ADVANCES IN FISH TAGGING AND MARKING TECHNOLOGIES: ENHANCING CONSERVATION AND FISHERIES MANAGEMENT

Abstract

The state of global fisheries and the health of aquatic ecosystems are of paramount concern in the face of increasing anthropogenic pressures. Fish tagging and marking technologies have evolved rapidly, offering unprecedented opportunities to gather detailed information on fish behaviour, movement patterns, and environmental interactions. The conservation and effective management of fisheries are critical components of maintaining aquatic ecosystems and ensuring sustainable seafood resources. This chapter provides a comprehensive overview of recent advances in fish tagging and marking technologies that play a pivotal role in enhancing conservation efforts and fisheries management strategies. The adoption of innovative tagging methods has greatly improved our ability to track individual fish, monitor their movements, and gather crucial data on behaviour, migration patterns, and habitat utilization.

Keywords: fish tagging, marking technologies, conservation, fisheries management.

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1. Introduction

The world's aquatic ecosystems, from vast oceans to freshwater lakes and rivers, host a staggering diversity of fish species that are essential to both natural ecosystems and human societies. Fish provide a critical source of food, income, and recreation for millions of people worldwide. However, the sustainability of fish populations and the ecosystems they inhabit face significant challenges due to overfishing, habitat degradation, and climate change. Understanding the behaviour, movements, and population dynamics of fish species is crucial for effective conservation and fisheries management. Fish tagging and marking have emerged as indispensable tools in the pursuit of this understanding. These techniques allow researchers, fisheries managers, and conservationists to monitor fish populations, track their migrations, and gather vital data for informed decision-making. Over the years, advancements in technology and methodology have led to innovative tagging and marking approaches that offer unprecedented insights into the lives of fish.

The essential actions for carrying out a successful tagging study are:
1. To make sure that the study's objectives are met, thorough planning is required,
2. Choosing a suitable tag or label,
3. Ensuring that there are enough marked and recaptured animals to produce parameter estimations with enough accuracy to suit management needs,
4. Fulfilling sometimes-strict assumptions needed to generate accurate parameter estimates,
5. Using the right analysis techniques, and
6. Correctly construing the findings

In the majority of tagging and marking research, a subset of animals from the population is created which are "known" and identifiable by their tags or marks. Subsequent recaptures of this subset of animals are used to track them over space or time (or both) and to gather data on the total population. Multiple variables of interest to researchers and management, such as movements, growth, and death rates, can frequently be addressed in a single study, which is one advantage of a well-planned tagging programme.

2. Factors affecting Tagging and Marking

- Size of fish
- Size and colour of tag
- Figure of fishes to be marked
- Range of the study
- Tag effects to the fish
- Price of tag
- Ability of tag to be detected by e.g. transmitter, X-ray etc.
- Time of retention of tags/marks
- Ability of tag to differentiate between individuals

3. History

Fish tagging records go all the way back to the first decade of the 20th century. They mostly focused on the movements of fishes like cod, haddock, and pollock, however occasionally other species like monkfish and sharks make an appearance as well. Since then, scientists have improved their techniques, and a whole industry of labelling related goods has emerged. The needs of fishery biologists were changed for many of the items that are now available to researchers; these products originally came from other industries.

4. Necessary Information Gained after Tagging Fish

- Identification of stock
- Migrations patterns
- Behaviour patterns
- Age of fishes
- Mortality rates
- Abundance of species
- Stocking success rate

5. Methods and Choice of Marking Techniques

A known subset of a fish population can be made using a wide range of tagging or marking techniques. In contrast to marks, which are typically described as anything recognisable that is external, internal, or embedded into the integument of the fish, tags are typically described as being attached to the fish either externally or internally and containing specific identification information (Jones, 1979; Guy et al. 1996). Fin clips can serve as simple tags and identifiers, while more complex tags can store a variety of spatial and biological data on a particular animal and then transfer that data to the researcher via satellite. The amount of time spent in designing the study, selecting the appropriate tag, and considering the essential expectations of the analysis will be reflected in the calibre of the data that is gathered (Nielsen, 1992). The time invested in choosing the right tag, creating the study design, and considering the underlying assumptions of the analysis will raise the calibre of the data gathered. Different types of marking techniques are as follows: -

A. Body Marks

One of the earliest and most basic methods of fish marking is a fin clip. Using wire cutters, scissors, or a hole punch, a part of the fin that will be marked is cut away all at once (Fig.1). Typically, a piece of the pelvic or pectoral fin is removed using scissors, around midway between the fin's end and base, perpendicular to or at an angle to the major fin ray (Eipper and Forney, 1965). After being clipped, fins typically grow back, but sometimes they are still noticeable.

