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ARTICLE

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ADVANCEMENT IN FISH MIGRATORY BEHAVIOR STUDY THROUGH TAGGING: AN OVERVIEW

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Migration is one of the fundamental mechanisms of fish behavioral physiology, for the purpose of feeding, breeding and recruitment. This branch of science plays an extremely critical role in developing conservation plans and measures for the declining population in an ecosystem through the identification of critical habitats. Therefore, these habitats could be protected for establishing the native population in the identified ecosystem. Till date migratory behaviour studies in all animals including avians, reptiles, mammals including fishes, tagging is the most suitable methodology to trace through different types of tags. Though over the years, there are so many advancements in the tags including satellite based tags, electronic tags and acoustic tags have been developed, the success depends upon the fish species and the aquatic habitat. Here we have provided our results on the tagging experiment for Indian fish species with encouraging results. In addition, this article provides insight into the recent developments in the type of tags used for the fish migration study around the globe including India.

Introduction

Fishes are considered to be a global source of animal protein, contributing about 17 % of the total animal protein intake and 7 % of all proteins (Fish site, 2020). Currently, Global fish production is estimated to have reached about 179 million tons(FAO, 2020). Of these, 18 million tons come from Inland open freshwater resources from rivers, reservoirs, lakes, and canals, as capture fisheries. Over the years, there is stagnation in the capture fisheries around the globe due to set of factors including aquatic pollution, dams/barrages, overfishing and climate change. Among these, overfishing and construction of dams and barrages across the rivers are critically responsible for decline in fish production in the rivers and estuarine environment. Therefore, collective efforts both from the State Government Departments and Central Government Departments are urgently required towards the declaration of protective zone/sanctuaries to conserve the fish population.

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Longitudinal connectivity in the stream/river is regarded as the most important connectivity dimension for fish species representing cold water, warm water, only freshwater, brackish water and marine water for their migration. Fish migrations are grouped into different categories such as anadromous, catadromous, oceanodromous, and potamodromous etc., based on their migration to the seawater /freshwater boundary. Anadromous fishes spent major part of the their life cycle in saltwater and fully grown adults move back into freshwater to spawn (Fig. 1). One of the most important and well-studied migratory species in the Bay of Bengal region is *Tenualosa ilisha*, commonly called as hilsa shad. Belonging to family Clupeidae, the species inhabits rivers, estuaries and coastal waters. While, catadromous fishes are ones those migrate from fresh water into the sea to spawn; or, ones that stay entirely in fresh water and migrate downstream to spawn (Sahoo, 2019). The species *Anguilla bengalensis*, commonly called as Indian mottled eel, is a semelparous, catadromous species. Potamodromous fishes move from coastal to freshwater habitat and vice versa for feeding and other (not breeding) purposes. These migratory behaviors are the fundamental physiological mechanisms of fishes as a part of their life cycle. In order to develop management strategies towards sustainable fisheries, it is imperative to understand their life cycle including the detailed migratory behavior and habitat. To understand the accurate migratory path, tagging is the most suitable method worldwide.

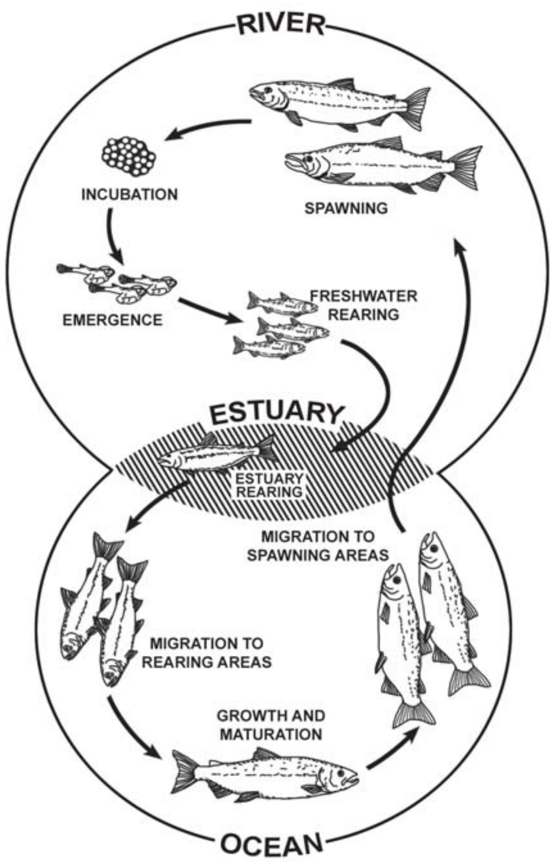

Fig.1 Anadromous life cycle (source: University of Washington, School of Fisheries Teaching and Research Fish Hatchery)

