

# Why use radio tags to study freshwater fish?

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## Abstract

*A wide range of techniques and methods is available for marking and tagging fish. Selecting the most appropriate tagging method depends both on the purpose for which tagging is required and the species on which it is to be used. Which method will best help answer the questions being asked? Tagging and marking can be divided into two categories: those which provide a batch mark and those which can identify individual fish. This paper provides a brief review of available tagging techniques considering the benefits and constraints of each. Sonic and radio tags have the added advantage of allowing individual fish to be tracked on a continuous basis and 'observations' and measurements made of 'natural' behaviour. The differences between the use of sonic and radio tags are discussed for the study of freshwater fish. Options for different radio frequencies, tag configurations, tracking devices, data loggers, remote stations, costs and attachment techniques are explored. The benefits of the development and use of radio tags in Australia for the study of Murray cod and other species are discussed.*

## Introduction

A wide range of tags, techniques and methods is available for both marking and tagging fish (see CATAG website; Hancock 1989; Kearney 1989) for use in studying fish migrations (e.g. Harden-Jones 1968). Selecting the most appropriate method depends both on the purpose for which the marking or tagging

is required and the species on which it is to be used. Identifying the correct questions to be asked must still be undertaken together with the appropriate experimental design (see Majkowski 1989) before the method which will best help to answer those questions can be selected.

Radio tracking has been widely used in a range of studies of terrestrial fauna in Australia (e.g. O'Connor and Pyke 1987; Newell 1999), but until recently had not been used on fish (Koehn 1996, 1997). Both radio and ultrasonic tagging have however, been used widely in overseas fish studies (see Priede 1980; International Society on Biotelemetry 1999). A wide range of telemetry techniques, equipment and study examples is provided in Amlaner and MacDonald (1980).

This paper provides a brief review of different tag types: the benefits and constraints of each; a comparison of the attributes of sonic and radio tags; choices of frequency; tag attachment techniques; and a review of uses for radio tracking.

## Tag options

Tag or mark selection always depends on the question which is to be answered, but other key considerations include: the size and species of the fish, their habitat, cost per fish, ease of application, the number of fish which need to be tagged and the duration of the study and likely recapture rates. Characteristics of different mark/tag types are given in Table 1.

**Table 1.** Characteristics of different types of tags and marks for use on fish. (\$=cheap (<\$5 per fish), \$\$=moderate (\$5-\$20 per fish), \$\$\$= expensive (>\$20 fish). \* These methods have substantial set-up costs. \*\* PIT tags can be detected and read at close range (<30cm), while coded wire tags can be detected at close range but the fish need to be captured and sacrificed so that the individual tag can be identified.

Tag/ mark type	Characteristic							
	Individual/ Batch mark	Cost per fish	Ease of use	Marine/ freshwater	Need recapture?	Continuous monitoring	Limitations	Comments/ references
Tattoo, brand, fin clips, O- rings, dyes, polymer	Batch, Individual	\$	Easy	Both	Yes	No	Not lasting	Kearney (1989), Hancock (1989)
Antibiotic, radio isotope marks	Batch	\$	Moderate	Both	Yes	No	Sometimes kill fish to retrieve	Hancock (1989)
Genetic tags	Individual	\$	Difficult	Both	Yes	No	Expertise	Keenan and MacDonald (1989)
Passive Integrated Transponder (PIT)	Individual	\$\$	Easy	Both	Yes/No*	No		Can monitor at close range
Dart, T-bar, streamer, disc	Individual	\$	Easy	Both	Yes	No		CATAG website
Coded wire	Individual	*\$	Moderate	Both	Yes/No**	No	Equipment, kill fish to retrieve	NMT website; Ingram (1989)
Satellite	Individual	\$\$\$*	Difficult	Both	No	Yes	Cost	e.g. ARGOS (see Roche 1999; Priede 1980)
Electro- magnetic	Individual	\$\$\$*	Difficult	Both	No	Yes		Jernakoff (1989)
Archival	Individual	\$\$\$*	Difficult	Both	Yes	Yes	Size, recapture, cost	Gunn and Young (2000)
Radio	Individual	\$\$\$*	Difficult	Freshwater	No	Yes	Fish size, numbers, attachment, tracking time, limited by battery life	e.g. ATS website, Lotek website, can monitor from a distance
Ultrasonic	Individual	\$\$\$*	Difficult	Both	No	Yes	Fish size, numbers, attachment, tracking time, limited by battery life	e.g. Lotek website, Vemco website, can monitor from a distance

As fish generally cannot be observed in freshwater situations, most tag types rely on fish recapture to obtain data. This poses a problem for data collection, with low percentages of tagged fish being recaptured and consequently the potential for capture bias. Sonic and radio tags however, have the advantage of allowing individual fish to be tracked, potentially on a continuous basis, with 'observations' and measurements made of 'natural' behaviour for a large percentage of the tagged fish.