Fin clips are rapid and inexpensive, but their usage in research is limited because to the few combinations that are conceivable and the unpredictability of regeneration. In actuality, fin clips are frequently utilised as quick visual cues to distinguish one group of fish from another, such as in a hatchery.

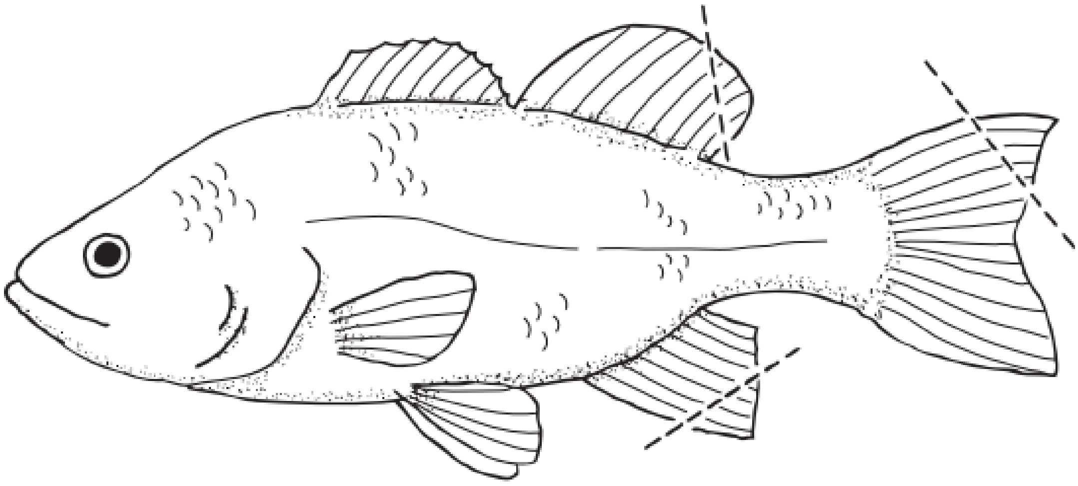

Figure 1: Clips on anal, caudal, and dorsal fins (Guy et al. 1996)

Both cold branding and heat branding leave noticeable marks on fish bodies. Branding allows for the swift marking of several animals. Similar to fin cutting, it is most effective for short-term branding because permanent markings might fade or become more difficult to see as fish get larger. However, branding can also be used to generate individual marks (Morrison and Secor, 2004). Branding is typically employed to provide a batch mark (Bryant et al., 1990).

B. Natural Marks

Morphological and meristic markers are physical characteristics such as scales along the lateral line or body shape, markings, size, or colour that are counted naturally. Oftentimes, animals from specific geographic regions have distinguishing markings that set them apart from conspecifics from other regions. For example, morphometric and meristic traits were used to locate stocks of Mediterranean horse mackerel and show that their migration routes were restricted to the Black, Marmara, Aegean, and eastern Mediterranean seas (Turan, 2004). The patterns of scars left on marine mammals' bodies or fins by encounters with predators like sharks, barnacle growth, or boat propeller strikes are frequently used to identify them. Marine mammals that are at the surface of the water to breathe are photographed during visual surveys to estimate marine mammal abundances. Following the analysis of these images, the distinctive features are identified and catalogued (Wilson et al. 1999). The locations and dates of animal relocation are recorded in "capture" histories created by looking back over these catalogues over time. Many studies have been devoted to these types of assessments because there is such a strong interest in keeping track of the status of rare and endangered marine mammals. However, because scars can change over time due to healing or new injuries, it can be difficult to identify specific animals (Yoshizaki et al. 2009, 2011).

C. Otolith Microchemistry

To identify natal origins and evaluate larval, juvenile, and adult fish migratory patterns over wide areas, researchers use naturally existing isotopic and elemental markers (Elsdon et al. 2008). Such data is necessary for creating spatial management programmes, such as marine protected areas or natal rivers identification. Fish heads have a pair of paired calcified structures called otoliths that aid with hearing and balance. They are extensively used in fisheries management to assess the ages of fish, and they are also trustworthy natural tags (Thorrold et al. 2001). Otoliths will reflect the environmental characteristics of the water the fish live in because they are mostly made of calcium carbonate and a range of trace elements, which are typically derived from the ambient water that fish swim in.

