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Sustainable Aquaculture of Hilsa in India and Legal Perspectives: A Comprehensive Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Purpose: Hilsa overfishing has become one of the most concerning threats India despite a range of legal or regulatory frameworks are in action. The purpose of this review is to evaluate the current aquaculture practices of Hilsa in India in relation to balancing water ecology. This review has focused on whether the Indian fishery system maintains sustainable practices to for Hilsa. **Methods:** A comprehensive review has been conducted to meet the specific aim of this study. In this context, a range of relevant literature, including research articles, industry reports, Government reports and news reports collected from Google, Google Scholar, ScienceDirect and MDPI have been reviewed.

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Findings: The outcomes of this comprehensive review indicate that last few decades, the production of Hilsa species has increased but due to overfishing, the population of this species adversely affected. It indicates the phenomenon of sustainable fishing is not strictly maintained in India for the case of Hilsa. However, the current legal framework is not sufficient to prohibit overfishing.
Recommendations: A trans-boundary management of Hilsa fishery can be suggested which mainly includes forming a joint scientific council, joint monitoring and facilitating data availability, imposing similar discount rates, ban periods, mesh sizes, and introduction of effort and landing taxes. Additionally, by considering the success by CIFRI, the Government can increase breeding of Hilsa using cryopreserved milt. Furthermore, cultivating Hilsa through effective sustainable practices is another sustainable alternative to overfishing as it can meet the growing demands for Hilsa.

Keywords: Aquaculture; sustainable practice; fishery; overfishing; hilsa conservation rules.

1. INTRODUCTION

Hilsa (*Tenualosa ilisha*), belonging to the family of "Clupeidae" maintain a systematic life cycle throughout the Indo-Pacific province from the Arabian Gulf (Bangladesh, India, Pakistan, and Burma) to South Vietnam. This species is considered a premium table fish in the eastern and some parts of the north-eastern region of India, specifically for the Bengali community [1]. Additionally, Hilsa has also a valuable contribution to the economic and societal significance of artisanal fisheries in the country. Hilsa has been recognized as an enriched source of a range of important minerals including omega-3 PUFAs, DHA, EPA, along with high-quality proteins [2]. Due to this nutritional value, this fish species has also created a huge demand in the Indian fish market. Hilsa is found in both estuaries and rivers, as well as in coastal waters. However, the deltaic habitats of river Ganga ranging through the "northern Bay of Bengal" is the main area of Hilsa fishery [3]. In fact, the greatest catch of Hilsa in India reported from the deltaic Ganga region in the "coastal Bay of Bengal" [4]. However, the life cycle of Hilsa is partially marine and anadromous in nature and it has a significant influence on the fishing system of Hilsa. It is also needed to be mentioned that, in India, the primary distribution of this fish species takes place throughout the Bhagirathi–Hooghly component of the Ganga River system.

In India, the annual production of this fish species has increased from 0.14 lakh tonnes in 2021 to 5.71 lakh metric tons in 2022-23 [5]. However, a range of commercial, and environmental deterioration and interest-group threats from anthropogenic impacts obstruct Hilsa migration into the estuarine system. For example, siltation in the estuary mouth of the "Hooghly–Bhagirathi River system" has been identified as one of the key reasons behind the disruption in Hilsa migration process [2]. This aspect further results in the decline of Hilsa in the upper reaches, juvenile fishing, exploitation of brood fish [6]. Apart from that a lack of compliance with mesh size regulation, poor or ineffective fish passes, as well as a loss of habitat are also caused from unsustainable Hilsa fishing. However, the population of Hilsa is declining as a result of climate change, increased water abstraction for irrigation and industrialization, and pollution [7]. For instance, a recent report has shown that in 2024, markets across Kolkata have been flooded with juvenile Hilsa weighing between 50 gm and 200 gm [6]. It further indicates that the rampant fishing of Khoka Ilish is causing severe damage to the overall Hilsa population or Hilsa ecosystem in the Ganga estuary. On the other hand, because of overfishing, the price of Hilsa is increasing day by day across the country. For example, it has been recently reported that the price of Hilsa in India has increased by 50% compared to the previous year [8]. However, this unsustainable practice is pushing the Hilsa population to spawn in Bangladesh, where catching overfishing or finishing Juvenile Hilsa is a valid punishable offence. Apart from that, the share of Bangladesh has increased to 97.01% in global Hilsa production while in India this production amount has been shrunk to 2.41% [3].

