4.7 Tagging with electronic tags

Conventional tagging experiments can be very useful for describing gross patterns of population movement (i.e. the location at release and capture), but the method is not able to provide information at fine temporal scales (i.e. where the fish went between release and recapture) or any detailed information about the behaviour of individuals. Also, population movements derived from conventional tagging studies rely on commercial and recreational fishers reporting details of the time and location of recapture of the tagged fish. Therefore, the results of such studies are inevitably an integration of both fish behaviour and fishing activity, and this confounds any analysis of population movements. Tagging data can be adjusted for spatial variations in fishing effort, where this is known, but movements of fish into un-fished or un-fishable areas, or changes in fish behaviour which alter availability or catchability, cannot easily be accounted for. Electronic tags yield more detailed and extensive information that provides the fuller understanding of tuna biology required for effective assessment and management.

4.7.1 Acoustic tags

Since the late 1960s electronic tags that transmit acoustic signals (radio signals do not be transmit effectively through sea water) have increasingly been used to track the movements of individual free-ranging fish for limited periods. Such work has yielded substantial advances in our understanding of how tunas and other large pelagic fish behave (Yuen, 1970; Carey and Lawson, 1973; Laurs *et al*., 1977; Carey and Robinson, 1981; Brill *et al*. 1993). But this technique is limited because, in most applications, only one fish can be followed at a time, each fish can only be followed for a short period (often only a few days), and sea-going work aboard research vessels is expensive. More recently, substantial advances in microelectronic technology have permitted the successful development of electronic “data storage” or “archival” tags that are small enough to be attached to fish.

4.7.2 Archival tags

Archival tags record and store environmental and behavioural data and, because there is no need for human observers to follow the fish, make it possible to monitor the behaviour and movements of many fish simultaneously over longer periods that can include entire migrations. A variety of such devices are now being used to study the movements of tuna (Gunn 1994, Gunn *et al*. 1994, Block *et al*. 1998a, Gunn and Block 2001) , billfish (Graves *et al*.,2002; Kerstetter *et al*., 2003;Prince *et al*. 2005; Prince and Goodyear 2006) and other large pelagic fishes.

Although most data storage tags currently measure only simple environmental variables such as pressure (depth) temperature (internal and external) and ambient daylight, the data can nonetheless be used to derive quite detailed information about the location and movements of fish. In the open sea, records of ambient daylight can be used to derive estimates of longitude (from the time of local noon) (Hill 1994, Gunn *et al*. 1994, Metcalfe, 2001) and latitude (from day length and/or sea surface temperature (Hill 1994, Gunn *et al*. 1994, Metcalfe, 2001, Block *et al*., 2005, Teo *et al*., 2004). The development of further onboard sensors that can monitor more complex variables such as compass heading, swimming speed, dissolved oxygen or feeding activity will do much to increase our understanding of the movements, migrations and ecology of tunas and other pelagic fish species.

4.7.3 Implantable archival tags

Although the data storage capacity of archival tags is high, their major limitation is the need to recapture the animal to access the data. This requires deployment of large numbers of tags in species with high exploitation rates. In addition, the multinational nature of most oceanic fisheries complicates the coordination of archival tag recoveries. Archival tags have been deployed recently on Atlantic bluefin tuna (Block *et al*., 1998a), but significant numbers of returns take years to retrieve. Satellite tags (conventionally towed or attached) have been employed to study the large-scale movements and physiology of marine mammals, birds, and sea turtles (see Block *et al*., 1998b). These tags have been deployed successfully on basking sharks, (Priede, 1984) but are only applicable for the largest pelagic fishes that frequent the surface.

4.7.4 Externally applied Pop-up Satellite archival tags

To avoid such problems and increase the probability of data recovery, a major area of development has been the “pop-up” tag. These tags are attached externally and have a release mechanism that causes the tag to detach from the fish at a predetermined time and “pop-up” to the sea surface where the data can be recovered via the ARGOS system aboard polar-orbiting NOAA satellites. The first-generation pop-up tags provided only very limited data: the pop-up position as determined by ARGOS, and a small amount of environmental (usually sea temperature) data. These tags therefore provide fisheries-independent measure of the straight-line distance travelled from the point of tagging. More recently pop-up tags have become available that record temperature, depth and ambient daylight that can be reduced (e.g. as time-at-depth and time-at-temperature histograms and profile-depth-temperature data) on board the tag before data transmission. Such devices are now being deployed on tuna (Block *et al*. 1998b, Lutcavage *et al*., 1999). Although data transmission capabilities are currently very limited, further developments in this field give the prospect of much improved data recovery rates in the future, while further miniaturisation will allow the technology to be applied to small species. In situations where the pop-up tag is physically recovered, either because the fish is re-caught before the tag releases, or because the tag is washed ashore and found, the full minute-by-minute depth and temperature record can be recovered.

