Loggers and transmitters on animals

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Preface

The making of this report was a part of the course ZO8091 Dyreforsøkslære at IBI, NTNU. The theme of this assignment was "Loggers and transmitters on animals", referred to in the following as 'tags'. Main emphasis is on tags used in fish, but some information on amphibians and reptiles is also provided.

The report will present a review of the different types of tags used on these species, and which kind of information they can provide. Interaction with the natural behavior of the tagged individual, and the possible negative effects these have on the animals' welfare, will be addressed.

Further, the legislations covering tagging of these species will be considered, along with the sections relevant for tagging of animals. At last, the guidelines, restrictions and requirements given by the National Animal Research Authority (FDU) through their approval or rejection of applications for such tagging experiments are considered.

Tag types, and the information they provide

Tags have been designed in many variations in order to suit specific needs when it comes to efficiency as a tool, but also applicability when it comes to the tagging procedure. Sometimes, the tag just has to provide an identification of the animal, regardless of the sophistication of the method. Other tasks demand a very efficient method for installing the tag, exposing the animal for a minimum of potential negative effects due to handling during the procedure.

Technology has also played an important role in the recent development of tags, especially when it comes to advanced tags providing the features of collecting some kind of information. This information could be stored, processed in the tag, or transmitted to a receiver. Also various combinations of these tasks could be found in a single tag in order to suit a specific problem. The advance in modern technology has led to a situation where many designs impossible a few years back, are feasible today.

Tag classification

The diversity within tag types is quite extensive, and only a selection will be discussed in the following. As many of the tag classifications could be used for multiple species, the presentation is sorted by tag type and not group of animal.

This report considers the use of electronic tags exclusively, and tagging of some groups of animals may be omitted as these groups mainly use non-electronic tags. However, these methods are often used to a greater extent than electronic tags, due to the often significant difference in unity cost and an efficient method of application. Examples of such tags are identification tags (for instance colored rings or wire) and chemical tags.

Electronic tags are often classified in the groups as indicated by the following figure:

