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ARTICLE

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TAGGING OF HILSA: AN APPROACH TO STUDY MIGRATION PATTERN UPSTREAM OF THE GANGA RIVER

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Hilsa is an iconic migratory fish species that undertakes upstream river movement for spawning. This study used T-Bar Floy tags to investigate the migration patterns, habitat preferences and biology of Hilsa in the upstream region of the Farakka Barrage in the River Ganga. The study examined biological parameters, such as size, weight and reproductive status, to understand the relationship between migration and spawning. This research highlights the effectiveness of T-Bar Floy tagging in studying the migration pattern of Hilsa.

Keywords: *Tenualosa ilisha, T-bar Floy tag, Migratory pattern, Recovery*

Introduction

Fish migration is the regular, often seasonal, movement of fish between different habitats for critical life functions such as spawning, feeding, and avoiding unfavorable environmental conditions. These migrations can occur in various directions and habitats, including freshwater, marine, and estuarine systems[1]. Based on their patterns, fish are classified as; Anadromous Fish (spend in marine and return to freshwater for spawning), Catadromous Fish (Freshwater dwellers, migrate to sea to spawn), Oceanodromous Fish (migrate varying ocean distances for feeding), Potamodromous Fish (migrate in freshwater to freshwater for feeding or spawning), Diadromous Fish (Fish migrating between freshwater and saltwater habitat and vice-versa) and Latitudinal Migration (Migration follows seasonal north-south directional patterns)[2].

Anadromous migration refers to the movement of fish from the ocean to freshwater rivers for spawning[3]. Hilsa (*Tenualosa ilisha*), a commercially significant species, exemplifies this behaviour. It inhabits marine and estuarine waters but migrates upriver during the monsoon to spawn in freshwater environments, such as the Hooghly-Bhagirathi River system. Environmental cues like temperature, salinity gradients, and river flow guide this migration. Post-spawning, the juveniles grow in freshwater before migrating downstream to estuarine and marine habitats. This migration plays a critical role in their life cycle and is influenced by factors like river obstructions (e.g., dams), fishing pressure, and habitat degradation[4].

Tenualosa ilisha, commonly known as a Hilsa, a migratory fish of significant ecological and economic importance, plays a crucial role in the livelihoods of millions of people across South Asia[5]. Known for its unique life cycle, Hilsa migrates between marine and freshwater environments. Adults spend most of their life in the sea but migrate upstream into rivers like the Ganga to spawn[6]. This upstream migration is essential for the species reproduction and sustenance of its population. In the last five decades, the construction of the Farakka Barrage in 1975 on the River Ganga has significantly altered the natural flow of rivers and disrupted migratory pathways[4,7].

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These obstructions pose challenges to Hilsa's migration, impacting its spawning success and overall population. To address these concerns, it is crucial to understand Hilsa's migration patterns, habitat preferences, and the impact of such barriers on its life cycle[8,9].

Fish behavioural physiology relies on migration as a basic mechanism for recruitment, breeding, and feeding. This field of study plays a crucial part in creating conservation strategies and actions for an ecosystem's diminishing population by identifying vital habitats. As a result, these habitats might be preserved in order to establish a native population within the designated ecosystem. According to research on migratory behaviour in all animals, including fish, birds, reptiles, and mammals, tagging remains the most effective technique for tracking using various tag types[10]. Tagging is a widely used scientific technique to study the movement and behaviour of fish[11]. Although there have been numerous advancements in tags over the years, such as satellite-based tags, electronic tags, and acoustic tags, the success of these tags still depends on the type of fish and its aquatic environment[12-16].

Among various methods, T-Bar Floy tagging is particularly effective for migratory species like Hilsa. This method involves attaching a small, durable tag near the dorsal fin of the fish, enabling researchers to track their movement when the tagged fish are recaptured. This approach provides crucial data on migration routes, timing, and distance travelled, as well as insights into their habitat preferences and spawning behaviour[16,17].

T-Bar Floy tags are advantageous because they are lightweight, durable, and visible, allowing for easy identification of tagged individuals during recapture or observation[18]. Researchers utilize these tags to track the movement of fish across different habitats, including rivers, estuaries, and marine environments. By recording the location and time of recapture, scientists can gather valuable information about migration routes, spawning grounds, and seasonal movement patterns[17].

