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Capture and handling of fish for electronic tagging- a review and a new non- intrusive capture method.

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Abstract

While tagging procedures are described in details the capture and handling of experimental fish prior to tagging is not given the same attention in most papers. However, traumas that originate from the capture and handling process may for a varying period of time influence the post-release behaviour of the animals studied with Smart-or other electronic tags introducing errors when interpreting the data collected. With emphasis on Atlantic species, the paper gives an overview of capture and handling methods reported in electronic tagging experiments, and where relevant, references are made also to methods used to capture and transport fish for aquarium or other live holding purposes. The advantages and disadvantages of different handling methods are discussed, and a promising new trawl-method for capturing viable individuals of delicate species is summarised.

INTRODUCTION

In order to get experimental fish in good physical condition for laboratory or *in situ* experiments, the methods of capture and the handling of the fish prior to and during tagging is of particular importance. Different capture and handling methods inflict different damages and stressors on the fish and different species have different tolerance for capture and handling. In addition, the vulnerability to handling may vary during different life stages. For example, salmonids, especially Atlantic salmon, vary greatly in their resistance to handling during their life span. While the fresh water related stages (parr, maturing and kelt stages) are less vulnerable, the skin of smolts, post-smolts and immature fish is very sensitive to handling. Atlantic halibut (*Hippoglossus hippoglossus*) are known to be difficult to handle without causing lethal damage (Midling, pers. com.), and several pelagic species such as herring (Clupeids) and mackerel (Scombrids) are similarly easily damaged (e.g. Wardle, 1968; Blaxter & Holliday, 1963).

This review of fish capture and handling methods in relation to electronic tagging is based on a selection of experiments mainly restricted to marine fish with emphasis on Atlantic species. Fresh water and non-Atlantic marine species are included where either the capture method or the physiological observations made are of particular interest.

DAMAGE DURING CAPTURE AND HANDLING

Most capture methods result in abrasion of the skin. The mucus layer protecting the epidermis and the scales is particularly delicate in most fish species. This 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. An undamaged mucus layer is essential for the well being of the fish after capture. 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, which must be considered during subsequent transport and handling of the fish. Stress may also result in a reduction of immune responses.

A particular problem to overcome when working with physoclist (closed swimbladder) fish, like gadoids, is the expansion or reduction of the gas contained in the swimbladder if the external pressure changes. Physoclists can overcome this by absorbing or secreting the gas in order to keep neutrally buoyant. The compensatory mechanisms are rather slow, and depend on temperature and pressure (Harden Jones & Scholes 1985). As a result, even relatively small involuntary upward movements transports cause substantial expansion, leading to rupture of the bladder and compression of internal organs.

Solomon & Hawkins (1981) and Wardle (1981) give an overview of the damage that may be inflicted on the fish during the capture and handling processes. The physiological and bacteriological processes set off by capture and handling will act in a similar manner after release back to nature. Experiences with methods used to capture fish for aquaria or aquaculture are therefore very relevant also in this context, even though they may not yet have been applied to electronic tagging.

CHOICE OF CAPTURE METHODS

The choice of a particular fishing method will depend on the species sought, fish density, location and possible legal restrictions. Solomon & Hawkins (1981) discuss some general advantages and drawbacks of various capture methods for obtaining good quality fish for aquarium use. Bottom *dragnets* (trawls, seines etc.) and midwater trawls, in which the fish is forced to swim with the gear during capture, may lead to exhaustion if towed too fast, or for too long. The risk of skin damage and scale loss is always present, although this effect can be alleviated to a certain extent by using a lined codend. The composition of the by-catch is also observed to have a significant effect on survival rates of demersal fish as shells or other benthos and rays in the cod end may cause lethal damage (Metcalfe, pers. com.). Despite these disadvantages, towed nets often are the only possible practical method. *Gillnets,* either stationary or drifting, enmesh the fish or entangle them and cause damage where the fish have been held, often by the head, the gills or the trunk. If enmeshed at the gill region, the fish may either suffocate or bleed to death. *Encircling nets* like purse seines have several advantages over gillnets, but if the catch is large, crowding during the final pursing may cause oxygen depletion and abrasions when the fish hit each other. Baited or unbaited *trapping gear* may be very effective. The fish enter voluntarily and are seldom damaged or severely stressed. However, the fish may be damaged if other fish enter later and when they are taken out of the trap. Solomon & Hawkins (1981) recommend that particularly delicate species are removed under water into a holding tank, or that the lower part of the trap is lined. In fresh water *electrofishing* may prove effective and inoffensive because the fish recover quickly. However, Solomon & Hawkins warn against the possibilities of spinal fracture and haemorrhage that can be caused if the voltage is not properly adjusted. Such effects have also been observed by other authors (see later sections). *Angling and handline fishing* are singled out as methods with many advantages over other methods. Damage is often slight and confined to the jaws and can be further minimised by using barbless hooks. Struggling time can be reduced by using heavy fishing tackle. The disadvantage of angling is the low number of fish that can be caught. *Longlines, set lines and drifting lines* catch many more fish but have the disadvantage that the hook may be swallowed with the bait by many species.

