amount of time and how often the medication is administered. conducted a thirty-day trial with shrimps under various schedules for treatment and found that once-daily synbiotic medication outperforms once-weekly or twice-weekly protocols. As the dosage of encapsulated synbiotics is increased, several health metrics appear to be improving [11].

3. Antiviral ability of synbiotics in WSSV

For preventing WSD included oral baculovirus and Bacillus subtilis spore injection. Another method for preventing the expression of viral proteins and boosting host immunity against WSD is RNA interference (RNAi). The possibility that M. japonicus can produce siRNA—small interfering RNA—that targets vp28 (vp28-siRNA) in response to WSSV infectiousness is uncertain. This further suggests that RNAi provides the host with a shielding effect. In a recent study, WSSV proliferation was significantly inhibited when vp28-siRNAs coated in β-1,3-d-glucan were administered along with WSSV in M. japonicas. Seaweeds are multicellular algae that are rich in bioactive chemicals including carrageenan, fucoidan, laminarin, and chitosan that stimulate the immune system of aquatic species, it has been acknowledged that marine algae are an important resource for aquaculture to develop resistance to diseases. Additionally, brown seaweed has recently been noted to be a source of polysaccharides and to have antibacterial and therapeutic qualities for aquatic organisms. In Penaeus monodon and Marsuspenaeus japonicus, respectively, fucoidan-containing extracts from Sargassum spp. and Cladosiphon okamuranus seaweed provide some resistance to WSD. It is assumed that feeding fucoidan substance orally has protective effects by directly inhibiting the replication of viruses and propagation generating the reactions of the innate immune system. Litopenaeus vannamei was shown to have stronger defenses against WSSV and Vibrio alginolyticus [14].

Conclusion:

The utilization of synbiotics emerges as a highly effective strategy in bolstering the resistance capacity of shrimp against White Spot Syndrome Virus (WSSV). Through a symbiotic interplay between probiotics and prebiotics, this approach enhances the shrimp's immune response, fortifying its defense mechanisms against WSSV infection. The synergistic combination not only mitigates the impact of the virus but also promotes overall shrimp health. As a sustainable and bio-friendly solution, synbiotics showcase considerable potential in contributing to the resilience of shrimp populations, thereby offering a promising avenue for the aquaculture industry to combat the challenges posed by WSSV.

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MINI-REVIEW ON FISH DIVERSITY OF JAMMU AND KASHMIR AND THEIR THREATS

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Abstract:

Fish species are an essential component of aquatic ecosystems, and any substantial changes in the medium they reside in can impact production, diversity, and ecology. Variations in altitude and geography have resulted in a distinct succession of water bodies in different sections of the state, resulting in the colonization of these waters by various varieties of fish. These ecosystems have enormous potential for the growth and extension of fisheries, particularly in cold waters. In the state of Jammu and Kashmir, there are 120 distinct fish species. Of these, 105 species inhabit the Jammu area, 23 in Kashmir Valley, and 15 in the Ladakh region. Due to constant anthropogenic stress, fish diversity is reducing quickly every day. But it also has significant effects on the fishery. Many species are disappearing quickly due to slow and insufficient conservation efforts to lessen the effects of the stresses.

Keywords: Fish diversity, Jammu and Kashmir, Threats, River, Ichthyofauna, *Schizothorax* spp.

Introduction:

The existence of living and non-living organic matter on the earth is related to diversity [8]. As one of northern India's most significant freshwater fish habitats, Jammu and Kashmir has tremendous potential for cold water resources. The Indian state of Jammu and Kashmir is also known as the bio-mass state and has been referred to as 'heaven on earth.' Jammu is a tropical zone, while Kashmir and Ladakh are temperate regions. As a result, the fisheries, flora, and fauna of Jammu and Kashmir are very diverse. Jammu, Kashmir, and Ladakh have distinct climatic conditions, topographies, ethnic groups, and cultures. There are many valleys in Jammu and Kashmir, including the Lidder Valley, Tawi Valley, Chenab Valley, Poonch Valley, and the Kashmir Valley; due to its rocky landscape, Jammu and Kashmir's climate changes widely. The inland region of Jammu and Kashmir has a vast potential for resources, including an abundance of fish. The nation has many resources, including a rich biodiversity and river biological legacy. Rivers of Jammu, Kashmir, and Ladakh include Ravi, Tawi, Chenab, Poonch River, Dhudganga, Jhelum, Neelum, Lidder, Rambi Ara, Sind River, Veshaw, Shyok, Tsarap, Nubra River, Zanaskar River and Drass River (Fisheriesindia.Com).

The streams' distinctive characteristics, topography, zonation, and morphology result in diverse fish species from source to mouth at various locations. Fish diversity can increase and is typically influenced by geography. Diverse aquatic ecological conditions, a population that understands the value of fish diversity, healthy aquatic ecosystems, optimal commercial fish species exploitation, legal compliance, and the implementation of fish habitat restoration programs in cases of ecologically degraded fish habitats are all factors that should be taken into consideration [1,12]. Fish variety documentation is essential for conservation [5].

Fish diversity

The Kashmir valley is renowned worldwide for its freshwater resources, ranging from high altitude to low-lying aquatic environments. These ecosystems have enormous potential for the growth and extension of fisheries, particularly in cold waters [14]. In the state of Jammu and Kashmir, there are 120 distinct fish species. Of these, 105 species inhabit the Jammu area, 23 in Kashmir Valley, and 15 in the Ladakh region. Different water bodies in other parts of the State have developed other successional orders due to changes in topography and altitude, finally leading to the colonization of these waters by various fish species. Eight fish species were widespread throughout the State in all three regions, whereas nine were shared by Jammu and Kashmir, Kashmir and Ladakh, and Jammu and Ladakh, respectively. From the 23 species that have been identified in the Kashmir Valley's Jhelum River system, 18 species (14 species from the family Cyprinidae, 1 from the family Cobitidae, and 3 from the family Balitoridae), 2 species (from the family Sisoridae), 2 species (from the family Salmonidae), and 1 species (from the family Poeciliidae) are members of the order Cypriniformes. The abundance of warm water fish in the Jammu region contributes to its excellent species variety. Still, Ladakh's low fish diversity and density may be caused by the region's high altitude and challenging climatic conditions, which include cold winter temperatures, frozen rivers, and high summer turbidity [4].

The ichthyofauna of the Kashmir valley has been extensively documented in the literature [9, 10, 24]. Numerous native fish species, including *Schizothorax* spp., *Glyptothorax* spp., *Triplophysa* spp., *Barbus* spp., *Crossocheilus* spp., *Nemacheilus* spp., etc., as well as two invasive trout species, *Oncorhynchus mykiss,* and *Salmo trutta fario*, are found in all of these freshwater aquatic bodies. Over eight years, fourteen native and four introduced fish species were caught in Kashmir Valley's Jhelum River and associated lakes [15]. They also saw five species of *Schiozothorax*, of which four are specialized lotic forms, and one (*S. niger*) is primarily found in lentic. Similarly, eleven different kinds of fish were also noted in Jhelum River [25]. In addition, six fish species, including *S. isoclines, S. palgiostoms, C. carpio communius, S. labitus, S. niger,* and *S. curviforns,* were reported from the same river [14]. In 2016, Sultan and Kant identified nine fish species consistent with our research, however a different distribution pattern was discovered. Fish from seven different species, including *S. plagiostomus, S. labiatus, S. esocinus, S. trutta fario, C. diplochilus, G. reticulatum* and *Triplophysa kashmirensis,* were caught from Lidder stream, an essential right bank tributary of the Jhelum [3]. The River Jhelum's fishing resource has decreased over the past few years, suggesting that stress and outside pressure may affect the health of this significant ecological and economic aquatic body [14].

Threats to the diversity of rivers

Due to constant anthropogenic stress, fish diversity is reducing quickly every day. Not only is this diversity the source of our world's wealth, but it also has significant effects on the fishery. To create an information system on freshwater fish diversity that includes bioinformatics and georeferenced fish and fish habitat databases, it is urgently necessary to properly investigate and document fish variety. Due to their extreme sensitivity to the quantitative and qualitative alteration of aquatic behaviors, freshwater fish are among the most vulnerable taxonomic groups [6, 13, 16, 17]. Fish are susceptible to anthropogenic activities in their catchment that alter the chemistry of the water. Compared to simpler animals, fish reactions to environmental perturbations, such as hydro-morphological factors, differ in time and space because they often integrate across longer time scales. Due to their simplicity of identification and high economic worth, fish have been deemed acceptable for biological assessment [18,20]. Because of their symbolic importance and sensitivity to even the slightest environmental changes, fish has been recognized as an efficient biological indicator of environmental quality and anthropogenic stress in aquatic environments [2, 19]. They stand for a broad spectrum of communal tolerance. Managing fish variety and related ecosystems is a significant concern today [7]. Many species are disappearing quickly due to slow and insufficient conservation efforts to lessen the effects of the stresses [22].

The world's freshwater ecosystems and biodiversity are gravely threatened by human activity. Above all else, this is unquestionably a result of expanding human populations and economic development [23]. Human activity has the potential to influence biological, chemical, and physical processes, changing the nature of the process. The following factors have an impact on the ecology and diversity of rivers:

i. Direct discharge of untreated sewage from agriculture and highly populated village activities; & Water Pollution
ii. Conversion of wetlands into paddy fields and apple orchards
iii. Use of biocides, Climate change, Watershed runoff;
iv. Pressure from tourists;
v. Sand mining; channelization and impoundment; and
vi. Illicit fishing.
vii. Hydroelectric power projects, barrages, weirs.
viii. Construction of houses close to river banks and wetlands.
ix. Excessive deforestation – 6281 ha of forest land put up for other uses between 2003-2012.

According to Hynes (1960) in his study, combinations of these danger variables impact biodiversity and put freshwater biodiversity, particularly, at risk [11]. To overcome these factors, some suggestions are given below.

- A master plan should be created to treat all point sources of pollution entering rivers, particularly for the sewage originating from residential areas, as doing so will hurt the water quality and the ecosystem's overall health.
- Sand mining should be prohibited or minimized since it damages the habitats and breeding grounds of wildlife in waterways.
- The establishment of sustainable fisheries to preserve or restore fish diversity and production.
- Enhancing biodiversity and managing invasive species.
- The ongoing depositing and pouring of residential wastes, trash, and dead animals into the Jhelum River must cease immediately.

- We have harmed our natural resources enough. Eco-restoration is the method we can use to improve the situation in this case. Small, decentralized decision-making groups such as study groups and cooperative societies must be established.
- Conduct environmental impact assessments regularly to guarantee resource conservation and sustainable use.

Discussion:

Jammu, Kashmir, and Ladakh have a lot of fish and fisheries resources; however, due to a lack of proper management and utilization policy, these resources face various challenges. The Kashmir valley is renowned worldwide for its freshwater resources, ranging from high altitude to low-lying aquatic environments. These ecosystems have enormous potential for the growth and extension of fisheries, particularly in cold waters. In the state of Jammu and Kashmir, there are 120 distinct fish species. Fish diversity can increase and is typically influenced by geography. Fish are susceptible to anthropogenic activities in their catchment that alter the chemistry of the water. Compared to simpler animals, fish reactions to environmental perturbations, such as hydro-morphological factors, differ in time and space because they often integrate across longer time scales. A master plan should be created to treat all point sources of pollution entering rivers. Sand mining should be prohibited or minimized to conserve fish diversity.

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MEDIA OPTIMIZATION AND BIOCHEMICAL COMPOSITION OF FRESHWATER DIATOM *NITZSCHIA* SP

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Abstract:

The need for clean and low-cost algae production demands for investigation on microalgae and their physiological response under different growth conditions. In recent years, microalgae have received more attention for the commercial exploration from pharmaceuticals to biofuels. Hence, we investigate the growth, biomass production and biochemical constituents of a freshwater diatom *Nitzschia* sp., using six different growth media (F/2, WC, PM, BG11, Bold Basal and Chu 10) respectively. The highest biomass production was observed in WC medium followed by F/2 and BG11 medium. PM medium fairly supports the growth, whereas, Chu10 and Bold basal Medium does not support the growth of *Nitzschia* sp. Carbohydrate (12%), lipid (31%) and growth of yield were highest in WC medium. Lipids and carbohydrates were reported to be characterized by strong vibrations the C-H 2922cm-1 and 2852 cm-1, C-O-C of polysaccharides at 722 cm-1. Further manipulation of media composition and conditions for increased biomass and lipid productivity of *Nitzschia* sp. at industrial scale is most warranted.

Keywords: Medium optimization, Lipid, *Nitzschia* sp., FTIR

Introduction:

Diatoms are important primary producers in marine and freshwater aquatic ecosystems, and it represents an important source biofuels, pharmaceuticals, fine chemicals and food for aquatic grazing organisms [1-7]. Microalgae are crucial for the development of fish larvae and other young animals in upper trophic levels [8]. Perturbations in diatom communities indirectly disturbing the productivity of the whole aquatic ecosystem [9]. The main thing got altering the balance of benthic diatom communities are mostly man-made disturbances [8]. Microalgae have high lipid content and have strong capacity to adapt the surrounding environment, because, it has rapid growth rate. The conversion efficiency of photosynthesis in microalgae can reach 10 % theoretical value and 4.5 % realistic value [10]. Per unit of biodiesel production are potentially 8 to 24 times greater than the best land plants [11]. By using mathematical modeling and engineering calculations, microalgae-derived biodiesel will definitely be the important replacement for petroleum fuels. Primary key to providing a solution to this problem is finding microalgae species which have high lipid content and rapid growth rate [12]. The production and storage of lipid by microalgae is also regulated by nutrients, especially nitrogen (N), phosphorus (P) and silicate (Si). Diatoms are one of the largest groups of silicifying organisms and most species have an obligate requirement for silica for cell wall formation. Fourier transform infrared (FTIR) spectroscopy is a novel method for monitoring carbon allocation in phytoplankton. This form of vibration spectroscopy can be used to collect mid-infrared absorbance spectra from air dried, intact microorganisms. It has been successfully applied to the analysis of bacteria [13] higher plants [14] fungi [15] and yeast [16]. When applied to whole organisms the resulting spectrum reflects the biochemical complexity of the cells, with absorbance bands from lipids, nucleic acids, carbohydrates and proteins.

The present study focused to evaluate suitable medium among F/2, WC, PM, BG11, Chu 10 and BBM media for culturing *Nitzschia* sp. The main objective of the present investigation is to analyze the growth and biochemical analysis of the *Nitzschia* sp. in order to find out best defined medium for the cultivation.

Materials and Methods:

Isolation

Nitzschia sp. was originally isolated from a Paddy field, Sooriyur, Tiruchirappalli, India (Lat. 9° 51' 30''–10° 48' 08'' N. and 78° 25' 40''–79° 16' 22'' E.).

Maintenance of diatom

The individual colonies were isolated and inoculated in liquid medium (F/2 medium) and incubated at 24±2°C under 35 $\mu mol^{-1} m^2 s^{-1}$ light intensity with 16:8 hours light: dark period and maintained in the Germplasm, Division of Microbial Biodiversity and Bioenergy, Department of Microbiology, Bharathidasan University, Tiruchirappalli, India.

Measurement of growth rate of different medium for cultivation of *Nitzschia* sp.

The experiments were carried out in Erlenmeyer flasks of 250ml capacity each containing 100ml F [17], BG11 [18], WC [19], Chu 10 [20], BBM [21] and PM, medium for a period of two weeks. The culture flasks were inoculated and incubated at 24±°C under 30 μmol- ^{1}m^{2}s^{-1} intensity with 16:8 hours light and dark cycle. The growth rates of isolated diatoms were measured by optical density of an aliquot of the culture at 750nm using UV-Vis Spectrophotometer (Agilent, USA).

Biochemical composition of *Nitzschia* sp.

Extraction of total lipids

Lipids were extracted by the modified procedure as described by Bligh and Dyer [22]. The cells were homogenized with chloroform: methanol: water (2:1:0.8, v/v/v) for 2 min. An equal volume of chloroform and distilled water was then added, to bring the final ratio of the mixture to 2:2:1.6 and the mixture were then homogenized for 1 min. The chloroform layer containing lipid fraction was separated, and the alcoholic layer, which contained the residues, were re-extracted twice with methanol and chloroform (1:2, v/v).

Quantification of carbohydrate

The freeze dried diatom powder to determine total carbohydrate was determined at 625 nm by Anthrone reagent method [23].

Analysis of lipids and proteins identified by FT-IR spectroscopy

Lyophilized dried biomass was mixed with KBR powder and ground well to fine mixture. The mixture was pressed to a disc using a Hydraulic press in to tablets. The disc was subjected to FTIR (Perkin Elmer) spectral measuring within the frequency varies of 4000–400 cm−1.

Results and Discussion:

In the study, *Nitzschia* sp. was isolated from paddy field and was maintained F/2 medium in the Germplasm of Microbiology, Bharathidasan University, Tiruchirappalli. The morphology of the *Nitzschia* sp. were studied under the Confocal Laser Scanning Microscope (Carl Zeiss, Germany) and light microscope (Micros Austria) were tentatively identified as *Nitzschia* sp. (Fig.1 and 2). Our previous research group reported that BG11 medium support for the growth of microalgae [24]. In the present study, we used five inorganic media with varying chemical composition were used in the present investigation. The *Nitzschia* sp. used in this study showed variations in growth pattern and biochemical composition. The present study deals with the evaluation of growth (OD value) in *Nizschia* sp. which showed variation their growth pattern and biochemical composition in all six media (Fig.3). In this study, we found that WC and F/2 medium were found to greatly influence the growth of *Nitzschia* sp followed PM, Chu 10 and BG11 medium whereas minimum growth was examined in BBM. In the present study, $NaCO_3$ and $NaSiO_3$ are the carbon and silicate source, higher OD value and biochemical composition content illustrated that these nutrients also supported the growth of microalgae. Moreover, these two inorganic nutrients maintain the alkaline buffering in the medium. Sharma *et al.* [25] reported that Sodium bicarbonate and Silicate in Modified Chu10 medium showed higher biomass production.

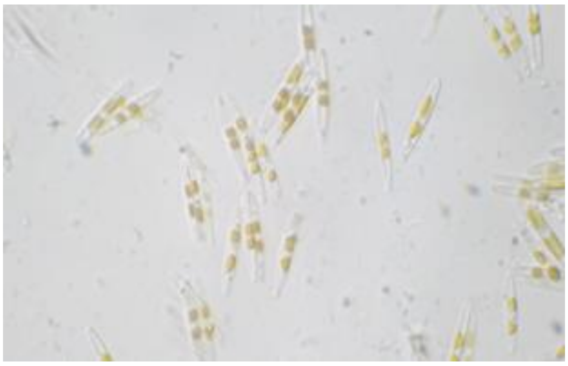

Figure 1: Microphotograph of *Nitzschia* sp.

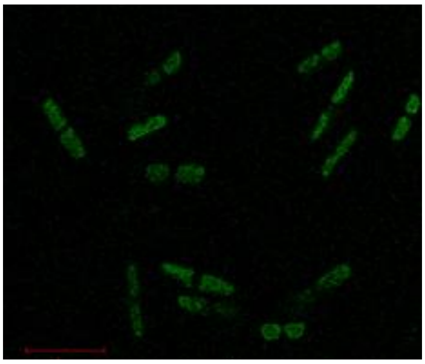

Figure 2: Confocal Laser Scanning Light Microscopic View of *Nitzschia* sp.