### Ultrasonic and radio tags

Ultrasonic tags use acoustic soundwaves generally around 50 KHz, whereas radio tags use signals in the 30-150 MHz range. Both ultrasonic and radio tags consist of three essential components: circuitry, a transmitting aerial and a battery. These components are encased in an epoxy resin. As these tags rely on battery power, they have a limited life determined by the battery, making tag longevity a consideration. There are currently new options which can assist in power saving such as microcontrollers, that allow tags to only be active for certain periods rather than in

**Table 2.** A comparison of the performance of sonic and radio tags under different study conditions.

Characteristic	Ultrasonic	Radio
Salt water	Excellent	No
High conductivity	Excellent	Poor
Low conductivity	Excellent	Excellent
Deep water	Excellent	Limited
Turbulent water	No	Excellent
Fast animals	Poor	Excellent
Long migrations	Poor	Excellent
Dense aquatic vegetation	Poor	Very good
In water obstructions	Poor	Very good
Turbid water	Poor	Very good
Algae	Poor	Excellent
Thermocline/Temperature gradient	Fair	Good
Ice	Poor	Good
Number of animals	Same	Same
Tracking options	Hydrophone (in water)	Many options: land, boat, air, remote (out of water)
Power usage	Poor	Good

continuous use. In general, radio tags make more efficient use of power, providing a longer life for comparable size transmitter. There is, however, always a chance of tag failure.

Ultrasonic and radio tags offer the option of individual tags which can allow information to be collected in a harmless manner without the need for fish recapture. Both of these tagging methods do, however, have some disadvantages over other tagging methods. These include: higher cost, the need for greater expertise, limitations on fish size and a limitation on the number of fish which can realistically be tagged. This limitation is somewhat overcome by the high level of 'recaptures' although most studies are forced to rely to some degree on repeat measurements from the same individuals. Manual tracking can also become very labour-intensive.

Another key limitation for radio tracking is water conductivity. Use of radio tags is essentially limited to 'freshwater' environments and difficulties can arise in areas such as estuaries and lowland rivers where

high salinity levels may occur. Areas with 'intermittent' high salinities such as those which change throughout the year or areas which have saline pools or haloclines may pose particular problems. Testing of the 48-49 MHz wavelength has indicated an effective limit to tracking at conductivity levels greater than about 600 EC. To overcome these difficulties combination ultrasonic/radio tags are now available from some suppliers (e.g. see Lotek, Vemco).

A comparison of the performance of ultrasonic and radio tags under different circumstances is given in Table 2.

Kenward (1987) asked the following questions in relation to whether radio tracking was an appropriate study method for terrestrial research:

- Do I have the time?
- Can I catch enough animals?
- Can they be tagged?
- Can I afford it?

**Table 3.** Relative performances of low (<50 MHz) and higher (>50MHz) radio frequencies for a range of characteristics.

Characteristic	<50 MHz	>50 MHz
Attenuation	Less (better signal)	Greater
Depth	Greater transmission	Less
High conductivity (>600EC)	Greater transmission	Less
Land vegetation	Less blockage	More
Signal efficiency	Less	More
Transmitter efficiency	Less	More
Antennae	Bulky	Smaller

- Can I collect appropriate data?

These questions are equally appropriate for the study of fish.

### Choice of radio frequency

Generally the frequency options for radio tags are in the ranges of 30-32 MHz, 48-49 MHz and 150-151 MHz. Most terrestrial radio tracking has been conducted using 150 MHz equipment, which can also be utilised for aquatic research, but there are some advantages with lower frequencies (Table 3). Lower frequencies provide better reception and range through water and therefore have advantages in deep or more saline waters. As the size of a conventional (yagi) antenna is based on the inverse of the wavelength, low frequency antennae can be large and unwieldy. This can be overcome by the use of smaller whip or loop antennae, but these are less directional for tracking.

### Transmitter attachment techniques

Transmitters can be attached to fish either externally or internally. Externally-attached tags can be wired through the flesh or bony structures such as spines or operculae. Such attachments have the potential for entanglement in natural environments, especially if the species utilises habitats such as woody debris or vegetation. Internal tags can either be inserted into the stomach or implanted into the body cavity. These procedures are much more difficult and are likely to

require some veterinary training, but encapsulate the tag within the fish. Such operations can however be stressful to the fish and there is the chance of infection of the wound or rejection of the transmitter. Using the generally accepted rule of a transmitter weight being less than 2% of fish body weight (Knights and Lasee 1996), this avoids balance and entanglement problems. Care must also be taken to ensure that the size and shape of the transmitter is appropriate for the body cavity of the fish to avoid contact with vital organs. This may be particularly difficult if female fish are in spawning condition.

Tags inserted into the stomach provide a relatively quick and easy form of attachment but have the potential to be ejected or interfere with feeding patterns. This type of attachment has proven ideal for use on large numbers of spawning salmon in North America as these fish no longer feed (Eiler 2000).