In many experiments the descriptions of how the fish were captured and handled prior to electronic tagging are rather non-specific, often only stating which gear was used for capture. The time elapsed from start of capture to landing on deck, the method of handling the fish on board, or in the hatchery, and recovery times before tagging are often omitted. The most widely applied method for obtaining experimental fish from natural environment, however, seems to be to catch large numbers of fish, place them in a tank and, after an observation period of relatively short duration, choose perfect looking specimens for tagging.

CAPTURE METHODS REPORTED FOR VARIOUS SPECIES

Demersal fish

Capture methods reported in electronic tagging experiments with demersal (bottom dwelling) fish have included hook-and-line fishing for lingcod, *Ophiodon elongatus* (Matthews, 1992), handline fishing for cod, *Gadus morhua* L. (Arnold *et al.*, 1990; 1994), trawl fishing for plaice, *Pleuronectes platessa* (Greer Walker *et al.*, 1978; Harden Jones *et al.*, 1977; Metcalfe *et al.* 1993; Metcalfe & Arnold 1997) and cod (Engås *et al.*, 1991, Godø & Michalsen, 1997), Danish seining for cod (Thorsteinson, 1995), and purse seining for cod, and plaice (Isaksen & Midling, 1999). Due to their robustness and economic importance cod have been the targets for many tagging studies.

Decompression of swimbladder gases of physoclists has commonly been dealt with by catching the fish at depths less than 10 m, or catching the fish with gear (e.g. pots, other cage-type gear, or hook and line) that enables the catch to be lifted slowly up to the surface. Tytler & Blaxter (1973) suggest a 5 hour decompression halt for gadoids for every 50 % reduction in external pressure. Engås, *et al.* (1991) captured cod by jigging in shallow water and let them recover in net pens for 3-8 days before tagging with hydroacoustic tags. Arnold *et al.*, (1994) caught cod by rod-and-line or long-line in shallow water (< 8 m) being careful to bring the fish slowly towards the surface, the maximum pressure reduction always lying well below the 50% recommended by Tytler & Blaxter 1973. Fish were kept and fed in a large laboratory tank for several months until taken on board the tracking vessel, transported to the release site, tagged and released from cages.

Another method commonly used to reduce mortality caused by over-inflation of the swimbladder is to release the internal gas by puncturing the body wall and bladder with a hypodermic needle once the fish is on deck (Midling, pers.com.; Olsen pers. com). Positive effects of decompression and swimbladder puncture are reported by Keniry *et al.* (1996), who conducted experiments on yellow perch, *Perca flavescens*, collected at 10 and 15 m depths in Lake Michigan. Decompressed fish had higher survival than non-decompressed fish and, as would be expected, this effect was greater for fish caught at 10 than 15 m. Puncturing the swimbladder had a significant, positive effect on 3 day survival; long-term survival was not affected.

There are no restraints on the speed at which demersal fishes without a swimbladder can be brought to the surface and flatfish like plaice and sole are relatively robust with respect to handling in general. Plaice have been electronically tagged by the Centre for Fisheries and Aquaculture Studies (CEFAS), Lowestoft Laboratory, since the early 1970s and until recently the technique has been to select undamaged fish from trawl catches and return them to laboratory tanks until viability was confirmed (Greer Walker et al., 1978; Harden Jones *et al.*, 1977; Metcalfe *et al.*, 1993; Metcalfe & Arnold, 1997). Recently fish have been tagged at sea with data storage tags immediately after capture to avoid disrupting natural patterns of movement and avoid problems with disease in the laboratory. Some species of rays such as *Raja clavata* and *R. naevus* and *R. microocellata* are very hardy and survive well capture methods suitable for plaice, while *R. montagui* is much more sensitive. Standard otter trawls, twin rigged trawls and bottom gill nets (0.3 m mesh size) have been used to catch rays for data storage tagging experiments at the CEFAS (Metcalfe, pers com).