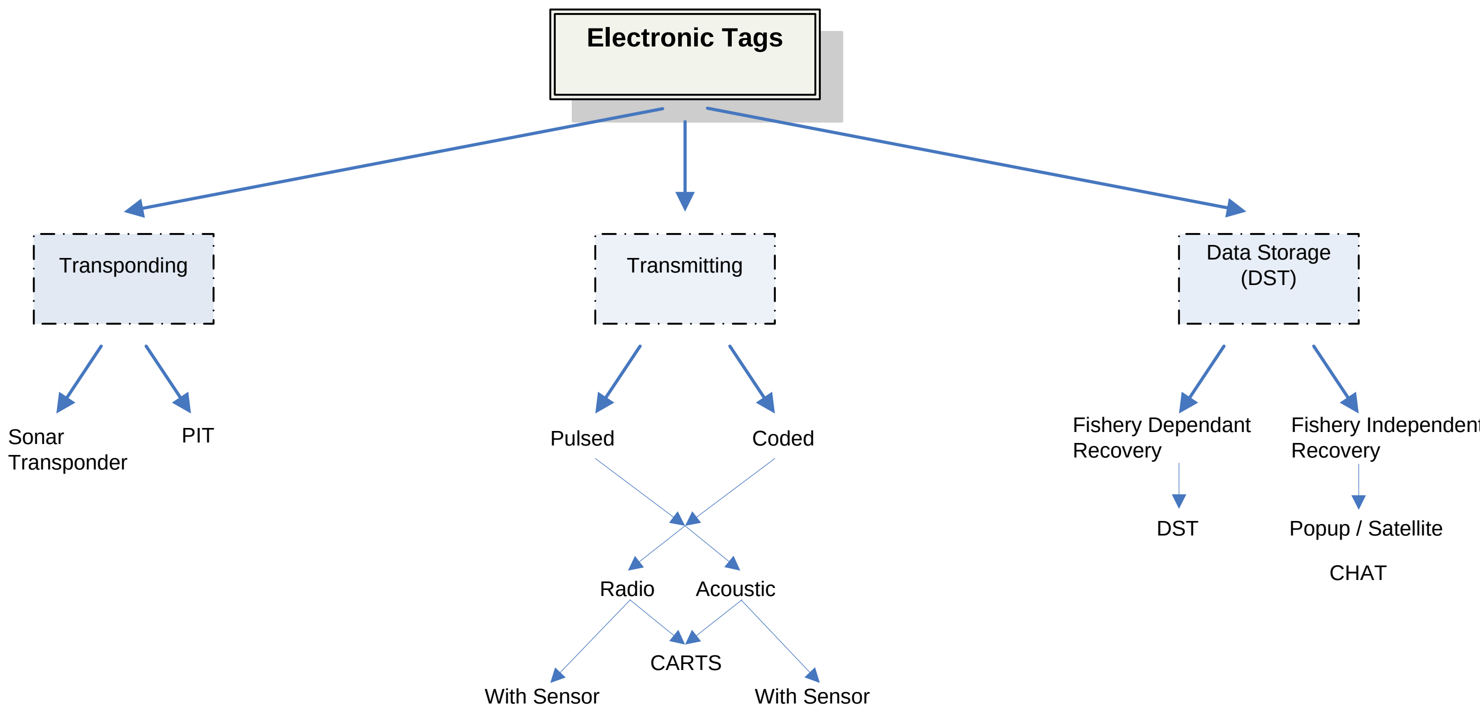

Figure 1: Common electronic tag classification groups. (Based on figure from [14].)

The combinations of two or more of these categories are of course also possible, resulting in a wide range of hybrid combinations. However, the main categories are presented in table 1.

As table 1 indicates, there are a wide diversity in tag types and the information they are able to provide. The table is, however, far from presenting a complete overview of possible configurations. The demand for deeper knowledge, along with the technological development in sensors, power sources and low-power integrated circuits, contributes to a continuous evolvement of the possible configurations.

In the following, some of the more common tag types and the usage of these will be further discussed.

Table 1: Tag types, typical applications and availible sensors

Tag type	*Application*	*Available sensors*
Inductively-coupled electromagnetic tags	**PIT:** -Stock monitoring -Tag passage **Sonar transponder:** -Tag tracking in the water column (typically fish)	-Depth, temperature (Very limited due to lack of battery source)
Continuously transmitting radio and acoustic tags	-Tracking in freshwater (radio and acoustic) and sea (only acoustic) -Migration studies -Fish entrainment behavior -Microhabitat utilization	-Temperature -Activity (EMG, tail beat) -Pressure (depth, height) -Salinity -Light -Conductivity (in order to detect freshwater to sea migration) -Position (radio - GPS)
Transponding acoustic tags	(As above. Tag only responds after receiving an interrogation pulse.)	(As above)
Data storage tags (DST)	-Vertical and horizontal movements -Habitat preferences -Samples from temperature, depth, position, etc.	(As above)
Remote data telemetry	(As above. Tag dumps stored information to remote receiving stations (for instance special buoys) when in range.)	(As above)

PIT-tags

PIT-tags (Passive Integrated Transponder Tags) provide no power source of their own, and depend of an external magnetic pulse in order to gather energy (induce an electric potential) to respond. This fact significantly reduces their possible sensor configurations, and they are usually limited to a simple alpha-numeric code respond. However, temperature readings could be implemented using PIT-technology. In this case, varying temperatures yield different code-responses at request. The technology makes identification of 34 billion codes possible, using a frequency ranging from 125 to 400 kHz [14].

Identifying animals, one of the biggest technological challenges in wildlife biology, is easier using the passive integrated transponder technology. These tags are widely used for identification of pets, but are also proving valuable for scientific studies on species which were earlier difficult to observe, like many snakes. In their mission to conduct long-term monitoring of reptiles and other wildlife populations, Savannah River Ecology

Laboratory (SREL – see www.uga.edu/srel/) researchers must capture animals, mark them with some sort of unique identification, release them and then recapture them periodically. With the use of PIT tags, researchers are better able to study the individual growth, reproduction, survival and movement patterns of reptiles and other wildlife.

SREL researchers began using PIT tags on reptiles in October 1991 and have tagged more than 1,500 non-poisonous snakes to date. The technology -- at $3 per tag, still very expensive -- has been available since the mid-1980s and has been used in other U.S. ecology laboratories on fish and turtles. SREL is among the first laboratories to use PIT tags on snakes.