By implementing T-Bar Floy tagging to Hilsa and releasing it upstream of Farakka Barrage to the reaches of the middle stretch of Ganga, researchers aim to gain valuable information on its migration patterns. Such studies are essential to developing conservation strategies, mitigating the impacts of barriers, and ensuring the sustainable management of this iconic species in the Ganga River system. The results provided insights into the extent of upstream migration, the impact of the barrage on migratory behaviour, and the factors influencing Hilsa's habitat selection.

Methodology

Study Area: For this study, the research team identified 2 to 3 ideal locations for Hilsa ranching, located between 24º82.0846′ N, 87º91.4084′ E and 24º86.9901′ N, 87º92.8403′ E, covering a 4.5 km stretch. These sites were chosen to help restore and rehabilitate *T. ilisha* populations in the middle Ganga River and to study their migration pathways. The middle stretch of the Ganga, from Prayagraj, Uttar Pradesh, to Farakka, West Bengal, spans about 958.4 km, crossing through Uttar Pradesh, Bihar, and Jharkhand. Data on Hilsa recoveries were collected from local fishermen and fish landing centres along the river, focusing on landing sites near Farakka, where Hilsa abundance was reported to be higher.

Tag and Tagging Procedures: T-Bar Floy anchor tags are widely used in fisheries research to study fish migration patterns, growth, and population dynamics. These tags are small, external plastic devices with a unique identification number printed on them. They are attached to fish using a tagging gun that inserts the tag into the dorsal musculature near the base of the dorsal fin. The tagging procedure involves careful insertion of the needle on the right side of the dorsal fin, specifically between the 3rd and 5th fin rays, into the dorsal musculature.

The tag is then securely placed. Special care is taken to avoid damaging the scales or creating unnecessary wounds. To minimize injury, the scale is gently lifted using the sharp point of the needle before inserting the needle into the muscle. The tagging process is efficient, allowing fish to be tagged quickly, typically within 15 seconds (Fig. 1). This includes picking the fish from the holding bucket, positioning it properly in hand, inserting the tag, and returning it to the water. After the tag is implanted, a 20% iodine solution is applied to the tagged area to prevent potential infections and ensure the fish's health during recovery. According to the experiment's findings, fish over 150g in weight are appropriate for tagging. The Floy anchor T-bar tag is a modification of the dart tag, which is a nylon T-bar that replaces a harpoon-like head of the dart tag. T-Bar Floy tagging is particularly important for studying migratory species like Hilsa (*Tenualosa ilisha*) or salmon, which undertake long journeys between freshwater and marine Ecosystems and vice versa. The data obtained helps understand the environmental factors influencing migration, the impact of barriers like dams, and the effectiveness of conservation measures. This

Fig. 1. Schematic diagram of Hilsa tagging procedure

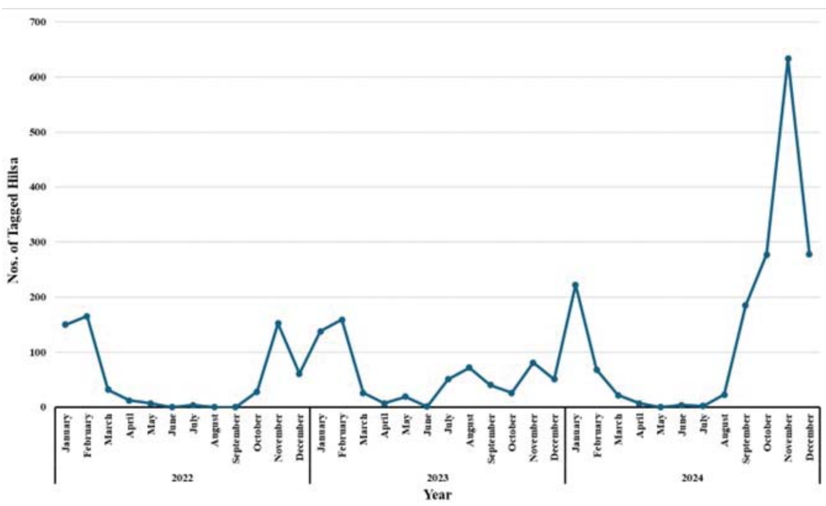

Fig. 2. Graphical representation of month-wise tagged Hilsa released, in 2022 to 2024