From these contexts, it has become clear that overfishing of Hilsa has become one of the most unsustainable and concerning aquaculture issues in India. However, the market value of Hilsa has been increasing rapidly in India, specifically in West Bengal due to low availability because of overfishing. As a result, this unsustainable overfishing practice both

economically and ecologically affects the Hilsa production as well as management in India. Due to this reason, it is essential to implement effective and strict legal actions to prevent this unsustainable practice. Although a number of laws are active for mitigating this issue, there may be some loopholes in this legal framework. As a result, overfishing or unsustainable aqua practice of Hilsa is still a major problem in India. Considering these aspects, this article aims to review the current sustainable aquaculture of Hilsa in India in relation to saving water biodiversity. Additionally, the legal initiatives needed to improve sustainable Hilsa aquaculture are also recommended at the end of this review.

2. METHODS

Databases: A total of three databases have been used in this study which include, Google Scholar, Science Direct and MDPI. A range of journals and research articles have been searched from these electronic databases for further incorporation in this review. Additionally, Google has been used as the most important search engine in terms of searching for relevant news reports, industry reports, government reports, legal websites and so on.

Search sentences: A number of keywords related to the topic area of this study review have been used to further set some relevant search sentences. In this way, it has been possible to narrow down the overall search process. These search sentences are as follows.

- “Sustainable fishing” AND “Hilsa fishing” AND “challenges”
- “Sustainable fishing” AND “Hilsa fishing” AND “legal frameworks”
- “Sustainable fishing” AND “Hilsa fishing” AND “Indian regulations”
- “Sustainable fishing” AND “Hilsa fishing” AND “India aquaculture”

Data analysis: A comprehensive review has been conducted in this context to meet the specific aim of this study. In this context, a range of relevant literature, including research articles, industry reports, Government reports and news reports have been reviewed. The relevant and valid information extracted from these data sources has been reviewed by comparing and contrasting.

2.1 Sustainable Fishing in India

Sustainable fishing practice is defined as ensuring the significant reproductive rate of fish in terms of maintaining a balance in the water ecosystem. This legal fishing system also ensures the survival of all fish species as well as the depended fish populations in the water ecosystem [9]. In this way, sustainable fishing further ensures sustainable marine biodiversity as well as sustainable fish production. In India, the phenomenon of responsible fishing initiatives for sustainability includes, responsible fishing gears, development of efficient fishing vessel designs, measures for bycatch reduction, energy conservation as well as minimizing negative impact of fishing gears [10]. According to a relevant literature, in order to ensure sustainable marine fishing practices, it is essential to have a complete understanding of the multifaceted relationship between the environment or water ecology and the legal framework that regulates them [11]. In this way, the diverse ocean ecosystem is maintained by sustainable fishing as well as it also protects the endangered species [12]. Supporting this aspect, another literature has also indicated that sustainable utilization of fisheries resources, along with protection or promotion of nutritional security and livelihood security of fisher community has become a key focus in different States of India [13]. It has already been proved by many existing literatures that all aquatic species have a unique and important role within water ecosystems. Additionally, effective fishery management is one of the key parts of a balanced food web of predators and prey [14]. In indicates that only strict restrictions and continuous monitoring can enhance sustainable fishing practices in India. Due to this reason, it has been that only coastal management measures are not able to ensure the sustainability of the fisheries if the riverine systems are not improved [15]. However, in recent years, the adoption of different advanced fisheries technologies developed by CIFT (Central Institute of Fisheries Technology) enables the fishermen to enhance sustainable fishing practices. These technologies mainly include synthetic fiber fishing gears, different gears such as four-seam trawl and bulged-belly trawl that can increase the catching efficiency by about 30% [16]. By adopting these types of technologies, different sustainable fishing methods are also adopted in India which mainly include methods such as stern trawling, out-rigger trawling, midwater trawling purse-seining, and long lining [17]. Apart from that the introduction of specialized gill nets for lobster fishing has also played a significant role in the fisheries development in India. Therefore, based

on the important information obtained from these relevant literatures, it can be said that the aquaculture sector in India has already focused on the phenomenon of sustainable fishing but it is not evenly followed in all the states for capturing all type of fishes. Among these, Hilsa fishing has become a major concern in this country in relation to overfishing or juvenile fish capturing.