However, some non- physoclist fish such as, anglerfish (*Lophius piscatorius*) and Greenland halibut (*Rheinhardtius hippoglossoides*) seem to be difficult to handle without causing skin abrasions. At the Norwegian Institute of Fisheries and Aquaculture Ltd. (NIFA Ltd.), Tromsø, northern Norway, where these species have been captured and kept in conjunction with various fish holding experiments, the experience is that anglerfish are difficult to handle without damaging the skin, although some individuals caught in a Danish seine survived in captivity for several weeks. Seine-capture being a somewhat more lenient method than trawling is also indicated from experiences made at CEFAS. In general, this species is considered to be very difficult both by the CEFAS staff and staff at the Sea Life Centre, Oban, Scotland (Metcalfe, pers. com.), and only diver caught specimens of angler fish seem to survive for any period of time. Although the halibut (H*ippoglossus hippoglossus*) is a fairly robust species that has been handled for more than a decade at the IMR , its relative the Greenland halibut is extremely difficult to handle, and the only fishing method resulting in surviving individuals has been long-lining in coastal waters (Albert *et al.* 1999). Lumpsuckers (*Cyclopterus lumpus*) are also easily damaged in both the demersal phase at the coast and in their pelagic phase, and require special attention when captured. Nets and trawl both cause lethal skin damage (Midling, pers. obs.). Studies performed at the NIFA Ltd., show that the wolf fishes are rather robust except if caught on hooks whereby the *Anarchichas* risk excessive bleeding from the large arteries in the head and mouth region and need several weeks for adaptation There seems also to be variances between capture methods for the *Anarchicas* variants as the grey wolf fish is best captured by Danish seine, while the spotted wolf fish is most easily taken in a trawl (Midling, unpublished). Plaice and lemon sole on the other hand cause few problems and have been captured with seine net and transported with little mortality in special holding tanks (Midling *et al.* 1998).

In order to avoid adverse effects of capture and to secure observation of entirely natural food search and reactions to olfactory stimulants, Løkkeborg & Fernö (1998) and Løkkeborg (1998) set up experiments where cod were allowed to voluntarily swallow tags wrapped in various types of bait. Engås *et al.* (1998) let cod voluntarily ingest the transmitters when studying fish behaviour towards an approaching trawler by means of a stationary positioning system. This tagging technique has also been applied with success to several deep-sea species, which are often stenothermal and stenohaline (Solomon & Hawkins, 1981), and could not otherwise be tagged because of the slow decompression rate and the time needed to get them to the surface. Grenadiers (*Coryphaenoides yaquinae, C. armatus*), deep sea eels (*Synaphobranchus bathybius*) and the deep sea gadoid *Antimora rostrata* have all been successfully tagged with acoustic tags after ingestion of bait hung beneath the cameras of a deep-sea lander (Armstrong *et al.*, 1991, 1992; Bagley *et al.*, 1994; Priede *et al.*, 1990, 1991, 1994a, b, c).

Shellfish

Shellfish have mostly been obtained by trapping the animals in pots or cages, or in some cases with tangle nets (González-Gurriarán & Freire 1994). Divers have been used at shallower depths. The risk of damage is small if the gear is carefully hauled; decompression is not a problem for shellfish. The attachment of tags is fast and the animals can rapidly be returned to their normal environment, if not tagged *in situ* by divers. Details of capturing and electronic tagging of Norway lobster, *Nephrops norvegicus* L., are given by Chapman *et al.* (1975). González-Gurriarán & Freire 1994 give similar details for the spider crab *(Maja squinado).* Collins & Jensen (1992) and van der Meeren (1997) have tagged and tracked European lobster (*Homarus gammarus*) after capturing them either in pots or by diving.

Pelagic fish

Most pelagic species are susceptible to handling. As far as is known, the smaller schooling species (e.g. Atlanto-Scandinavian herring (*Clupea harengus* L.) and Atlantic mackerel (*Scomber scombrus* L.)) have not been used in electronic tagging studies so far. But as tags continually get smaller and sensors more varied the possibility of tagging these species increases and methods of handling will be of interest. Since 1968, the Norwegian Institute of Marine Research has been quite successful in tagging large numbers of mackerel and herring using conventional (internal) steel tags. Mackerel are caught by jigging, carefully unhooked and placed in tanks for observation prior to tagging. Bleeding or wounded fish are discarded (Myklevoll, 1994). Reference to successful purse seine capture and handling of mackerel for long term storage made in Beltestad and Misund (1993) and herring were captured and kept for experiments with spawning on kelp by Beltestad (1996). Public aquaria, such as the North Sea Centre (NSC) in Hirtshals in Denmark regularly obtain these species for display in tanks. The NSC relies on professional fishermen, who use very fine meshed purse seines to catch schools of herrings and mackerel close to the coastline. Fish are transferred to holding tanks, and viable looking specimens chosen for transport to the aquarium. As mackerel are extremely sensitive to touch, great care has to be taken to avoid skin damage and this is achieved by only handling the fish when they are immersed in water. Herring are caught by similar methods as the mackerel (Flintegård, pers. com).