The tag, about the size of a grain of wild rice, consists of a coded microchip encased in glass. Researchers inject the tag into a snake's body cavity through a syringe poked between its lower belly scales. This procedure causes no known discomfort. When they recapture the snake researchers use a decoder to read the individual reptile's unique identification number [15].

PIT-tags are also valuable for identification of fish, if the fish comes in close contact with detecting equipment. The range of automatic detectors is often limited to a merely 15cm [14]. In studies of stream living fish PIT-tags are often used in combination with electro-fishing. Recapturing of marked individuals can provide information on body growth, population size and movement patterns.

Figure 2: Pit-tag inserted into salmon juveniles

Transmitting radio tags

Radio tags have gained a great popularity, and are used with many different species and purposes. They are widely used on great sea-mammals like whales and dolphins, but also on big reptiles like turtles. But radio tags have a significant limitation when it comes to saline waters, which lies in the great attenuation of electromagnetic waves. The range of a radio tag transmitting in seawater is often limited to such an extent that it is useless for any practical purpose. But many sea-living species will surface over a period of time long enough for the tag to make a successful transmission. If communication with the device is required while submerged, a combination of radio and acoustic transmission could be used. The CARTS-tag shown in figure 1 is an example of this. In freshwater, the use of radio waves for transmission is highly applicable and very common.

The transmitting radio tags used for big animals like the great sea turtles and marine mammals have the greatest variety in features and sensors available, due to the possibility of using a correspondingly big power source. These tags can make use of satellites for the transmission (satellite-tags), providing a significant range, even world-wide coverage. When used on long-ranging animals, the radio tags often include a GPS positioning system. Such tags are often used to reveal the route the animal travels, but also depth, temperature, light, activity and any other demanded configuration. The commercial available tags off-the-shelf still have, of course, limitations, when it comes to available sensors. Satellite-tags often use the UHF frequency band, around 400MHz.

Figure 3: Backpack tag. The harness replaces glue, which won't hold a satellite tag to the leatherback's leathery shell. Photo: Monterey Bay National Marine Sanctuary [16].

Radio tags could also be of very small size, if made for tracking small fish in lakes or rivers, for instance. Handheld receivers are then the most adequate equipment, and the tags have a shorter range. The range could be up to a kilometer, but often less then 100m, due to tag lifetime versus transmitting power considerations. Radio tags usually use the frequency range from 20 to 250MHz. Transmission baud rate is potentially quite high, dependant of communication protocol selected.

As a curiosity, a radio transmitter has recently been developed for use on insects (see figure 3). The device weighs 0.2g, and has a lifetime of three weeks. The range is astonishing two kilometers [6].

Figure 4: The world's smallest radio tag. Photo: [6]

Transmitting acoustic tags

Acoustic tags are common when continuously tracking animals in the sea, and could also be used for more extensive transmissions of data from tag to shore. The acoustic environment in the sea is on the other hand often complicated, resulting in short range and even shadow zones where the tag has no possibility to transmit or receive signals. These phenomenons are a result of the shifting sound velocity profiles in the sea, varying with temperature, depth and salinity. Acoustic transmitters could use a frequency range from 30 to 300 kHz, and the detection range is highly dependant of the receiving equipment. The transmission baud rate is quite limited due to the sound speed in water (approximately 1500m/s) and possible distortions from reverberations and the water itself

[5]. Experiments at NTNU in a tank environment have shown success using a baud rate of approximately 400 kilobits per second [12].

Acoustic transmitting tags have been used for tracking of fish in Norway since 1974. These were ‘pingers’, and provided no other information but the position of the fish, and this is still the most common use of small acoustic tags today. Later, information of depth was added to the features of these tags, and today there are numerous possible sensor configurations available. To mention a few, tail beat, temperature, EMG (activity in a specific muscle), ECG, absolute and differential pressure are well documented sensor configurations used for scientific purposes.

I Norway, the range of fish species where these tags have been used include cod, saithe, flounder, eel, salmon, trout and arctic char. The tasks or purpose for the tagging have been (among others):

- Tracking of fish offshore (Barents sea) in order to study migration speed and direction of juvenile cod
- Tracking of heart rate in saithe during conditioning experiment (acoustic or light signals followed by feeding)
- Tracking of salmon migrating up rivers, in order to see relations between the rivers water level in correlation with migration success
- Tracking of cultivated salmon smolt in order to study whether the behavior is comparable with wild fish
- Tracking of wild salmon smolts migration in fjords
- Tracking of eel in order to map the area covered while foraging
- Measure of internal temperature in free swimming cod
- Measure of opercular differential pressure in salmon in order to detect food intake

Data storage tags

Satellite-tags are covered by the first section of *Transmitting radio tags.* They provide the possibility of collecting data while out of range (typically submerged), and transmitting them as soon as the animal surfaces. Data storage tags (DSTs) could also be small tags for small animals, like small fish.