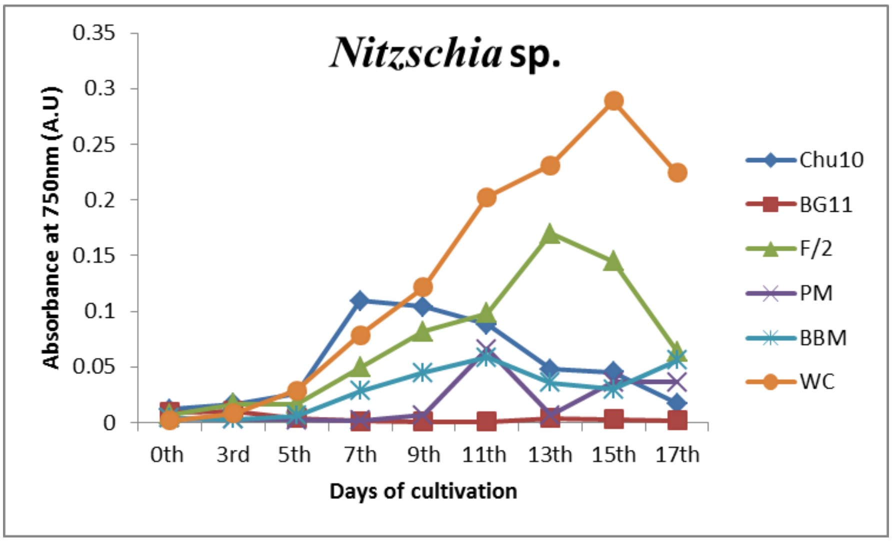

Figure 3: Growth analysis of *Nitzschia* sp. using different freshwater medium

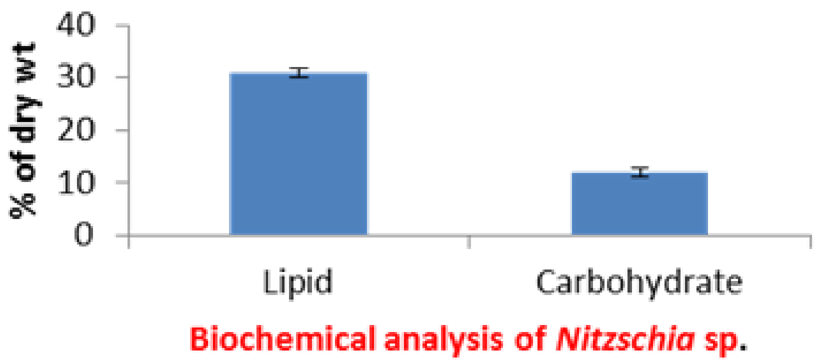

Figure 4: Biochemical composition of *Nitzschia* sp.

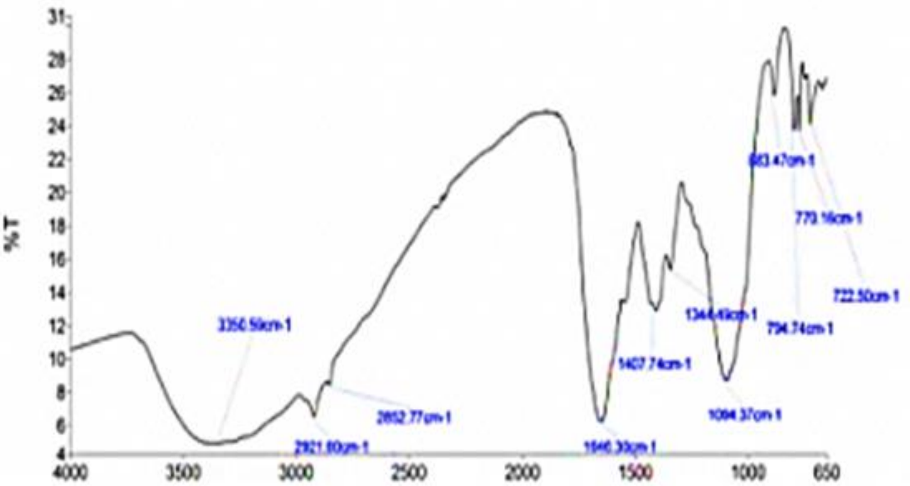

Figure 5: FTIR spectra of *Nitzschia* sp.

Table 1: Functional group of *Nitzschia* sp.

Biomolecules	**Wavelengh (cm^{-1})**
Silicates	1094
Lipids	2921
Lipids and Proteins	2852
Carbohydrate	722

Lipids and carbohydrates are considered cellular fuel, besides their important function as structural constituents of membranes [26]. Hence, their decrease can negatively affect growth and metabolism of cells. Carbohydrates have been found as intermediary reserves in some algae, due to the fact that they are required when nitrogen becomes limited in the lipid synthesis. Carbohydrate tends to accumulate in the stationary phase [27, 28] of algal growth. This is in accordance with the report of earlier researchers that there is a coupling between protein and carbohydrates in algal cells, which also reflects the budget of carbon and nitrogen available to the cells [29, 30]. According to Enright et al. [31], when the rate of cell division in a phytoplankton culture is limited by nutrients, cells alter their metabolism and convert energy to produce reserve substances. In the present study, total carbohydrate and lipid content were tested at various intervals and found that the maximum lipid content (31%) and carbohydrate (12%) recorded on 10th day in F/2 medium (Fig. 4).

In FTIR spectra with regard to specific functional group, each peak consigned a functional cluster. The molecular assignments of FTIR bands square measure supported revealed information of plant life, microorganism and alternative biological materials. Lipids and carbohydrates were reported to be characterized by strong vibrations the C-H

2922cm^{-1} and 2852 cm^{-1}, C-O-C of polysaccharides at 722 cm^{-1} (Fig 5 and Table 1). The WC medium has optimal amounts of macronutrients which resulted in maximum growth and biochemical composition.

Conclusion:

The present work investigated the effect of five effect of six different medium namely Chu 10 medium, Bold Basal medium, BG11, F/2 medium, PM medium and WC medium on growth and biochemical composition of *Nitzschia* sp. present experiments clearly showed that the WC medium favours the growth of *Nitzschia* sp. The cultivation of *Nitzschia* sp. offers many new opportunities in microalgal product development.

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A REVIEW ON FISH WASTE FERTILIZER AND ITS EFFECT ON PLANT GROWTH

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Abstract:

Global aquaculture production has been enhanced rapidly in recent years, due to the increasing population caused by urbanization and industrialization. A good quality of protein produced by sea foods plays a major role in day-to-day diet. Which in turn increases the fish waste production by fish processing industries. They are not utilised properly, which causes pollution and has a negative impact on the environment. They contain a good quality of micro- and macro nutrients including carbohydrates, proteins, bioactive peptides, collagen, fatty acids, secondary metabolites like phenols, tocopherol, etc which are essential for growth and development of human beings as well as plants. Some of the waste is utilised but most of it is thrown out as thrash. Awareness should be created to manage this fish waste and turn it into valuable products worldwide. They act as a valuable source for increasing plant growth, the concentration of nutritive constituents and the yield of a plant.

Keywords: Fish waste, Fertilizer, Fish waste compost, Plant growth

Introduction:

In recent years, consumption of fish has been increased because it acts as a key constituent of a balanced diet and healthy lifestyle (Coppola *et al*., 2021). Aquatic food consumption has grown at a pace of 3.0 percent per year on average since 1961, more than double the rate of population expansion worldwide and reaching 20.2 kilogram per person now. Animal aquaculture production increased by 6% from 2018 to 87.5 million tonnes in 2020. Growing demand for fish and other aquatic foods is rapidly changing the fisheries and aquaculture sectors. Consumption is expected to increase by 15 percent to supply on average 21.4 kg per capita in 2030, driven mostly by urbanization, changes post -harvest practices and distribution, as well as dietary trends focusing on better health and nutrition (FAO, 2018). Many countries' economies depend extensively on the aquaculture and fishing industries and as a result of their expansion large amount of fish waste is produced across the globe. Most of the fish waste is thrown away despite its active and functional qualities, which has a negative impact on the environment where it is dumped. In less likeliness, it is made into some products, so it is important to manage fish waste produced. Fish waste includes complete fish, whether dead or injured, fish trimmings, and particular parts including heads, scales, tails, fins, skins, gut, and bones. When filleting a whole fish, roughly 30-50% of the meat is typically lost; the remaining 4-5% of skin, 2-25% of the head, and 24-34% of the bones make up more than 45% of the fish's body and are generally wasted (Brooks, 2013). Fish waste includes an immense variety of nutrients that are vital for the growth and development of plants, which act as an effective organic fertilizer. By incorporating this type of organic fertilizer, which includes all the necessary micro- and macro nutrients, the production and use of chemical fertilizers can be decreased, which pose a significant risk to the soil and the people. The field of reusing and recycling these waste materials has gained more interest and importance recently. It is anticipated that using these wastes and turning them into usable goods will also help to reduce environmental pollution.

Necessity of fish waste management

Consumption of fish and other aquatic animals result in an ample amount of fish waste resulting from industrial process. This fish waste is not harnessed effectively; these untreated fish wastes are disposed of on lands and dumped into the sea. Fish waste contains constituents like proteins (with well-balanced amino acids 16-18), oil, bioactive peptides, collagen, enzymes, minerals, chitin, pigments, etc. that are wasted (Kim *et al.,* 2009). Measures should be taken to utilise these nutritive components which play a major role in animal feed, plant growth, oil production, etc. The most widely used applications for processed fish waste in recent times include the isolation of collagen and antioxidants for cosmetics, biogas/biodiesel, fertilizers, dietary applications like chitosan, food packaging (gelatin) and enzymes(proteases) (Arvanitoyannis & Kassaveti, 2008). So, to decrease the adverse effects and impact on environment and to utilise the nutrient content, fish waste management is inevitable.

Environmental hazards of using chemical fertilizer

Application of chemical fertilizer increases plant yield and productivity. Prolonged exposure and excessive use of chemical fertilizer lead i.e., loss of soil fertility, increases soil acidity, rapid deterioration of soil and ground water. Also, it has harmful effects on human health and environment, such as eutrophication. Inorganic fertilizers affect and decrease soil micro flora. Soil micro flora is an essential factor that plays an eminent role in growth of a plant and is improved by organic fertilizers (Ranaweera *et al.,* 2013).

Fish processing steps

The following steps are used to process fish in most of the fish processing units. They include: stunning of fish, grading, slime removal, scaling, washing, deheading, gutting, fins removal, slicing, meat bone separation, packing, labelling, distributing (Brooks, 2013)

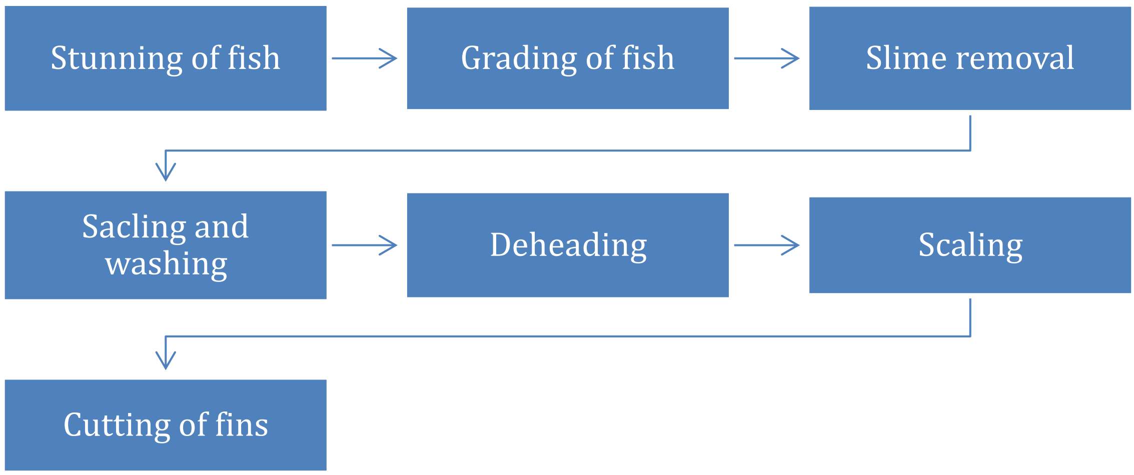

Figure 1: Fish processing steps

Nutritive supplements present in fish waste

A complete fish is made up of 20 to 30% protein, 2 to 12% fat, and 70 to 80% water (Caspers, 1981) and (Begum *et al.,* 2016). Fish products' quality and attributes vary greatly depending on the processing techniques used and the potential raw material content. A significant amount of byproduct is produced when fish is processed for different goods, and about 45% of the fish is wasted. Fish heads, bones, scales, and other trash items are among the discarded materials. These byproducts do, nevertheless, have a nutritious makeup. They contain valuable micro- and macro nutrients like potassium, phosphorous and nitrogen. More than half of this fish waste is composed of bone-rich heads and backbones, which are important sources of unused calcium, phosphorus, and nitrogen which makes up 60-70% of the waste. In the fish processing industry, the waste processed materials produced are eminent sources of proteins (amino acids), collagen, gelatin, oil and enzymes (Esteban *et al.,* 2007).

Fish bones are also excellent sources of hydroxyapatite, which is thermodynamically stable in physiological pH and can be used in dental care and medical applications as a bone transplant material (Larsen *et al.,* 2011).

Table 1: Composition of fish (Waterman, 2002)

Component	Percentage
Head	21
Guts	7
Liver	5
Roe	4
Backbone	14
Fins and lungs	10
Skin	3
Fillet, skinned	36

Table 2: Nutritional and Mineral composition of fish waste (Esteban *et al.,* 2007)

Nutrient	Amount
Crude protein (%)	57.92+5.26
Ether extract (%)	19.10 + 6.60
Crude fibre (%)	1.19 + 1.21
Ash (%)	21.79 + 3.52
Nitrogen free extract (%)	
Ca (%)	5.80 + 1.35
P (%)	2.04 + 0.64
K (%)	0.68 + 0.11
Na (%)	0.61 + 0.08
Mg (%)	0.17 + 0.04
Fe (ppm)	100 + 42
Zn (ppm)	62 + 12
Mn (ppm)	6 +7
Cu (ppm)	1 +1

These fish waste constituents also contain 58% protein, 19% fat, minerals, palmitic acid and oleic acid. The fish skin is a good source of gelatin and collagen, which play a major role in the cosmetic industry. Fish is also a good source of enzymes like pepsin (present in gut), trypsin, chymotrypsin, and collagenase. Peptides with diverse biological activity, including antihypertensive, immunological modulatory and antioxidative capabilities can be found in fish muscle protein extracts (Kim *et al.,* 2000; Brooks, 2013). The potential of peptides obtained from fish to neutralise coagulation factors in intrinsic pathway of blood coagulation is mostly due to the anticoagulant and antiplatelet activity of the peptides present in fish (Je *et al.,* 2004).

It is also evident that the peptides isolated from fish waste contain anti-microbial activity, anti-oxidant activity, anti-inflammatory activity, prevent cardiovascular diseases and neuroprotective activity which acts as an effective nutraceutical in food. Which highlights the possible application of bioactive compounds from fisheries byproducts in the food and pharmaceutical industries (Caruso *et al.,* 2020).

Fish waste compost

To overcome the pollution caused by fish waste composting is one of the easiest and cheapest methods. It has a great nutritive value and improve the yield and quality of plants in the garden.

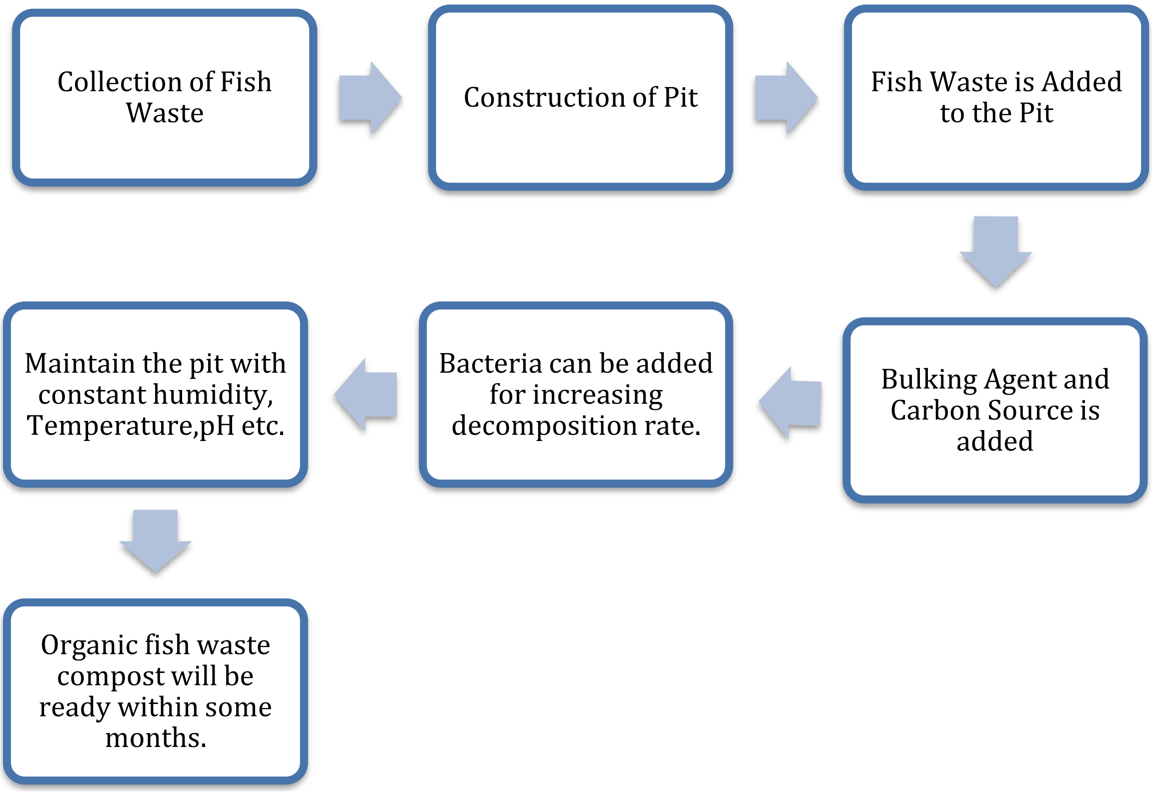

Figure 2: Steps involved production of fish waste compost

1. Fish waste (includes head, tail, fins, scales, gut) should be collected. They are minced into small pieces.

2. A pit is constructed. Fish waste is added layer by layer in the pit.
3. Bulking agents like saw dust, coconut husk and soyabean residues as carbon sources have to added.
4. It is continuously monitored for the humidity (for the growth of microorganisms), temperature. Watering should be done regularly to maintain humidity.
5. To increase the rate of decomposition some types of bacteria species can be added, for example, PSB (*Phosphate solubilizing bacteria, Bacillus, Azatobacter and Rhizobium*.
6. The pit is mixed thoroughly, and direct sunlight should be avoided.
7. Fish waste starts to decompose. It gets completely decomposed in 180 days.
8. Compost is ready to use (Balkhande, 2020).

Profound effects on plant growth

Plant requires a complete set of nutrients, like primary macro nutrients like (N) Nitrogen, (P) phosphorous, (K) Potassium and secondary macro nutrients like (Ca) calcium, (Mg) magnesium, (S) sulphur. Micro nutrient like iron, manganese, zinc, copper, chloride for its growth and development (White & Brown, 2010). Fish waste contains all the metabolites, micro and macro nutrients required for plant growth. It is an effective alternative for chemical fertilizers which are commercially available and have adverse effects on human health and the environment. The toxic and chemical components that are used to improve the crop yield that are absorbed by plants, intake of which causes chronic illness and tumours. This organic fertilizer has good nutritive value and is cheap, ecofriendly and harmless. It increases the growth of the crop and increases soil fertility. Organic fish waste fertilizer obtained from Tilapia fish waste increases the growth of plants Jackfruit Tulo and Beka. It also increases the concentration of phytochemicals and secondary metabolites likes phenols, flavonoids, etc. present in plant (Tiwow *et al.,* 2020). Fish waste fertilizer also increased the yield and nutrient property of Tropea's red onions (*Allium cepa*) with 65% higher bulb weight ,133% bulb diameter. It has also amplified the concentration flavanols, anthocyanins, with 66% higher total phenolic and 75% total flavonoid content (Muscolo *et al.,* 2022).

Conclusion:

Marine-derived biomolecules which have unique properties can be used in variety of biomedical, cosmetic, pharmaceutical, food and biotechnological fields of application depending upon the distinctive structural and functional properties (Caruso *et al.,* 2020). Fish waste which contains enormous number of nutritive constituents which is needed for plant growth and development. It is an eco-friendly and easiest way to manage fish waste. Farmers can use these types of organic fertilizers instead of chemical fertilizers which affect both soil and mankind. They are naturally occurring which needs little attention and time to process this kind of waste into a useful resource which drives a sustainable future.

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EXPLORING THE INGREDIENTS AND NUTRIENTS IN FISH FEED: FROM CONVENTIONAL TO UNCONVENTIONAL APPROACHES

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Abstract:

Fish Feed is a great way to support the bottom of the food chain and help maintain a healthyfish community. Aquaculture is made with a vast pool of ingredients to meet nutritional requirements of fish for normal Physiological functions, including maintaining a highly effective natural immune system, growth and reproduction. Fish nutrition research has advanced in recent years with the development of commercial diets that has significant role in promoting fish growth and health. Fish feed is an important factor in Aquaculture Farming. This chapter provides information about the fish feed formulation and fish feed Technology concerned with fish feed, fish feed ingredients, different methods of production and diet in feed.