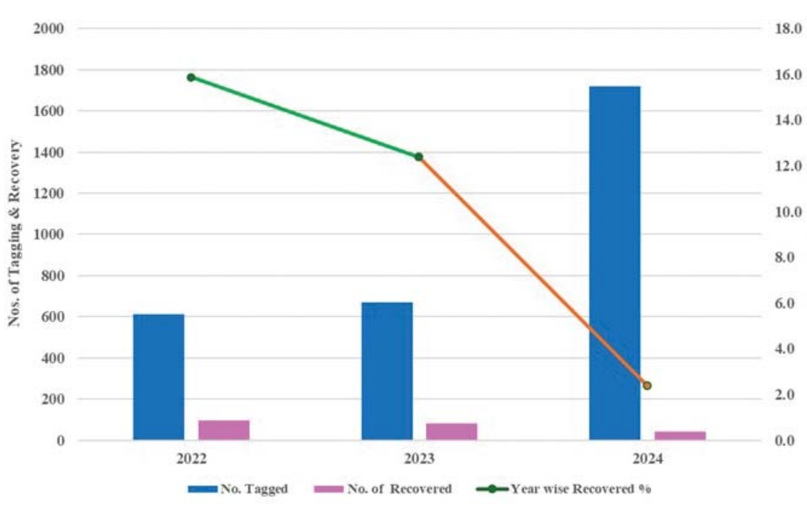

Fig. 3. Graphical representation of year wise tagged and recovery (%) of Hilsa

information is crucial for developing sustainable management strategies to ensure the long-term survival of migratory fish species.

Fish Tagging: A total of 3277 adult Hilsa (BW= 178.52 ± 8.15 gm) and (TL= 26.53 ± 0.41 cm) were tagged and released along the 4.5-kilometre section of river using T-Bar Floy tagging between 2022 to 2024. The releasing date, species, length, location and date of capture were recorded. Each tag had a unique identification number. The mean distance from capture to recapture was estimated, and the timing of the capture events was noted for individuals that were recaptured upstream of Farakka Barrage, river Ganga.

Results

The dataset represented in the graph shows the percentage change over time, measured monthly, from January 2022 to December 2024. The graph displays significant fluctuations in percentage values, with notable peaks at certain intervals. There are noticeable spikes in the month of January (150 nos.), February (165 nos.) and in November (152 nos.) 2022. In 2023, January to February (138 & 159 nos.) was the highest tag conducted throughout the year, and the highest peaks took place in November 2024 (633 nos.) among the three years (Figure 2). These peaks suggest increased upstream migration and recapture during these periods, possibly linked to favourable environmental conditions and breeding migrations. Due to the unavailability of the ideal adult Hilsa, this dataset likely represents temporal variations in a specific variable, potentially influenced by seasonal or external factors, with periods of significant increase indicating notable events and changes.

The provided dataset represents the number of Hilsa fish tagged each

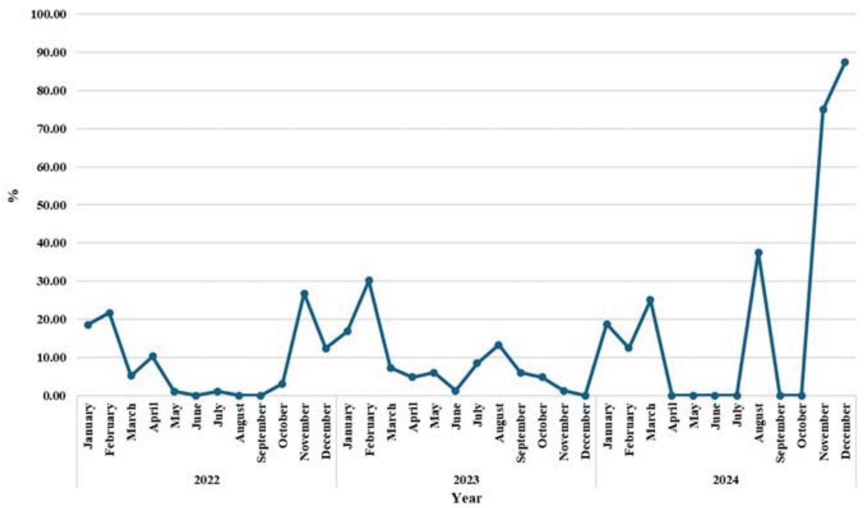

Fig. 4. Graphical representation of month-wise recovered tagged (%) of Hilsa in 2022 to 2024