Some types of DSTs are dependant of being found and delivered back to the scientist for data extraction, providing no means of distant communication. As an extreme, DSTs have been designed to work actively for up to five years, storing the data safely for up to twenty years. Pop-up tags, although they might utilize radio transmission, are also a category of DSTs. These tags provide the possibility of tagging animals in the sea which never or rarely surfaces. The tag will release itself from the attachment after a given period, and surface. Then it typically starts a radio transmission, revealing its position, and could be traced for retrieval. [14].

When it comes to sensor configurations of DSTs, they have no obvious limitations compared to other tags. Still, as the concept of a data storage tag provides no direct communication link between tag and shore, the selection of desired information is often affected. As an example, ECG readings from a swimming fish could not be stored over long periods of time before consuming all the memory of the tag. Rather, the information is processed and compressed as a measure of the heart activity over some prolonged fraction of the day. When the scientist retrieves the tag, the heart activity during the specific intervals of the tag-life period could be extracted along with corresponding timestamps. This way, a good resolution of the data is sacrificed in favour of an average over multiple samples. On the other hand, a detection mechanism could initiate (and stop) the sampling, reducing the consumption of memory to the most interesting actions.

Figure 5: The full installation of an opercular differential pressure tag. This tag falls in a category of its own, as it is only a prototype for laboratory experiments, and utilizes a hard-wire transfer of sensor signals.

Animal welfare considerations

Tagging of animals will always have negative effects on the animal. Minimizing the negative effects is of importance due of animal welfare considerations, but it is also essential in order to get relevant and high quality data based on animals behaving naturally. The tagging procedure can be divided into three steps where different negative effects might be of major concern: 1) capturing, 2) tag attachment, and 3) post-tagging.

Stress, damage and mortality risk during capture and transportation

Different capture and handling methods inflict different damages and stressors on the animals. For many fish species capture is performed by some kind of a net (trawls, purse seines, gillnets, encircling nets etc). Possible negative effects of net capture are scale loss, skin damage, exhaustion, tissue damage, and if entangled in the gill region the fish may suffocate or bleed to death. Baited or unbaited traps where the fish enters the trap voluntarily usually cause little damage and stress. In fresh water electrofishing may prove effective and inoffensive due to fast recovery, but there is a risk of spinal fracture and haemorrage if the voltage is not adjusted to the size of the fish. Angling, hand lines and other lining techniques often impose no or only minor damage to the jaw region, but if the hook is swallowed the damage might be severe [14].

In fish most capture methods result in abrasion of the skin as the mucous layer protecting the epidermis and the scales is particularly delicate in most fish species. The mucous layer protects the fish against fungal, bacterial and viral invasions and, together with skin and scales provides a barrier against leakage or dilution of body fluids. Damage such as scale loss and skin wounds will cause problems of increasing seriousness depending on the degree of body cover lost. Prolonged struggles or swimming activity during capture leads to exhaustion with subsequent conversion of muscle glycogen to lactate acid. In the case of severe exhaustion lactates are released into the blood stream from the muscles and cause lethal metabolic acidosis. The post-capture metabolism of accumulated lactates in the muscles will also lead to an elevated oxygen demand. Stress may also result in a reduction of immune responses [14].

Also a problem when working with physoclists (fish with closed swimbladder), is the expansion of the gas contained in the swimbladder as the external pressure get less in an upward transport. As the compensatory mechanisms are rather slow, an involuntary upward movement could cause substantial expansion, leading to rupture of the bladder and compression of internal organs [14].

Land living reptiles like reptiles and amphibians are often caught by hand or in traps. In traps there is a risk of deaths from exposure, drowning, cardiogenic shock, or to capture myopathy [1].

Amphibians, especially larvae and tadpoles, have delicate skin, making them vulnerable to damage of skin and removal of their protecting mucus layer during capturing and handling [3].