Keywords: Fish feed, Nutrition, Formulation, Growth Performance, Aquaculture, Sustainability

Introduction:

Aquaculture industry is a major sector in many countries, and it will continue to grow as the demand for fish products are increasing. In the field of aquaculture, the growth of fish is a prime important factor, the growth is affected either due to less intake of good feed. Fish feed formulations play a crucial role in the growth, health, and sustainability of aquaculture. One of the factors that contribute to the development of different species of fishes is the feed formulationsand hence there is a need for affordable, safe and high-quality fish and seafood products to support the aquaculture industry. The production of nutritionally balanced feed requires good ingredients, efforts in research and quality control. The feed formulations and production technologies are gaining importance due to the number of golden opportunities in future and challenges. Fish feedcontains many important ingredients like amino acids, proteins, carbohydrates, vitamins and minerals. These all ingredients play a key role in feed because areneeded forthe growth and development of fish. Fish meal is also known to contain essential amino acids that are needed to meet the protein requirement of most fish species. High quality Fish meal contains 60 % to 72% crude protein by weight. Since the Fish meal is expensive as feed ingredients, the use of locally available ingredients or Conventional food stuff has been reported with good growth promotion and better cost benefit value. This feed made from waste of agricultural origin like fish offal, duckweed, soybean meal, groundnut cake, maize bran. This includes all locally available ingredients and are cheap to purchase. As the demand for seafood continues to rise, the development of efficient and nutritionally balanced fish feed has become paramount.

This review article aims to explore the advancements in fish feed technology, discussing its composition, formulation, processing, and the impact it has on fish health and overall aquaculture sustainability. By diving into the key aspects of fish feed technology, we can better understand its importance and potential for innovation in meeting the growing global demand for seafood. Basically, scientists and researchers are working to develop the perfect combination of ingredients like fishmeal and vegetable protein, oils, vitamins and minerals to ensure that meet the nutrient requisites of the fish. By improving fish feeding technology, we can help make the fish farming industry more sustainable and efficient.

Recent advances in fish feed technology have focused on improving feed efficiency, reducing dependence on wild fish stocks and minimizing environmental impact. This includes exploring sustainable alternative ingredients, such as insect meal or plant protein, as well as implementing interesting techniques such as precise feeding techniques and automated systems to improve feed utilizationto ensure the fish eat the right amount and reduce waste generated or to achieve waste minimization.By continuously improving fish feed technology, we are able to contribute to the growth and sustainability of the aquaculture while minimizing ecological problems and optimizing fish health and productivity. Researchers are exploring new formulations that optimize nutrient composition and digestibility, thereby improving fish growth and health, such as extrusion and pelletizing; that has led to the development of pellets with improved stability and palatability. These technological advances not only contribute to improving the overall productivity of farmed fish, but also reduce nutrient waste and environmental pollution.

What is fish feed technology?

Fish feed technology refers to the science and engineering involved in the formulation, production and use of fish feed in aquaculture. It covers various aspects such as the selection and processing of ingredients, the development of nutritionally balanced feed formulations and the optimization of feed production processes. The goal is to provide fish with the nutrients they need for their growth, health and reproduction while maximizing feed efficiency and minimizing impact on the environment. Fish feeding technology plays an important role in ensuring the sustainable development of aquaculture by improving fish growth rates, reducing production costs and minimizing nutritional waste. Furthermore, fish feed technology also takes into account the specific nutritional needs of different fish species at different stages of their life cycle. This includes conducting research to understand the dietary needs of different fish species and developing tailored, specialized food formulations. This includes determining the optimal levels of proteins, fats, carbohydrates, vitamins and minerals in the feed to support the growth and overall health of the fish. In addition, advances in fish feed technology have resulted in the incorporation of functional ingredients such as probiotics, prebiotics and immunostimulants, which can strengthen the immune system and provide resistance to Fish diseases. By continuously improving and innovating fish feeding technology, aquaculture can become more efficient, more sustainable and able to meet the growing global demand for fish products. 1

Types of fish culture

Fish culture is classified based on the number of fish species as monoculture and polyculture. Monoculture is the culture of single species of fish in a pond or tank. The advantage of this method of culture is that it enables the farmer to make the feed that will meet the requirement of a specific fish, especially in the intensive culture system. Whereas Polyculture is the practice of culturing more than one species of aquatic organism in the same pond. The motivating principle is that fish production in ponds may be maximised by raising a combination of species having different food habits. The mixture of fish gives better utilisation of available natural food produced in a pond.

In a polyculture system where different fish species are kept together, fry and fingerling ofherbivore fish will be predated by predators. As the growth rate of stocked fish increases, the natural food available in the pond will not be enough to maintain the fish population. Therefore, it is necessary to supplement natural food with artificial food to improve the growth of fish. In addition, fish feed technology plays an important role in solving the environmental problems associated with aquaculture. By optimizing feed composition and reducing nutrient waste, it helps to minimize the negative impact of fish farming on water quality and ecosystems. Sustainable feed ingredients, such as alternative protein sources such as insect meal or plant protein, are being studied to reduce dependence on wild fish. Advances in feed production are aimed at improving feed conversion efficiency, reducing energy consumption and minimizing carbon emissions in aquaculture operations. Through continuous research and innovation, fish feed technology continues to evolve, contributing to the advancement and sustainability of the aquaculture industry.

Feed ingredients/ nutrients:

Fish feed ingredients play a crucial role in the aquaculture industry, as they provide the necessary nutrients for the growth and development of farmed fish. The composition of fish feed can vary depending on the species being farmed, their nutritional requirements, and the availability of ingredients. Fish feed technology includes the research, development and production of nutritionally balanced feed for farmed fish species. It plays a central role in optimizing the growth performance, health and sustainability of aquaculture systems. Through food formulation and processing, using a wide range of ingredients including fishmeal, vegetable proteins, oils, vitamins and minerals, the aim is to meet the specific dietary needs of different fish species in different stages in their life cycle.

In the natural Environment, Fish have grown widely in many dietary specialties (Behavior and Physiology) to obtain essential information Nutrients and use a variety of food sources. Based on the Feed of Fish, Fishes are classified into:

- Carnivores - They consume large numbers of animals for food such as crustaceans, water fleas, insects such as beetles, water beetles, damselflies, dragonflies, larvae, mollusks, and other small fishes. Each other, tadpole larvae, etc.
- Herbivores - This fish survives, grows and reproduces by eating unicellular algae, filamentous algae, small aquatic plants, partly higher aquatic plants, detritus and some mud or sand. In this case, plant materials in their diet account for about 75% or more of the total intestinal content, while animal foods make up 1-10% of their diet.
- Omnivores -These Fish eat all kinds of Food, although their Preferred food is insects, they also eat Plant food such as unicellular algae and filamentous algae.

Regardless of them sorting food, fish in captivity can learn to readily accept food containing essential nutrients. The nutrients needed by fish are the same as those they need for most other animals. These include Protein (Amino acids), lipids (fats, fatty acids), carbohydrates (sugar, starch), vitamins and minerals. Carotenoids are also added in some fish feed. These fish feed ingredients /nutrients describe as follows:

Proteins: Protein sources are an essential component of fish feed, as they provide the amino acids necessary for fish growth. One of the most commonly used protein sources in fish feed is fishmeal. Fishmeal is made from whole fish or fish trimmings that are cooked, pressed, and dried. It is highly digestible and contains a balanced profile of essential amino acids. However, due to concerns about overfishing and sustainability, alternative protein sources such as soybean meal and poultry meal are being increasingly used in fish feed formulations. These plant-based protein sources can provide a cost-effective and sustainable alternative to fishmeal. Fish meal, soybean meal, skimmed milk fish meal, legumes and wheat gluten is a great source of protein.

Carbohydrate: Carbohydrates are the least expensive form of food energy for humans and livestock, but their uses in fish vary widely and are still somewhat unclear. Carbohydrates are another important component of fish feed, providing energy for fish metabolism. Common carbohydrate sources in fish feed include corn, wheat, and rice. These ingredients are rich in starch, which is converted into glucose during digestion and used as an energy source. However, it is important to note that fish have a limited ability to digest complex carbohydrates, so the inclusion of carbohydrates in fish feed should be carefully balanced to avoid digestive issues.

Lipids: This group of nutrients includes a number of different compounds. Dietary lipids also provide essential fatty acids that cannot be synthesized by the organism. Lipids, or fats, are essential for fish health and growth. They provide a concentrated source of energy and are also important for the absorption of fat-soluble vitamins. Fish feed often contains lipid sources such as fish oil, which is rich in omega-3 fatty acids. Omega-3 fatty acids are crucial for fish growth, development, and overall health. However, the sustainability of fish oil has become a concern, leading to the exploration of alternative lipid sources such as vegetable oils and algal oil.

Vitamins and minerals: Vitamins and minerals are micronutrients that play a vital role in fish health and metabolism. Fish feed formulations are typically fortified with a range of vitamins and minerals to ensure that the nutritional needs of the fish are met. These include vitamins such as vitamin A, vitamin D, and vitamin E, as well as minerals like calcium, phosphorus, and zinc. The inclusion of these micronutrients in fish feed helps to support immune function, bone development, and overall growth. Pre-mixed vitamin blends are available and can be added to prepared diets so that fish receive adequate amounts of the vitamins, regardless of feed ingredient content. They help maintain proper metabolic processes, enzyme function, and hormone regulation.

Pigments: Pigment or Carotenoids in Fish feed serve Multiple roles. They enhance the natural colors of the fish, giving it a vibrant and attractive appearance. Pigments also contribute to the health of the skin and scales of fish, protecting them from damage and maintaining their general condition. In addition, these pigments act as visual lures to mate and keep predators away. Some pigments, such as astaxanthin, provide nutritional benefits and support immune function. The inclusion of colorants in fish food depends on the specific needs of the fish being fed.

Fiber and ash: Fiber and ash are a group of mixed materials found in most fish feed

1. Fiber: Fiber in fish feed aids in digestion and promotes gut health. It provides bulk to the diet, helping to regulate the fish's digestive system and prevent issues such as constipation. Fiber also promotes the growth of beneficial gut bacteria, which can improve nutrient absorption and overall digestive efficiency.

2. Ash: Ash in fish feed refers to the mineral content of the feed, which includes essential minerals like calcium, phosphorus, magnesium, and trace elements. These minerals are necessary for various physiological functions in fish, including bone development, muscle contraction, and enzyme activity. Ash also helps maintain the acid-base balance in the fish's body.

Role of probiotics in aquaculture:

Probiotics play a crucial role in fish feed by promoting a healthy gut microbiome in fish. Here are some key roles of probiotics in fish feed:

1. Improve digestion by helping break down feed components, making them more easily digestible for fish.
2. Enhanced Disease Resistance: Probiotics can compete with harmful bacteria in the gut, preventing their colonization and reducing the risk of infections.
3. Detoxification: Certain strains of probiotics have the ability to bind and detoxify harmful substances, such as ammonia and nitrites, in the gut.
4. Water quality improvement: Probiotics can contribute to the maintenance of a healthy microbial balance in the fish's environment. This can help improve water quality by reducing the accumulation of harmful bacteria and the production of toxic metabolites.

Some common conventional feedstuffs

Groundnut cake: This one contains about 45% crude protein but lacks the essential amino acid lysine. When mouldy, it becomes toxic due to the presence of a mycotoxin called 'aflatoxins'.

Soybean meal: This dish is rapidly gaining popularity. It has a balanced amino acid profile and can Substitute a significant portion of fishmeal.

Palm kernel powder: It contains quite a high amount of Crude Fiber. Crude protein is 17%. Palm kernel powder is Useful only when its crude Fiber content is high.

Dry yeast: It is a by-product of the brewing process Industry. It contains enough crude protein but restricts the amino acids methionine and cystine.

Dried beer beans: This is available and contains Protein levels similar to palm kernel meal.

Crude fiber: The content is so high that its use is limited. But It is delicious and contains no anti-nutritional factors. Its energy content is high. This limits its use in fish feed.

Wheat offal: Nutritional properties of wheat offal are Similar to palm kernel powder. Both can be used Interchangeably but hardly together. Wheat offal is very Rare due to unfavorable government policies.

Fish meal: Fish food can hardly be prepared without fishmeal. In addition to high protein content, fishmeal also works as a food Attractive. Fishmeal produced from waste Obtained from fishing or fish waste from canning Industry. Protein ratio depends on the source Fish products and methods used to produce fishmeal.

Unconventional fish feed:

Unconventional fish feed refers to alternative or non-traditional types of feed that are not commonly used in the aquaculture or aquarium industry. These feeds are typically derived from unconventional sources and may offer unique nutritional profiles or environmental benefits. Some examples of unconventional fish feed include:

Animals source: This is the food of all living things, not human for example: Insect Meal, tadpole Meal, fly larvae, earthworm meal, toad meal, shrimp waste, Crab meal and animal waste such as pork and blood meal. These animal-based ingredients are commonly used in fish feed due to their nutritional value and their ability to enhance fish growth, development, and overall health.

a) Insect meal: Insects are the most diverse group of animals and a natural food Source of fish, especially carnivorous and omnivorous fish, as these are Fish species require relatively high amounts of protein in their diets. The production of insect powder increased rapidly in China, Europe, North America, Australia and Southeast Asian countries. It involves using insects, such as black soldier fly larvae or mealworms, as a nutritious and long-lasting ingredient. Insect meal has high protein, amino acid and fat content, so it can replace traditional ingredients of animal origin such as fish meal. It has shown promising results in promoting fish growth and health. The use of insect meal in fish feed is gaining increasing attention as a more sustainable and eco-friendly aquaculture option.5)

b) Earthworm meal (Lumbricusterrestris): They are terrestrial scavengers Towards oligochaetes. They live underground and feed Rotting leaves and other organic matter, though Disappeared like an insect caste. In other words, they convert organic matter Material on the ground. Earthworm meal is sometimes used as a source of protein in fish feed. Earthworms are rich in protein, amino acids and minerals, making them a potential ingredient in fish feed formulations.

c) Blood meal: Made from dried animal blood, it is a great source of protein and essential nutrients. Blood meal can be used as a protein supplement in fish feed to promote growth and provide essential nutrients. However, it is important to ensure that the blood meal used in fish feed is from safe animals and is handled properly to maintain quality and avoid the risk.

Plant sources: Leaf proteins, leaf meal, aquatic plants, and legumes that can be grown. Such as mucuna beans, yam beans, bread beans, wing beans or any ornamental legume that can produce seeded fruit.

Leaf protein: Leaves are abundant in the tropics and grow freely without cultivation. They all contain different levels protein, which can create an inexhaustible supply and inexpensive source of nutrition for fish. The leaves of cassava (*Manihot esculenta*), papaya (*Carica papaya*), pineapple (*Ananas comosus*), peanuts (*Arachis hypogea*), soybean/soybean (*Glycine max*) and banana (*Musa paradisica*) are great source of leaf protein for fish feed. Some techniques have been evolved to extract protein from leaves.

Aquatic macrophytes: They are common aquatic plants found growing on the surface of the water. Including: comes from flowering plants such as grass and common sedge visible along the edges of freshwater bodies; rotten flower plants with submerged leaves such as ceratophyllum, and floating leaves like water lilies (nymphaea); free float Crops such as duckweed, lettuce, water hyacinth and Salvinia, an aquatic fern. These plants are rich in proteins, carbohydrates, and minerals, and can serve as a sustainable and cost-effective source of nutrients for fish. However, the use of aquatic macrophytes in commercial fish feed is still in the experimental stage.

Unconventional pulses: A series of pulses used as Cover crops or ornamental plants. They are not eaten for a reason. Suspected toxic substance content. For example, mucuna beans, broad beans, sword beans, wing beans, yam beans etc. Their protein content varies from 18 to 20%, fat content from 3 to 10% and Carbohydrates 50-60%, making them easily gelatinized.

Preparation of fish feed formulation:

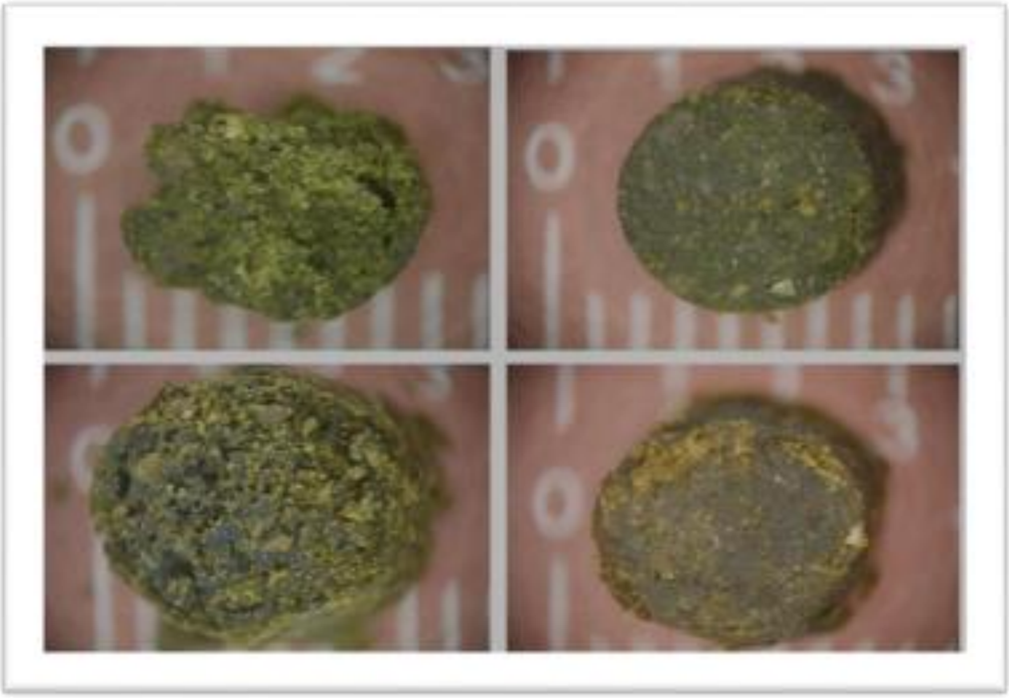
Formulated feeds are with ultimate moisture 6-10% content; semi-moist with 35-40% water; or wet with 50-70% water. The most used food production systems or in commercialized home aquariums produced as dry food. Dry food can include simple types: bulk mixture of dry ingredients, such as flour or coarse flour, to more complex pellets or pellets. the pellets are often broken down into smaller pieces called "crumbs". the pellets or pellets can be made by steaming or by extrusion. Depending on the fish's food needs pellets can be made to sink or float. Flakes are another form of dry food and a popular diet for aquarium fishes. The scales are made up of a complex mixture of ingredients, including colorants. These are turned into a paste Baked and rolled on a steam-heated drum. Semi-moist and moist foods made from Ingredients, such as trash fish or cooked beans, and may Shaped like a cake or a ball. There is no single method to prepare recipe fish food; however, most methods begin with the formation of a powder as a mixture of ingredients. The ingredients can be obtained from pet food stores, grocery stores, pharmacies and specialty stores such as health food stores, as well as various companies can be found on the Internet.

Fish feed manufacturing process, which includes several steps, such as:

1. Nutritional requirements: The first step in fish feed formulation is to determine the nutritional needs of the target fish species at different life stages. This involves understanding the necessary levels of proteins, carbohydrates, fats, vitamins and minerals required for their growth and development. Nutrition research and research plays an important role in establishing these needs.

2. Selection of ingredients: Once nutritional needs are identified, a variety of ingredients are selected to create a balanced food formulation. The choice of ingredients depends on factors such as availability, cost, nutritional composition and durability.

3. Feed production: In this process, a mixture of raw materials (called grinding) is compressed through the machine's barrel extruder, while heat and steam are fed into the mill as it passes the length of the barrel by a rotating screw. At the end of in the extruder, the crushed mixture is pushed out through a small hole called the die. The whole process takes place at high temperature conditions where the moisture content of the internal milled mixture is between 15 and 45%. At the exit of the die, the extruder undergoes a sudden process pressure is then reduced, causing rapid moisture loss and volume expansion. The method of construction and extrusion of food has a profound effect on the appearance of food, based on cross sectional photographs. Conventional food exhibits a coarse, porous texture with larger holes. Adding Wheat flour to the mash makes Conventional foods more porous in terms of texture and has a larger cross-section, suggesting that the addition of a binder such as Wheat flour stimulated further expansion during extrusion. On the other hand, new food has a smooth texture with smaller pores and a smaller cross-sectional area, and the addition of wheat flour did not cause significant changes in the feed texture or cross-sectional.



Cross section of fresh (extruded) food. LEFT: By conventional extrusion; RIGHT: By new extrusion; High: Milled without flour; Down: from Mashed with wheat flour.

Current trends in fish feed technology

Current trends in fish feed technology focus on improving the sustainability, nutrition and overall performance of aquaculture operations. It includes:

1. Sustainable ingredients: There is increasing emphasis on the use of sustainable and alternative ingredients in fish feed formulations. This trend aims to reduce the environmental impact of fish feed production and promote the sustainability of aquaculture.