Aim of Tagging

The primary aim of tagging is to identify an individual fish or group of fish with their preferred habitat during entire period of migration. The knowledge gained from such studies could be used to develop a greater understanding on the feeding, reproduction and growth physiology of the species. Therefore, these scientific information supports in developing the conservational measures or plan or guidelines to protect the species or population. Some of the information sought through tagging is listed below :

Habitat Identification: Habitat plays a critical factor for successful recruitment of fish species. These habitats are preferred based on the quantity and quality of the environmental parameters such as breeding habitat of fishes is different from feeding habitat. Furthermore, the habitats at different life stages of migratory fish species are different such as juveniles prefer shallow water depth and lower water velocity than the adults. Therefore finger printing of each habitat is paramount to conserve the fish species. Tagging make easier for identifying the preferred habitat.

Population Estimates: Tagging provides a way to estimate total number of fish in the population in an ecosystem. Initially a known number of fish are being tagged and are released to an ecosystem. Estimations are made based on the number tagged fishes returned to native locations. The proportion of tagged to untagged fishes can be used to determine the size of the population. In studies of salmon, shad and other fishes those leave the sea to spawn in rivers and streams, individuals captured near the river mouth are marked with conspicuous tags and then release to resume their migration upstream. Observers are assigned to patrol the river bank to determine the ratio of tagged to untagged fish. Knowing this ratio and the number of fish originally tagged, it is possible to calculate the total number of fish on the spawning grounds(Pine et al., 2003).

Age and Growth Studies: Age determination of the individuals in a population is an important part of most fishery studies. Tagging provides a valuable check on the method of age determination used since the interval between the time of release and the time to recapture is definitely known. Where the fish are aged by scale reading, scales are collected from the same fish at tagging and at recapture are compared to see if change in scale age is equivalent to the interval at liberty. Similarly, the growth rate of the marked fish can be established since the fish is measured both at the time of release and the time of recapture(Jensen, 1962).

Stocking of Hatchery Fish: The success of stocking hatchery-reared game fish, such as trout or black bass can be often determined from tagging studies. The fish are tagged just before they are released into the stream or lake and the number of tagged fish caught by the sportsmen gives an index to the success of the stocking program (Leber and Blankenship, 2011).

Genetic Improvement Studies: Tagging are also being used as marker for genetically improved fish species towards periodic data recording of individual growth, feed acceptance, breeding physiology in the confined aquaculture facility.

Methods of Tagging

Several different ways of marking the fish have been tried over the years. Branding, tattooing and injecting coloured dyes under the fish's skin have been used, but usually with only limited success. The most common technique is tagging. Tagging, is a methodology in which a device is attached to the fish is probably the most common way of marking fish for future identification. Tagging of fish can provide a wealth of information about species from migratory behavior to growth patterns. The biologists studying marine and fresh water fishes are concerned with learning as much as they possibly can about the life histories of the fish species. Researchers are interested on the growth pattern, age determination, and habitat identification and have attempted a number of methods towards understanding the migration physiology of fish species to learn about the conservation and management of fishes. One of the frequently used methods is tagging. Briefly this consists of catching a number of fish being studied, marking each with a tag or other means of identification and releasing them. When the tagged fish are caught again either by a commercial fishermen or by an angler, the biologists gains valuable information about some phase of fish life (Rounsefell and Kask, 1945).

Advances in Tagging

The first recorded fish tagging was done about 150 years ago by wealthy landholders in Scotland(Jensen, 1962). In United States, the earliest successful tagging took place in 1873 when Atlantic Salmon in the Penob-scot river Maine were tagged and a fair number of these tagged fish were caught again(Rounsefell and Everhart, 1953). Today thousands of fish of many species are marked by biologists who have set up well planned experiments designed to yield definite information. Within last 20 years marketing and recovery of fishes has come to be recognized as powerful tool for studying fish population. The first tags were simply lengths of copper or silver wire, but as tagging experiments became more refined many different kinds of tags were developed.