2.2 The threat of Overfishing to Hilsa

Hilsa is one of the ecologically important fish species in India but overfishing of this specific threaten different aspects of the country. In this context, a relevant study has shown that freshwater ecosystems are the most endangered ecosystems across the world [18]. Therefore, freshwater fish stocks are in a state of crisis because of overfishing. For a long period, Hilsa fishery has been recognized as the largest "single-species fishery" in the "Hooghly-Bhagirathi River system". Additionally, this fish species also has long been crucial to the economic as well as socio-cultural heritage of the people of the entire Gangetic plains [19]. The fishery is one of the most important sources of livelihood and occupation for the riparian fisher communities. However, this riparian fishery system in relation to zoology is characterized by open access fishing with crowding of effort in the estuarine and tidal freshwater stretches. In this context, a lack of alternative sources of subsistence has been identified as a reason of promoting riparian fishery [20]. This scenario is synergized by a lack of appropriate policies, poor understanding, and inefficient enforcement of existing management measures. As a result, both the water biodiversity and economic or social aspects of India are adversely affected as a result of this overfishing threat [21].

From a recent literature it has been noted that in 2021, the global average production of Hilsa was about 5.83 lakh tones and the annual production of Hilsa particularly in India in 2021 was 0.14 lakh tones [22]. Overfishing of juvenile Hilsa weighing between 50 and 200 gm is leading to damage to the overall Hilsa ecosystem in the Ganga estuary [23]. As a result, the overall water ecosystem is impacted and thereby, the population of Hilsa is declining day by day [15]. For instance, the overall production of Hilsa in West Bengal declined from 80,000t to 20,000t over 10 years since 2001 [22]. The existing situation of the Hilsa fishery indicates that proper assessment is necessary for identifying a strategy to further make the Hilsa fishing process sustainable. In addition to that, it is also necessary to maximize the economic benefits by balancing the overall life cycle, production and catching of Hilsa [21]. In the case of Hilsa fishes, it grows significantly faster within a short time span but due to higher demand, it accounts higher prices. In order to meet this demand, catching small or juvenile Hilsa has become a key trend in India and Bangladesh as well [19]. It further results in the biological as well as economic damage due to the harvesting of fish before they have reached to marketable size in still in India, indicating an unsustainable fishing practice. Efforts were thus taken place in terms of estimating the level of overfishing along with the mean of annual economic deficit resulted from catching juveniles along the "Hooghly Bhagirathi River system". However, a study has inferred that the fishing practice of Hilsa in India is unsustainable in nature because of overfishing [24]. Due to this reason, the government of this country needs to provide an interdisciplinary as well as up-to-date guide for practicing sustainable fisheries. Thus, the fisherman as well as the associated companies can make the right decisions to successfully manage fisheries for sustainability. However, the ICAR-CIFRI (Central Inland Fisheries Research Institute) in West Bengal has been working for the past 10 years breed hilsa using cryopreserved milt collected from the wild [25]. However, the report of 2024 has also indicated that this institute has become successful in this cultivation or breeding process of Hilsa that further provides a valuable insight into sustainable cultivation development of this fish species inters of meeting growing market demands.

2.3 Legal Framework of India for Sustainable Aquaculture

The Governments of different states in India have already introduced some regulations for enhancing sustainable fishing. For instance, the State Government of West Bengal has introduced a mesh size regulation in the use of gill nets that further indicates that only 90–110mm gill net should be used and that monofilament gill nets below 90mm mesh size and other nets with mesh size below 40mm are banned [22]. Apart from that, there is specific time period only when Hilsa fishing is allowed. For example, there is a Hilsa fishing ban period for 10 days in the month of September or October and a general fishing ban on all kinds of fishes in the state from 15 April to 15 June [10].

Apart from that there is also a mass awareness creation for Hilsa conservation from 2010 onwards that indicates harvesting, transporting, marketing, as well as selling Hilsa with less than the body size of 23cm, especially from February to April every year, is illegal in West Bengal. Moreover, Hilsa fishing is prohibited within 5 sq. km of the Farakka barrage around the year to facilitate brooders spawning in the area [22].