2. Function streams: Supplements are designed to provide additional benefits beyond basic nutrition. These feeds may include additives such as probiotics, prebiotics, immunostimulants and enzymes that support fish health, immune function and resistance. Functional feeds are gaining popularity as they offer potential improvements in fish performance and overall farm productivity.

3. Precision Feeding: This method uses advanced technologies such as underwater cameras, sensors and automatic feeding systems to monitor fish behavior, growth and food consumption in real time. Precise feeding will optimize feed efficiency, reduce waste and improve overall fish health and performance

4. Nutrigenomic: Nutrigenomics has the potential to revolutionize fish feeding technology by providing a deeper understanding of how different nutrients affect fish metabolism and performance. Nutrigenomics is the study of how nutrients and food ingredients interact with an organism's genes and influence its physiological responses. Nutrigenomics is the study of how nutrients and food ingredients interact with an organism's genes and influence its physiological responses.

5. Food additives for disease prevention: With the increasing incidence of diseases in aquaculture, there is growing interest in developing feed additives that can help prevent or minimize disease outbreaks. These additives may include antimicrobial peptides, natural immune boosters, and plant extracts with antibacterial properties. Incorporating such additives into fish feed can improve disease resistance and reduce the need for antibiotics or other chemical treatments. (10).

6. Innovations in animal feed processing: Advances in feed technology are aimed at improving feed quality, pellet strength and nutrient digestibility. Innovations include extrusion technology, which improves feed digestibility and nutrient bioavailability, as well as new pellet coating techniques to improve feed stability and reduce nutrient leakage. Nutrients into the water. These processing innovations contribute to improved food performance and reduced environmental impact.

Conclusion:

Fish feed technology has undergone significant advancements, transformed the aquaculture industry and offering a range of benefits. One major development is the shift towards alternative protein sources, such as insect-based protein, plant-based ingredients, and single-cell protein sources. This move has reduced the industry's reliance on fishmeal, a resource-intensive and unsustainable feed ingredient. In addition to alternative protein sources, advancements in nutrient encapsulation techniques and precision nutrition have improved the availability and utilization of nutrients in fish feeds. Looking ahead, the future of fish feed technology holds great promises. Continued research and innovation will further improve the nutritional value, digestibility and environmental impact of fish feed.

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AQUACULTURE FARMING OF CARP AND SALMON: A REVIEW

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Abstract:

Aquaculture, the controlled cultivation of aquatic organisms, plays a pivotal role in meeting the growing global demand for seafood. Among the myriad of species farmed, salmon and carp stand out as two of the most economically significant and widely cultivated fish worldwide. This chapter provides a comprehensive analysis of the current state of aquaculture farming practices for salmon (*Salmo salar*) and carp (*Cyprinus carpio*), highlighting key advancements, challenges, and environmental considerations.

The first section of the chapter explores the aquaculture of salmon, focusing on various aspects such as breeding and genetics, nutrition, disease management, and sustainable farming practices. It delves into the development of selective breeding programs to enhance growth and disease resistance, advances in feed formulations to optimize nutrition and minimize environmental impact, and the ongoing efforts to combat prevalent diseases like Infectious Salmon Anemia (ISA). The second section turns its attention to carp farming, discussing the historical significance of carp in aquaculture, strategies for improving their growth and quality, and the role of carp in food security, particularly in Asia. Furthermore, the chapter addresses environmental concerns associated with both salmon and carp aquaculture, including the impact on water quality, escapes from farms, and the use of antibiotics and chemicals. Throughout the chapter, a comparative analysis between the two species offers valuable insights into the diverse challenges and opportunities within the aquaculture industry, aiming to inform future research directions and sustainable practices for the production of these important food resources.

Keywords: Aquaculture, Aquafarming, Salmon, Carp, Fishery, Feed, Production

Introduction:

Aquaculture, the practice of cultivating aquatic organisms, has emerged as a critical solution to address the burgeoning global demand for seafood while alleviating pressures on wild fish populations and promoting food security. Among the numerous species raised in aquaculture systems, salmon (*Salmo salar*) has ascended to a position of paramount importance. Renowned for its exquisite taste, nutritional value, and marketability, salmon aquaculture has witnessed remarkable growth and innovation over the past few decades. This chapter embarks on a comprehensive exploration of the multifaceted world of salmon aquaculture, aiming to provide an insightful overview of the current state of the industry, its key challenges, recent advancements, and the pivotal role it plays in shaping the global seafood landscape.

Salmon aquaculture has undergone a remarkable transformation from its humble beginnings as a small-scale endeavor to the modern, highly mechanized and technologically advanced industry it represents today. The industry's evolution has been driven by a relentless quest to meet the rising consumer demand for salmon, a fish species renowned for its exceptional flavor and health benefits due to its high omega-3 fatty acid content. Consequently, salmon farming has become a global enterprise, with operations spanning various geographic regions, from the rugged coastlines of Norway and Scotland to the pristine fjords of Chile and the remote reaches of Alaska. This geographical diversity not only underscores the adaptability of salmon farming but also underscores the need to address region-specific challenges and opportunities.

The controlled cultivation of aquatic organisms has emerged as a cornerstone of global food production, offering sustainable solutions to address the ever-increasing demand for protein-rich seafood. Within this expansive field, carp (*Cyprinus carpio*) stands as an enduring and historically significant species. Revered for its versatility, adaptability, and cultural significance in various regions around the world, carp aquaculture holds a unique position in the realm of fish farming. This chapter embarks on a comprehensive exploration of the intricate world of carp aquaculture, aiming to provide a comprehensive overview of the current state of the industry, its historical evolution, key challenges, recent innovations, and its critical role in bolstering global food security. Carp, with its diverse subspecies and wide-ranging habitat preferences, has a storied history in aquaculture that spans centuries. Its journey from the ancient fish ponds of Asia to modern, scientifically-managed farms is emblematic of the sector's enduring adaptability and resilience. Carp aquaculture has been instrumental in supporting livelihoods, especially in regions where it is a dietary staple, contributing significantly to local economies and food security. Moreover, the versatility of carp as a hardy fish that thrives in varied environmental conditions has made it a symbol of hope for resource-poor communities seeking to harness the potential of aquaculture. While carp aquaculture has enjoyed considerable success, it also faces a myriad of challenges, from improving growth rates and disease management to addressing environmental concerns associated with farming practices. This review paper delves into these facets, illuminating the nuanced landscape of carp aquaculture and offering insights into the promising avenues and critical considerations that lie ahead for this iconic fish species.

Breeding and fish feed for carp:

There is the necessity for addressing the low genetic quality of common carp through meticulous breeding programs. Various approaches, such as selection, hybridization, and genetic manipulation, have been employed to enhance the characteristics of common carp, resulting in the development of superior varieties like Super RD carp, Mustika carp, Mantap carp, Jayasakti carp, Marwana carp, and Najawa carp. These breeds exhibit advantages such as rapid growth, disease resistance, and efficient feed conversion ratios, contributing to higher productivity and reduced waste in aquaculture. The use of superior breeding programs leads to improved feed efficiency, reducing the amount of uneaten feed and organic waste in the water. The research demonstrates that these superior carp varieties, developed through breeding programs, can significantly mitigate the environmental repercussions associated with conventional carp farming, promoting sustainability in aquaculture.

Approach for carp aquafarming:

The excerpt underscores the importance of genetic improvement through breeding programs in common carp aquaculture and sheds light on the environmental consequences of inefficient feed utilization. It highlights the benefits of utilizing superior breeding carp, which not only enhance productivity but also reduce waste, contributing to the sustainable and environmentally responsible development of carp aquaculture practices (Ariyanto, 2022).

The excerpt discusses the "typical farm approach" employed in aquaculture research to create empirically grounded virtual farm datasets for economic analysis. This methodology involves close collaboration between practitioners and researchers, resulting in comprehensive datasets containing up to 243 economic variables. These variables allow for high-resolution microeconomic analysis and serve as indicators of data quality. The approach relies on diverse sources for pre-defining selected cases, with the validation of these characteristics being empirical. Focus groups with fish farmers play a crucial role in defining the economics of typical farms, ensuring a coherent picture. These typical farm models are used for various economic analyses, including profit and loss accounts, profitability assessments, sensitivity analyses, and productivity evaluations.

Furthermore, the typical farm approach classifies farms based on stability in characteristics and adequate profitability, representing a group of farms using a common production method. These farm models are built upon real costs, investments, and prices and integrate resources, labor, and capital. The data collection process involves focus groups with fish farmers and aims to create consensus among participants to define farm characteristics. The defined variables in the models are cross-referenced, ensuring coherence, and the models are validated by both fish farmers and researchers. Each modeled farm is assigned a unique code representing its country, species, and annual production, facilitating reference and analysis. The approach considers various economic indicators, including productivity, variable and fixed costs, wages, depreciation, opportunity costs, and profitability, ultimately leading to comprehensive economic analyses of carp farming practices (Lasner Tobias, 2020).

Integrated fish farming:

Integrated fish farming involves cultivating multiple compatible animal and plant components alongside fish to efficiently recycle nutrients and enhance yields. Specific components are chosen based on regional significance, such as fish-cum-pig farming in North Eastern States and rice-fish farming in West Bengal and Assam. This holistic approach supports ecosystem health, benefits small household ponds in rural areas, generates income, ensures nutrition security for small farmers, and creates employment opportunities.

Different systems of farming:

Wastewater-fed aquaculture:

Wastewater-fed aquaculture is a practice dating back to the 1930s, mainly observed in West Bengal. Research has focused on characterizing sewage and optimizing fish production potential in sewage-fed ponds. Sewage in paddy-cum-fish farming has enhanced rice production and allowed for 0.5-1.2 t/ha of fish harvest. This method also aids in sewage treatment.

Cage and pen culture:

Cage and pen culture is gaining popularity in open waters for rearing seed for stocking and farming large fish. ICAR-CIFRI has played a pivotal role in standardizing this technology. States like Chhattisgarh, Odisha, Bihar, and Maharashtra have adopted cage farming, achieving high production levels of 3-5 tons per cage. These practices are vital for increasing production from open waters, driven by government support.

Modern farming practices - Biofloc-based farming:

Biofloc-based farming is a sustainable intensification technique using heterotrophic microflora and C-N ratio manipulation. It's relatively new in India but gaining interest, especially among youth. It's applied to both freshwater and brackishwater systems with various species. ICAR-CIBA has standardized the technology. While promising for production, species like tilapia and striped catfish face lower market values, affecting profit margins.

Modern farming practices - In-Pond Raceway System (IPRS):

The In-Pond Raceway System (IPRS) is designed to increase fish production with reduced environmental impact. Developed in the USA, IPRS concentrates fed fish in cells within a pond, ensuring optimal water quality and feed management. Challenges include disease outbreaks due to higher densities but offer effective disease management. High stocking density in IPRS has demonstrated improved fish production, with yields up to 150 kg/m^3 per year (Das, 2022).

Impacts of salmon aquaculture:

The production of farmed Atlantic salmon involves two main phases: a freshwater phase for producing juveniles (smolts) and a marine grow-out phase. During the freshwater phase, smolts are raised from eggs, either in land-based hatcheries or transferred to outdoor tanks. In the marine phase, smolts are transferred to net pens or sea cages in nearshore coastal waters, where they are grown to harvestable size. These marine aquaculture operations are typically located in sheltered coastal areas, including estuaries, salt marshes, and mud flats. Estuaries, known for their high biological productivity, support various commercial species like clams, oysters, lobsters, salmon, and more, making them ecologically significant. However, salmon aquaculture activities in these areas can potentially interact with the environment and its wildlife.

Net pens or sea cages used in salmon aquaculture occupy space in the water column and vary in size. They can attract and deter wildlife due to the presence of fish and uneaten feed. These structures may provide shelter for some benthic animals while acting as physical or olfactory barriers for others. The exact impact of net pen structures on wildlife varies based on factors such as farm size, age, and structure, salmon species, proximity to wildlife concentrations, and site management practices. While there are limited studies and reports on the direct impact of net pen structures on wildlife, incidents like bird entanglement have been documented. Additionally, there are concerns that the physical barriers created by net pens could alter the migratory behavior of pelagic fishes, birds, or marine mammals, potentially affecting local fisheries. However, more comprehensive research is needed to assess the extent and significance of these interactions and impacts on the environment (Milewski).

Salmon production:

The shift from ocean-based salmon aquaculture to land-based tanks, using Recirculating Aquaculture Systems (RAS), represents a significant transformation in the industry. RAS technology allows for a more controlled and secure environment compared to open net pens, reducing vulnerabilities to issues like sea lice, diseases, escapes, and extreme weather events. This controlled environment leads to consistent and faster salmon growth, which can potentially improve capital turnover. However, it also introduces higher operational costs, as the ecosystem services provided by the ocean must now be managed on land. To address these challenges, companies are planning large-scale land-based production systems globally.

Despite the advantages, land-based infrastructure is not without risks. The complexity of these systems makes them more vulnerable to disasters, with any deviation from the norm having the potential for catastrophic impacts. Disease outbreaks, referred to as "mass mortality events," can occur within land-based systems. To mitigate these risks, the RAS sector designs infrastructure to prevent diseases and other events from affecting the entire system. This transformation in aquaculture infrastructure is attracting substantial investment from financial actors, private equity funds, and even traditional agrifood corporations, as they seek to meet the growing demand for salmon in a more controlled and sustainable manner. The shift in salmon aquafeed is another critical aspect of the transformation. Terrestrially-based agrifood transnational corporations (TNCs) are entering the aquafeed market, contributing to the reconfiguration of aquafeed infrastructural ecologies. Aquafeed has evolved from a low-value bulk commodity to a high-value, highly processed product, primarily based on terrestrial crops like soy and canola. These TNCs bring expertise in transforming bulk terrestrial commodities into specialized feeds, using technology and packaging to add value. They are also introducing genetically modified oilseeds to substitute for omega-3 fatty acids found in pelagic fish.

This transformation benefits powerful corporate actors while changing the ecological basis of feed from the capture fishery to surplus terrestrial commodities and technologies. The nutritional science and genetic modification capabilities of agrifood corporations play a crucial role in overcoming challenges related to salmon adapting to new diets and maintaining their omega-3 fatty acid content (Martin, 2023).

Effect on environment:

Fish Growth and Survival; Chitwan, Nepal, the growth and survival rates of common carp (*Cyprinus carpio*) and grass carp (*Ctenopharyngodon idella*) fingerlings were investigated in a polyculture system. The research found that common carp exhibited a higher daily weight gain (0.41 g/fry/day) compared to grass carp (0.1 g/fry/day). The specific growth rate (SGR) of common carp was notably higher at 7.32% per day when fed 2% of their body weight twice a day. This study attributes the relatively lower growth rates of both species to their limited response to the commercial diet used in rearing. Furthermore, the survival rates of common carp and grass carp were 29.71% and 20.21%, respectively. Common carp's higher survival rate may be attributed to grass carp's lower tolerance for dissolved oxygen. Predation and the open system of the rearing pond were also identified as potential factors contributing to fry mortality. The economic analysis indicated a favorable benefit-cost ratio (BC ratio) of 1.43, suggesting that fingerling production in earthen ponds is a profitable venture. Overall, the research highlights the potential for successful fingerling production in the Terai region of Nepal, emphasizing the importance of proper water quality management, predation control, and quality feed for improved fry survival and growth (Balami, 2020).

The presence of common carp in aquatic environments plays a significant role in nutrient turnover and ecosystem dynamics. Common carp, with their specialized feeding behavior, particularly the browsing of benthic macroinvertebrates in sediment, have a profound impact on the aquatic ecosystem. These fish are known for their ability to resuspend bottom sediments during their foraging activities. This resuspension leads to various ecological consequences, such as increased water turbidity, nutrient cycling, and alterations in the abundance of phytoplankton, zooplankton, and benthic macroinvertebrates. One of their primary food sources in sediment is chironomid larvae, which commonly reside several centimeters deep. Common carp employ a unique technique involving digging and sieving of sediments to access this prey. This activity resuspends bottom soil and enhances oxygen availability in the sediment, accelerating the aerobic decomposition of organic matter. As a result, the ecosystem experiences increased nutrient cycling, favoring aerobic decomposition, and stimulating the abiotic and biotic properties of the overlying water column.

Furthermore, common carp contribute to nutrient cycling in aquatic systems through two essential mechanisms. Firstly, they enhance decomposition in the bottom soil by promoting oxygen penetration into the sediment. The disturbance caused by carp bioturbation extends the depth and extent of oxygen diffusion, thereby increasing aerobic conditions and the mineralization of organic matter in the sediment. Secondly, these fish induce decomposition in the water column by exporting organic matter from the bottom soil during resuspension events. This export of organic matter occurs where oxygen concentrations are generally higher. The increased decomposition releases carbon dioxide and contributes to reduced pH and alkalinity in the water. Additionally, resuspension increases the concentration of various nutrients, including nitrate nitrogen, ammonia nitrogen, total nitrogen, phosphate phosphorus, and total phosphorus in the water. Common carp also substantially accelerate the transport of nitrogen and phosphorus from the sediment into the water column through their excretion, further stimulating nutrient availability for phytoplankton. This heightened nutrient presence results in increased phytoplankton biomass, which in turn supports higher zooplankton production rates, creating a complex ecological cascade driven by the activities of common carp in aquatic environments (Rahman, 2015).

Model description of aquaculture:

Two production models were developed to assess the economic viability of salmon aquaculture in the Black Sea. The first model focused on the traditional surface cage system, where salmon weighing 400 grams were purchased and grown for a 7-month production period, from November to May. This practice aligns with the predominant approach in the Black Sea region. The second model introduced a novel approach involving submerged cages that take advantage of the cold deep water during the high-temperature season. This approach extended the production period to a year by temporarily submerging the cages during the warm months. The study aimed to compare the initial investment costs, operational expenses, harvest gains, and net profits between the two production models. Additionally, a "What-if" analysis was conducted to evaluate the economic impact of a 10% variation in the export market for Turkish salmon produced using either the 7-month surface cage system or the year-round submerged system. The analysis indicated that variations in sale price had the most significant impact on net operating profit, followed by factors such as survival and growth rates, while the initial fish stock cost had the lowest influence on net profit.

Several assumptions were made to standardize parameters used in the study. Economic variables, production variables (such as fish stocking and feeding), water temperature, environmental factors, fish stocking size and density, feeding management, feed quality, cage net biofouling occurrence, and hydrodynamic conditions were assumed to be equal for both surface and submerged cage models. However, the key difference lay in the production period, with the surface cage model limited to the 7-month period matching the traditional farming season in the Black Sea, while the submerged cage model extended production to a full year by utilizing the cold deep water during the warm months. These assumptions were made to provide a fair basis for comparing the two production systems and assessing their economic feasibility for salmon farming in the region (Ümüt Yigit, 2023).

Ireland atlantic salmon:

The research focused on several key regions and utilized control populations for comparison. In the case of sea trout in Ireland, the study compared rod catches in Ireland's Western Region to rod and in-river fixed engine catches in Wales, covering the years 1985 to 2001. While salmon farming was concentrated in Ireland's Western Region, no fixed engine fisheries targeting sea trout were present in Ireland. Sixteen rivers in Western Ireland were considered exposed to salmon farming, while 32 Welsh rivers served as control populations. The impact of salmon farming, mainly in the Connemara area, on sea trout populations was assessed.

In Scotland, the study investigated the impact of salmon farming on Atlantic salmon populations, comparing the east and west coasts. Salmon farms were predominantly located in bays on the west coast, affecting all salmon populations in rivers on this coast. In contrast, there was no salmon farming on the east coast, making east coast salmon populations the control group. The analysis considered total catch data from 1971 to 2004 for both marine and rod catches, with a focus on modeling returns to assess the influence of salmon farming.

Additionally, incorporated data on Atlantic salmon populations in Scotland, including counts of salmon returning to rivers from 1960 to 2001. Two exposed populations, Awe Barrage and Morar River, were assessed, as well as ten control populations on the east coast of Scotland. Farmed salmon production data for all of Scotland were used in the analysis, with proportions allocated to specific bays based on farm locations. The study aimed to determine the potential impact of salmon farming on salmon survival and returns in different regions (Ford, 2008).

Production scale in Norway:

The salmon farming industry in Norway has experienced significant growth and intensification over the years. Between 1980 and 2012, salmon production in Norway has skyrocketed from 7,800 tons to an anticipated 1.2 million tons. This remarkable expansion is primarily attributed to increased production intensity per license, although the industry has also seen the issuance of new licenses. Salmon farming in Norway is regulated by licenses that specify the production location and impose limits on production capacity. Until 2002, these limits were typically based on pen size, but since 2004, Maximum Allowable Biomass (MTB) has become the key production constraint. Furthermore, until 1992, regional policy restrictions restricted ownership, which contributed to the dominance of non-Norwegian companies in the early years of the industry. However, the removal of ownership constraints in 1992 led to mergers, acquisitions, and significant growth in the industry, with some companies listing on the Norwegian stock exchange.

