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A REVIEW ON DISEASE MANAGEMENT IN INLAND FISHERIES OF INDIA

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ABSTRACT

The future sustainability of aquatic food resources hinges upon the success of fisheries, making it a cornerstone for meeting the escalating demand for food. However, the sustainable development of the fisheries sector faces a critical challenge in the form of diseases, necessitating adept management strategies. Over recent years, aquaculture production has shifted away from extensive culture systems towards semi-intensive and intensive technologies. However, disease management becomes paramount, as it poses a substantial challenge to the expansion and sustained viability of the aquaculture industry, leading to increased production costs. The current study seeks to enhance our understanding of fish diseases and their effective management. Diseases induced by fish pathogens, including bacteria, fungi, viruses, and protozoa, have the potential to cause significant financial losses to aquaculture industries. Outbreaks commonly occur when fish experience stress due to various physical, chemical, and biological factors, including suboptimal nutrition. Effectively managing stock, soil, water, nutrition, and the environment proves to be a pivotal strategy in controlling or preventing disease problems within any aquaculture system. In the context of India, fish farmers often lack expertise in aquaculture health management strategies. This study addresses this gap by focusing on fish diseases management, recognizing its critical importance to the fish farming industry. The aim is to identify major gaps and formulate policies that can fortify and streamline disease management in inland fisheries. The insights derived from this paper are anticipated to enhance the disease management skills of fish farmers involved in aquaculture practices. By addressing the challenges posed by diseases in aquaculture, this research contributes to the overall sustainability and productivity of the fisheries sector, paving the way for informed policies and practices in aquaculture health management.

Keywords: Inland fisheries, Fish Disease, Health management, Zoonosis, Biosecurity, India.

INTRODUCTION

Aquaculture currently stands as the fastest-growing agricultural industry globally. The significance of the fisheries and aquaculture sector was emphasized by the Blue Revolution in India, solidifying its position as the world's third-largest fish producer and the second-largest aquaculture nation after China. India contributes 6.3% to global fish production, with a 1.1% share in GDP, 5.15% in agricultural GDP, and per capita fish availability at 9.0 kg. The total fish production is 10.1 million, with annual export earnings amounting to Rs. 33,441.61 crores, and the sector employing 14 million people.

The intensification of the culture system has led to a significant increase in the threat of diseases, posing a major challenge to the production levels. The aquaculture industry is currently grappling with difficulties in ensuring its sustainable development. Various direct negative effects have emerged as a result of the intensified culture system, including the emission of eutrophying substances and poisonous chemicals, the transmission of viruses, illnesses, and parasites to both wild populations and cultivated stocks, as well as the introduction of foreign and genetic materials into the ecosystem. Within the aquatic ecosystem, a delicate balance exists among fish, pathogens, and the environment. Disease manifests when an imbalance in these components is triggered by various factors. In this context, inadequate nutrition stands out as a significant factor that can render individuals more susceptible to infections, as highlighted by Kabata (1985).

In the realm of fish production, disease represents a significant challenge for farmers, exerting a substantial impact on both the quality and quantity of yields. The resultant increase in production costs adds

to the woes of farmers. The reduction in yields is predominantly attributed to disease prevalence. Fish parasites emerge as an inherent and unavoidable component of the natural environment in which fish thrive. Within this context, various groups of parasites pose a threat to fish populations. Notably, these parasites include protozoan ciliates such as (*Ichthyophthirius spp*. and *Trichodina spp.),* monogenetic trematodes (*Dactylogyrus spp.* and Gyrodactylus sp.), and larger crustacean ectoparasites, (*Lernae spp., Argulus spp*. and *Ergasilus)*. The presence of these parasites contributes significantly to economic losses within the fish culture system in India, as highlighted by (Das and Mishra 2014).