A tag is a label attached to someone or something for the purpose of identification or to give other information. Effective fisheries management often requires reliable information on population, size, survival and mortality. Tag and release is a form of catch and release fishing in which the angler attaches a tag to the fish which records data such as date, time, place, and type of fish on a standardized postcard and that card is submitted to a fisheries agency or a conservation organization. (Akinicheva and Rogatnykh, 1996; Jensen, 1962;Francis, 1988; Lagler et al., 1952)

Types of Tags

Petersen Disc Tags: The Petersen disc tag is one of the first tags used to study fish populations. Although the Petersen disc tag has undergone modifications over the years. The tag consists of two plastic discs that are placed on each side of the fish and are connected by a wire or a pin running through either the dorsal fin or the musculature at the base of the dorsal fin (Fig.2). The tag information is generally printed on the discs. Petersen disc tags were used in many of the early shark tagging studies, which studied the growth and movement of a variety of shark species. There are two main drawbacks associated with the use of Petersen disc tags firstly, they are prone to fouling by barnacles and algae and secondly, they can severely limit body and fin thickness by restricting growth, especially when used for long-term tagging studies. The restriction of growth can lead to splitting and deterioration of the dorsal fin.

Internal Anchor Tag

It is designed to overcome some of the problems associated with the use of Petersen disc tags, particularly the restriction of growth. There are two types of internal anchor tags. The first tag, which is sometimes referred to

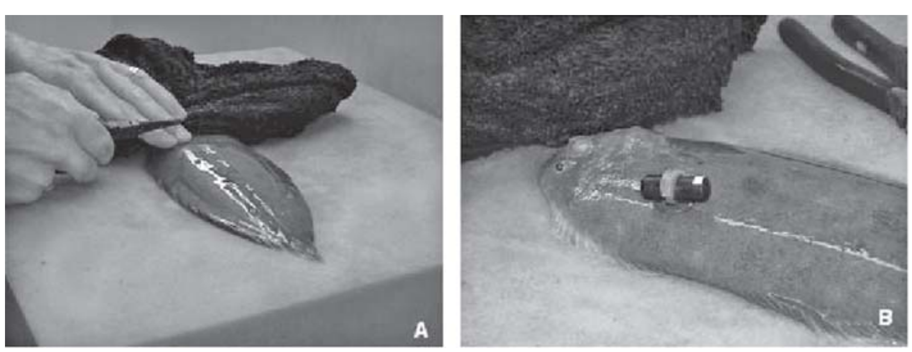

Fig.2 Petersen Disc Tags Source: (Mueller-Blenkle et al., 2010)

as a "body cavity tag", is small and rectangular in shape and is inserted completely into the body cavity through a small incision in the lower half of the body wall (Fig.3). The second tag is sometimes referred to as a "button tag" and is comprised of a vinyl streamer attached to an elongated plastic disc. An advantage of internal anchor tags is that they can be retained for many years.

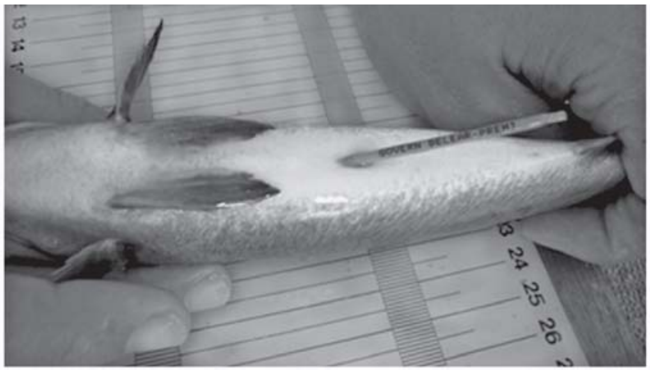

Fig.3 Internal anchor Tag, Source: (del Mar Gil et al., 2017)

Roto Tag: It has been adapted for marine and wildlife tagging studies. The Jumbo Roto tag and the ORI(oceanographic research institute) tag are typically applied with an applicator through a hole in the leading edge of the first dorsal fin created by a leather punch. Both tag-types are made from a high-grade nylon with the Jumbo Roto tag being semi rectangular in shape and the ORI tag more circular in shape. Early experiments with the Jumbo Roto tag indicated that the tag was susceptible to vertical movement due to the hydrodynamics of swimming. The suspicion that this vertical movement caused swelling and irritation prompted the design of the ORI tag. As with the Petersen disc tag, the Jumbo Roto tag and ORI tag are susceptible to fouling and can negatively influence growth. The tag is comprised of a vinyl streamer attached to an elongated plastic disc. The disc serves as the anchor and it is inserted into the body cavity through a small incision in the body wall with the streamer protruding external to the individual.