The increase in production intensity has also been facilitated by technological advancements and innovations in the salmon farming industry. This includes improvements in fish health management through vaccines, accelerated growth rates due to selective breeding programs, and enhanced feed formulations, significantly reducing the time required for salmon to reach harvest size. The larger-scale pens and farms have become more common in Norway, and the average production per license has surged from 26 tons in 1980 to 1,130 tons in 2010, marking a substantial increase in production efficiency. Nevertheless, the continued expansion of farm size is constrained by environmental considerations, technical challenges in building and managing larger pens, and concerns related to the interaction between farmed and wild salmon populations, particularly concerning sea lice infestations. While Norway has witnessed tremendous growth and intensification in salmon farming, other salmon-producing countries have also played significant roles in the industry's development, with variations in farm sizes and regulatory dynamics over the years (Asche, 2013).

Fish health and processing:

The processing of farmed salmon involves several key steps to prepare the fish for market. Prior to harvest, salmon are subjected to a five-day fasting period to empty their gut, reduce fat content, and firm their flesh. Harvesting methods typically involve collecting the fish in baskets or using fish pumps to transfer them from net cages. The fish are then humanely killed, often by tranquilization with carbon dioxide or salt brine, followed by bleeding through a cut near the gill arch. It's worth noting that in Chile, only a small percentage (12%) of processors treat their discharge water, which contains blood and other byproducts from processing.

Farmed salmon are primarily sold fresh with their heads intact and are typically shipped on ice in Styrofoam boxes weighing approximately 27 kilograms (60 pounds). These boxes may also include ice or gel packs to maintain proper temperature during transport. Salmon are graded based on factors such as texture, color, and oil content, following industry grading standards. The processing of salmon can occur near the farms or at larger distribution centers. Larger salmon producers often have their own processing plants, while smaller producers may rely on larger companies' processing facilities. Processors have the capability to trace salmon back to specific farms and, in many cases, specific net cages. Additionally, the salmon processing industry has developed value-added products, including boneless and skinless fillets, salmon burgers, premarinated steaks, precooked portions, and breaded steaks, although the production of these products can be challenging due to the difficulty of stabilizing salmon flesh, which can lead to high costs for new frozen brand products at retail. Salmon health is a critical concern in the aquaculture industry, as diseases can significantly impact fish populations. Salmon can suffer from various diseases caused by parasites, bacteria, and viruses. Some of the major salmon health concerns include sea lice infestations, bacterial kidney disease (BKD), infectious salmon anemia (ISA), enteric redmouth disease (ERD), coldwater disease (CWD), vibriosis, infectious pancreatic necrosis (IPN), salmon swim bladder sarcoma virus (SSSV), and more. These diseases can affect both farmed and wild salmon populations, and their management involves various strategies, including vaccines, surface disinfection of eggs, and treatments. The interaction between farmed and wild salmon, coupled with the challenges of containing diseases in net-cage rearing environments, presents ongoing concerns in the industry (Bostick, 2005).

Farm management and use of chemicals:

The use of chemicals in carp and shrimp aquaculture in several Asian countries was examined through surveys, revealing some key findings. Lime and fertilizers were the most commonly used chemicals, primarily for soil and water treatment and pond fertility enhancement in both carp and shrimp farming. These chemicals were considered to pose limited environmental and public health risks. Piscicides, such as rotenone and teaseed cake, were the second most common class of compounds used after water and soil treatments. While they were used for predator control, some of these chemicals had the potential to pose local environmental and health risks if not used carefully. Disease control chemical usage was relatively low in these countries, with less than 5% of farmers using antimicrobial compounds. The expenditures on these chemicals were generally low, representing less than 1% of production costs, indicating that chemical usage in aquaculture was limited and cost-effective.

In shrimp farming, the use of chemicals increased with the intensity of farming, and antimicrobial compounds were more commonly used compared to carp culture. Nevertheless, the use of these chemicals was still relatively low. The survey data suggested that farmers faced challenges in effectively controlling diseases in both carp and shrimp farming systems, highlighting the need for improved health management strategies at the farm level. Overall, while there were some concerns about the use of certain chemicals, the limited chemical usage in Asian aquaculture systems reduced the likelihood of adverse environmental and health impacts, and alternative approaches to reduce chemical dependency were recommended and worth exploring further (Phillips)

Characteristics of fish farmers to be selected:

The study examined various characteristics of fish farmers in the surveyed area. It found that the majority of fish farmers were middle-aged, indicating that younger individuals were actively involved in fish farming. The education level of these farmers varied, with most having completed secondary education, and even some graduates were participating in fish aquaculture. Family size was generally small to medium, with a limited number of large families. Pond size among the farmers varied, with slightly more than half having medium-sized ponds. Additionally, the majority of fish farmers had medium to high income, reflecting the profitability of fish farming in the region.

Furthermore, the fish farmers in the study area had significant experience in fish farming, with over three-fifths having medium experience. Cosmopoliteness, which refers to engagement in development activities, was primarily low to medium among the respondents. Extension contact, which plays a vital role in technology adoption, was mostly low to medium. Lastly, fish farming knowledge was generally good among the farmers, with a majority possessing good to excellent knowledge, although there was a deficiency in scientific fish farming knowledge due to factors such as limited education and communication barriers. These findings provide insights into the demographics and characteristics of fish farmers in the surveyed area, highlighting their diverse backgrounds and levels of experience and knowledge in fish farming (Goswami, 2020).

Global antimicrobial consumption in aquaculture is projected to increase by 33% between 2017 and 2030, largely influenced by the expansion of aquaculture in Asia, especially in China. This rapid growth in antimicrobial use is of significant concern as the most commonly used antimicrobial classes in aquaculture are also classified by the World Health Organization as important for human medicine. Classes classified as highly important and critically important antimicrobials for human medicine collectively represented 96% of all use in aquaculture. This raises the risk of antimicrobial use in aquaculture contributing to the development of antimicrobial resistance in aquatic environments, with potential implications for public health, especially in areas relying on untreated water sources and consuming raw fisheries products. Strategies to reduce antimicrobial use and explore alternative approaches, such as bacteriophage therapy, pre- and probiotics, and genome editing, are crucial for the sustainable development of aquaculture, particularly in low- and middle-income countries. Salmon, despite being a significant species in aquaculture, accounted for the lowest antimicrobial use among various species groups. This difference in antimicrobial consumption could be attributed to the well-structured commercial salmon production industry that benefits from vaccines for disease prevention. Some countries have successfully reduced antimicrobial use rates in aquaculture by introducing vaccination and improving management practices. These success stories serve as models for antimicrobial stewardship in aquaculture. Future strategies should focus on finding economically sustainable solutions, especially in low- and middle-income countries, to minimize the reliance on antimicrobials and promote responsible aquaculture practices (Schar, 2020).

Aquaculture prospects in Bangladesh:

The study was conducted in Bangladesh, focusing on four key aquaculture centers: Mymensingh, Rajshahi, Jashore, and Cumilla. These districts were chosen due to their favorable meteorological conditions and geographical suitability for fish production. Data collection took place over a period of six months, from January to June 2021. To gather information, a structured questionnaire was developed, covering various aspects related to commercial fish farming, including the use of probiotics. A total of 200 commercial fish farms were visited, with 50 farms surveyed in each of the four selected regions. Data collection involved a combination of primary and secondary sources. Primary data were obtained through questionnaire interviews and participatory rural appraisal (PRA) tools such as cross-check interviews, focus group discussions (FGD), and large group discussions (LGD) involving fish farmers and fish medicine shop personnel. Secondary information was collected from government officials, including district fisheries officers and local extension agents, as well as representatives from pharmaceutical companies. Additionally, secondary data were sourced from journals, theses, reports, government documents, and other relevant literature. The collected data were processed and analyzed using Excel 2010, and the findings were presented through text, tables, and graphical representations to facilitate comprehension and interpretation in line with the study's objectives (Hossain, 2023).

Conclusion:

Breeding programs have been instrumental in enhancing the genetic quality of common carp, leading to the development of superior varieties that promote sustainability and efficiency in aquaculture practices. Additionally, the excerpts shed light on innovative farming practices such as integrated fish farming and modern techniques like biofloc-based farming and the In-Pond Raceway System, which aim to improve production while minimizing environmental impacts. The impact of salmon aquaculture, both in terms of traditional net pen systems and the emerging land-based Recirculating Aquaculture Systems (RAS), is discussed, emphasizing the need to balance production growth with environmental sustainability. Furthermore, the use of chemicals in aquaculture is examined, highlighting the importance of responsible chemical usage and exploring alternatives to mitigate environmental and health risks. Lastly, the demographic characteristics of fish farmers in specific regions provide valuable insights into the diversity of individuals engaged in aquaculture and their varying levels of experience and knowledge. Overall, these excerpts underline the evolving landscape of aquaculture, emphasizing the importance of responsible practices, innovation, and sustainable management to meet the growing demand for seafood while minimizing negative environmental and health impacts.

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CORAL REEF: AN IMPORTANT ECOSYSTEM OF THE MARINE ENVIRONMENT

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Abstract:

About 71% of the earth's surface is covered by the aquatic environment and the remaining part is the terrestrial environment. Such a vast aquatic environment includes a wide variety of species and their ecosystems. A geographical area in which animals, plants, and other forms of life, weather, and landscape come together to form a bubble of life is called an ecosystem. The livelihoods of more than 500 million people depend directly or indirectly on coral reefs, making coral reefs the most diverse group of ecosystems. Coral reefs serve the same introductory laws as other ecosystems but are viewed as an end member of a continuum due to their structural complexity and high internal cycling. Coral reefs are the most ecologically diverse ecosystems in the world, and they serve as genetic repositories and breeding grounds for marine organisms, supporting an incredible diversity of life and contributing significantly to world biodiversity. But now the coral reef is facing various problems due to rising sea temperatures, pollution, overfishing, and ocean acidification. Therefore, this book chapter explores the complex web of coral reefs, the description of their ecological importance, the difficulties they face in the modern era, and the methods used to protect them.

Keywords: Coral Reef, Environment, Ecosystem, Diversity, Livelihood

Introduction:

Coral reefs are known as the rainforests of the ocean and are the most diverse group of ecosystems. Apart from this, it provides support to the ecosystem. Most of the islands, tropical and sub-tropical countries have extensive coral reefs which directly or indirectly support the economic condition of that country. Coral reef functioning focuses on eight interacting ecological processes: calcium carbonate production and bioerosion, primary producers and herbivores, secondary producers and prey, and nutrient uptake and release. Corals secrete calcium carbonate skeletons that accumulate over time to form a three-dimensional matrix known as a reef, which serves as a habitat for many fish species and other species. Many warm-water coral reefs produce limestone-like calcium carbonate in sufficient quantities to form carbonate structures. High rates of calcification can reduce significant rates of bio-erosion and wave-driven physical erosion. Barrier reefs and islands, which are important to tropical coastlines, are supported by these structures. Tropical coral reef ecosystems support at least 25% of all known marine species, with many reef species still to be identified, although they occupy less than 1% of the ocean floor [1].

Coral reef ecosystems are complex and rich assemblages of species that engage in interactions with each other and their surroundings. Coral belongs to the same group of colonial animals as hydroids, jellyfish, and sea anemones. The foundation of the reef is a type of coral called stony coral, which is distinguished by its hard skeleton. Colonies of stony coral are made up of millions of individuals, living polyps. Polyps have the ability to take dissolved calcium from salt water and convert it into a hard mineral structure (calcium carbonate) that supports their skeleton. Only the thin layer of live coral that is visible on the surface of a coral colony may be seen; the calcium carbonate skeleton, which may be decades old, is present underneath [2].

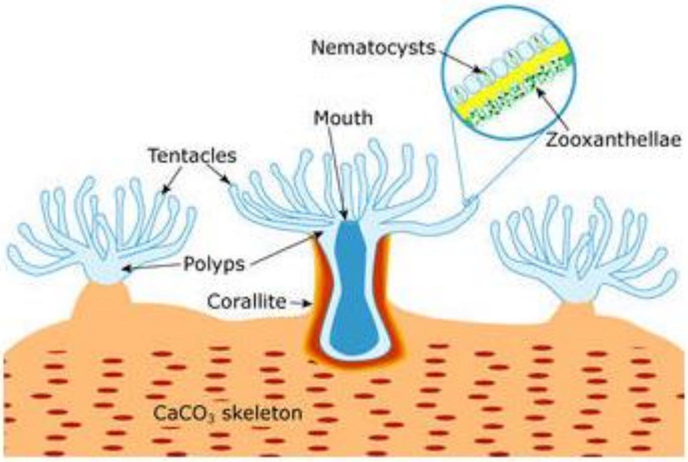

Figure 1: A labeled diagram of coral reef [33]

Definition

A few terms are there that sound similar but are different in meaning, namely coral reefs, corals, hard corals rock corals.

a) **Coral reef:** Large limestone structures known as coral reefs are created by coral animals and other calcareous creatures to create a confined environment that serves as a habitat for marine life [3].

b) **Corals:** The phylum colentereta, the class of anthozoa, and particularly the order scleractinia, which gives rise to both hard and soft corals, are the group of creatures collectively known as corals [4].

c) **Hard corals:** Those are the calcareous types of corals.

d) **Rock corals:** are dead corals in the form of limestone.

Environmental factors affecting the distribution of corals

The corals are typically found between 30 degrees north and 30 degrees south of the equator. Most coral reefs are found in tropical and subtropical nations. Below is a discussion of the variables influencing coral dispersion[5].

- Water temperatures below 20 degrees Celsius are intolerable to corals. Corals can endure water temperatures between 20 and 30 degrees Celsius. Changes of more than 3 degrees from the normal coral temperature might stress the corals. The ideal water temperature for corals is between 23 and 25 degrees Celsius [6, 14].
- Corals require bright water; the ideal intensity for coral growth is 50 to 20 times that of the subsurface. Corals need light for photosynthesis.
- High salinity levels are intolerable to corals. 32 to 35 ppt is the ideal salinity range.
- Between pH 7.5 and 8.5, coral can survive.
- Corals need an adequate concentration of oxygen.
- Corals require specific currents and waves because they can improve nutrition, boost oxygen solubility, and refresh or modify water.
- Since zooxanthellae, which are symbiotic with corals, need water with low solid content, suspended small particles can cover the coral surface and hinder photosynthesis.
- Corals like water with hard bottom substrate, hard substrates are needed to adhere.
- Corals prefer clean water, and pollution can cause them to die.
- Corals require a limited amount of nutrients, but if those nutrients are abundant, phytoplankton will grow quickly and block the passage of light into the ocean.
- Corals do not prefer the presence of high phytoplankton because if it is present, their ability to get enough light will be compromised, and they may even perish [7, 8, 9, 10, and 11].

Note: The name "zooxanthellae" refers to single-celled dinoflagellates that can coexist with a variety of marine invertebrates, such as demosponges, corals, jellyfish, and nudibranchs.

Classification of corals

Depending on the depth of the coral present, corals can be divided into 2 types.

i. **Warm water corals:** Corals can be found up to 200 meters below the surface where sunlight can penetrate. Corals use zooxanthellae for energy during photosynthesis, which requires a higher temperature for growth.

ii. **Cold water corals:** Corals can be found at depths between 200 and 1000 meters. They are unable to perform photosynthesis at temperatures below or equal to 4 to 13 degrees Celsius. They are mostly found in the water in the northeast.

Types of coral reefs

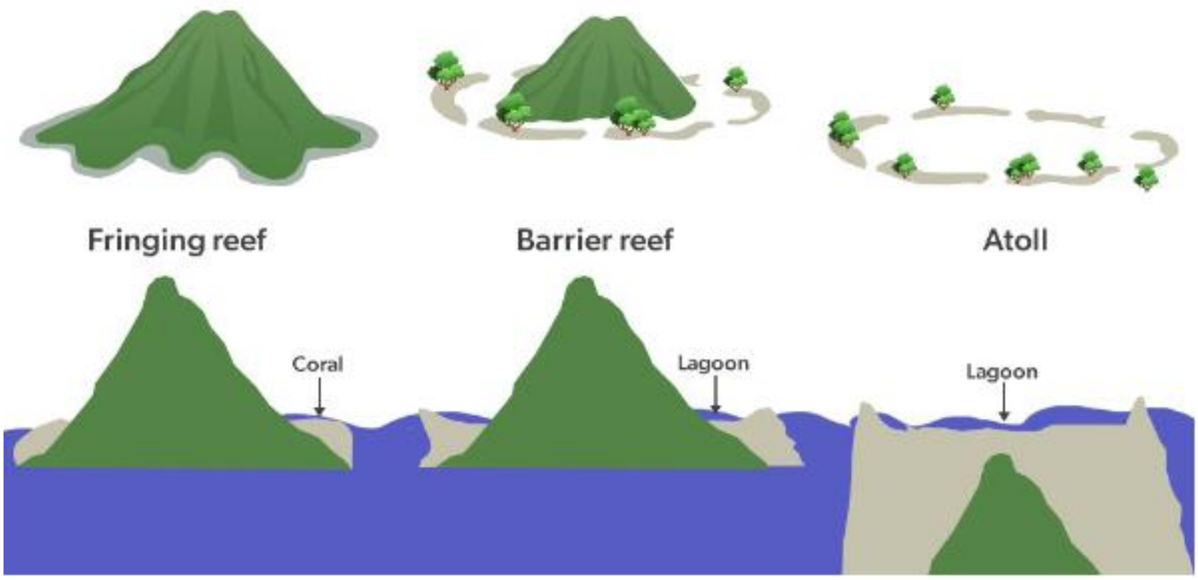

Figure 2: Different types of coral reef [34]

Coral reefs are three types:

i. **Fringing reef:** Coral reefs that form in shallow waters are known as fringe reefs. They are either directly adjacent to the coast or are separated from it by a short section of water. There are numerous fringing reefs surrounding Thailand and Sri Lanka [13].

ii. **Barrier reef:** While growing parallel to the coast, barrier reefs are isolated from the surrounding land by a lagoon. They are occasionally located 10 to 100 kilometers offshore. Because living coral sometimes grows on the remains of coral that once flourished in the same region when the sea level was lower, during the last ice age, barrier reefs can develop in rather deep water. Australia's huge barrier reef stretches along its east coast for about 2010 kilometers [13].

iii. **Atolls:** Atolls surrounding (or partially surrounding) an island that dips to the sea level (often because of the island's volcanic activity ceasing) or was submerged as the sea level rose following the last ice age. A center Lagoon was ringed by atolls, either completely or partially. There are 26 atolls total in the Maldives [13].

Biotic and abiotic components of corals

Diverse biotic and abiotic components make up coral reef ecologies. The producers, consumers, and decomposers make up the biotic component. Algae from the dinophyceae family, specifically zooxanthellae, which coexist with coral animals, are the primary producers in the ecosystem of coral reefs. Multiple types of algae coexist in coral reef ecosystems as other producers. Reef fish, mollusks, sponges, echinoderms, and other marine life are some of the consumers that inhabit coral reef environments. Decomposing bacteria are decomposers. Organic and inorganic materials and substances are referred to as abiotic components. Temperature, oxygen levels, nutrients, and other physical factors are examples of environmental characteristics that, if they are outside of an organism's tolerance range, may operate as limiting factors[17, 18, 19].

Importance of coral reef

- Coral reefs protect coastal areas from strong ocean currents, waves, storms, cyclones, and tsunamis.
- It is a place for the accumulation of petroleum deposits.
- Coral reefs are of important significance to oil painting assiduity.
- Some coral reefs are used for habitation by man as well.
- Some corals are largely priced for their ornamental value.
- *Corallum rubrum* is considered to be a precious gravestone in India and China and is treated as auspicious.
- Coral reefs are called the 'Medicine Chests of the Oceans'. The red coral and organ pipe coral are used in some indigenous systems of drugs in South India.
- Gobbets of coral shells belonging to the species Porites are used as structure material.
- Coral skeletonsserve as raw materials for lime, mortar, and cement due to their calcium carbonate and magnesium carbonate content.
- Coral skeletons are helpful in making crests that may act as natural walls against ocean corrosion and volcanic storms.
- Coral reefs serve as good nursery grounds for commercially important fishes.
- Coral reefs are an important carbon storage area and aid in ocean carbon sequestration, making them an essential component of the carbon cycle.

- Corals help to increase the economy of the world through coral-related tourism and the export of marine fisheries.