Fish health management has evolved into an indispensable and ongoing operation to prevent the sudden outbreak of epizootics, which can be attributed to environmental deterioration, improper feeding practices, overcrowding, and other factors. The foundational step in preventing fish diseases is the proper management of water quality and nutrition. Without meticulous attention to these aspects, disease outbreaks become inevitable. Unfortunately, most of the farmers lack the necessary knowledge in aquaculture health management, coupled with limited opportunities to enhance their management skills and effectively address disease-related challenges. The prevailing lack of understanding regarding the signs of diseases and their treatments further exacerbates the situation. Consequently, the impact of diseases on fish production has reached a notably severe level. Understanding the root causes of fish diseases and implementing effective control measures in aquaculture are crucial steps in addressing these challenges. This knowledge not only provides valuable insights into disease problems but also lays the foundation for the development of improved health management strategies in freshwater aquaculture production.

MATERIALS AND METHODS

The information presented in this review paper has been collected from various secondary sources, including peer-reviewed national and international journals, newsletters, proceedings, reports, related books, and online resources such as internet searches. Primary data for this study were extracted from a range of sources, including literature, newspapers, research papers, and public and government portals (websites). The utilization of primary data facilitated the creation of secondary data, which was essential for conducting a more in-depth examination of fish pathogens. These secondary data played a crucial role in the comprehensive review of existing research in this field. To retrieve published data, universally recognized databases were employed, including Scopus, PubMed, ScienceDirect, and Google Scholar. These reputable search engines were instrumental in accessing a wide array of scholarly information, ensuring the robustness and reliability of the data used in this review.

DISCUSSION

In recent years, the landscape of Indian fisheries has undergone a significant transformation, transitioning from a dominance of marine fisheries to a substantial focus on inland fisheries. The contribution of inland fisheries to the overall fish production has surged, rising from 36% in the mid-1980s to an impressive 70% in the recent past. This noteworthy shift positions the sector as a major player in the Indian fisheries scenario. Regarded as a sunrise sector, inland fisheries are poised to exert considerable influence on the Indian economy in the near future. The strategic shift within inland fisheries, moving from traditional capture-based methods to more sustainable culture-based fisheries, marks a pivotal development. This transition not only reflects a shift in practices but also opens avenues for the establishment of a sustained blue economy within the sector. This evolution underscores the dynamic and progressive nature of India's fisheries industry as it adapts to changing paradigms for enhanced productivity and sustainability.

Inland fisheries

While there has been growth in both inland fisheries and aquaculture in absolute terms, the full realization of their potential is yet to be achieved.

INLAND WATER RESOURCES OF INDIA

WATER RESOURCES	*AREA*
Rivers and canals	191,024 km^2
Floodplain lakes	1.2 million Ha
Ponds and tanks	2.36 million Ha
Reservoirs	3.54 million Ha
Brackish water	1.24 million Ha

The vast and diverse resources that remain unutilized or underutilized present significant opportunities for increased production. Leveraging these resources has the potential not only to boost production levels but also to contribute to livelihood development and foster economic prosperity. The unexploited potential within inland fisheries and aquaculture emphasizes the possibilities for further development, emphasizing the need for strategic and sustainable utilization of these

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resources to unlock their full economic and social benefits.

Fish Diseases

Fish, comprising over 35,400 reported species (Fish Base, 2023), stand as the most numerous vertebrates on Earth. Similar to other animals, fish are susceptible to various illnesses, and these diseases can inflict significant economic losses upon fish farmers. Disease, in the context of fish health, manifests as a disorder in the structure or function exhibited by host organisms, presenting specific signs and symptoms. Many of these diseases are contagious, necessitating specific precautions, treatments, and control measures to prevent their spread. A state of health in fish is denoted by the sound status and normal functioning of all bodily organs. Any deviation from this normal functioning, induced by adverse factors, is termed as a diseased condition. Poor water quality and nutrition contribute to stress in fish, creating an environment conducive to pathogens causing diseases. Chronic over-supplementation of protein can result in increased protein excretion by fish, leading to elevated ammonia levels in the aquatic environment.

In commercial fish culture, diseases are more frequently attributed to various microorganisms, including parasites, bacteria, viruses, and fungi. Understanding the complex interplay between environmental factors, nutrition, and pathogenic agents is crucial for implementing effective measures to maintain the health and well-being of fish populations in aquaculture settings.