Special methods have been developed for capturing and tagging large pelagic species such as sharks, tunas, marlins and sailfish, which are difficult to handle and sedate on board a boat because of their size and strength. Pole and line fishing from vessels using lures with special barbless hooks is the main method of capture. The fish are handled rapidly without anaesthesia and care is taken not to cause skin damage by using soft plastic covered tagging or measuring cradles (Williams, 1992). Carey & Robinson (1981) and Carey & Scharold (1990) carried out pioneering work to develop methods for handling and tagging swordfish (*Xiphias gladius*) and blue sharks, (*Prionace glauca*). Holland *et al.* (1990a, 1990b), tracked yellow and bigeye tunas and blue marlins (*Makaira nigrans*) caught by trolling and pole-and line fishing. The chosen tag attachment method enabled release of fish after approximately one minute out of water. Block *et al.* (1992) caught blue marlins for tracking by trolling artificial lures with rod and reel from boats. Block *et al.* (1998) have developed a successful method of capturing and handling Atlantic bluefin tuna (*Thunnus thynnus*) for use in archival tagging and acoustic tracking studies. The fish are caught by heavy tackle using circle hooks and bait presented in a chum stick ("chunk fishing"), a technique which allows chasing down the fish in order to keep fight times less than 15 minutes. The fish are taken on board a boat with specially designed leaders through a "tuna door" in the stern and tagged and released immediately. The method is suitable also for handling large individuals (> 50 kg) with low risk of damaging the fish. A similar approach has been used with southern bluefin tuna (Gunn *et al.* 1994).

Sharks lack a swimbladder and must swim to maintain position in the water column. Muscular movement assists in venous return of the blood and oxygenation at the tissue level is maintained in many by swimming at some optimum speed. Care is therefore needed when capturing and handling sharks to minimise struggling and the time for which the shark is restrained (Gruber & Keyes, 1981). Prolonged struggles affect blood serum protein deleteriously and accumulate lactates. Capture by trapping or trawling should therefore be avoided and Gruber & Keyes recommend the use of a handline. This method reduces the risk of injuring the mucous layer, skin and eyes and keeps the time for capture short. References to capture of shark species for electronic tagging by handline or rod and line are given by Nelson (1978), Carey *et al.* (1981) and Stevens (1996).

Salmonids

Four main lifestages of Atlantic salmon are recognised with different spatial distributions and different vulnerability to capture and handling. These stages must be considered separately in relation to the use of electronic tags (Anon, 1997).

Smolts. These fish are in transition from the fresh water phase to salt water tolerance and have started their down-river migration towards the sea. Wild fish (10 - 17 cm fork length depending on river environment and genetic origin) are generally too small to be tagged with electronic tags at present. Many experimenters have used hatchery fish instead, although smolts from wild stocks have been tagged where they are large enough to tolerate the application of the smallest available electronic tags. Tytler *et al.* (1978) used wild smolts caught in a trap in the river N. Esk. Holm *et al.* (1982) obtained a few wild fish from a fish trap in the river Imsa in south-western Norway. After capture, the smolts were stored for 2 - 14 days in a hatchery trough before tagging; they were released within 24 h of tagging. Moore & Potter (1994) and Moore *et al.* (1990b, 1990c, 1992, 1995) used wild fish, which they caught in streams in Wales and southern England using fyke-nets and a keep box for the trapped fish. The fish were anaesthetised, tagged and put in oxygenated water for a recovery period of 30 - 60 min. before release into the river. Other techniques used for capturing wild fish for electronic tagging in rivers include electro-fishing and beach seining (Knutsson, unpublished). However fish traps and trapnets have advantages over electrofishing as trapping will capture only actively migrating smolts, while electrofishing takes all fish including those not yet in the active migratory phase (Anon, 1997).

Post-smolts are salmon in their first year after leaving fresh water. Depending on genetic origin and the time of capture after entering the marine environment, Atlantic salmon in this stage range from approx. 15 - 35 cm in length. Until recent years few captures of post-smolts had been made but they are now regularly caught in surface trawls (Holst *et al.*, 1993; Hvidsten *et al.*, 1995). Trawl caught post-smolts lose 50 - 100% of their scales even in short tows (Hvidsten, pers. com.; Holm *et al.*, 1998; Holst *et al.*, in prep.). Other reported capture methods include floating long-lines and drifting gillnets (Reddin & Short, 1988; Sturlaugsson & Thorisson, 1995), although none of these methods of capturing post-smolts has yet produced fish in a fit condition for tagging. Instead, most tracking studies have been performed with hatchery fish, or with wild fish trapped as smolts in freshwater (Moore *et al.*, 1995, 1999; Lacroix, 1996, pers. com.) and then released in rivers, estuaries, or fjords. A device for obtaining post-smolts in viable condition from trawl catches has been developed and tested with promising results (0 -6 % scale loss) (Holst & MacDonald, submitted). It is hoped this device will allow post-smolts to be caught in the open sea in a fit state to be tagged with electronic tags once these tags get small enough.