Threats of coral reefs

According to estimates, 20% of the world's coral reefs have been destroyed[15] and another 24% are at significant risk of collapsing due to human activities, despite their enormous ecological, economic, and aesthetic significance. By 2050, 70% of the world's coral reefs will be gone if the current rate of degradation holds[16]. Some natural and anthropogenic causes of coral threats are given below-

1. Natural causes

- **Strom and tidal action:** The effects of wind and tide may harm coral and the environment in which it grows.
- **Increase in sea surface temperature and salinity:**The sea level is rising day by day as a result of global warming, and the temperature and pH are also changing. Due to the limited temperature range that reef-building coral species can tolerate, even a slight shift in temperature can have major negative effects. The vital equilibrium that preserves hematypic corals' mutualistic relationship with zooxanthellae is lost when they encounter such a temperature rise. A significant source of nourishment and color for coral, zooxanthellae, may be lost in part or all. Coral in this state is referred described as "bleached." Some creatures' life cycles are messed up[20, 21].
- **Predator outbreak:** Crown of Throne starfish (COT) are coral predators. They quickly and effectively consume coral polyps by secreting digestive liquid from their bodies. Crabs, barnacles, and other animals are also natural coral predators in addition to a large number of starfish[21].
- **Dust outbreak:** Coral grow by incorporating particles and chemical compounds from the water around them into their skeletons, therefore dust outbursts can stunt their growth or even kill them entirely.

2. Anthropogenic causes

- **Over-exploitation:** According to a recent analysis, coral reef environments have been destroyed by centuries of overfishing by humans, which has depleted the world's oceans of gigantic fish, whales, and other large sea species. Coral reefs are particularly susceptible to exploitation since they are within small boats' range. Groupers, nippers, and giant wrasses are just a few of the coral reef fish species that have been overfished[22, 25].

- **For aquarium trade:** In recent years, more people have taken up the pastime of owning marine aquariums. According to reports, more than 800 different types of reef fish, hundreds of different kinds of coral, and other invertebrates are currently transported for aquarium markets[23].
- **For the trinket trade:** Around 40 species of coral are also traded for this purpose, along with up to 5000 species of molluscs, which are processed or used raw to build dishes and trinkets.

  Note: The group of corals known as Corallium spp., which has a global distribution, consists of roughly 31 species with main colors ranging from white to pink to orange and red. Due to overharvesting, they are currently in danger of going extinct. They are widely used to manufacture jewelry and other trinkets[22, 23].
- **For medicinal purposes:** Coral reefs are accessible and home to several species of non-moving, soft-bodied invertebrates that are armed with a variety of chemicals for defense. Reefs are targeted for bioprospecting because of the wide range of possible medical and industrial uses for these compounds[23].
- **Destructive fishing practices:** Unsustainable harm leads to destructive fishing methods like purse seining and fine mesh fishing. Overfishing and destructive fishing affect the equilibrium of the coral reef ecosystem by upsetting ecological linkages[22].
- **Coral mining:** Corals are mined for limestone and building materials throughout South and Southeast Asia. This procedure involves blasting the reef and removing the corals, which results in immediate destruction as well as indirect negative impacts including sand erosion and sedimentation[25].
- **Sediment, nutrient, and chemical pollution:** Human development that changes the physical environment on land or in the ocean is one of the biggest risks to coral reefs. The turbidity of the water is increased by direct cementation onto the reef, which can exacerbate eutrophication. Eutrophication reduces the quantity of sunlight that reaches the corals, and both are turbidity. For the zooxanthellae that live among them to photosynthesize and supply them with nutrients, reef-building corals require sunshine. Therefore, corals will cease developing and finally perish if they do not receive enough light. In addition to nutrient and sediment contamination, farm runoff and industrial influences that end up in waterways also bring chemical pollutants[22].
- **Marine-based pollution:** Additionally harming the coral reef in the area is marine pollution in the form of oil (which frequently seeps into the sea), ballast water discharge, and ship garbage dumping [24, 25].

- **Irresponsible tourism:** Many of the countries in the region depend heavily on tourism for their economic growth. Poorly managed tourism has a detrimental direct and indirect impact on coral reefs. Direct physical harm to reefs can result from snorkeling, diving, and boating, while over-exploitation of reef species for food, aquaria, and tourist-market trinkets poses a threat to their survival. Building infrastructure carelessly and recklessly too close to beaches, river mouths, lagoons, or right on the reef leads to increased sedimentation and makes the infrastructure vulnerable to damage from severe weather events. Another unintended consequence of tourism is the frequent improper dumping of solid waste and sewage[22].
- **Ocean acidification:** Increased carbon dioxide dissolved in the sea creates carbonic acid, making the water more acidic and limiting coral polyps' ability to precipitate calcium carbonate. It has been predicted that calcium carbonate precipitation has already decreased. Ocean acidification is anticipated to affect coral reef services provided to humans as well as marine food webs.
- **Land development:** Human activity severely damages corals because of dumping and land development. Damage to coral might result from island construction[22, 24].
- **Beach area destruction:** Corals that are beside the shore have been severely damaged by sand mining[22].

Conservation of coral reef

If efforts are not made to conserve coral reefs in time, the remaining coral reefs will soon be destroyed. Below we have described some conservative strategies.

- **Establishment of marine protected areas:** The creation of marine protected areas (MPAs) is one of the most important mechanisms for safeguarding coral reefs. Although there are many different types of primary protected areas, all MPAs have marine sections that are off-limits to unrestricted human activity. However, a significant issue with MPAs is that most of them fall short of their management goals and are essentially just parks on paper [25].
- **Prevention of over-harvesting through legislation:** Worldwide, several species are protected by general species protection laws. The majority of these protections are given to marine vertebrates; however, regulations safeguarding various species of coral, mollusk, and echinoderm are in place in some nations, including India and Sri Lanka[28].
- **Monitoring:** The creation of efficient management plans depends on coral reef monitoring. Only via monitoring can trends, patterns, and the condition of the reef be

determined. Numerous organizations around the world keep an eye on the condition of coral reefs. The goal of the global coral reef monitoring network (GCRMN), which works closely with reef check and reef bases, is to enhance coral reef management through knowledge exchange and capacity building[29].

- **Building awareness:** Increasing people's knowledge of coral reefs, their diversity, and the benefits they offer significantly reduces the stress on this delicate environment. The best way to change behavior so that coral reef users can sustainably exploit this ecosystem is through community-level awareness. National awareness is raised through media coverage and environmental education. Making sure that policymakers incorporate coral reef protection into all phases of development is crucial. It is crucial to protect against land-based environmental problems such as pollution and poorly planned or uncontrolled inland development[27].
- **Reef resilience:** The greatest difficulty that coastal managers currently face in coral reef conservation and management is probably adapting to climate change[28].
- **Supporting participation and sustainable livelihood to reef-dependent communities:** There is a considerable link between the coral reef environment and poverty. Coral reefs support the national economy and offer valuable resources to the underprivileged. The poor community, which depends on coral reefs, is expected to be impacted by the current trend of rising risks to coral resources. It is now understood that such populations need to be provided with alternate means of subsistence to protect coral reefs from harm and to alleviate poverty in coastal areas[27].
- **New management initiative:** It is now acknowledged that changing how coastal zone management is done will be more effective in attaining goals for conservation and sustainable development. The current tendency is to move away from local, isolated management efforts and toward large-scale networks employing collaborative management**[26].**

Artificial coral reef formation

Rapid destruction of reefs has very adverse effects on the aquatic biodiversity. Very negligible restoration works are going on in a few places. To conserve biodiversity the restoration works with the help of several governmental and non-governmental agencies. In contrast, there is considerable interest in preventing anthropogenic damage as well as mitigating, rehabilitating, and/or restoring coral reef environs subjected to human disturbance. In recent years, there has been increasing interest in using artificial substrates to aid in accomplishing these goals. Corals need artificial substrates for the attachment of growth and development. A variety of materials have been used in the construction of artificial reefs: e.g., wood, steel, fiberglass, PVC, materials-of-opportunity, tires, boulders, concrete, etc structures made out of those materials settle down at the bottom act as an adhering material for coral restoration[32].

A. Tires B. Steel frame C. PVC frame

Figure 3: Materials used for coral restoration [35, 36, 37]

Conclusion:

In summary, coral reef ecosystems are priceless gems of our world that sustain an astounding diversity of biodiversity and offer a wide range of ecological, economic, and cultural advantages. However, these delicate ecosystems are now under tremendous threat from human activities including habitat destruction, overfishing, pollution, and climate change. We must act swiftly and consistently to safeguard and conserve coral reefs. It is crucial to make efforts to counteract climate change, lower greenhouse gas emissions, and lessen the impact of warming water temperatures on coral reefs. Controlling coastal development, implementing sustainable fishing methods, and reducing pollution are all essential actions. Additionally, it is necessary to raise public awareness of the value of coral reefs and the part they play in preserving the health of our seas [31]. Maintaining coral reefs is an investment in our well-being as well as a moral commitment to maintain the astounding variety of species that they house. Millions of people rely on coral reefs for their livelihoods, they shield coasts from erosion, and they help maintain the overall health of the oceans, which in turn affects how the world's climate is regulated[31]. We can ensure that future generations will continue to be in awe of the beauty and wonder of coral reefs and benefit from their essential functions by taking proactive steps to protect these extraordinary ecosystems. Coral reefs' future is in our hands, and it is up to us to take care of these vulnerable and unique ecosystems [30].

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TRENDS OF INDIAN MAJOR CARP (IMC) PRODUCTION IN GUJARAT

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Introduction:

India is the second-largest producer of aquaculture in the world, after China [1], and freshwater aquaculture now accounts for the majority (>80%) of global aquaculture output [2]. Technological advancements such as induced breeding, polyculture, and composite fish culture in ponds and tanks have significantly increased freshwater aquaculture production and productivity and transformed the industry into one that is rapidly expanding [3, 4]. For millions of people, fishing and aquaculture continue to be vital sources of food, nutrition, money, and livelihood. Fish is a good and economical source of animal protein, offering a solution to the nation's problems with hunger and malnutrition. The Indian fishing industry underwent progressive development throughout the years and developed into a significant socioeconomic factor for the country. India is the third-largest producer of fish and aquaculture, contributing roughly 16% of all inland fish production and 5% of all marine fish production worldwide. India produced 162.48 lakh tonnes of fish overall in 2021–22, including 121.21 lakh tonnes and 41.27 lakh tonnes from the inland and marine sectors, respectively. One of the major contributors to the nation's foreign exchange earnings and one of the most important sectors of the economy at large is the fishing industry. From 56.56 lakh tonnes in 2000-01 to 162.48 lakh tonnes in 2021–22, India's fish production has increased. Andhra Pradesh, West Bengal, Karnataka, Odisha and Gujarat evolve to be the five major fish-producing states in India during 2021-22. India is among the top 5 fish exporting countries in the world at third place preluded by China & Indonesia. About 1.1% contribution is of Fisheries sector in Indian economy and about 6.72% contribution is in agriculture. In 2021-22, the country exported 1.36 million MT of seafood worth US$7.76 billion which is all time high export by value. India has exported marine products to 123 countries. USA and China are the major importers of Indian seafood. India mainly exports frozen shrimps, fish, cuttlefish, squids, and dried items, live and chilled items.

Frozen shrimp ranks as the top marine export among these, accounting for more than 53.18% of the total export volume and roughly 75.11% of the total export revenue. Frozen fish, cuttlefish, and squid made up 6%, 3%, and 5%, respectively, of the total export value of marine products in 2021–2022. A cheap source of protein that aids in ensuring the nutritional security of our population, our current annual fish production through capture and culture fisheries is 16.25 million tonnes. Additionally, our nation makes yearly foreign currency gains from the export of fish and fishery products [5]. The target freshwater fish production under PMMSY has been set at 2.91 lakh tonnes by 2025, of which 1.90 lakh tonnes are expected to come from carp. (65.3%) [6].

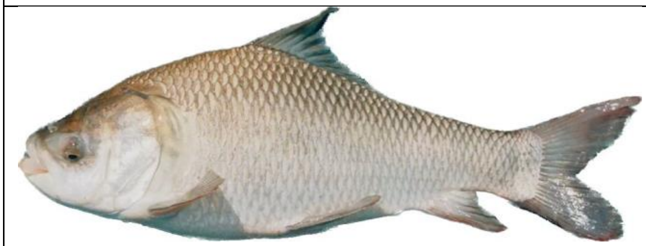
Biology of Indian major carp

Cultured carps are typically found in large river systems and are of riverine origin. The Catla, which is a planktivorous fish, primarily feeds on zooplankton and inhabits the upper layers of the water column. As a surface feeder, it has a large head and deep body in comparison to other Indian carp. On the other hand, the Rohu is a column feeder that feeds on both phytoplankton and zooplankton. It has a smaller head than the Catla, with a terminal mouth and fringed lips. Despite being slightly pinkish, its body is longer than that of the Catla. The Mrigal is a bottom feeder that feeds on detritus and plankton. Unlike the Catla, it has a smaller head and a longer body, which is generally white with pinkish fins. Its mouth is sub-terminal and does not have fringed lips, making it easily distinguishable from the Rohu [7].

Systematic position and biology of Indian major carp [8]

Phylum	Chordata	**Sub-division**	Euteleostei
Sub-phylum	Vertebrata	**Super- order**	Ostariophysi
Super-class	Gnathostomata	**Series**	Ostophysi
Class	Actinopterygii	**Order**	Cypriniformes
Sub-class	Neopterygii	**Family**	Cyprinidae
Division	Teleostei	**Sub-family**	Labeoninae

Genus	Labeo	Labeo	Cirrhinus
Species	*Labeo catla*	*Labeo rohita*	*Cirrihinus mrigala*

Labeo catla (Hamilton, 1822)	
	
Origin	restricted to the sind, the ganges, the Brahmaputra and the adjacent river system
Feeding habit	Plankton feeder, prefers zooplankton and surface feeder
Sexual maturity	Second year
Fecundity	2-4 lakhs
Field identifying characters	
Egg	None floating, non-adhesive and round in shape. Diameter of egg:- 4.6 mm and reddish
Fry **(14-25 mm)**	Large head Dorsal profile convex and ventral profile concave. Margin of the dorsal and caudal fins darker No distinct spot on the caudal fin or at the caudal peduncle First ray of dorsal fin black Operculum region brightly reddish No barbels Lips thick, but no fringed More than 11 number of undivided dorsal fin rays.
Adult	Fin formula: D 17-19, V 9, L.I. 40-43 Head broad The upper lip absent, the lower moderately thick, having a continues and free posterior margin No barbels Long gills, fine and closely set Pharyngeal teeth plough shaped Lateral line continuous to the center of the base of caudal fin Colour: grayish above, becoming silvery on the sides and beneath

Labeo rohita (Hamilton, 1822)	
	
Origin	absence in madras, but found in freshwater of greater part of indian subcontinent
Feeding habit	Omnivorous planktophage; predominantly a column feeder
Sexual maturity	First year
Fecundity	2.26-2.80 lakhs
Field identifying characters	
Egg	Non floating, non-adhesive and round in shape. Diameter of egg:- 3.78 and bluish
Fry **(14-25 mm)**	A dark diffused transverse band present at the caudal peduncle A pair of whitish or light grayish maxillary barbels Lips fringed More than 11 number of undivided dorsal fin rays.
Adult	Fin formula: D 3/12-13,P 17, V 9, A2/5, C19, L/40-45,Lrt 6 ½ /9 Body oblong or elongate Mouth inferior, wide, transverse and protractile Lips thick, fringed a with a distinct inner fold above and below snout broadly rounded. Snout broadly rounded Pharyngeal teeth often covered with tubercles Gill rakers short Scale with red marl on each side, fin grayish or black. Lateral line from 6 to 6 ½ rows of scales between it and base of the ventral fin.

Cirrihinus mrigala (Hamilton, 1822)	
	
Origin	Limited to rivers and tanks of Bengal, Deccan, and north west provinces, Punjab, Sindh, Kutch and Burma.
Feeding habit	Omnivorous, prefers detritus, predominantly a bottom feeder
Sexual maturity	First year
Fecundity	2-4 lakhs
Field identifying characters	
Egg	Non floating, non-adhesive and round in shape. Diameter of egg: 5.5 mm and brownish
Fry (14-25 mm)	Small head and slender body Triangular dark spot at the caudal peduncle No barbels visible Lips thin, but not fringed. Tip of the lower lobe of caudal fin has a reddish tinge in larger size fry
Adult	Fin formula: D 3/12-13, P 15, V 9, A 3/5, L/40-45, Lrt 6 ½ -7/8 ½ Snout depressed, wider mouth and thinner lips Colour: silvery dark to grey along with back. The pectoral, ventral and anal are orange stained with black. Barbels are faintly visible The lips of the Lower lobe of caudal fin are vermilion red Eye golden green

History of carp culture

The family Cyprinidae is home to carps, which are extensively cultivated worldwide. The techniques and principles of carp culture are mostly similar, but some differences are observed in terms of management, which is adapted to local conditions. There are three primary systems of carp culture: the Chinese system, which involves the cultivation of Chinese carp together; the Indian system, which primarily focuses on the culture of Indian major carp; and the European system, which revolves around the culture of common carp.

In India, traditional fish culture practices involved the cultivation of three endemic species - Catla, Rohu, and Mrigal. However, in the late 1950s, three exotic carp species were introduced for culture along with Indian major carp. India boasts vast and varied aquatic resources, including marine and inland water bodies. Inland aquaculture has emerged as a rapidly growing industry and a viable alternative to declining capture fisheries in the country. India is blessed with a large inland water resource base, including 0.19 million ha of backwaters and lagoons, 0.3 million ha of estuaries, 29,000 kms of rivers, 3.15 million ha of reservoirs, 0.2 million ha of floodplain wetlands, and 0.72 million ha of upland lakes. It is estimated that different types of inland open water systems contribute about 0.8 million tonnes of inland fish in India [9].

Inland water resources in Gujarat state

Gujarat has been blessed with vast inland water resources, which include 3865.00 kilometers of rivers and canals, 0.93 lakh hectares of large reservoirs, 0.21 lakh hectares of estuarine areas, and 3.76 lakh hectares of brackish water area.

Table 1: Freshwater fisheries resource of Gujarat [10]

Resources	Unit	Area
Area of villages ponds/ Tanks	Lakh Hectare	0.22
Small Irrigation Tank	Lakh Hectare	0.93
Area of medium and large reservoirs	Lakh Hectare	2.55
Length of rivers	Kms	3865.00
Esturine Areas	Lakh Hectare	0.21
Brackishwater Area	Lakh Hectare	3.76
Suitable brackishwater area for aquaculture	Lakh Hectare	1.87
Sardar sarovar project (Expected area to be developed)		
Reservoir Area	Hectare	34867
Commamd Area ponds/Tanks	Hectare	10500
Water- logged Area	Hectare	6000
Esturine Area	Hectare	500

1) IMC production in India (2020-21) (in lakh tonnes)

Andhra Pradesh is a significant producer of Indian Major Carp (IMC), with a production of 23.14 lakh tonnes in 2020-2021, contributing about 36.74% of the total Indian production. West Bengal is the second-largest producer of IMC with a production of about 10.04 lakh tonnes, contributing about 15.94% of the total production. Gujarat's IMC production is around 0.40 lakh tonnes, contributing 0.63% of the total Indian production.

Table 2: Major carp production of India [2020-2021] [In Lakh Tonnes] [5]

States/UT's	Major Carps (Catla, Rohu, Mrigal)
Andhra Pradesh	23.14
Arunachal Pradesh	0.02
Assam	1.01
Bihar	3.42
Chhattisgarh	4.63
Gujarat	0.40
Haryana	1.83
Himachal Pradesh	0.15
Jharkhand	1.96
Karnataka	1.29
Kerala	0.21
Maharashtra	0.82
Manipur	0.1
Meghalaya	0.06
Madhya Pradesh	1.91
Mizoram	0.02
Nagaland	0.05
Odisha	4.14
Punjab	0.96
Rajasthan	0.42
Tamil Nadu	0.59
Telangana	2.25
Tripura	0.54
Uttar Pradesh	2.95
Uttarakhand	0.02
West Bengal	10.04
Delhi	0.01
Jammu & Kashmir	0.01
Puducherry	0.02
Total	62.97

2) IMC production in Gujarat

There is increase production of catla from 2014-15 to 2020-21 while in case of rohu and Mrigal, production is decrease.