Metazoan Diseases

Metazoan parasites include the myxozoas, helminths, crustacean, annelids, and molluscs are common in both wild and cultured fish. The very common *L. cyprinacea* is considered one of the most invasive ones. A number of species have been reported from Indian region (*L. chackoensis* and *L. bengalensis*) (Chandra 2004). Whirling Disease is caused by Myxobolus *cerebralisui.*

Protozoan Diseases

The *Ichthyophthirius multifiliis* parasite, also known as "Ich," is the infectious agent that causes "white spot disease." It is the protozoan disease that affects freshwater fishes more frequently than any other disease in the globe. (Jessop 1995, Dickerson and Dawe 1995, Buchmann et al., 2001, Matthews 2005, Dickerson 2012). *Chilodonella hexasticha* is most likely to be harmful when the water temperature is lower. (Bauer et al., 1973). According to Lom and Dyková (1992), the Trichodinidae family is comprised of the genera *Trichodina, Trichodinella*, and *Tripartiella*, all of which are significant ectoparasites of marine and freshwater fish around the world. *Ichthyobodo necatrix* (Costia necator), the flagellate that is responsible for the sickness known as costiasis, is most known for its role as a dangerous fish pathogen.

Crustaceans Diseases

Parasitic crustaceans are among the most serious gill and skin parasites of fish worldwide. Argulus commonly referred to as "fish lice", is causing problems in fisheries and aquaculture worldwide (Fryer 1968, Kabata 1970, Ahmed and Sanaullah 1976, Post 1987, Rushton-Mellor 1992). Anchor worms' are important ectoparasite parasites in freshwater aquaculture of cyprinids. A number of species have been reported from Indian region (*L. chackoensis and L. bengalensis*) (Chandra 2004). This parasite also creates problems in commercial aquariums.

Trematode Diseases

Dactylogyrus are commonly known as 'skin flukes' and are found all over the surface of the body, including fins and occasionally in the gills of both marine and freshwater fish. Some species of Dactylogyrus have proved to be very dangerous in cyprinid culture, especially to fry, where relatively few parasites can cause severe gill damage. A number of species of this genus *(Dactylogyrus mrigali, D. chauhanus, D. yogendrai, D. labei, D. kalyanensis*) have been reported from the Indian major carps and other several exotic and indigenous fishes (Chandra and Jannat 2002, Chandra and Yasmin 2003).

Bacterial Diseases

Bacterial infections are likely the most prevalent cause of diseases that are discovered in fish at this time. Bacterial diseases are responsible for heavy mortality in both wild and cultured fish. Aeromonas is a most important genus of the bacterial pathogen of warm water fishes. *A. hydrophila* is the major causative agent for ulcer diseases. Tanguthai, (1985) reported A. hydrophila as a principal causative agent of ulcerative diseases noticed in culture fish in the Indo-Pacific region. Nayak et al., (1999), isolated and identified *A. hydrophila* from a variety of diseases spectra e.g., eye diseases, epizootic, ulcerative syndrome, haemorrhagic septicaemia in carps, mullets, Puntius, Channa from the culture pond and natural habitats in

India. There was a strain of *Aeromonas salmonicida subsp. Salmonicida* is known as an etiologic agent of furunculosis, which is one of the earliest diseases that have been documented. *Aeromonas salmonicida,* is the pathogen that is responsible for causing the Goldfish Ulcer disease. Motile Aeromonas Septicemia Infections brought on by *Aeromonas hydrophila, Aeromonas sobria, Aeromonas veronii, and Aeromonas caviae.* Yersiniosis also known as enteric red mouth disease is one of the most devastating illnesses that can affect salmonids and can result in significant financial losses for salmonid farms located in both freshwater and marine environments (Austin and Austin, 2012; Bullock and Snieszko, 1975; Toranzo, 2004). *Yersinia ruckeri* is the organism that is responsible for the sickness. *Fusobacterium psychrophilum*, is responsible for the cold-water sickness, *Fusobacterium columnare,* is responsible for the columnaris disease, and *Fusobacterium branchiophilum,* is responsible for the bacterial gill disease.