year from 2022 to 2024, specifically in the context of monitoring their migration and behaviour upstream of the Farakka Barrage. In 2022, 611 Hilsa were tagged. In 2023, the number of tagged Hilsa increased slightly to 671. This indicates a continued effort to monitor the species, possibly expanding the study to gather more comprehensive data on migration patterns. In 2024, a significant increase in tagging is observed, near about three times (1721 nos.) fold than other two years (Fig. 3).

This substantial rise suggests an intensified focus on the study, possibly due to promising results from previous years or an increase in the Hilsa population in the upstream areas. The sharp rise in the number of tagged Hilsa in 2024 may be linked to efforts to greater availability of Hilsa for tagging and more extensive migratory movements. This could also reflect identifying the migration pathway. The increasing number of tagged Hilsa over the years provides a robust dataset for analyzing trends in migration, population dynamics, and the effectiveness of conservation measures in the upstream region of the Farakka Barrage.

In 2022, the highest recovery rates occurred in November (26.80%) and February (21.65%). Recovery rates were nil in the months of June, August, and September due to the huge flood situation. After the drastic monsoon, a sharp peak in the winter months (November, December) and another smaller peak in February (Fig. 4). The highest recovery rate was in 2023, in the month of February (30.12%), followed by August (13.25%). No recovery was recorded in December (0.00) and very low in June (1.20%). There was a notable increase in recovery in the summer months of July and August compared to 2022 (Fig. 4).

In 2024 the highest recovery rates are in November (75%) and December (87.5%). Recovery rates are significantly lower during most of the months from April to October, indicating a shift in seasonal Hilsa fishing patterns. But March (25%) and August (37.5%) show considerable recovery rates, unlike the previous years where these months had lower values (Fig. 4). A total of 221 Hilsa were recovered from different sites downstream of the Farakka barrage in the period of 2022- 2024. Among all the years, the maximum recovery of hilsa was made during 2023 but gradually decreased during 2024.

In the map (Fig. 5), the locations of Hilsa recaptures illustrate their upstream migration along the Ganga River, extending as far as Khurshela in Bihar and several key areas in Jharkhand, including Begamganj, Kathalbari, Nakitala, Rajmahal, Rajnagar Ghat, Shreeghar, and Sahibganj. Notably, upstream of the Farakka Barrage, Hilsa recaptures have been documented in various locations within the Malda district. These areas, situated near the