Adult stage - immature fish. Immature salmon (both one- and multi-sea-winter fish) are found in feeding areas in the open ocean. Handling must be done with great care as the risk of scale loss is substantial (Hansen & Jacobsen 1997). Adult immature salmon are occasionally caught by surface-trawling in the Norwegian Sea (Holm *et al.*, 1998), but this method is unsuitable for obtaining fish for electronic tagging because of the large loss of scales that occurs. Drifting gill nets have been used to catch salmon for tagging in the Pacific. Fish caught by long-line have been used for electronic tagging studies in the north Atlantic (Jakupstovu, 1988) and experiences from a Carlin tagging programme in the Faeroes give valuable indications of how to handle the fish. The lines were patrolled constantly to remove hooked salmon. The fish were carefully lifted over the ship side with a scoop-net and placed in a recovery tank where undamaged, viable looking fish were chosen for immediate tagging and release. It is sometimes more deleterious to remove a long-line than it is to leave it in the fish. Hansen & Jacobsen (1997) stress the importance of hook shape for ease of removal and recommend using non-galvanised material in case the hooks have to be left in place.

Adult fish- maturing salmonids and kelts. Maturing fish homing to their natal streams have been captured in coastal and estuarine waters using gear such as bag-nets, trap-nets, other fixed engines or beach seines. These methods are relatively harmless and, in addition, the salmon are much more resistant to handling at this stage in their life history as a result of physiological changes to skin and mucus, which occur in conjunction with maturation. Several authors (Westerberg, 1982, 1984; Potter & Solomon, 1988; Potter *et al.*, 1992; Heggberget *et al.*, 1993; Smith & Smith, 1995; and Karlsson *et al.*, 1996) have used salmon obtained from trapping gear in the vicinity of the rivers to study various aspects of the homing behaviour of Atlantic salmon. Fish were tagged and released when they had regained their equilibrium after anaesthesia. Brawn (1982) caught Atlantic salmon with a mackerel net and lure in an estuary and kept them in cages for around 1 day prior to anaesthesia and tagging with acoustic tags. After tagging the fish were left in a cage for up to 1 day to recover. *Kelts* are post-spawning fish that will return to the sea. Like maturing fish, they are relatively resistant to handling because of the condition of their mucus. Where they are installed, fish ladders provide excellent facilities for capturing fish in rivers and good survival of ladder-caught adult Atlantic salmon and rainbow trout is reported by Peake *et al.* (1997a).

When tagging anadromous trout (*Salmo trutta* L.) and arctic char (*Salvelinus alpinus L.)* with data storage tags in north-western Iceland, Sturlaugsson & Johansson (1996) and Sturlaugsson *et al.* (1998) captured the fish by angling from a boat in a lagoon (Sturlaugsson pers. com.). The tags were immediately implanted in the fish under anaesthesia; the char were released after a short recovery in a deck tank.

HANDLING AND RECOVERY

Anaesthesia

Rendering fish quiet (sedation) or unconscious (anaesthesia) is crucial to several aspects of fish tagging. A variety of methods of calming fish have been applied during the tagging process, ranging from use of blindfolding, to full anaesthesia involving continuous irrigation of the gills with fresh or sea water containing diluted anaesthetic agents.

Choice of anaesthetics

Different handling procedures demand different anaesthetic approaches. Light anaesthesia (=sedation) is defined as 'reduced activity and reactions to external stimuli', and is sufficient for procedures such as transport or weighing of fish, while full anaesthesia can be defined as 'loss of consciousness and reduced sensing of pain, loss of muscular tonus and reflexes' and is needed when surgical procedures are applied (MacFarland 1959).

The behavioural changes occurring in fish passing through sedation to full anaesthesia were classified by MacFarland (1959) into 4 stages with subclasses ranging from normal (stage 0) where the fish reacts to external stimuli and where the muscular tonus and swimming ability is normal, to the stage of total physiological collapse (stage IV) where gill movements have stopped and which in a few minutes will lead to heart failure. In a tagging context, the stages where the fish is in a state of light/deep anaesthesia (stages II and III) are of greatest relevance, as the animal is then insensitive to pain caused by the attachment of transmitters/DSTs.

Choice of sedatives/anaesthetics must be based on the species to be tagged, the number and size of fish involved, and the duration of the operation in question. Water temperature and chemistry have also to be taken into consideration when choosing the method. Lastly, the work often has to be done under primitive field conditions without accurate control of concentrations and exposure times. An anaesthetic with a good safety margin between effective anaesthesia and irrevocable collapse is essential in such circumstances. Methods of anaesthesia, chemical descriptions, reported advantages, unwanted side effects on fish species of various anaesthetics, and legislative and fish welfare aspects are dealt with in a recent project report to the EU (Anon 1999)

It is well known that anaesthetics cause physiological effects that can be measured as changes in levels of corticosteroid and other parameters, which in turn may lead changes in the behaviour of the fish for a varying time after sedation. On the other hand, the handling stress will be reduced under anaesthesia and tagging can be carried out more rapidly with less risk of the fish damaging themselves when trying to get loose. Although the use of anaesthetics in some cases may be unwanted due to their detrimental effects on the physiology and behaviour of the fish, considerations of animal welfare will in most cases prohibit tag attachment to unsedated fish if surgery is involved (Anon 1999). On the other hand , in some countries there are restrictions for what type of chemicals can be used for fish that may end up as food fish.