Fig.3 Gun with Roto Tag, Source: Google Website

Dart Tag: The dart tag was developed primarily to facilitate the safe and effective tagging of individuals in the water, since many pelagic species attain sizes that are too large to be handled onboard a vessel. Fundamentally, a dart tag is comprised of a streamer, which can be made of monofilament line, vinyl or nylon line that is attached to either a stainless steel, plastic or nylon pointed head. All pertinent tag information is either printed on the streamer itself or on a legend that is enclosed by a capsule and attached to the streamer. Efforts are generally made to apply the tag at an angle so that streamer lies alongside the individual when it swims. The main advantage of using a dart tag is its ease of application. Relative to the Petersen disc tag, Rototag and internal anchor tag, little time is needed to successfully mark an individual with a dart tag. Specific large-scale and longstanding tagging studies that use the dart tag include the NMFS Cooperative Shark Tagging Program and the Australian Cooperative Game-Fish Tagging Program.

Spaghetti Tag: Spaghetti tags are used in various lengths, depending on size of the fish being tagged, and usually are drawn through the back muscles with a needle and tied in a simple overhand knot. The spaghetti tag has been successfully used on haddock, striped bass, spiny dog fish and tuna. It is quickly applied; the plastic material is not injurious to the fish nor is it affected by prolonged immersion in sea water. Two variation of the tag are lock-on and cinch-up tags, which use

Fig.4 Roto Tag, Source: Google(https://www.daltontags.co.uk/management-tags/roto-tags-printed/)

special locking devices instead of a knot. The tag is retained well and inexpensive, but application is time consuming.

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Fig. 6 Spaghetti Tag, Source: Google(https://www.saambr.org.za/research-2/olympus-digital-camera-2/)

Anchor Tag (Floy Tag): It is applicable for long term studies on migration on adult migratory species. This tag is modified dart tag in which a nylon T-bar replaces the harpoon like head of the dart tag. These tags are exactly like tags used to attach prices to clothing. The tags are inserted with a gun which can be loaded with one or a clip of anchor tags, marking the tagging of individuals or hundreds of organisms quick and easy. Like dart tags it is important that anchor tags penetrate deep enough into the fish that the T-bar interlocks with the skeleton.

Radio Tag: Tags that transmit radio signal to a receiver. Radio tags are used most often in shallow and low conductivity water. Antennas that receive the transmitter signals can be fixed to airplane, boats, trucks, snowmobiles and portable towers and can be carried along a stream by hand.

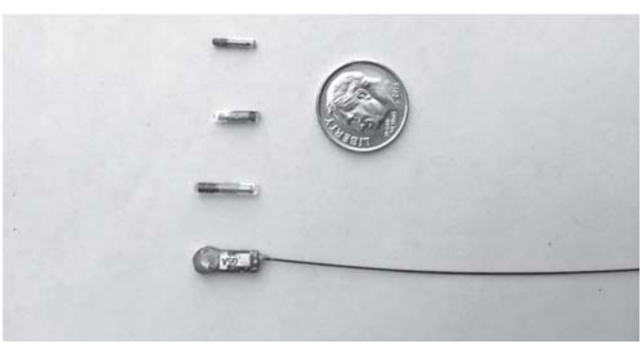

Fig. 7 Radio Tag, Source: (Porter et al., 2019)

Pulsed Tag: Radio and acoustic transmitting tags can transmit a simple pulsed signal at a selected pulse rate. Theoretically, large number of fish can be monitored simultaneously using multiple frequencies or pulse rate. In practice, however it is very difficult to distinguish more than four or five pulse rates on an individual frequency.