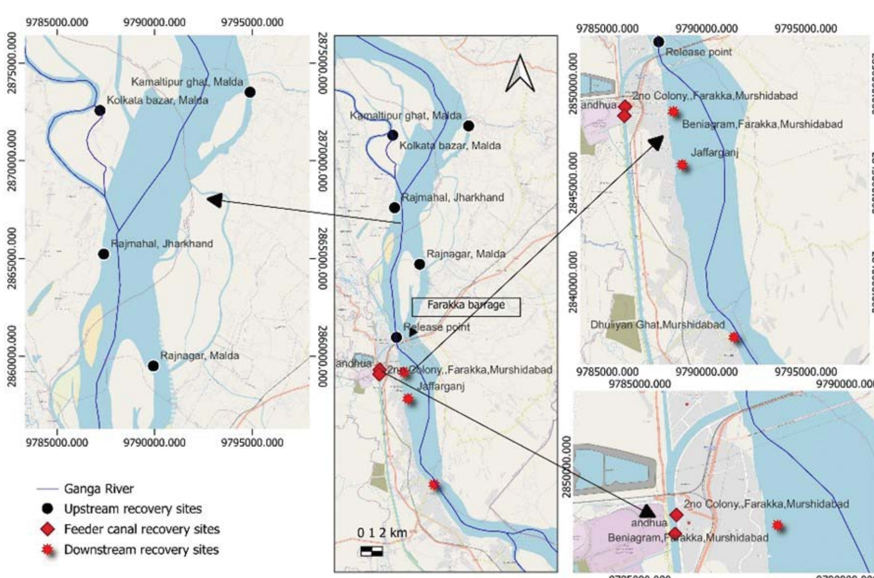

Fig. 5. GIS map from recovered tagged Hilsa in 2022 to 2024

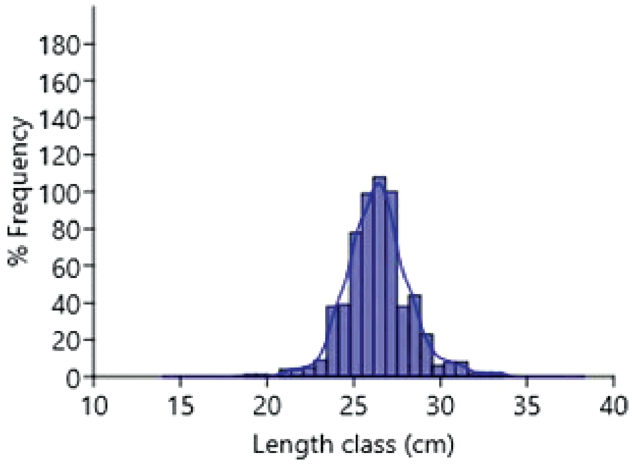

Fig. 6. Graphical representation of length class frequency (%) of Hilsa in 2022 to 2024

Fig. 9. One fishermen caught 2 tagged adult Hilsa from Maniknagar & Kamaluddinpur, upstream of Farakka Barrage he kept only Tag & eat the Hilsa, also rewarded him

border between Jharkhand and West Bengal, include Uttar Chandipur, Kulidiar Ghat, Kamaluddinpur, Manikchowk, Pagla Ghat, and Shimultala Ghat, covering distances ranging from 25 to 80 km from the barrage.

Fig. 7. Rewarding fisherman for Tagged adult Hilsa at Uttar Chandipur, upstream of Farakka Barrage

Additionally, evidence of downstream migration has been observed towards the Bangladesh border, with Hilsa recaptures recorded in several sites within the Murshidabad district. These locations include Nimtita, Dhuliyan, Raghunathganj, Jagnathpur, Bhangatola, Hossainpur, Feeder Canal, and Jangipur. Remarkably, Hilsa has also been recaptured at Nimaitritha Ghat, Barrackpore, West Bengal, which is approximately 230 kilometres downstream from the Farakka Barrage. This extensive movement highlights the significant migratory behavior of Hilsa within the river system, encompassing both upstream and downstream journeys over considerable distances.

The variation in recovery rates might reflect Hilsa's seasonal migration patterns, with higher recovery during

Fig. 8. Fisher caught Tagged adult Hilsa at Jaganathpur, Down stream of Farakka Barrage

Fig. 10. Tagged adult Hilsa collect from of downstream Farakka Barrage

peak migration periods. It depends on environmental factors like water flow, temperature, and oxygen levels could influence these patterns, especially around critical times like spawning. It also depends on the fishermen's catch pattern. The recovery information are gathered from fishermen and local market surveys. Sometime face diffculties to gather the information regarding tagged Hilsa as they deny to share any information regarding captured tagged Hilsa. This recovery information suggests clear seasonal trends in Hilsa recovery, with significant interannual variation that might relate to environmental changes. It was observed that the percentage frequency of tagged Hilsa was mostly in the 25-35 cm length group in the three consecutive years (Fig. 6). Most tagged individuals are in the size group of 25-30 cm, followed by 20-25 cm of Hilsa.

Discussion

Tagging experiment was carried out to better understand the migratory pattern of Hilsa upstream of Farraka barrage and the middle stretch of the River Ganga, India. Floy anchor T-bar tags of standard size with a unique serial number printed on them was used for the experiment. A total of 3277 specimens of Hilsa shad, with an average length of 26.53 ± 0.41 cm and a weight of 178.52 ± 8.15 g, were tagged and released upstream between 2022 and 2024.

A tagging study on the migratory fish species *Prochilodus lineatus* in South America provided important insights into how dam construction affects their movement patterns[19]. Their findings are particularly valuable because there is limited knowledge about the behaviour of these species in relation to the widespread damming of major river systems across the continent. Because these fish are migratory, it is challenging to recapture them in large river systems.