Anaesthetics are easy to apply in the hatchery. Kreiberg & Powell (1991) identified the netting and capture phase of various hatchery operations as the major contributor to overall stress and developed a standard procedure for lightly sedating fish with metomidate before any major handling disturbance. They recommend this procedure for handling of all sensitive fish such as chinook and other salmonids.

In field experiments, the ideal conditions for handling the fish cannot always be met. Setting up facilities for anaesthesia and recovery may be difficult because of spatial restrictions or poor weather at sea. The experimenter must then evaluate the relative difficulties of applying anaesthesia against possible trauma and damage caused by handling unanaesthetised fish, although legal considerations may be paramount.

When electronic tags can be attached rapidly and non-intrusively, anaesthesia has often been replaced by simpler methods of keeping the fish quiet during tagging. Arnold *et al.* (1994) blindfolded cod with wet paper over the eyes and Thorsteinsson (1995) used a similar method with the same species. Blindfolding is also commonly used when tagging adult salmon. These fish are relatively easily calmed if kept in their natural swimming position, for example in a moist handling cradle with the head covered with a wet soft cloth. Handling of unanaesthetised salmonids smaller than 60 cm is, however, not recommended (Sturlaugsson, 1995; Hansen & Jacobsen, 1997).

Anaesthesia has in general not been applied when tagging large pelagic species such as tunas and sharks. The capture process is likely to be much more stressful and time consuming than attaching the tag, which generally only requires a minor incision. Instead, the fish are usually quietened by covering the eyes. Special devices to ease the process and minimise handling time have been developed by Block *et al.* (1992, 1998), Carey & Robinson (1981), Carey & Scharold (1990), Stevens (1996), Holland *et al.* (1990a; 1990b) and Williams 1992.

(b) Recovery from capture and handling

McCleave & Stred (1975), Moore *et al.* (1990a) and Lacroix & MacCurdy (1996), among others, have investigated experimentally the effects of tagging and handling on salmonids using dummy tags. In most cases it was shown that the fish recovered quickly from the handling process.

Once the fish has been released it is difficult to assess the impact of the capture, handling and tagging process, although information from data storage tags may provide some useful indications. The various studies performed to estimate survival of fish escaping from fishing gear may, however, aid the assessment of short and long term effects of capture on the survival of electronically tagged fish.

A number of studies have been made on demersal fish escaping from codends of trawls, although estimates of mortality vary according to circumstance. Soldal *et al.* (1991) found no mortality of cod (*Gadus morhua*) and less than 10 % mortality of haddock (*Melanogrammus aeglefinus*) that were kept in cages anchored on the sea bed and observed for 12 to 16 days after escaping from the codend. Jacobsen *et al.* (1996) observed saithe (*Pollachius virens*) for 6-7 days by underwater television in cages drifting freely at 40 m depth. Only low mortalities were recorded from these fish, which had escaped from a trawl at 150 m depth. On the other hand, Sangster & Lehmann (1994) recorded 11- 52 % mortalities of haddock and whiting (*Merlangius merlangus)* escaping from codends when collected and stored in cages on the seabed for 60 days. No mortality was observed in the controls and there were no significant differences between the two species. In trawl simulation studies Soldal *et al.* (1993) and DeAlteris & Reifsteck (1993) recorded 100% survival of cod after escapement, while haddock suffered 10% mortality. Additional mortality occurred in all groups due to infection of wounds. Jonsson (1994) studied survival and scale damage of long-line caught haddock in aquarium after simulating escape through the meshes of cod-end; the survival rate in these experiments was only 30-50%.

The swimbladder of gadoids is observed to heal relatively rapidly. Experiments made at the University of Tromsø in the early 1980s (Olsen, pers. com) show that healing started 2- 3 days after capture in cod caught in a trawl at 100 m depth. Nevertheless, the use of fish with recently ruptured swimbladders should be avoided (Solomon & Hawkins, 1981), particularly if the aim is to use hydroacoustics to observe natural behaviour in the short term (Mohus & Holand, 1983).

The time the fish have been subjected to a fishing operation will also have consequences for tagging and must therefore be considered. After seven days of post-capture observation in cages Oddsson *et al.* (1994) recorded significant differences in survival of Pacific halibut (*Hippoglossus stenolepis)* subject to towing durations of 30 and 120 minutes. The trawl method and the towing speed are also crucial for survival and rapid recovery of the fish. Based on various CEFAS experiences, Metcalfe (pers. com) recommends beam trawling from relatively low powered ships rather than stern trawling and that towing times should not exceed 15 minutes. The main advantage of a beam trawl is that the ship can stop as soon as the gear is at the surface while a stern trawler has to continue mowing forward until the gear is aboard to prevent it fouling the propeller. The result is that by stern trawling the fish will swirl around in the cod end for several minutes with consequent bruising of the body and abrasion on the tail and fins. A methods of avoiding such abrasion will be described under the section on new methods.