4.7.5 Attachment methods for electronic tags

External attachment of electronic (acoustic or archival) tags

Three types of transmitter attachment have been used to attach tags externally to pelagic fish: the "harpoon" technique, stomach insertion and intramuscular sutures. The harpoon technique has been successfully employed for large species (bluefin, marlins, sharks, etc.), although most investigators would prefer a more reliable technique if one could be devised. However, as stated for conventional tagging, this approach has become more reliable with the advent of special devices for maintaining control of the fish at boat-side to insure accurate, precise and safe tag placement, as well as provide opportunities for resuscitation for increased survival of tag fish **(Figure 4.6.1)**. The harpoon method involves the use of monofilament nylon or stainless steel leader material to secure the body of the tag to a flattened stainless steel harpoon tip or medical grade nylon anchor. For stainless steel or titanium anchors, the tip fits loosely into a notch at the end of the applicator pole (harpoon) and the tag body is loosely fastened to the harpoon pole with light rubber bands. The tag is attached to the fish by impaling the tip into the dorsal musculature with a thrust of the harpoon. The harpoon tip lodges in the muscle or beneath the skin, allowing the harpoon pole to be withdrawn and the tag to trail alongside the body. If the fish has been hooked to bring it to the boat the leader is cut and the fish allowed to swim away (Yuen *et al*., 1974). This method has also been successfully used with free-swimming swordfish that have been harpooned from above as they swim at the surface (Carey and Robison, 1981). Although no adverse reactions to the harpoon type of attachment have been reported, the major problem is the uncertainty of the tag attachment and how long the tag will remain in place before being shed. Nevertheless, tracks of several days duration have been acquired using this technique.

The general trend in tuna tracking in recent years has been toward attachment of the tag to the external surface of the fish using intramuscular sutures. Two variations have been used. Tags have been attached to yellowfin using a single nylon "tie-wrap" suture passed through the muscle and pterygiophores of the anal fin, allowing the tag to hang below the fish (Carey and Olson, 1982). The other method is to use two tie-wrap sutures to attach the tag to the dorsal surface of the fish. This technique has been successfully employed on albacore (Laurs *et al*., 1977), and has been employed in the study of yellowfin movements around Oahu, Hawaii (Holland *et al*., 1985). This technique involves bringing the fish aboard the boat and immobilizing it in a foam-lined cradle. A wet cloth is placed over the fish's eyes to further subdue it while the tag is attached. Sharpened hollow needles are used to pass the tie-wrap sutures through the dorsal musculature and pterygiophores associated with the second dorsal fin. One tie-wrap is placed through a loop on the end of the tag, and the other is placed around the middle of the body of the tag to prevent it from wobbling from side to side. Both tie-wraps are cinched down and trimmed, and the fish is released. Yellowfin with tags carried in this way have been observed to swim normally in captivity and have yielded consistent data from field tests. Also, a fish with a dorsally-attached transmitter was caught 4 weeks after release by a fisherman using a trolling lure (Holland *et al*. 1985). These results indicate that intramuscular attachment is a viable method with minimal effects on the fish's behaviour. The biggest problem with this technique is the need to bring the fish aboard the boat and this may preclude its use with larger specimens.

Stomach insertion

Stomach insertion involves gently forcing the tag down the oesophagus into the stomach of the fish. This is usually performed with a detachable rod that is removed once the tag is in place (Yuen, 1970; Carey and Lawson. 1973; Laurs *et al*., 1977; Dizon *et al*., 1978). This technique seems to work best with large fish such as northern bluefin (Carey and Lawson, 1973). For smaller species, such as skipjack and albacore, problems have occurred due to regurgitation of the tag or attenuation of the signal (Laurs *et al*., 1977; Dizon *et al*., 1978). Of course, when stomach temperature is of particular interest (Carey and Lawson, 1973), there is no alternative to placing the transmitter in the stomach.

Internal implantation of electronic (acoustic or archival) tags

As with external attachment methods (except harpooning) this method requires that the fish is brought aboard the boat and/or immobilised in a cradle. Once the fish is motionless, an incision of about 2 cm length is made in the abdominal wall, about 5–10 cm anterior to the anus and about 2 cm to the left of the centerline of the fish. Special care should be taken to cut only through the dermis and partially through the muscle, but not into the peritoneal cavity. A gloved finger is then inserted into the incision and forced through the muscle into the peritoneal cavity (Block *et al*. 2001 a & b). The tag, previously sterilized by soaking in Betadine solution or similar, is then inserted through the incision into the peritoneal cavity. Two sutures are usually sufficient to close the incision, using a sterile needle and suture material [e.g. Ethicon (PDS II) size 0, cutting cp-1, 70 cm]. The fish is measured using marked graduations on the liner of the cradle and then released back into the sea (Schaefer and Fuller, 2005).