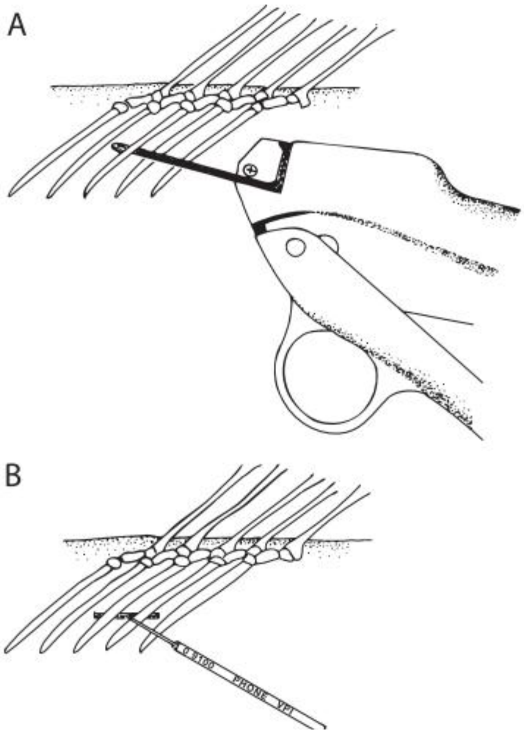

Figure 2: (A) tagging with gun needle and (B) tagging between pterygiophores of fish (Guy et al. 1996)

If a fish moves between different places as it matures, its otolith development layers will reflect the spatial diversity of these water parameters. By extracting and chemically analysing samples of the otolith material that were deposited at various ages, it is possible to determine where a fish resided at various points during its life.

D. Coded Wire Tags

Bordner et al. 1990 and Johnson, 1990, stated that in order to distinguish hatchery fish from their wild counterparts, coded wire tags are frequently employed to tag a large number of animals. Small magnetised steel wire pieces (1.1×0.25 mm) with a code that can be used to identify certain fish are called coded wire tags. They must be read under a microscope because of their small size. Many different types of bony and cartilaginous fish and invertebrates have been successfully tagged using them in the hundreds of millions. The application of coded wire tags on little fish is possible due to their size and high retention. It is considered that the use of coded wire tags has little to no impact on the growth or mortality risk of tagged animals.

In areas of the body with high retention rates, such as the head or snout, injections of coded wire tags are used (Buckley and Blankenship, 1990). Mostly portable or semiautomated injectors are used to tag a large number of animals in short time period (Guy et al. 1996). They are typically found using automated or handheld detectors. An animal may be detected to be tagged, but in most cases the tag cannot be decoded to identify the specific animal without killing the animal and removing the tag. The placement of the tag between fin rays, for example, is an exception because it allows for surgical recovery of the tag without causing the fish undue harm (Haw et al. 1990). A more feasible strategy might be to utilise coded wire tags for group level identification or to accept the necessity to sacrifice recaptured fish at shallow tagging locations where loss rates may be higher. It is feasible to distinguish various fish batches by injecting tags into various body parts, such as the cheek one year and the snout the next. This enables the marking of multiple groups of animals for use in Brownie-type survival analyses.

E. Visible Implant Elastomer Tags

Tags made up of visible implant elastomer (VIE) are inserted into tissues of fish that are transparent or translucent, like the cheek. A coloured elastomer and a clear catalyst are combined to make a liquid that is then injected with a hypodermic needle to form them. The substance stabilizes into a flexible solid that appears as a coloured dot or thin stripe after a few hours. Unique identifications can be made by using various tag placements and colours. Visible implant tags are frequently employed because, with the exception of small individuals (Reeves and Buckmeier, 2009), they have little impact on fish development, survival, and behaviour. They can also be applied to invertebrates and amphibians (Replinger and Wood, 2007, Phillips and Fries, 2009). As the tag material degrades or is covered up by new growth of tissue, retention times of tags vary depending on the position, species, and colour of tags (Summers et al. 2006; Bolland et al. 2009).

F. Anchor Tags

An external coloured plastic tube or streamer with information specific to the study imprinted on it and an internal attachment end that is placed into the tagged animal's body make up an anchor tag. Dart-style tags have an attachment end that is either T-shaped (T-bar tag) or shaped like a single-barbed arrowhead (dart tag). A flattened rectangular or oval plate that rests flush against the body wall is where internal-anchor tags are connected (Nielsen, 1992). These tags are frequently used on a variety of fish and invertebrates because they are reasonably simple to apply, are clearly visible, and can convey a straightforward informational message (such as the agency that tagged the fish, the return and reward information, and a unique identification number). To create management plans for this species, anchor tags have been employed to collect crucial data on striped bass migration (Boreman and Lewis, 1987) and mortality (Dorazio et al. 1994; Diodati and Richards, 1996) along the Atlantic coast (Richards and Rago, 1999). Transbody Carlin tags, which may have an impact on growth, are favoured over other external tags (Nielsen, 1992). Dart-style tags are frequently attached to fish using a hollow-needle applicator that is inserted behind the fish's dorsal fin and through the pterygiophore bones.