The capture process affects small and large fish differently. Hansen and Jacobsen (1997) and Anon (1998) found evidence of size dependent vulnerability to long line capture and subsequent handling in Atlantic salmon. Larger salmon had significantly better Carlin-tag recovery rates than smaller fish, which during tagging were observed to lose scales more easily than the larger ones. The deleterious effects of capture on small fish have also been demonstrated for other species. Soldal *et al.* (1991) examined scale loss of escaped cod and haddock compared to a control group. On average, less than 1% of the total body surface of cod was injured, while haddock, particularly those smaller than 40 cm, showed substantial scale loss and therefore greater mortality.

Harrell & Moline (1992) have assessed the effects of electrofishing. Striped bass (*Morone saxatilis*) captured by electrofishing showed significantly lower effects of stress and shorter recovery times than striped bass caught in gillnets. Dalbey *et al.* (1996) observed that rainbow trout (*Oncorhynchus mykiss*) suffered significantly more incidents of spinal injury if pulsed rather than smooth DC was used. The severity of injuries was increasing with increasing fish length and, although long term survival was not affected, 28% of the fish had markedly lower growth and condition.

Angling appears to be a good way of catching some species of fish. Pankhurst & Dedual (1994) found no mortality in rainbow trout as a result of capture or any of the handling protocols. In most fish initially elevated blood plasma levels returned to normal within 24 h of capture indicating that metabolic recovery had occurred.

Tytler *et al.* (1978) gave wild smolts a recovery time of 3 - 48 h after anaesthesia and tagging in a portable holding tank before transporting the tank to the release site, where they were given minimum one hour to adapt to local river conditions. Moore *et al.* (1990a) conclude that consideration must be given to a satisfactory recovery time before the fish are released from the controlled experimental conditions. Their results indicate that smolts can be safely released as soon as they are fully recovered from anaesthesia. Recovery from anaesthesia was judged to have occurred when full equilibrium was regained, and the fish reacted to external stimuli. Far better results have also been obtained for several Pacific salmonids (*Oncorhynchus* spp.) released immediately (e.g. Mellas and Haynes, 1985) instead of after prolonged recovery. Keeping wild salmonids for extended periods in tanks to recover after handling may give adverse results and may not improve fish survival (Nettles, 1983, in Moore *et al.*, 1990a).

In contrast, with hatchery fish, survival appears to be improved by the provision of a recovery period after handling. Sharpe *et al.* (1998) studied the effects of various hatchery practices, including tagging and fin-clipping, on juvenile chinook salmon. No lethal effects were observed, and though indeed stressful the physiological effects measured as elevated cortisol levels were of relatively short duration. Sharpe et al., nevertheless recommend that fish to be released into a more challenging environment than a hatchery should be given a recovery time of at least 24 h. The work of Hansen & Jonsson (1988) supports this observation: the survival of 1 and 2-year old hatchery smolts was reduced if they were handled immediately prior to release for sea ranching. Of the various treatments given, dip-netting significantly reduced the survival of the younger smolts, although it did not affect the older smolts significantly.

NEW DEVELOPMENTS IN CAPTURE AND HANDLING

Live fish sampling with trawls

The fish "LIFT"

When catching delicate species like Atlantic salmon post-smolts with surface trawl, so far the most successful method of obtaining such fish at sea, these post-smolts in general suffer serious scale losses by being swirled around in the cod end. Even in short tows their shell cover is mostly so badly damaged that the fish are unsuitable both for tagging/release studies and for investigations of parasites living on the body surface.

A prototype of a device for capturing undamaged pelagic species was first developed and tested in 1997 in co-operation between the Marine Laboratory (CEFAS), Aberdeen, and the Institute of Marine Research (IMR), Bergen. This "Live Fish Trawl Sampler" (LIFT) was a towed rectangular metal "aquarium" attached to the anterior part of a trawl cod end by four ropes (Holst and MacDonald, submitted). This prototype "LIFT" has undergone several modifications to create as low interior turbulence within the aquarium as possible.

The principle of the device is that fish entering the trawl continuously flow into the aquarium through a net funnel running from the open cod end, along the top of the aquarium and into an opening at the aft top of the otherwise closed aquarium. The fish remain in low turbulence in the aquarium until removed after hauling. The last version of the "LIFT" has a boat shaped front and is equipped with floats along the upper sides and additional flotation attached to a rope at the aft end to stabilise it while in the water, Figure 1. The top of the aquarium is designed as a lid that can be opened in order to facilitate removal of fish, or it may be emptied into another aquarium onboard the vessel through a valve in the side. In order to avoid fish of unwanted size or jellyfish to fill up the aquarium, a grid may be mounted at the front of the aquarium, between the cod end and the net funnel (Holst and MacDonald, submittted)

The two versions currently in use at the IMR, are one 250 l rectangular "LIFT" Mark II and one 1000 l "LIFT " Mark III with boat shaped frontpart.