Passive Integrated Transponder Tags (PIT): Many researchers use PIT tags and readers to study migration habits and movement to and from specified areas. A PIT tag is a radio frequency device that transmits a unique individual code to a reader where it is displayed in a numeric or alphanumeric form. The tag has no internal battery, hence the term "passive". The reader powers or excites the tag circuitry by radio frequency induction and receives the code back from the tag. Radio frequency identification does not require line of sight, tags can be read as long as they are within the range of a reader. PIT tags were designed for positive identification; because they are passive they are not capable of long distance tracking. The implant site is dependent upon the species, size of the animal and size of the tag.

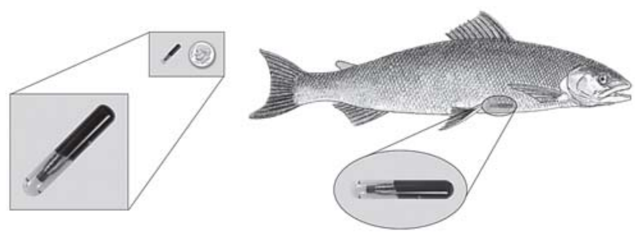

Fig. 8 PIT Tag, Source: Google (www.uidevices.com/pit-tags/pit-tag/)

Thermal Tags: Thermal marking isan efficient means of marking 100% of the fish at the hatchery. Therefore, we can take fish that have been thermal marked, remove its otoliths or ear bones and tell whether or not it is a hatchery fish. The hatchery fish are marked prior to hatch or soon thereafter in incubators. By manipulating the water temperature in the incubator, hatchery technicians can place a series of rings on the otoliths that will identify them by hatchery and brood year. This process forms a type of "bar code" on the otolith that remains with the fish for its lifetime. These patterns of bands can be customized for each hatchery and brood year by varying the number of bands and the width and spatial placement of these bands.

Data Storage Tags (DSTs): These tags, which are also known as archival tags, range from simple data loggers, capable merely of recording depth or temperature, to sophisticated programmable position of the fish at regular intervals over periods of many months. Developmental work over the last ten years has led to the production of a number of tags that are beginning to be used very successfully with free-ranging fish in the open sea.

DST GPS Fish Tag, Fish Postioning Sounder and Simrad GPS Sonar : Data Storage tag(DST) Global Positioning System (GPS) can be attached externally or implanted into fish. DST GPS can receive information about geographic position from the satellites via Simrad sonars onboard vessels. The vessels's GPS position is coded and transmitted underwater via the Simrad sonar signal. If a tagged fish is within 4 km range of the GPS sonar, the DST GPS will receive the vessels's geographic positioning and the GPS information together with the measured temperature, depth, date/time. For use in rivers, lakes and smaller ocean areas, a small and portable acoustic GPS transmitter, named Fish Positioning Sounder(FPS). The DST GPS fits well for medium sized round fish.

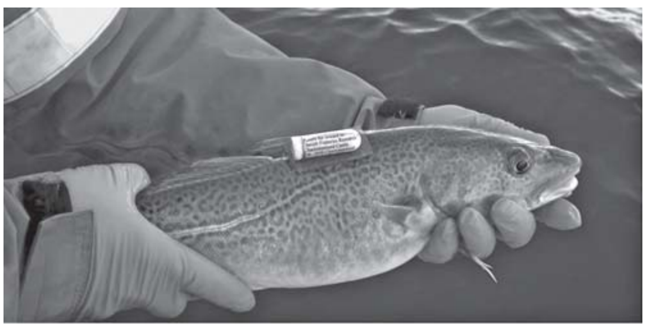

Fig. 9 DST GPS Fish Tag, *Source: Google(https://www.star-oddi.com/products/data-loggers/data-storage-tag-temperature-depth-sensors)*

Case Reports: ICAR-CIFRI Tagging Experiments

During last five years ICAR-CIFRI has initiated tagging for the Indian migratory fish species including hilsa shad and some selected hill stream fish species (Chocolate Mahseer). Tagging experiment was carried out to better understand Hilsa's migratory pattern upstream of the Farakka barrage in river Ganga. For the tagging experiment in this study, Floy T-bar anchor tags of standard size with serial numbers printed on them were used.