Viral Diseases

Viruses, as frequently highlighted, surpass the conventional boundaries of life and non-life; they occupy a unique space, existing somewhere between the realms of biochemistry and biology. Notably, various viral diseases have been reported in India, including those caused by Koi ranavirus (KIRV), Similar damselfish virus (SRDV), Red sea bream iridovirus (RSIV), Infectious spleen and kidney necrosis virus (ISKNV), Carp edema virus (CEV), Viral Nervous Necrosis (LCNNV-In), Tilapia Lake Virus (TiLV), and Snakehead rhabdovirus (SHRV-In) (Kollanoor Riji John, Panchavarnam Sivasankar, and Mulloorpeedikayil Rosalind George, 2023). One noteworthy viral affliction is infectious pancreatic necrosis (IPN), where mortality rates are alarmingly high. The causative agent for this disease is the infectious pancreatic necrosis virus (IPNV), emphasizing the significance of understanding and managing these viral threats in the context of aquaculture and aquatic health.

Fungal Diseases

Saprolegnia is associated with damage to the integument, often known as open skin lesions. Once an infection with Saprolegnia has begun in a fish, the disease will often spread and eventually become fatal. *Achlya* and *Dictyuchus sp.* were more significant as causes of mortalities than *Saprolegnia*. This finding was published in 1973 by Nolard-Tintigner. This was demonstrated by Srivastava and Srivastava (1978), whose research demonstrated that the host range of Achlya has been extended to include *Puntius sophore, P. conchonius, P. ticto, Colisa fasciata, Chanda ranga, Labeo rohita* (fingerlings), *L. bata* (fingerlings), *Notopterus notopterus*, *Anabas testudineus*, and *Channa punctatus*. Gill rot is a fungal illness that is associated with various species of *Branchiomyces*. It has been discovered that the gill tissue of carp and other cyprinids can be infected with it. (Hoole et al.,2001). This disease is wide spread in culture ponds with deteriorating water quality (Das, 1995). According to Das (1995), the gill rot is brought on by the pathogenic fungus *Branchiomyces demigrams*. Degeneration of a piece of the gill may occur over time, particularly in more advanced stages of the disease.

Nutritional diseases

Nutritional diseases in fish result from either an excess or deficiency of nutrients beyond their normal requirements. The occurrence of active fish diseases is closely linked to various pathogens, and the nutritional content of fish feed shows a negative correlation with the occurrence of diseases. Essential nutrients for proper fish growth include lipids, carbohydrates, proteins, vitamins, and mineral salts. Changing the existing feed often leads to the disappearance of disease symptoms. Signs of nutritional diseases include reduced fecundity, slow growth rate, decreased appetite, increased susceptibility to diseases, morbidity with clinical signs and pathological lesions, and mortality. While these diseases are noncontagious and rare, they cannot be cured by medications. The most effective prevention and control method involves ensuring good water quality and implementing sound management practices. Timely observation of fish behaviour and feeding aids in the early detection of diseases, facilitating easy diagnosis before a majority of the population becomes affected. Fish scurvy is a deficiency condition that is non-infectious in nature, primarily caused by a deficiency of Ascorbic acid. Broken Back Syndrome is a well-known ailment in channel catfish within super-intensive culture systems and occurs when fish are fed vitamin C deficient diets for an extended period. Lipidosis, a common non-infectious nutritional disease, affects various cultured fish species. Nutritional Myopathy is associated with rancid fat or diets containing polyunsaturated fatty acids (PUFA) with low vitamin E content. Conditions such as Steatitis and white fat disease arise from Vitamin E Deficiency. The absence of specific vitamins can lead to severe metabolic disorders known as Avitaminosis, which can be fatal. Accumulation of water-soluble vitamins under certain conditions may result in a toxic condition referred to as Hypervitaminosis.