Table 3: Last five year major carp production in Gujarat [Production in M.T] [10]

Fish	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020 - 2021
Catla	12033	12022	12341	13985	14246	13869	13413
Rohu	14503	14401	14423	14502	14763	14325	12857
Mrigal	11627	11688	11701	12468	13046	12801	11053

3) Reservoir production of IMC in Gujarat

Gujarat boasts the longest reservoir area in India, spanning 347,875 hectares. However, the primary purpose of these reservoirs is irrigation, rather than fishing activities. As a result, the fishery industry is not well-developed in such a vast reservoir area. Gujarat is composed of a total of 26 districts, and the state has 1635 reservoirs in total, including 1547 small, 38 medium, and 50 large reservoirs.

a. Reservoir of Gujarat state

Table 4: Classification of reservoir of Gujarat [10]

Reservoir	No	Area [hectare]
Small	1547	92675
Medium	38	25865
Large	50	229336
Total	1635	347875

b. Category wise reservoir of Gujarat state

In Gujarat, there are approximately 1119 reservoirs ranging from 10-50 hectares in size, covering a total area of 23,831 hectares. There are also around 428 reservoirs ranging from 50-500 hectares in size, covering a total area of 68,845 hectares. Additionally, there are about 38 reservoirs ranging from 500-1000 hectares in size, covering a total area of 25,865 hectares. There are approximately 50 reservoirs with an area of 1000 hectares or more, covering a total area of 229,336 hectares. The Ukai reservoir is the largest reservoir in Gujarat, with an area of 60,075 hectares. This reservoir makes a significant contribution to Gujarat's fish production.

Table 5: Classification of reservoir based on area [10]

Reservoir	**No**	**Area at FRL [hectare]**
10 to 50 hectare	1119	23831
50 to 500 hectare	428	68845
500 to 1000 hectare	38	25865
More than 1000 hectare	50	229336
Total	1635	347875

Table 6: Last two year IMC production in reservoir [Production in M.T] [10]

Area of reservoir	**2018-19**			**2019-20**			**2020 -2021**		
	Catla	Rohu	Mrigal	Catla	Rohu	Mrigal	catla	Rohu	Mrigal
0 to 10 hectare	2304	2291	2274	2238	2240	2242	1317	1240	1109
10 to 50 hectare	1721	1643	1387	1611	1611	1447	1242	1164	1012
50 to 500 hectare	1781	1894	1672	1730	1785	1499	1405	1282	1136
500 to 1000 hectare	374	362	339	379	357	360	332	307	275
1000 above hectare	2843	2814	2703	2613	2531	2498	1577	1496	1386

3) Estuarine and riverine production of IMC (production in M.T)

In Gujarat, estuarine area is 0.21 lakh ha. Length of rivers and canals of Gujarat is 3865 km. Tapi and Narmada are two major large rivers of Gujarat.. In Gujarat development of Riverine fisheries is much better than reservoir fisheries. Total riverine production of Gujarat in 2020-2021 is 19091 M. T. Total estuarine production of Gujarat in 2020-2021 is 11445 M. T.

Table 7: Reverine and estuarine production of IMC [10]

	2018-19			**2019-20**			**2020 - 2021**		
	Catla	**Rohu**	**Mrigal**	**Catla**	**Rohu**	**Mrigal**	**Catla**	**Rohu**	**Mrigal**
Estuarine	183	282	156	180	278	161	1285	1370	954
Riverine	3470	3131	2955	3532	3177	2993	3005	2897	2556

4) Seed production of IMC in gujarat

The quality of seed is a crucial factor in the success of aquaculture. In 1957, Dr. H.L. Chaudhary and Dr. K.H. Alikunhi achieved the first successful induced spawning of carps in Cuttack, Odisha. This breakthrough had a significant impact on the aquaculture industry as it led to the production of carp seed in different parts of the country. Today, over 90% of carp seed production is achieved through induced spawning in hatcheries [11].

Fish seed production in Gujarat has historically been limited to Indian major carps like catla, rohu and mrigal, leading to a shortfall in demand. In 2007-08 and 2009-10, fish seed production was 610.20 million fry and 689.89 million fry respectively, but drastically reduced to 185.23 million fry in 2017-18. However, in 2019-20, fish seed production in Gujarat increased significantly to 2608.37 million fry, suggesting a positive correlation (R2 = 0.78) and indicating that the state has immense potential for fish seed production. Despite this, the growth in fish seed production in Gujarat has been slow compared to the overall growth in India's fish seed production trends over the years. This is mainly because of the presence of less number of fish hatcheries in the state and most of them are belongs to Government sector.

Availability of Hatchery for IMC seed production

Table 8: List of hatcheries in Gujarat [12]

Hatchery name	District	Year of construction	Capacity
Palan	Valsad	1989-90	100 million
Thala	Navsari	1986-87	-
Bhadrania	Anand	1984-89	-
Lingda	Anand	1975-76	100 million
Kosmada	Surat	1988-89	100 million
Pipodara	Surat	1981-82	100 million
Ukai	Tapi	1982-83	200 million
Umarvada	Bharuch	1988-89	-
Sisodra (private)	Bharuch	-	150 million
Rayndhanpur (KVT)	Kutch	-	100 million
Valod (GFCCA)	Tapi	-	100 million

There are a total of eight hatcheries in Gujarat that produce Indian major carp (IMC) seed. These hatcheries are spread across various districts of the state and were constructed between 1975 and 1989. The Palan hatchery is located in Valsad district and was built in 1989-90, while the Thana hatchery in Navsari district was constructed in 1986-87. The Bhadrania hatchery in Anand district was built in 1975-76, followed by the Lingda hatchery in the same district in 1989-90. The Kosmaba hatchery is located in Surat district and was constructed in 1988-89. The Pipodara hatchery in Valsad district was built in 1981-82, while the Ukai hatchery in Tapi district was constructed in 1982-83. The Umarvada hatchery in Bharuch district was built in 1988-89.

Production of IMC

Last six-year seed production of IMC given below. There is increase in production of carp spawn from 2015-16 to 2020-21 while in case of rohu and Mrigal spawn production there is decline in spawn production.

Table 9: Last five-year spawn production of IMC [in lakhs] [10]

Year	Catla	Rohu	Mrigal
2015-16	2694.50	4154.50	2635.00
2016-17	2650.00	3892.00	2284.00
2017-18	2299.00	4031.85	1983.00
2018-19	2038.00	3793.25	2304.00
2019-20	3356.50	2740.00	1598.00
2020 – 21	1531.50	3404.00	2384.00

Conclusion:

In conclusion, the Indian major carp (IMC) culture in Gujarat has seen both positive and negative trends in recent years. While the state has a large inland water resource base, including rivers, canals, and reservoirs, the fishery potential of these resources has not been fully realized due to the dominance of irrigation activities. Additionally, the production of IMC seed in Gujarat has seen fluctuations over the years, with a significant increase in 2019-20 but still falling short of the demand. Despite these challenges, there are several hatcheries in the state dedicated to IMC seed production, indicating a growing interest and potential for the development of the sector. Further efforts are required to optimize the utilization of Gujarat's inland water resources for aquaculture and to increase the production of high-quality fish seed to meet the growing demand in the state and beyond.

The Pradhan Mantri Matsya Sampada Yojana (PMMSY) is a government scheme aimed at promoting sustainable and responsible development of the fisheries sector in India. Under the PMMSY, there are several components and sub-schemes that cover various aspects of the fisheries sector, including carp culture.

For carp culture, the PMMSY provides support for the establishment of new carp hatcheries, renovation of existing ones, and strengthening of the fish seed production infrastructure. It also provides financial assistance for the creation of new carp rearing ponds, renovation of existing ones, and for the adoption of advanced technologies and practices in carp farming.

In addition, the PMMSY also focuses on enhancing the value chain of carp culture by providing support for the establishment of fish feed mills, fish processing and packaging units, and cold storage facilities. The scheme also aims to promote the establishment of fish farmer producer organizations (FFPOs) to provide a collective platform for small and marginal fish farmers to access markets, credit, and other services.

Overall, the PMMSY aims to promote sustainable and responsible carp culture practices, increase production and productivity, and enhance the socio-economic status of fish farmers and stakeholders in the fisheries sector.

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HARVESTING EQUALITY: WOMEN'S CRUCIAL ROLES AND CONTRIBUTION IN AQUACULTURE AND FISHERIES

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Abstract:

Aquaculture and fisheries, essential components of global food production, have witnessed a significant transformation in recent years. While traditionally male-dominated, there is a growing recognition of the pivotal role women play in these sectors. This research article delves into the nuanced and multifaceted contributions of women in aquaculture and fisheries, exploring their roles, challenges, and the potential for fostering sustainable and inclusive growth.

Keywords: Aquaculture, Fisheries, Gender Equality

Introduction:

Aquaculture and fisheries form the backbone of global food security, providing a primary source of protein for millions. Historically, women have been active participants in these sectors, predominantly engaging in post-harvest activities. However, their contributions have often been marginalized. This research aims to offer a comprehensive analysis of the multifaceted roles played by women in aquaculture and fisheries, highlighting their significance in achieving sustainable and inclusive growth.

Traditionally, women have been associated with the post-harvest segment of fisheries, including fish processing, marketing, and trading. However, contemporary trends reveal an expanding role for women throughout the fisheries value chain. From active participation in harvesting to resource management, women contribute substantially to the sector's efficiency and sustainability.

In aquaculture, the roles of women extend far beyond traditional post-harvest activities. With the rise of small-scale and household-level aquaculture, women are actively involved in various aspects of the aquaculture value chain, from pond management to hatchery operations.

The role of women in aquaculture and fisheries is multifaceted, and their contributions are integral to the sustainability and success of these sectors. The role of women in aquaculture and fisheries is evolving, and there is a growing recognition of the need to address gender inequalities and empower women to contribute effectively to the sustainable development of these sectors. Traditionally, women in Indian fisheries have been associated with post-harvest activities such as drying, smoking, and trading of fish. These activities, deeply rooted in local cultures, have been crucial in sustaining coastal livelihoods.

India, with its vast coastline and diverse aquatic ecosystems, has a long-standing tradition of fisheries and aquaculture. While traditionally perceived as male-dominated, the active involvement of women in these sectors has been a silent force, shaping the industry's landscape. This research aims to unravel the specific roles played by women in Indian aquaculture and fisheries, shedding light on their indispensable contributions.

Historical context:

India's maritime history is intertwined with the contributions of women in fisheries and aquaculture. Historically, coastal communities have relied on women for post-harvest activities, including fish processing and marketing. Over time, their roles have evolved, encompassing various aspects of the value chain. The historical context of women in aquaculture and fisheries reflects a dynamic interplay of cultural, economic, and social factors. Ongoing efforts are crucial to ensuring that women continue to be integral contributors and beneficiaries in these sectors. The role of women in aquaculture and fisheries has evolved over time, shaped by cultural, social, and economic factors. In many traditional societies, women have long played essential roles in fishing and aquaculture, although their contributions were often underrecognized.

During the colonial era, women's roles in aquaculture and fisheries were often marginalized as these activities became more commercialized. European colonization impacted local fishing practices and social structures. Post-independence, as fisheries modernized, women continued to contribute, often engaging in ancillary activities such as processing, marketing, and trading of fishery products. Recognition of Contributions: In the late 20th century, there was an increasing recognition of the significant contributions of women in fisheries, not only in processing but also in pre- and post-harvest activities. Efforts to empower women in aquaculture and fisheries gained momentum. Various organizations and initiatives focused on recognizing and enhancing the roles of women, advocating for equal opportunities and rights. Women began taking on diverse roles, including leadership positions in fisheries management, research, and policy-making. The narrative shifted from viewing women solely as beneficiaries to recognizing them as key agents in sustainable development.

Harvesting and resource management:

Women's involvement in fishing activities has evolved, with an increasing number engaged in various aspects of harvesting and resource management. Their intimate knowledge of local ecosystems, coupled with skills in traditional fishing techniques, has proven vital for sustainable fisheries practices.

Processing and marketing:

The contributions of women in fish processing and marketing remain crucial to the economic viability of the fisheries industry. From small-scale operations to large processing units, women play a pivotal role in ensuring the quality and marketability of seafood products. Women-led small-scale aquaculture operations have emerged as a significant force in enhancing food security and economic empowerment. Their role in managing and operating small aquaculture enterprises has proven effective in addressing community-level challenges. Women's involvement in hatchery operations is gaining prominence, contributing to the sustainable development of aquaculture. Their expertise in maintaining optimal conditions for fish breeding and fry production is instrumental in ensuring the success of aquaculture ventures.

Women in Indian fisheries:

Traditional roles:

1. Active participation in harvesting:

In recent years, there has been a noticeable shift with an increasing number of women actively participating in fishing activities. In states like Kerala and Gujarat, women engage in both traditional and mechanized fishing, showcasing their adaptability and resilience.

2. Small-scale aquaculture ventures:

The rise of small-scale aquaculture ventures in India has opened new doors for women. From managing backyard ponds for fish cultivation to participating in community-based aquaculture projects, women are actively contributing to the growth of this sector.

3. Hatchery operations:

In regions like Andhra Pradesh and West Bengal, women are making significant strides in hatchery operations, playing a vital role in ensuring the sustainable breeding and stocking of fish. Their expertise in maintaining optimal conditions for fish fry production is invaluable.

Challenges faced by women:

Despite their integral contributions, women in aquaculture and fisheries encounter numerous challenges that hinder their full participation and recognition. Gender disparities persist in terms of access to resources, credit, and technology. Cultural norms and discriminatory practices often limit women's involvement in decision-making processes and access to critical information.

1. Gender disparities:

Unequal access to resources, including land, credit, and technology, remains a significant impediment to women's active participation in aquaculture and fisheries. Addressing these disparities is crucial for fostering gender equality in these sectors.

2. Cultural and societal constraints:

Deep-rooted cultural norms and societal expectations often perpetuate gender stereotypes, restricting women's participation in decision-making processes and leadership roles. Breaking these barriers is essential for creating an inclusive and equitable environment in aquaculture and fisheries.

3. Limited access to resources:

Access to resources such as credit, technology, and training remains a significant barrier for women in Indian fisheries and aquaculture. Initiatives focusing on bridging these gaps are essential for unlocking their full potential.

4. Cultural constraints:

Cultural norms and societal expectations often limit women's participation in decision-making processes and leadership roles. Addressing these cultural constraints is crucial for fostering an inclusive and equitable environment in the sector.

Empowering women for sustainable fisheries:

Efforts to empower women in aquaculture and fisheries are gaining momentum globally. Initiatives focused on capacity building, access to finance, and technology transfer are proving instrumental in bridging gender gaps. Case studies from diverse regions showcase successful models of women-led aquaculture and fisheries enterprises, emphasizing the potential for transformative change.

1. Capacity building and training:

Investments in capacity building and training programs are essential for enhancing women's skills and knowledge in aquaculture and fisheries. Training programs should address both technical aspects and leadership skills, empowering women to take on diverse roles within the industry.

2. Access to finance and technology:

Ensuring equal access to finance and technology is paramount for women's meaningful participation in aquaculture and fisheries. Financial institutions and policymakers must prioritize creating gender-inclusive policies that facilitate women's access to credit, technology, and market information. An empowered and inclusive approach to women's participation in aquaculture and fisheries can yield substantial economic benefits. Recognizing and valuing women's contributions can lead to increased productivity, improved livelihoods, and sustainable economic growth.

3. Government initiatives:

Government initiatives like the National Fisheries Development Board's (NFDB) Women in Fisheries program aim to empower women by providing training, financial assistance, and technology support. These initiatives focus on enhancing women's skills and knowledge, enabling them to take on diverse roles in the sector.

4. Community-based programs:

Community-based programs, such as the Fisherwomen Self-Help Groups in Kerala, exemplify the transformative potential of collective action. These initiatives empower women economically and socially, fostering a sense of community resilience.

Conclusion:

In conclusion, the role of women in aquaculture and fisheries is pivotal for the sustainable development of these industries. Acknowledging and addressing the challenges faced by women is crucial for achieving gender equality and ensuring the long-term viability of aquaculture and fisheries. This research article advocates for a holistic and inclusive approach that empowers women to contribute actively to the growth and sustainability of these essential sectors. Fostering gender equality in aquaculture and fisheries is not only a matter of social justice but also a key strategy for achieving broader economic and environmental goals.

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ZOOPLANKTON COMMUNITY DYNAMICS AND TROPHIC INTERACTIONS IN TULASHI WATER RESERVOIR, KOLHAPUR DISTRICT, M.S., INDIA

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Introduction:

The dynamics of zooplankton communities in freshwater reservoirs are influenced by a range of factors, including water temperature, nutrient concentrations, and the presence of predators (Dmitrieva, 2011). These communities can serve as indicators of water quality and ecosystem processes (Picapedra, 2020). The spatial and temporal variability of zooplankton communities can be influenced by hydraulic and water quality factors (Descloux, 2016). In subtropical systems, nutrient recycling by zooplankton may play a more significant role than grazing impacts on phytoplankton growth (Hunt, 2005).

Tulashi Water Reservoir Dhamod is strategically located in the Dhamod Village, Radhanagari, Maharashtra state, India, serving as a crucial water body within this geographic area. The dam was constructed on 12 Feb. 1970. This expansive reservoir serves as a vital water resource within the region, contributing to various essential functions such as irrigation, hydroelectric power generation, and providing a reliable water source for local communities.

The dam's gross storage capacity is an impressive 10,429.00 km^3 (2,502.05 cu mi), ensuring a consistent and substantial water supply. The dam's height above its lowest foundation stands at 26 m (85 ft.), emphasizing the scale of its engineering and its role in managing water resources.

In terms of structure, Tulashi Water Reservoir Dhamod boasts a remarkable dam height of 26 m (85 ft.) above its lowest foundation, with a total length of 186 m (610 ft.). These specifications underscore the engineering prowess involved in the construction of the dam, highlighting its role not only in water management but also in providing stability to the surrounding ecosystem.

The vast surface area and impressive storage capacity of the reservoir contribute to its ecological significance. Understanding the dam's specifications is crucial for assessing its environmental impact, as variations in water levels, controlled releases, and the overall hydrological balance influence the dynamics of the aquatic ecosystem within and around the reservoir. The extensive size and storage capacity of Tulashi Water Reservoir Dhamod have direct implications for the human population in the region. The reservoir caters to diverse needs, from agricultural irrigation to sustaining local communities, and its engineering specifications play a pivotal role in facilitating these various uses.

A diverse fish population and a balanced zooplankton community are indicative of a healthy and stable aquatic ecosystem. Understanding the temporal patterns in fish diversity and zooplankton composition provides critical insights into the overall health of Tulashi Water Reservoir Dhamod, enabling researchers to identify any disruptions or imbalances that may have occurred over time.

Zooplankton serves as a valuable indicator for assessing water quality, trophic status, and pollution levels in aquatic ecosystems. Various ecological aspects of zooplankton have been a subject of study in India by several workers [Somashekhar RK 1994, Siva Kumar K 2001].The physico-chemical parameters and nutrient status of water body play an important role in governing the production of plankton which is the natural food of many species of fishes, especially zooplankton constitute important food source of many omnivorous and carnivorous fishes and also support the necessary amount of protein for the rapid growth of larval carps [Rahman S,2008]. They respond quickly to aquatic environmental changes (e.g., water quality, such as pH, colour, odor and taste, etc.,) for their short life cycle, and are therefore used as indicators of overall health or condition of their habitats [Thorpe HJ, 2008]. The qualitative and quantitative abundance of zooplankton in a lake are of great importance for successful aquaculture management, as they vary from one geographical location to another and lake to lake within the same geographical location even within similar ecological conditions [Boyd CE,1982].

Material and Methods:

Study area

The Tulashi Water Reservoir is situated near Dhamod villages, with coordinates of approximately 16°31'43″ "N latitude and 74°02'31"″ E longitude. It is strategically located on the Tulashi River, covering the geographical expanse of Dhamod and its surrounding areas, including villages of Burambali, Keloshi Bk, kumbharwadi, and Keloshi Kh.etc. The reservoir encompasses a catchment area extending up to 20 square kilometers.

This catchment area plays a crucial role in regulating the inflow of water into the reservoir, thereby influencing the overall hydrological dynamics of the Tulashi Water Reservoir. The Tulashi Water Reservoir is defined by its impressive dam structure. The dam has a length of 4961 feet, and the total storage capacity of the reservoir is measured at 3.4 thousand Million Cubic feet (TMC), making it a significant water resource for local communities. Additionally, the dam reaches a depth of 960 ft, further enhancing its ability to effectively store and manage water resources.