The tags were applied using a scissor grip and a pistol grip tagging gun. Tag manufacturing Inc., Seattle,

Washington, 98105, USA, provided the purchased tag. Prior to that, a trial-and-error tagging experiment was conducted in confined water bodies to determine the size and feasibility of the tagging experiment. The experiment concluded that fish weighing more than 150g are suitable for tagging. Fish were caught directly downstream of the Farakka barrage using experimental fishing with specially designed net operation. Before tagging, the length and weight of each tagged fish were measured. A total of 913 Hilsa individuals of average weight of 157.61 g and length of 27.18 cm were tagged and released in the upstream of Farakka barrage. Tagging programme was widely disseminated through various means of communication, such as raising public awareness, distributing ranching fish posters/pamphlets, and writing articles in newspapers about Hilsa conservation among fishermen from Farakka to Allahabad for recovery reports to analyse Hilsa migration patterns in the selected study stretch. In our investigation, total recovery % within the stipulated period was 3.8% within 120 days. Our study showed that maximum travel was around 640 km in 120 days. While within 15 days, fishes were recovered from Sahebganj (84 km) and Kahalgaon (120 km) from the ranching sites. These results were extremely useful and interesting towards establishing the breeding habitat of hilsa in river Ganga. In an another study, live hilsa are being tagged to understand the

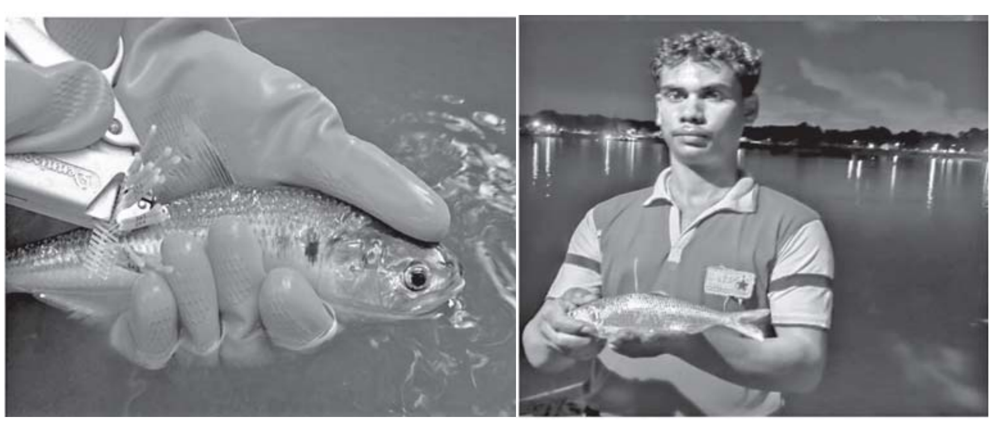

Fig. 10 Recovered hilsa by the fisherman from upstream of Farakka barrage, West Bengal.

migratory path and the behaviour in both upstream and downstream of Farakka barrage in the river Ganga. A fish of average length 28.5cm and weight 209g bearing tag no. 1516 was ranched in the upstream of Farakka barrage area (24° 49' 0.8358" N, 87° 54' 57.8802" E) and the same the same tag number was captured from Nimai tirtha ghat, Chapdani, Baidyabati (22Ú47’29.5’’ N, 88Ú20’18.8’’E) after 5 days. During this period the fish has migrated 225 km downstream of Farakka barrage in Ganga indicating the migration rate at 1.9 km/hr = 0.52 m/s. Of these, 225 km, approximately 70 km is tidal freshwater stretch. This shows that the hilsa fish not only migrated unidirectional water flows but also counteracted up/down tidal flows.

Conclusions

Tagging is a unique technique towards understanding the fundamental behavioral physiology of fish. Tagging of fish allows biologists to gather a wide variety of information. Certain tagging techniques allow fish to be tracked giving a better understanding of movement and migration patterns. Other mark and recapture methods provide population estimates, fish growth, and estimates of fish and natural mortality. Tags play important role in estimating the physiological information. All these fish tags have one thing in common regardless of the shape or kind of tag; each is stamped or printed with a serial number and the name of the laboratory or agency that is conducting the tagging study. And with time and technology new type and more evolved type of tags are emerging and are coming into use. ICAR-CIFRI has experimented on two important Indian migratory fish species i) Hilsa, an anadromous fish ii) Chocolate Mahseer, a hill stream fish, to understand their migration path, identification of breeding grounds and identification of preferred feeding habitat. We could estimated from our recent study that hilsa could travel around 640 km in 120 days against the water current. While, along the water current hilsa travels 225 km in 5days. These results would support in establishing the managerial measures towards protecting the migratory fish species, which are under the threats due to various anthropogenic stress. ❐

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