Damage and stress during attachment of the tag

An electronic tag can be externally or internally attached. For animals with shell, like turtles and decapods, an external tag can be glued to the shell. This also comes to insects. For many animals attachment can also be made by harnesses [2, 14]. For snakes, fish and amphibians, external tags are often attached by fine wires or nylon cord passing through some part of the body [11, 14]. Internal tags are often inserted in the stomach or implanted surgically in a muscle or in the peritoneum [14].

Anesthetization is needed when internal tags are to be surgically implanted but may also be used during external attachment. All known anesthetics have unwanted side effects. The most important one is hypoxia due to reduced respiratory and vascular activity. In addition to physiological deterioration of blood parameters, hypoxia can cause brain damage [14]. There is a risk of mortality if the dosage is too high or the anesthetization procedure takes too long.

Surgical implantation of tags may cause hypoxia if the procedure takes too long. During surgery scalpels may puncture viscera or ovaries [14].

Internal tags can be inserted into the stomach either by voluntary ingestion, having the tag embedded in bait, or by forced ingestion with a tube often fitted with a plunger. Plungers may cause damage to the stomach or the oesophagus [14], and if the tag is too large the animal might suffocate. Anesthetics are often recommended to reduce coughing reactions and immediate regurgitation [9].

When anesthesia is not used for externally attached or stomach inserted tags the handling of animals during attachment may cause stress and inflict pain in the case of skin and muscle penetration.

Post-tagging negative effects

In fish short recovery-time after surgery may influence the swimming performance, making the individuals vulnerable to predation or making it difficult to swim in fast-flowing water. Long recovery-time may on the other hand also have negative effects imposing stress over a longer period of time [4].

Fish with externally-attached and surgically-implanted transmitters may have infections and wounds at the attachment points and the incision. Similar problems are also encountered frequently for gastrically-inserted transmitters with trailing antennas that cause abrasion of the mouth corner. The severity of wounds is often worse in cryptic or highly structured environments, in which externally-attached tags can become entangled in surrounding vegetation, or torn by rocky substrata [14].

External tags may also change the appearance of the animal, making them more easily detected by predation or influence on their behavior [2, 14]. In fish and water living animals, especially in coastal areas, fouling is a potential negative effect. The problem will be most pronounced for externally attached antennas, but for internal transmitters fouling ca occur on an external antenna. Fouling will lead to increased drag and can decrease swimming performance [13]. Increased drag may also cause deep cuts in the dorsal musculature.

Movement of internal tags after implantation may cause damage to tissue or viscera [14]. Sutures may cause irritation and inflammation and they can also be shed or absorbed before the incision has healed [4]. Open wounds will in turn increase infection risk and influence the osmotic balance of fish [14].

Both internally and externally attached tags will impose an increased weight to the animal. In fish the extra weight might influence buoyancy, swimming performance, behavior and growth [4, 14]. For gastrically-inserted transmitters the extra volume applied may cause reduced appetite [14].

For growing individuals an externally attached tag may mechanically restrict growth. Wire attached tags may also cause wounds. Studies on fish has shown that internal tags mainly has a short-time effect on growth, while the effects of external tags may be progressive and increase in the long run [14].

Relevant legislation for experiments using electronic tags

In Norway there are no specific articles in laws or regulations that are directly aimed for tagging experiments. Relevant sections from the *Norwegian Animal Welfare Act* which applies to tagging experiments as well as many animal experiment in general are:

CHAPTER I General provisions

- Section 2 General provisions on how animals should be treated
- Section 4 Animal accommodation
- Section 5 Breeding, supervision and care
- Section 7 Medical and surgical treatment

Chapter III Special provisions concerning fish and crustacea

- Section 14 Various prohibitions, point 1

CHAPTER VI Use of animals in teaching and research

- Section 21 Use of animals in research, etc.

Section 7 is of special interest with regard to the tagging procedure. This section states that "Only a veterinarian may carry out a surgical operation on, or initiate medical treatment of, animals, when there is reason to believe that such operation or treatment may result in the animal suffering." However an adjustment of this section (Law of June 15, 2001, Number 75) states that for aquatic animals, excepted sea mammals, fish health biologists are allowed to do similar procedures. Hence, for tagging experiments in fish, researchers with a FELASA[1] Certificate C are allowed to do surgical tag implantation.