Indian Fisheries Act of 1897: In this particular context, one of the important Acts enacted to control fisheries in India is the Indian Fisheries Act of 1897 [26]. This enactment, by the then ruling British, was to ensure that fish resources in the country would be properly managed and conserved. The Act is mainly oriented toward the preservation of populations by banning certain activities that are likely to harm them. Crushing fish using poisons and explosives was banned because these methods may mean significant destruction of aquatic ecosystems. This therefore means the Act tries to conserve the species of fish and their habitats generation after generation by preventing these practices. Another critical aspect of the Act deals with the regulation of fish seasons [27]. It allows the authorities powers to establish closed seasons during which no fishing can take place. This should allow fish to breed and replace themselves without human interference and thus ensure fisheries in the long term. It also allows for the establishment of fish sanctuaries or protected areas wherein fishing is totally prohibited or limited. The sanctuaries shall act as the safe haven for fish to protect biodiversity and ensure a balanced ecosystem. The enforcement power of this Act is in the hands of a public servant who has powers of inspection, seizure of illicit fishing gear, and prosecution of offenders. Offenders can also be tried under the Act for penalties, including fines and imprisonment, depending on the seriousness. Overall, the Indian Fisheries Act of 1897 is a crucial legal framework aimed at promoting responsible fishing practices, conserving fish populations, and protecting aquatic environments [26]. Its provisions are essential for ensuring that India's fishery resources remain viable and productive, benefiting both current and future generations. The Indian Fisheries Act of 1897, more than a hundred years ago, had some very fundamental legislation for controlling and managing fishing, conserving aquatic resources within its ambit. Previously, there was also an Act, namely, “THE UNITED PROVINCES FISHERIES ACT, 1948” that prohibit the capture of or attempt to capture or kill breeding fish in Roe and Milt except Hilsa [28]. In summary, the Indian Fisheries Act of 1897 incorporates several forward-thinking provisions aimed at promoting sustainable fishing practices and conserving aquatic resources. While some aspects may need updating to address modern challenges, the Act’s fundamental principles remain relevant. By understanding and enforcing these provisions, we can ensure the long-term viability and health of India's fisheries, benefiting both the environment and the communities that depend on it.

The Maritime Zone of India, 1981 (Regulation of Fishing by Foreign Vessels Act): The Maritime Zones of India Regulation of Fishing by the Foreign Vessels Act, 1981, being a principal legislation, has been enacted to regulatory control and regulate the fishing activities carried on by foreign vessels within the maritime zones of India [29]. In sum, what the Marine Fisheries (Regulation and Management) Bill, 2009, purports to do is establish a comprehensive framework for the sustainable management and conservation of marine fisheries in India. This shall be achieved through the regulation of fishing activities, promotion of conservation measures, and cooperation between stakeholders, in order to secure marine resources and their long-term use for future generations. These provisions underscore the need to foster responsible fisheries management and preserve India's rich marine biodiversity. On the contrary, a recent research article has argued that inefficient administration is one of the major issues associated with this Act [30]. It further leads to considerable confusion and encourages over-exploitation of marine species. On the other hand, small boats are mainly causing overfishing in fisheries around the world, including India but due to a poorly defined and unenforced administration of this Act, it is ineffective to ensure sustainable fishing in this country. Thus, it has been clear from these existing relevant literatures that only this legal framework cannot enhance sustainable fishing in India.

The Wildlife Protection Act, 1972: Though the Indian Wildlife Protection Act, 1972, is mainly concerned with terrestrial wild life, still, there are important provisions for fish protection. Through including fish in the schedules, prohibiting their illegal hunting and trade, establishment of protected areas, and promotion of community involvement and scientific research, the Act acts

to save many fish species in India from becoming extinct, which means the loss of their habitats [31]. These provisions are thus of paramount importance to be understood toward inculcating a culture of conservation and managing aquatic biodiversity sustainably. In this particular context, a recent research article has indicated that being the most consumed non-human animal, fish are also considered to be one of the most numerous companion animals [32]. Due to this reason, this particular Act is also applicable for sustainable consumption or catching of fish in terms of ensuring availability and conservation in nature. In support to this particular information, another study has revealed that in order to maintain sustainability in both marine and inland fishing practices, it is one of the most effective and active legal frameworks. [33]. Reviewing all these articles, it has been understood that "The Indian Wildlife Protection Act of 1972" is one of the prime legislations to protect wildlife and its habitat all over India. While the Act deals specifically with the protection of land and bird species, it contains provisions that will have a bearing on fish with their conservation; hence the analysis of these provisions in the following manner:

2.4 Indian Government's initiative for sustainable Hilsa fishing

The Hilsa Conservation Rules, 2013: The Hilsa Conservation Rules, 2013, were established to regulate the fishing and conservation of Hilsa fish, particularly in Bangladesh and India where Hilsa is a significant part of the economy and culture [34]. These rules aim to ensure the sustainable management and conservation of Hilsa fish populations, balancing ecological health with economic needs.

Fishing Ban Periods: Specific periods during the breeding season when fishing Hilsa is prohibited to ensure sustainable reproduction. This is usually enforced during the peak spawning periods.