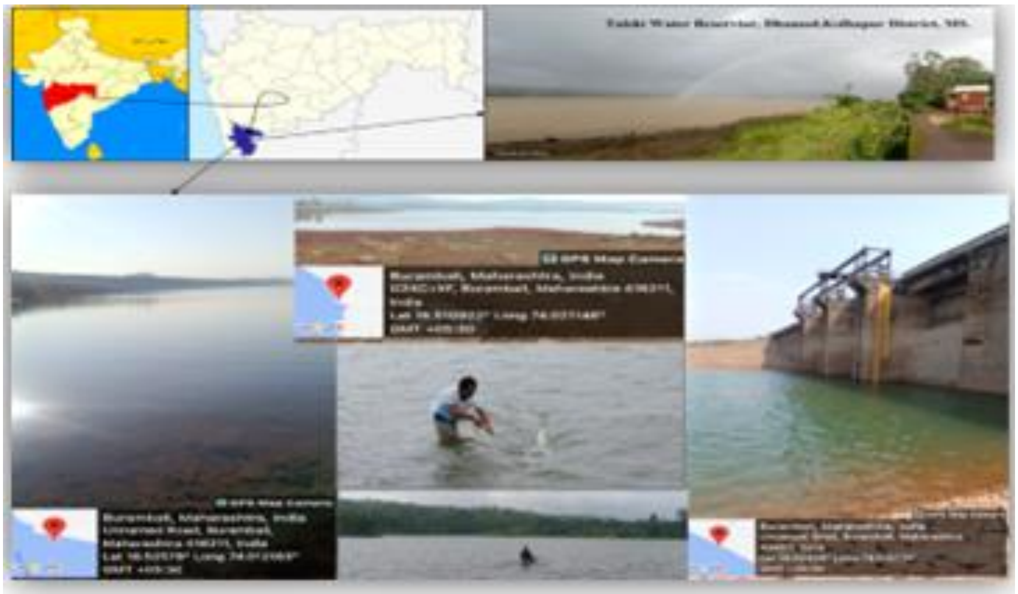

Figure 1: The Map showing in a study area in Tulashi Water reservoir (Dhamod), Kolhapur District, M.S., India

Sample collection

Water samples were collected randomly in different four selected sites of the water reservoir on monthly basis for a period of January 2023 to September 2023 (January 2022;2023, Feb. 2022; 2023, November 2022, December 2022 (Post-Monsoon); March, April, May 2022;2023 (Summer); June, July 2022;2023 (Pre-Monsoon); August 2022;2023, September 2022; 2023, October 2022; (Monsson).) Covering Post monsoon, summer, Pre monsoon, Monsoon. Water samples were collected during the early hours between 7.00 am to 10.00 am. The plankton samples were collected by filtering 50 litters of water through standard plankton net (77 mesh bolting silk) and the concentration samples were fixed in 4% of formalin.

Zooplankton sampling

Zooplankton distribution and abundance were assessed by straining 30 L of water through a 25 cm diameter zooplankton net with a 45 µm mesh size to a concentrated volume of 30 ml. This was preserved in 4% formalin. Zooplankton species in 3 ml concentrate subsample were identified and counted under the scanning (x40) and low power (x100) magnifications. Identification was done using the descriptive keys of Adoni (1985), IAAB (1998), Michael and Sharma (1988), Krishnaswamy (1973), Edmondson (1959), Pennak (1968), Dhanpathi (2000) and APHA (1995). Community structure was assessed using the indices of species diversity, Simpson's dominance index (S),

Statistical analysis of diversity indices

The data was subjected to analysis the species individuals, Shannon and Weaner's diversity index, richness and evenness were calculated using the software PAST (Paleontological Statistics), ver. 4.03.

Results and Discussion:

Table 1: List of zooplankton recorded in Tulashi water reservoir Dhamod, Kolhapur district during January -2022 to September 2023

Sr. No.	Group	Family	Scientific Name
1.	Rotifera	Brachionidae	*Brachionus calyciflorus*
2.			*Brachionus angularis*
3.			*Brachionus caudatus*
4.			*Brachionus angularis*
5.			*Brachionus quadridentata*
6.			*Keratella species*
7.			*Notholca species*
8.			*Mytilina species*
9.			*Platiyas species*
10.			*Lepadella species*
11.			*Platyias*
12.		Lecanidae	*Lecane species*
13.		Notommntidae	*Cephalodella species*
14.			*Scaridium species*
15.		Trichocercidae	*Trichocerca species*
16.		Asplanchnidae	*Asplanchnopus species*
17.		Conochilidae	*Conochilus species*
18.		Gastropodidae	*Gastropus*
19.		Trichocercidae	*Trichocerca multicrinis*

20.	Cladocera	Daphnidae	*Daphnia species*
21.			*Monia species*
22.		Sididae	*Diophonosoma species*
23.		Macrothricidae	*Macrothrix species*
24.		Bosminidae	*Bosmina species*
25.	Copepoda	Cyclopidae	*Cyclopoid copepod*
26.			*Calanoid copepod*
27.			*Cyclops*
28.			*Tropocyclops species*
29.		Diaptomidae	*Daiptomus*
30.	Oligochaeta	Lubriculidae	*Lumbriculus*
31.	Diptera	Culicidae	*Chaoborus*
32.	Diatoms' / Others	Anuracopsididae	*Anuracopsisa cochlearis*
33.		Astrociaidae	*Asteromphalus*
34.		Asterionellopsidaceae.	*Asterionellopsis*
35.		Chaetocerotaceae	*Chaetoceros*
36.		Coscinodiscaceae	*Coscinodiscus*
37.		Cylindraceae	*Cylindratheca*
38.			*Entomoneis species*
39.		Chydoridae	*Alona species*
40.		Mytilidae	*Mytilia species*
41.		Macrothricidae	*Macrothrix Baird*
42.			*Macrothrix agsensis*
43.			*Streblocerus*
44.		Naididae	*Chaetogaster species*
45.		Dinophysiaceae	*dinoflagellates oxyphysis*
46.		Gymnodiniaceae	*Amphidinium*
47.		Stenocaraidae	*Streblocerus serricaudatus*
48.		Didiniidae	*Didinium species*
49.			*Anabaena circinalis*
50.			*Microcystis species*
51.			*Prorocentrum species*

Table 2: Seasonal diversity indices of zooplankton in Tulashi water reservoir Dhamod, Kolhapur district during January -2022 to September 2023

Diversity Indices		Zooplankton diversity indices																			
		Post Monsoon						Summer						Pre Monsoon				Monsson			
		Jan-22	Jan-23	Feb-22	Feb-23	Nov-22	Dec-22	Mar-22	Apr-22	May-22	Mar-23	Apr-23	May-23	Jun-22	Jul-22	Jun-23	Jul-23	Sep-22	Oct-22	Sep-23	Jan-22
Rotifera	Density	860	880	930	1020	900	920	1250	1590	1810	1510	1670	1920	1540	1150	1400	1160	850	820	840	860
	Dominance_D	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	Shannon_H	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	Simpson_1-D	2.88	2.85	2.87	2.87	2.86	2.85	2.83	2.92	2.93	2.87	2.91	2.92	2.90	2.90	2.92	2.83	2.87	2.85	2.90	2.88
	Evenness_e^H/S	0.94	0.91	0.93	0.93	0.92	0.91	0.89	0.97	0.98	0.93	0.96	0.98	0.96	0.96	0.97	0.89	0.93	0.91	0.95	0.94
Cladocera	Density	350	450	430	460	370	350	520	540	580	520	540	560	370	300	310	270	230	240	250	350
	Dominance_D	0.21	0.21	0.20	0.20	0.21	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.21	0.23	0.23	0.24	0.22	0.25	0.21	0.21
	Shannon_H	0.79	0.79	0.80	0.80	0.79	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.77	0.77	0.76	0.78	0.75	0.79	0.79
	Simpson_1-D	1.57	1.58	1.60	1.61	1.59	1.60	1.61	1.61	1.61	1.61	1.61	1.61	1.60	1.54	1.54	1.51	1.57	1.49	1.58	1.57
	Evenness_e^H/S	0.96	0.97	0.99	1.00	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.93	0.93	0.91	0.96	0.89	0.97	0.96
Copepoda	Density	310	270	230	240	250	380	500	510	540	440	510	550	410	330	370	370	450	430	460	310
	Dominance_D	0.23	0.24	0.22	0.25	0.21	0.21	0.20	0.20	0.20	0.21	0.20	0.20	0.22	0.21	0.22	0.21	0.21	0.20	0.20	0.23
	Shannon_H	0.77	0.76	0.78	0.75	0.79	0.80	0.80	0.80	0.80	0.79	0.80	0.80	0.78	0.79	0.78	0.79	0.79	0.80	0.80	0.77
	Simpson_1-D	1.54	1.51	1.57	1.49	1.58	1.60	1.60	1.60	1.61	1.59	1.61	1.60	1.56	1.58	1.56	1.59	1.58	1.60	1.61	1.54
	Evenness_e^H/S	0.93	0.91	0.96	0.89	0.97	0.99	0.99	0.99	1.00	0.98	1.00	0.99	0.95	0.97	0.96	0.98	0.97	0.99	1.00	0.93

Oligochaeta	Density	40	40	80	60	40	30	100	40	60	40	80	80	120	60	100	50	60	40	40	40
	Dominance_D	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Shannon_H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Simpson_1-D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Evenness_e^H/S	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Diptera	Density	30	30	30	40	60	40	80	90	90	110	100	120	90	60	80	70	60	30	50	30
	Dominance_D	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Shannon_H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Simpson_1-D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Evenness_e^H/S	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Diatoms' / Others	Density	710	730	940	990	910	900	1100	1100	1150	1140	1200	1250	1040	960	970	980	820	790	850	710
	Dominance_D	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06
	Shannon_H	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.95	0.94	0.94	0.94	0.94	0.94	0.94
	Simpson_1-D	2.94	2.94	2.94	2.92	2.93	2.89	2.91	2.90	2.92	2.89	2.89	2.86	2.89	2.95	2.93	2.88	2.94	2.92	2.93	2.94
	Evenness_e^H/S	0.94	0.94	0.94	0.92	0.94	0.90	0.91	0.91	0.93	0.90	0.90	0.87	0.90	0.95	0.93	0.89	0.94	0.93	0.94	0.94

Zooplankton composition

Throughout the study period at Tulshi Water Reservoir in Dhamod, Kolhapur District, M.S. India, a comprehensive examination revealed the presence of 51 distinct zooplankton species. These species were systematically categorized into six orders: Rotifera (comprising 19 species), Cladocera (with 5 species), Copepoda (including 5 species), Oligochaeta (1 species), Diptera (1 species), and a miscellaneous group encompassing Diatoms and Others (totaling 20 species) as detailed in Table I. Zooplankton, a diverse assemblage of minute organisms suspended in natural water bodies, owes its mobility to the interplay of water currents and wave dynamics [Moss, 1982].

The study shed light on the multifaceted factors influencing the dynamics of zooplankton populations, encompassing elements such as light intensity, food availability, dissolved oxygen levels, and predation. The density and diversity of these populations can be significantly impacted by external factors such as excessive salinity or low pH [Horne *et al.*, 2002].

The observed order of zooplankton diversity in this investigation is delineated as follows: Rotifera > Cladocera > Copepoda > Oligochaeta > Diptera > Diatoms and Others. Notably, Rotifera emerged as the most dominant forms during the present investigation in the studied reservoir area. Expanding upon this, the study explored the intricate interplay of various environmental factors shaping the composition and prevalence of zooplankton species in the Tulshi Water Reservoir.

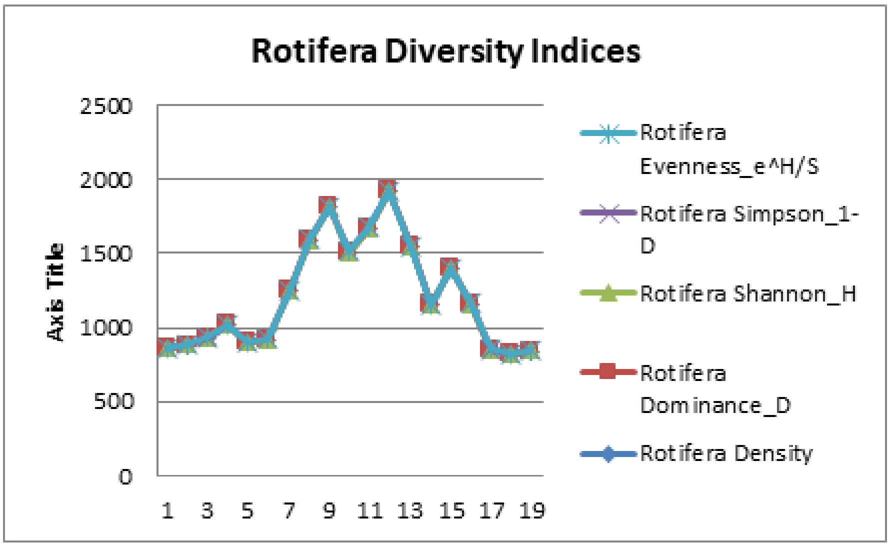

Figure 2: Graphical representation of Group Rotiera diversity indices

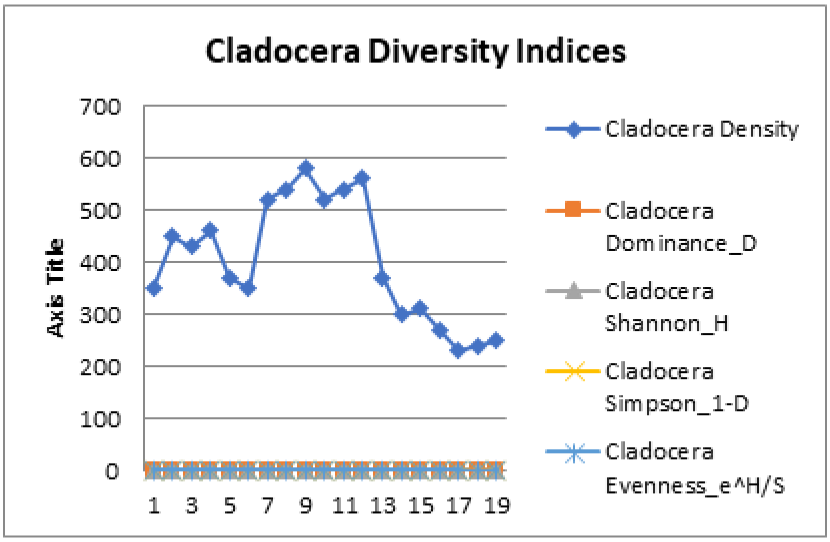

Figure 3: Graphical representation of Group Cladocera diversity indice

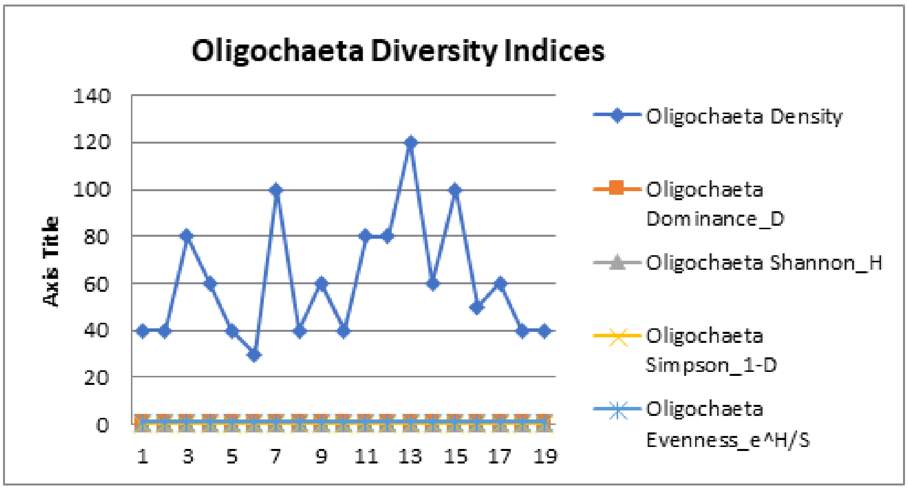

Figure 4: Graphical representation of Group Oligochaeta diversity indice

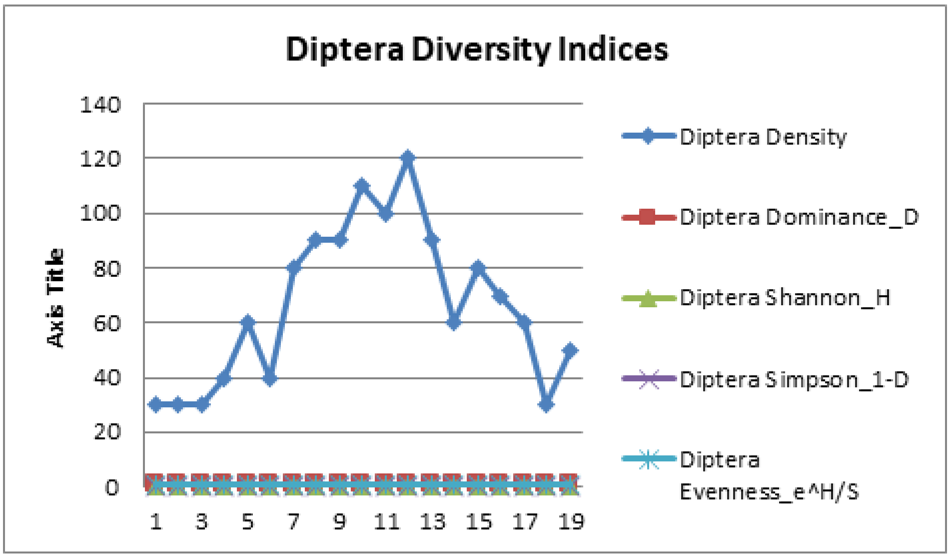

Figure 5: Graphical representation of Group Diptera diversity indice

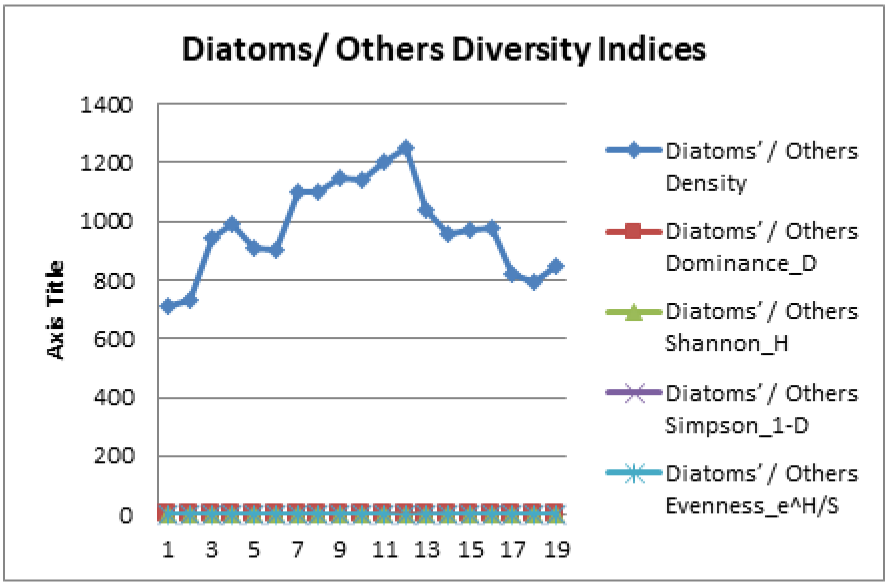

Figure 6: Graphical representation of Group Diatoms/ Other's diversity indice

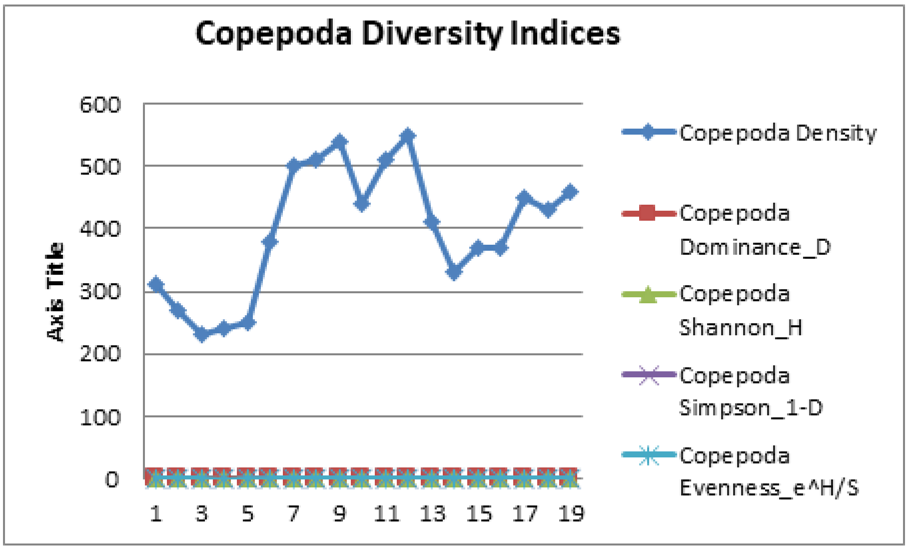

Figure 7: Graphical representation of Group Copepoda diversity indice

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