Most sections in the *Regulation on Animal Experimentation* are of general relevance to tagging experiments too. However, a few sections are of special interest. Section 2 defines the area of application and states that excepted from the regulation are "…simple marking of animals (…) should there not be reason to assume that the experiment will affect the animal's normal way of life, or cause other than slight pain or discomfort of a highly temporary nature". For this exception there is room for interpretation and marking individuals with pit-tags might be a case of doubt. At the Norwegian Institute for Nature Research (NINA) the competent person recommend to apply for a permit when pit-tags are to be used, but this might be practiced differently other places.

Section 14 in the Regulation states "(…) Should there not be reason to assume that the intensity of pain experienced in an experiment exceeds the pain intensity of anesthesia, anesthesia may be omitted. (…)" This point may be relevant for the use of sedation in external tagging, because even though anesthesia relieves the pain, it has other negative effects. The interpretation of this law by The National Animal Research Authorities decision is considered in the next section of this report.

The National Animal Research Authority's decisions regarding electronic tagging

The National Animal Research Authority (FDU) gives only one decision as to principle regarding electronic tagging of animals, but this decision deals only with Norwegian predators. The declaration was made from the Judicial Council for Veterinary Medicine in October 1997 and states that the employment of intraperitoneal (abdominal cavity) implants of radio transmitters should not be a part of the management of big predators. The judicial council means that such an intervention, after preceding hunting and immobilization, will result in risk of unnecessary suffering of the animals, cf. Norwegian animal welfare act § 2.

The Norwegian Animal Health Authority (Statens Dyrehelsetilsyn) has in a letter endorsed this statement. FDU considered the use of intraperitoneal transmitters on principle basis in June 2002, and made the following declaration: The National Animal

[1] Federation of European Laboratory Animal Science Associations

Research Authority will show great restrictions consenting applications regarding the application of intraperitoneal transmitters. Substantial scientific reasons must exist in order to allow such practice.

The current secretary at The National Animal Research Authority answered an e-mail regarding this question by phoning the author during the work of this report, and confirmed that no direct regulations or directions existed as a declaration from FDU, except from the question regarding implants in predators mentioned above. Regarding predators, he said the Authority has history of being especially restrictive. Every single application is treated with regards to scientific and social utility values as opposed to the extent of the intervention of the animal. Alternatives are always considered, he said, and the database of alternatives to animal research at the Norwegian School of Veterinary Science is an extensive tool in this connection. He could not make any statement regarding the history of allowances and rejections of previous applications for electronic tagging experiments.

NINAs (Norwegian Institute for Nature Research) experience regarding experiments on fish is that externally attached tags are less accepted from FDU than internal. This is quite the opposite of the predator policy mentioned above, but could possibly be explained by the increased strain on a fish using an external tag. [Finn Økland, NINA, pers. comm.]

For external tagging of fish FDU requires anesthetization [Eva Thorstad, NINA, pers. comm.]. Hence, FDU considers the relieve of pain during the procedure to be more important then the negative effects of anesthetics.

In relation with NINA applications for fish telemetry studies, FDU has had comments or objections with regard to the low number of individuals included [Eva Thorstad, NINA, pers. comm.]. The information gained from telemetry studies is often descriptive data on behavior of a relatively low number of fish where power analysis are not always relevant. Another problem of concern for the FDU is the lack of recapturing of tagged fish. This has been commented in notes after acceptance of applications by NINA's local competent person [Eva Thorstad, NINA, pers. comm.]. Recapturing of the individuals are difficult, resource demanding and often impossible. Usually the tags are surgically implanted in order to stay put for the whole life, though some tags are expelled or rejected.

Although not a declaration from the research authority, another legislative declaration regarding tagging for identification is relevant in this context: The Norwegian ministry of agriculture and food (Landbruks- og matdepartementet) has stated in *White paper 6: Norwegian husbandry today*, chapter 6.2.18.6 (Interventions on horses), that "Branding, tattooing or branding by freezing is not employed in Norway. There is an agreement of utilizing electronic branding using microchips as identification method. Branding using chips is without any problems from an animal protection point of view." This branding method is also mentioned as preferable for other animals discussed in this white paper, and is typically carried out using PIT-tags in glass ampoules.

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