1. **Restriction on Net Size**: Regulations on the mesh size of fishing nets to prevent the capture of juvenile Hilsa, ensuring they can reach maturity and breed [15].
2. **Sanctuaries**: Designation of certain areas as Hilsa sanctuaries where fishing is strictly prohibited to provide safe breeding grounds.
3. **Awareness Campaigns**: Programs to educate fishermen and the public about the importance of Hilsa conservation and the long-term benefits of sustainable fishing practices [35].
4. **Enforcement and Penalties**: Implementation of strict penalties for violations of the conservation rules, including fines and confiscation of fishing equipment.
5. **Support for Fishermen**: Initiatives to support fishermen affected by the fishing bans, such as providing alternative livelihoods or compensation during the no-fishing periods [15].

2.5 Criticism on Hilsa Conservation Rules 2013 in India

The Hilsa Conservation Rules, 2013, while aiming to protect and sustain Hilsa fish populations, have faced several criticisms. For instance, a relevant research paper has shown that the struct implementation of this rule can result in economic loss of fishermen [15]. Supporting this aspect, another study has indicated that fishing bans during peak breeding seasons result in a significant loss of income for fishermen who rely heavily on Hilsa fishing for their livelihoods [35]. In this particular context, a large number of any fishermen in India argue that the compensation or support provided during the ban periods is insufficient to cover their needs. In this similar area, Small-scale and subsistence fishermen often bear the brunt of the regulations, while larger commercial operations may find ways to circumvent the rules. in such cases, it has been noted that small-scale fishermen may have limited access to alternative sources of income or livelihood programs compared to larger, more organized fishing operations [15]. Another argument has risen in this area that because of a lack of education and knowledge, a group of fishermen may not be adequately informed about the conservation rules and their importance, leading to non-compliance. Therefore, it is another limitation of this particular rule. Furthermore, some relevant studies have criticized that the immediate economic and social hardships faced by fishing communities can overshadow the potential long-term ecological and economic benefits of conservation [36]. Therefore, ensuring consistent and fair application of the rules over time is crucial for achieving the intended long-term outcomes. From these contexts, it has become clear despite a range of

benefits, there are also some criticisms related to this particular rule introduced by the Indian Government.

Apart from that, a recent research paper has indicated that the inland and marine fisheries laws should be more effective to strictly ban on Hilsa fishing during the spawning as well as breeding seasons [34]. Due to this reason, according to a recent report, “The West Bengal Fisheries Department” is planning to implement a process that includes strict provisions under BNSS 2023 and BNS 2023(Bharatiya Nagarik Suraksha Sanhita and Bharatiya Nayaya Sanhita). This initiative will also allow the police to arrest anyone for catching, selling and buying Hilsa weighing less than 500 grams [37]. Therefore, by considering the information collected from the existing research articles as well as reports, it can be contended that then current laws and regulations of fishing are not effective for completely stopping Hilsa overfishing.

3. CONCLUSION

This study has aimed to critically review whether Hilsa fishing practices in India are sustainable. In relation to this aspect, it has been found that in the last few decades, the production of Hilsa species has increased but due to overfishing, the population of this species adversely affected. This type of unsustainable practice of Hilsa has a direct link with the economic, social, legal as well as environmental consequences. This review also indicates that the current legal or regulatory frameworks of India are not sufficient for enhancing sustainable finishing practices for protecting the population of overall Hilsa species.

Moreover, it can be inferred that in order to conserve or protect the Hilsa population in its natural habitat, the overall Hilsa fishery system in this country needs to be more effectively managed. In this context, the activeness of suitable fishing regulations is important in relation to restricting the number of boats. In addition to the legal initiatives, it is also essential to increase the awareness of overfishing among the fishermen. Focusing on this aspect, the Central, as well as the State Governments, can also organize training programs for fishermen to know and strictly maintain sustainable fishing practices. Apart from that a trans-boundary management of Hilsa fishery can be suggested which mainly includes forming a joint scientific council, joint monitoring and facilitating data availability, imposing similar discount rates, ban periods, mesh sizes, and introduction of effort and landing taxes. In this way, overfishing as well as juvenile Hilsa fish catching can be strict banned in India in the future to ensure sustainable fishing practices. Additionally, focusing on the success by CIFRI, different aquaculture authorities can increase breeding of Hilsa using cryopreserved milt. Furthermore, cultivating Hilsa through effective sustainable practices is another sustainable alternative to overfishing as it can meet the rowing demands for Hilsa.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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