Attachment techniques must also give consideration to the type of aerial which the tag uses to transmit its signal. Aerials which are incorporated within the tag are convenient, but seriously compromise transmission power (see ATS). Most transmitters use a stainless steel, trailing aerial which can be kept inside the body of the fish or, more commonly exited from the body either through the implant sutures or *via* a separate incision (Koehn 1997). Externally-attached transmitters do not have this problem and those inserted into the stomach can allow the aerial to protrude from either the mouth or be folded back

**Table 4.** Characteristics of different types of transmitter attachments for freshwater fish.

Characteristic	Attachment type		
	External	Stomach	Implant
Installation time	Moderate	Quick	Slow
Difficulty	Moderate	Low	Highest
Recovery time	Moderate	Quick	Longest
Balance problems	Greatest	Least	Least
Transmitter size	Smallest	Moderate	Largest
Entanglement	Greatest	Low	Low
Infection	Moderate	Low	Highest

through the operculum (Brown and Eiler 1999). The performance of externally-attached and oesophageal tags in salmonids have been assessed by Brown and Eiler (1999). Rejection of internally-implanted tags is a possibility and the survival, growth, health and healing of surgically-implanted transmitters in bluegills has been assessed by Knights and Lasec (1996).

## Discussion

Fish are not readily visible in their natural environment and knowledge of their biology and movements has usually been assembled from many isolated and discontinuous observations (Priede 1980). Both radio and ultrasonic tagging allow better information to be obtained through the ability to follow individuals. In reference to marine studies, Arnold (2000) concluded that 'we have learnt more about fish migration over the last 30 years, since the introduction of acoustic tag, than in the preceding 75 years, following the invention of the Petersen disc.' Radio tracking has the ability to have the same effect on the studies of freshwater fish.

Many applications of fish radio tracking have concentrated on small-scale studies which detailed aspects such as movements and habitat use (Coeck and Colazzo 1999). Advances in technology, however, are providing new tools for collecting detailed information (Eiler 2000). Radio telemetry studies are now under way on larger scales, in which large

numbers of fish are tagged. Adams *et al.* (1999) report behavioural data from over 4 000 juvenile salmon, while Eiler (2000) and Bjorn *et al.* (1999) report telemetry studies where in excess of 3 000 individual fish have been tagged per year. Such large scale tagging now allows radio tracking to provide information previously obtained by more traditional tagging methods including abundance (Hasbrouck *et al.* 1999), population estimates (e.g. English *et al.* 1999), survival rates (English *et al.* 1999) and stock assessment (Fish 1999). Behavioural studies on fish have included schooling (Johnsen 1980a), the effects of heated effluent (Johnsen 1980b; Langford *et al.* 1980), homing and spawning activity in salmonids (Hawkins *et al.* 1980; Weatherly *et al.* 1996) and tracking around and through fishways (Adams *et al.* 1999).

Other options for radio tags now include activity, mortality and depth sensors (ATS; Beeman *et al.* 1998), temperature sensors (Venditti and Rondorf 1999), movement sensors, temperature probes, heart rate/metabolism monitors (Hinch *et al.* 1996) and other physiological and environmental monitoring (e.g. Miller *et al.* 1980).

Tracking can be undertaken manually by land, boat or aircraft or by remote stations using data loggers. Tracking by air can provide considerable advantages, especially along river systems (Holder and Eiler 1999), although it can be weather limited, provide staff hardships and be difficult when tracking large numbers

of fish. It is now possible to incorporate GPS (Olexa *et al.* 1999), GIS (Hooge *et al.* 1999) and satellite up links (Eiler and Masters 1999) as part of remote monitoring systems (Bridger *et al.* 1999). Options used by acoustic tags such as those for swimming speeds on marine fish (Webber *et al.* 1999) can easily be added as options to radio tags for use in freshwater. Microcontroller tags which can be pre-set to determine when tags are operational, and provide considerable savings on battery power, hence extending tag life. Similarly, trade offs can be made with power outputs and pulse times to reduce power consumption.

The benefits of the relatively recent development and use of radio tags in Australia for the study of Murray cod (Koehn 1996, 1997) and other species (Koehn and Nicol 1998) can be given as examples where significant new biological information on movement patterns, homing, and habitat preferences has been collected which could not have been possible without radio tracking as a technique.

## Conclusion

The use of radio tags to study freshwater fish has the ability to transform the way freshwater fish are studied in Australia. Radio tags have considerable advantages over ultrasonic tags in relation to tracking methods and power usage. They are, however, limited by water conductivities. Radio tracking can allow data to be collected on difficult-to-capture species in a cost-effective manner to answer questions on basic biological parameters such as movement and habitat preference. More advanced utilisation of this methodology, together with technical advances, mean that more detailed and extensive studies can be undertaken. The use of radio tracking will prove to be a quantum leap in the study of freshwater fish.

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