External attachment of electronic Pop-up archival tags

Pop-off satellite tags are usually attached to tuna or billfish by using a dart machined of stainless steel, titanium, or moulded in medical grade nylon (Block *et al*., 1998b;Graves *et al*. 2002;Prince *et al*., 2005; Prince and Goodyear 2006). The dart is inserted about 10 cm deep (depending on the size of the fish), at the base of the second dorsal fin (see **Figure 4.6.1**), where it can anchor between the pterygiophores and connective tissue radiating ventrally from the fin. The tag is connected to this anchor by a 20- to 25-cm-long, 136-kg monofilament leader attached through the eye loop at the front end of the tag. The eye loop is fixed in place by a thin, stainless steel wire that is exposed to sea water externally and connected internally to a battery. At the programmed time, a low voltage is passed across the wire promoting corrosion and release. During tagging, the fish are usually on deck for about 2 minutes. Alternatively, the fish are tagged using the in-water method **(Figure 4.6.1)** while the tagging vessel moves slowly forward. Experiments on captive tunas indicate that, because the tuna body narrows after the second dorsal fin, tags placed here had minimal contact with the body and did not disturb normal swimming patterns.

4.7.5 Post tagging and release of fish

If no anaesthesia has been used, the general consensus is that fish should be released back to the sea as soon as possible, provided that the fish appears to be in sufficiently good condition to maintain forward movement. As all pelagic tunas and billfish are ram ventilators, the ability to maintain forward movement is essential for respiratory function and post-release survival. If the fish is showing signs of stress (based on physical appearance and color), every effort should be made to resuscitate the fish until vigor and color return. Methods for resuscitation of tuna and billfish are given in Prince *et al*. (2002). Details on the condition of the fish (attitude in the water, vigour of swimming etc.) at release should be recorded.

Antibiotics for prevention of infection

Bayliff (1973) sprayed the tips of about half the applicators and tags used on one cruise with oxytetracycline hydrochloride equivalent to 3.5 mg per g, 1.2 mg per g of hydrocortisone, and 1,200 units of polymyxin B as the sulfate. The return rates for the fish (yellowfin) with the sprayed and unsprayed tags were not significantly different. Majkowski (1982) states that southern bluefin *Thunnus maccoyi* tagged during the early 1960's were “injected with an antibiotic to help combat tag shock, handling and infection.”

Tetracycline injection

Tunas and billfishes are sometimes injected with tetracycline at the same time that they are tagged to gain information on the meaning of the natural marks formed in the various hard parts (otoliths, vertebrae, spines, etc.) of the fish that could be used for age determination (Antoine and Mendoza, 1986). Veterinary-grade oxytetracycline hydrochloride solution (100 mg oxytetracycline base as oxytetracycline HCL per ml) is used for this purpose. Tetracycline that has exceeded its expiration date as an antibiotic is also ineffective as a marking agent. The tetracycline is incorporated into the peripheries of the otoliths (and probably the other hard parts) within 24 hours. When a fish is recovered and the otoliths are examined under ultraviolet light the tetracycline mark can be seen and the number of natural marks between the tetracycline mark and the edge of the otolith can be counted and correlated with the time elapsed between tagging and recapture.

The following amounts of tetracycline have been used by various workers:

Species	*Size*	*Amount*	*Reference*
Yellowfin	42-95 cm (1.5-17.4 kg)	1.25ml	Wild and Foreman, 1980
Skipjack	41-61 cm (1.3-5.0 kg)	1.25 ml	Wild and Foreman, 1980
Bigeye	88-134 cm	5-10 ml	Schaefer and Fuller, 2005
Albacore	51-85 cm (3.3-14.7 kg)	1.5 ml	Laurs, *et al.* 1985

The fish were all injected intramuscularly, the small to medium fish being given a single injection lateral to the first dorsal fin and the large ones two or three 1.25-ml injections in various locations.

The injection with tetracycline apparently does not affect the survival of yellowfin or skipjack, as the return rates of injected and control fish are not significantly different (Wild and Foreman. 1980). Injection is time-consuming, however, so in most circumstances it will result in less fish tagged.

4.7.6 Further reading

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