Fish borne Zoonotic Diseases

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A large number of parasites can infect fish, but only a few pose health risks to humans, typically transmitted through the consumption of raw or undercooked fish. Among fish-borne parasitic diseases, those caused by digenetic trematodes are the most prevalent. Noteworthy examples of these digeneans include *Clonorchis sinensis*, *Opisthorchis viverrini,* and *Opisthorchis felineus* (Roberts 2012, Lima dos Santos and Howgate 2011). Many freshwater fish species, particularly those belonging to the Cyprinidae family (carps), can transmit infective trematode metacercariae (WHO 1995, Touch et al. 2009, Chen et al. 2010). Diphyllobothriasis, a major cestodiasis, is transmitted by freshwater, marine, and anadromous fishes infected with pseudophyllid cestodes from the genus *Diphyllobothrium*. At least 13 species of this cestode genus have been identified in humans. Fish-borne nematodiasis typically occurs when humans are incidentally infested with nematodes whose natural definitive hosts are marine mammals, birds, pigs, or other animals. Capillariasis, caused by the nematode *Capillaria philippinensis*, was initially considered an indigenous disease in the Philippines but has since been reported in Thailand, Japan, Taiwan, Indonesia, Korea, Iran, Egypt, and India, with freshwater fish serving as potential sources of human infection (Cross et al. 1972). Gnathostomiasis, induced by members of the genus Gnathostoma undergoing visceral larval migration, is prevalent in Southeast Asia, China, Japan, Korea, the Indian subcontinent, and the Middle East. The control of zoonotic fish parasites presents a multifaceted challenge due to the complex interactions among hosts, pathogens, and the aquatic environment in an aquatic ecosystem.

MANAGEMENT OF FISH DISEASES

Aquaculture health management means the management approaches to prevent and control the outbreak of emerging and re-emerging diseases which begin with prevention of disease. Even on fish farms where management practices and feeding standards are good, the disease and parasite problems can occur from time to time, and control measures become necessary.

Good Aquaculture Health Management Practices

A comprehensive health management plan for aquaculture industries must encompass various aspects of production activities. At the production level, creating a conducive environment for health involves securing robust seeds and young fish, ensuring proper nutrition, effective waste management, maintaining optimal water quality, and regular monitoring. Providing a well-balanced diet is crucial for delivering high nutrients to combat deficiency diseases and achieve optimal yields. However, diets can potentially have negative effects, such as inducing nutrient deficiencies, toxin production, or introducing pathogens to the fish. Effective management necessitates maintaining thorough farm records. These records should include information on disease treatment, clinical signs (behaviour and appearance), farm layout (inflow, outflow, pond connection), breeding animals (species, number, origin, age group), yield (per pond, each cage, each farm, normal survival rate), nutrition (live food, processed food, source, feeding method), management practices (continuous stocking, closed operation, stocking density), mortality data (affected locations, approximate percentages, and numbers), and unusual events (abnormal weather changes, higher-than-average mortality rates, lower-than-average yields, land use activities, runoff, overflow, abnormal growth, spawning events). In addition to maintaining regular records, continuous monitoring and updating of information are essential. This includes staying abreast of new animals introduced to the farm, replacing feed, connecting new ponds, and incorporating new farms upstream. This dynamic and proactive approach to information management is crucial for effective disease prevention, treatment, and overall health optimization in aquaculture.

Understanding the initiation of disease

Effectively managing stock, soil, water, nutrition, and the environment stands as the most impactful strategy for either preventing disease problems or mitigating their occurrence within a given system. While proper management is not foolproof, pathogens can establish themselves in animals and cause disease. In a natural ecosystem, a complex and dynamic balance is maintained through interactions among hosts, pathogens, and ambient elements. Disease has the potential to spread when this equilibrium is disrupted. The host's physiological ability to defend itself is directly tied to its overall nutritional health. Specimens that are nutritionally sound and immunologically robust are better equipped to ward off attacks. Understanding the mechanisms involved in fish disease identification is crucial for effective fish health management, especially in deriving optimal value from semi-intensive aquaculture techniques. In aquatic ecology, pathogens are consistently present, and the manifestation of sickness in fish involves a complex set of mechanisms.