T-bar tag applicators can be loaded with strips of numerous tags, but dart tag applicators must be reloaded with a tag for each fish. Proper anchor placement behind pterygiophores or other stiff body structures to give a secure attachment site is the key to high tag retention (Waldman et al. 1990; Sprankle et al. 1996). Tag shedding results from failure to affix to a hard structure; implantation into the muscles is insufficient. According to Nielsen (1992), the base of internal-anchor tags is typically inserted through a tiny incision in the body wall. There are two ways that anchor tags can be shed (Ebener and Copes, 1982). Long-term or "chronic" shedding is likely due to tag wear; it happens right away (hours to days) after tagging and is likely due to faulty attachment.

The state of the ecosystem and the rate of animal development both have an impact on tag lifespan. A tag anchor in the form of a dart can be put into soft tissue of an animal that is growing swiftly to prevent it from being removed by structural growth. In clear, productive waters, animals may have tags covered by algae growth, making it difficult to interpret the data and increasing tag shedding rates due to higher drag. Algal-covered tags are also more likely to be missed in studies utilising fishing tag returns, which leads to underreporting.

G. Passive Integrated Transponder Tags

Radio-frequency identification (RFID) tags known as passive integrated transponder (PIT) tags are injected into an animal's bodily cavity or musculature and can be read and detected without the animal being dissected. The PIT tag is made up of an antenna for receiving and transmitting signals as well as an integrated circuit for information storage, processing, and signal modulation. An external energy source is used by the PIT-tag reader to switch on the tag, which then emits a radio signal carrying a unique alphanumeric code that the reader decodes and utilises to display the data. Compared to other tag kinds, the PIT tag has a number of significant benefits. Fish have PIT tags inserted into their muscles or bodily cavities; as a result, they cannot be entangled and lost, or have their shedding reduced by the growth of algae. Without removing the fish's tag, they can be read. They are also tiny, which helps tagged fish swim, survive, and grow more normally. Finally, they are virtually permanent because the reader's power powers the tag rather than an internal battery.

The size of the PIT tag affects both the maximum size of the animal that can be tagged and the detection range of the tag reader. The most common PIT tags are tiny full-duplex PIT tags that are around 12 mm in length and 2 mm in diameter. These tags must be detected quite close to a reader, usually within a few centimetres. Various fish species can have these tags implanted in them. Wherever tagged fish may be identified by autonomous receivers and stream-spanning antennae, half-duplex technology with larger 23 mm 3 mm tags is used (Jepsen et al. 2000; Adams et al. 2006; Zydlewski et al. 2006).

H. Genetic Tags

An animal's distinct DNA can act as a tag (Waits 2004). In wildlife management, molecular genetic techniques are used somewhat frequently and more frequently in fisheries applications (Buckworth, 2004) to identify species, estimate abundances, and track population trends. In a gene-tagging programme, a tissue sample is collected from every animal and preserved in alcohol before these animals are released. Muscle punches or fin clips are frequently used for this tissue biopsy. Depending on population variance, the tissue sample is subjected to the polymerase chain reaction (PCR) in order to amplify 4–12 nuclear DNA microsatellite markers, the combination of which is utilised to identify the particular animal. When animals are captured, biopsied, and released in the future, their DNA will be compared to a library that has already been compiled. It is feasible to directly quantify the mortality caused by fishing by collecting tissue samples from fish that have been captured (for example, through a creel survey or port sampling programme) and comparing them to the previously known (genetically defined) population of animals.

Genetic tags help to mitigate some of the downsides of conventional tagging studies, such as tag shedding and low reporting rates. Technical and analytical issues must be resolved since gene tagging calls for assumptions about genetic analysis that typical tagging programmes do not (Yoshizaki et al. 2009, 2011). The cost of "tagging" (analysing the tissue sample) is high compared to most other tag kinds, however it is going down as sequencing technology advances. Another issue is amplification failure, in which the intended portion of the animal's genome is not sufficiently duplicated by PCR, maybe as a result of insufficient DNA in the sample.

Conclusion

The advances in fish tagging and marking technologies represent a powerful toolset for promoting sustainable fisheries management and conservation. The combination of precision, data-driven decision-making, and international collaboration positions these technologies as essential components in the ongoing effort to safeguard aquatic ecosystems and the livelihoods that depend on them. As technology continues to evolve, the future holds even greater promise for innovative solutions to the complex challenges facing our oceans and freshwater environments.

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