The recovery percentage in 2022 is relatively high compared to the subsequent years. This suggests either favourable conditions for Hilsa recovery or efficient tracking and monitoring practices during this year. The tagging and recovery efforts likely captured a significant portion of the migrating population, which could indicate good environmental conditions or effective fishery management.

Despite tagging more fish than in 2023, the recovery percentage decreased. There might have been challenges in monitoring or retrieving the tagged fish, such as changes in water flow, increased predation, or human interference. Hilsa may have altered their migration routes, making recovery more difficult. In the year 2024, there was a large increase in the number of tagged fishes, but the recovery rate dropped dramatically. Several factors could explain this sharp decline, such as Environmental Stressors. There may have been severe environmental disruptions, such as a flooded situation during the month of July till the first week of October and reduced oxygen levels, adversely affecting Hilsa migration and survival. The drop might also reflect increased natural mortality, predation, and fishermen not willing to share the recovery information. The declining recovery percentages over the three years suggest increasing challenges in tracking and recovering tagged Hilsa. Also this could be due to environmental degradation, increased natural mortality, the impact of human-made barriers or issues with the local poachers who are not regular fishers and do not share the information (Table. 1).

Table. 1 Advantages and disadvantages of using external tags given by previous author[17]

	Advantages	Disadvantages
1	This tagging process a unique biological marking method, it is easy to identify the migration pathway of Hilsa in the upstream and downstream of Farakka Barrage, river Ganga.	Information is limited to identification of the fish and its origin, i.e. reporting does not provide information on the fish during the interim period from release until recapture.
2	This marking process is inexpensive, or simple to produce, which may make their use cost effective.	Precision of the information on recoveries may be variable and also difficult to recover due to fishermen not sharing the information regarding recovery.
3	Easy and fast to apply, requiring only simple technology for the application.	Return rates may be variable, since they often depend on reporting from all fisher.
4	Useable for a large range of fish sizes (depending mainly on the size of the tag).	May affect growth, health and survival due to penetration of the skin, providing an access route for infections, and due to the continuous drag on the tag if this protrudes from the fish.
5	Applicable to large numbers of fish and to a great range of species.	Fouling of the tags may be a problem. Overgrowth of algae, barnacles and mussels may increase the drag on the tag considerably and may also make detection difficult.

When either commercial fishermen or anglers recapture tagged fish, biologists obtain valuable data regarding various aspects of the fish's life[20]. Finally, based on the results obtained in this study, we can infer that i) Captures of Hilsa in the upstream areas of the Farakka Barrage, spanning the states of West Bengal, Jharkhand, Bihar, and up to Uttar Pradesh, indicate that Hilsa can migrate upstream in the river (Fig. 7-10). The locations where these fish were found suggest favourable aquatic environmental factors, such as adequate dissolved oxygen content, water flow, better water current and fewer human activities. This is a positive sign for the biology of Hilsa, showing their potential to re-establish in the middle stretches of the Ganga River after a gap of two to three decades. Additionally, Hilsa also reproduces in the freshwater zones upstream of the Farakka Barrage. ii) Recaptures downstream from the baragge indicate that a considerable percentage of migratory fishes, especially the Hilsa, on encountering this tend to move toward sea. It is their normal phenomenon to move downwards. It also indicates the positive sign of their life cycle.

Conclusion

Tagging is a distinctive method for studying the fundamental behavioural physiology of fish. It enables biologists to collect a wide range of data. Some tagging techniques allow for fish tracking, offering insights into their movement and migration patterns. Other mark-and-recapture methods help estimate population sizes, fish growth rates, and both fish and natural mortality. Tags are crucial for obtaining physiological information. ICAR-CIFRI conducted this study to identify the accurate migration pathway, breeding ground and favourable habitat of this iconic fish. The result of recovered Hilsa depicted that Hilsa migrates up to Bihar, Jharkhand upstream of Farakka Barrage, up to 284 km, and Hilsa also show down migration towards the Bay of Bengal, recovered near about 230 km from Farakka Barrage. CIFRI also encouraged fishermen by rewarding them for providing information about the tagged Hilsa, which incentivised their participation. It also underscores the importance of improving tagging and monitoring techniques to better understand and manage to understand their migration path, identification of breeding grounds and identification of preferred feeding habitat and Hilsa conservation. This suggests the need for more comprehensive studies on the environmental and anthropogenic factors affecting Hilsa populations and their migration patterns.

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