Physical disease control measures

Disease prevention can be achieved through proper nutrition supply, good quality water supply and healthy sanitation condition. Physical disease control measures to prevent infectious agents from entering the farm include quarantine, vaccination, regulation of temperature, use of recommended stocking densities, and filtration and irradiation of inflow water using ultraviolet light. Development of standardized cleaning and disinfection protocols backed with proper records keeping would be key to effective management and control of commercial important diseases.

POLICY RECOMMENDATIONS

Fish health management has emerged as a fundamental prerequisite for ensuring sustainable development in aquaculture. However, a significant challenge persists as many farmers engaged in aquaculture lack sufficient knowledge about health management practices in this domain. Therefore, a critical focus on disease prevalence and fish pathogens becomes imperative. Providing farmers with essential knowledge about sound aquaculture management practices is crucial in this context.

Recognizing the escalating trend of infections in fish, it is imperative to establish robust preventive measures to effectively control the spread of diseases. This necessitates the implementation of measures such as governing aquatic health issues, conducting routine surveillance, establishing quarantine facilities, and enhancing the linkages between various stakeholders involved in aquatic animal health issues.

In these aspects, the recommendations for effective fish disease management include:

Keeping good records

Maintaining comprehensive records on the farm site is imperative for effective aquaculture management. These records should encompass all facets of farm operations, and it is crucial to train farmers to recognize the significance and value of this meticulous approach. Accurate and timely information pertaining to the development and nature of a disease outbreak can play a pivotal role in swiftly diagnosing the issue and making informed decisions for intervention and control. The practice of keeping thorough records is indispensable in aquaculture, serving as a foundational element for effective health and productivity management. By systematically documenting various aspects of farm activities, farmers can enhance their ability to monitor, analyse, and respond to emerging challenges, ultimately contributing to the overall success and sustainability of aquaculture operations.

Monitoring of disease invasion

Addressing health issues through proactive planning and effective management has become a crucial necessity for sustaining aquaculture production. The persistent risk of significant disease outbreaks and the emergence of new diseases poses an ongoing threat to the sector. Appropriate and well-implemented health management measures are vital to mitigate these risks and uphold the health of aquaculture systems. Without such measures, both the government and the private sector are likely to incur substantial costs in terms of production losses and the resources required to combat diseases. Allocating funds towards controlling and eradicating diseases, while necessary, could be more efficiently utilized in preventing the entry of diseases into the system in the first place. By prioritizing preventive measures, the aquaculture sector can potentially reduce the economic and operational burdens associated with disease outbreaks, ensuring a more sustainable and strong industry.

Practical training to fish farmers

The government should initiate practical training programs to assist fish farmers in disease management. This comprehensive training encompasses the entire aquaculture process, covering aspects such as pond preparation, stocking rates, the importance of quality seed, feed management, water quality, and more. Farmers are educated on the principle that knowing the specific cause of a disease is not always necessary for effective management. Instead, they need to be empowered to eliminate or manage the risk factors associated with disease occurrence, enabling them to adopt proactive measures to safeguard their aquaculture operations. Through practical training initiatives, fish farmers can enhance their skills and knowledge, contributing to the overall health and sustainability of the aquaculture sector.

Expertise development

It is imperative for all fisheries research institutions to enhance their expertise in disease management, an area currently limited in the country. In states where aquaculture has a longstanding tradition or has been recently introduced, there is a critical need to develop disease management capabilities. Each state should have officers trained specifically in disease management, depending on the size of the state and the extent of water areas involved. Establishing disease laboratories in each state is essential to facilitate necessary preliminary investigations by these trained officers. These laboratories should be adequately equipped to handle various aspects of disease diagnosis and research. Diseased specimens can be

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sent to these state laboratories, and experts can be consulted as needed. This decentralized approach ensures timely and efficient responses to disease outbreaks, promoting effective disease management strategies at the state level. By building local expertise and infrastructure, the aquaculture sector can better address and mitigate the impact of diseases, contributing to the overall health and sustainability of fisheries.

Awareness among fish farmers

Fish farmers must be educated about the challenges posed by disease infestations and the resulting losses due to both mortality and morbidity through regular monitoring practices. Every farmer should be accustomed to control methods for common diseases, enabling them to take immediate and informed steps to safeguard their crops. Despite various diagnostics developed by institutes such as the Indian Council of Agricultural Research (ICAR) and Fisheries colleges for different fish diseases, many are primarily designed for laboratory use and require validation. To bridge this gap, the organization of fish health camps and awareness programs is essential. These initiatives aim to provide fish farmers with comprehensive knowledge about newly emerging and reemerging viral infections, contemporary health management techniques, the dynamics of disease prevention, necessary infrastructure, and regulatory norms. Furthermore, integrating systems for effluent treatment, resource management, and pond environment sanitation becomes crucial to enhance aquaculture productivity. Moving forward, it is imperative for fish farmers to acquire basic theoretical expertise regarding disease management. This foundational knowledge equips them to implement effective measures, contributing to the overall health and sustainability of aquaculture practices.

Farm-level diagnosis

Aquatic diseases were not historically considered a significant concern in our country, as the economic impact on fish culture was not well understood. However, recent incidences of various emerging diseases have brought this issue to the forefront. Addressing these challenges requires collective efforts to ensure sustainable aqua-farming and fisheries, thereby preventing significant production losses.

In the current scenario, a reliance on imported diagnostic kits is evident for various testing purposes and farm-level diagnoses. These kits are utilized by private diagnostic laboratories. Therefore, it is of principal importance to develop and commercialize diagnostic kits for important and emerging diseases. These kits should be designed for on-site use by farmers, particularly at pond sites. This approach aims to empower farmers with the tools needed to promptly identify and address diseases, contributing to the overall health and sustainability of aquaculture practices. Furthermore, establishing diagnostic laboratories in various parts of the country can enhance the capacity for disease detection and monitoring. This decentralized approach would facilitate quicker responses to disease outbreaks, contributing to the overall health and flexibility of the aquaculture industry.

Implementation of Biosecurity measures

Biosecurity encompasses a set of measures designed to prevent the introduction of infectious agents into specific geographical locations or facilities. In traditional fish culture, which was historically extensive, diseases did not pose a serious threat. However, the landscape has evolved with modern aquaculture characterized by high stocking densities and the incorporation of external inputs like feed and fertilizer of variable quality. This shift has led to an increased susceptibility of farmed fish to diseases caused by various pathogens such as protozoans, helminth parasites, fungi, bacteria, and viruses.

The significant losses for fish farmers, both in terms of mortality and morbidity, have prompted an elevated use of chemicals and antibiotics. Unfortunately, this practice is not ideal given the potential adverse impacts on the human food chain. To mitigate these challenges, the implementation of effective biosecurity measures by farmers becomes imperative to prevent the spread of infections among farmed fish. Remarkably, many hatcheries in India lack quarantine facilities, which may be attributed to inadequate fish disease reporting in the country. To ensure biosafety in aquaculture, biosecurity measures should be implemented at all stages of the aquaculture production cycle. This includes broodstock stations, individual farms, as well as national and international organizations responsible for aquaculture exports and imports. A comprehensive and integrated approach to biosecurity is essential for sustaining the health of aquatic populations and ensuring the safety of aquaculture products.

Surveillance on diseases

Modern health management practices, rooted in epidemiological principles, emphasize the implementation of active and passive surveillance programs for the advanced prediction of disease

occurrences, particularly in the context of fisheries. In India, the "National Surveillance Programme on Aquatic Animal Diseases (NSPAAD)," initiated in 2013, exemplifies a concerted effort to address the challenges of disease control in both fish and shellfish species. This program's objectives include recording the prevalence of diseases, monitoring emerging and re-emerging diseases, and developing immediate response measures. The primary focus is on identifying, notifying, and containing diseases, particularly viral infections, to prevent their escalation. The control of zoonotic fish parasites presents a multifaceted challenge, necessitating comprehensive strategies. In this regard, conducting fish health camps and awareness programs becomes essential. These initiatives serve to empower farmers with the knowledge needed to take precautionary measures before diseases spread uncontrollably. By fostering awareness and providing proactive measures, these programs contribute significantly to disease prevention and control within the aquaculture industry.

Investments

Substantial investments are essential to enhance aquatic animal health and disease prevention. This includes investment in skilled personnel, such as researchers and technicians, who play a pivotal role in advancing the field. Additionally, investments are crucial in research endeavours focused on the development of pertinent biotherapeutics and chemotherapeutics to combat aquatic diseases effectively.

Establishing well-equipped laboratories is a key component of these investments. A state-of-the-art diagnostic laboratory, equipped with advanced technologies and instrumentation, is highly needed. Equally important is ensuring that the laboratory is staffed with appropriately trained and experienced personnel. This team of experts is instrumental in conducting accurate diagnoses of infected fish, facilitating prompt and effective disease management strategies.

Vaccinations of fish

As proper management is not always effective, pathogens produce the disease and subsequently these pathogens pose health hazards to consumers and handlers leading to zoonotic problems. If the pathogens pose health risks to consumers and/or handlers, which can result in zoonotic problems, then it is necessary to prevent the disease from occurring in humans indirectly by preventing it from occurring in animals through immuno-potentiating against a broad-spectrum range of pathogens. Fish vaccination is a beneficial preventative measure and effective way for managing viral and bacterial illnesses in fish populations. The range of bacterial infections for which vaccines are commercially available now comprises classical vibriosis (*Listonella anguillarum, Vibrio ordalii),* furunculosis (*Aeromonas salmonicida subsp.* salmonicida), cold-water vibriosis (*Vibrio salmonicida*), yersiniosis (*Yersinia ruckeri*), pasteurellosis (*Photobacterium damselae supsp.* piscicida), edward siellosis (*Edwardsiella ictaluri*), winter ulcer (*Moritella viscosa*), and streptococcosis/lactococcosis (*Streptococcus iniae, Lactococcus garviae*) and one for viral disease (Infectious pancreatic necrosis) (Hastein et al., 2005). Due to the fact that certain viruses can be passed from animals to humans, it is essential for those working in aquaculture, fish processing, and fish technician jobs to practice proper hygiene. Through the implementation of the appropriate management techniques and the administration of vaccines, it is possible to completely avoid the occurrence of several diseases.

CONCLUSION

Fish holds a crucial position as a dietary staple for humans, but they are prone to various diseases. Therefore, the development of robust preventive and control measures is imperative for fish health management. The outbreak of diseases in farmed fish is often attributed to faulty management practices, deteriorating environmental conditions, and infectious microorganisms. Addressing the challenge of diseases has become a primary concern for sustainable aquaculture practices. The economic repercussions of infectious diseases, leading to high mortality rates in farmed fish and commercial systems, pose a significant risk to the fisheries sector. Parasitic diseases are prevalent worldwide, causing substantial quality and economic losses for farmers. Given the zoonotic nature of some pathogens, practicing good hygiene is paramount for aqua farmers, fish technicians, and processors. Raising awareness among fish farmers is instrumental in preventing many diseases.

A comprehensive understanding of disease prevalence, coupled with indigenous technologies for prevention and control, is crucial. While the Government of India has initiated fish disease control programs, there is a need for further efforts to eradicate fish diseases. Enhanced laboratory facilities, diagnostic expertise, control protocols, and therapeutic strategies at the national level are continuously improving to handle disease outbreaks. Research focusing on disease surveillance, pathogen zoning, and disease forecasting is essential for implementing effective preventive and control measures to safeguard the fisheries. Inland fisheries present significant

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opportunities for production enhancement through optimal resource utilization, technology infusion, and capacity building. Holistic approaches should be adopted, not only addressing the occurrence of diseases and pathogens but also focusing on the awareness development programs for farmers. Government initiatives, including manpower and infrastructure development, and the formulation of policies for fish health management, are crucial to ensuring sustainable aquaculture production. Emphasizing prevention, better management practices, and maintaining healthy fish is paramount. Strengthening and streamlining the diagnostics and quarantine system in Indian aquaculture should be a part of policy formulation to bridge major gaps. Health management is a shared responsibility, and the collaboration of each stakeholder is essential for a robust health management process.

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