Results

With the smaller Mark II "LIFT" around 100 hauls at a speed of approx. 2.5 knots have been carried out in 1998 and 1999. The Mark II is hoisted on board the vessel and emptied into another aquarium through a valve. More than 700 post-smolts of salmon and 150 sea-trouts have been caught with a scale loss of 0 - 5 %. From a haul of 300 post-smolts, 240 fish were brought to the IMR laboratory facilities in Bergen. As an indication of the good state of the fish after capture and transport, the mortality was < 10 smolts during the first week, and some fish started feeding within the first day in laboratory (Holst, Jakobsen and Nilsen, in prep) which is rather extraordinary.

The larger Mark III is designed for offshore use on larger vessels equipped with a trawl slip. It has been tested during two IMR in May and July-August 1999. More than 350 post-smolts and around 200 sea trout were captured with a mean scale loss per haul in the order of 15% (Holm pers. obs), i.e.. slightly higher than the Mark II results. Catching blue whiting at 350 m depth, however, proved unsuccessful as the fish had no scales left when brought onboard and Holst (pers. com.)

Good quality scale samples and a reliable counts of external parasite infestations have been obtained as, due to only minor losses of scales, the samples could be taken from the optimum positions on the fish's body, and the parasites were still attached to the fish. It is concluded that the equipment may yield viable fish also for tagging experiments on salmonids at sea.

Regarding species other than salmonids, Holst and MacDonald (submitted) conclude that the LIFT principle may also be used for collection of high quality samples of other fish species, although the technique should be further developed in order to approach new fields in fisheries research.

Anaesthetics

During the last years several papers have been published dealing with experiences with use of clove oil as a fish anaesthetic. This oil has been used in tropical Asia in popular medicine for a long time, and has also been applied in some artisanal fisheries. Soto & Burhanuddin (1995) used this agent in Indonesia for anaesthetising rabbitfish (*Siganus lineatus*). They report it to be efficient yet safe with regard to mortality and side effects. The inexpensiveness of this drug due to local production of the oil is pointed out as an additional advantage. In a comparative study of the efficacy of quinaldine, benzocaine, MS-222, 2- phenoxyethanol and clove oil for anaesthetisation of a tropical coral reef fish, Munday and Wilson (1997) found clove oil only marginally less effective than quinaldine and more effective than any of the other chemicals tested. Survival rates were excellent for all agents, but with clove oil the fish showed a much calmer induction to anaesthesia than e.g. with quinaldine. The lengthy recovery time after anaesthesia is regarded as desirable for use in field studies. In temperate regions clove oil has been tested with excellent results on rainbow trout (*Oncorhyncus mykiss)* by Keen *et al.* (1998). Clove oil anaesthesia on arctic gadoids and flatfish has given very promising test results Midling (unpublished).

CONCLUSIONS AND RECOMMENDATIONS

The identified incompleteness points to a need for systematic investigations to determine the effects of capture and handling on the condition and survival of different species of fish at various stages of their life history. While there is a general need for more research on the effects of these processes on commonly tagged fish in temperate waters, there is an even greater need research on tropical species. Special attention also needs to be paid to methods of handling endangered species and delicate species or delicate life history stages.

As much of the relevant expertise is passed on by word of mouth rather than in scientific publications, much useful knowledge thereby remains hidden for wider use. There is therefore a general need for improved documentation of the various capture procedures and a codification of general principles. This clearly needs to be done in respect of each type of fishing gear (lines, trawls, traps etc.) and capture method.

Careful records should be kept of the size and condition of the fish, as well as environmental conditions, and any factors relevant to the specific method of capture. For trawls these factors include speed of towing, haul duration, and depth. The size and composition of fish catch is also important, as is the quantity and type of by-catch. By-catch can significantly increase mortality, especially in bottom trawls, where sharp objects such as shells and spiny fish and invertebrates can do a great deal of damage. Qualitative observations suggest that it is probably possible to define levels of debris in trawl catches above which it is not possible to use fish for tagging at all. Other, comparable constraints may apply in the case of line- and trap-caught fish.

Mortality and condition of fish after capture, generally regarded as a more serious cause of damage than the tagging itself, may be observed in the laboratory. The fish must, however, be taken to the laboratory from sea and this process may augment any problems caused during capture. It may therefore be better to make the observations at sea using cages to monitor condition and survival. Even though it is not easy to do so for logistic reasons further work should be encouraged. Another option is to obtain information from data storage tags, which may reveal how long fish exhibit atypical behaviour after tagging and release before resuming natural activities such as migration and spawning. Dummy tagging is recommended before starting DST tagging programmes as the dummies can clarify the effects of capture, handling and tagging on the fish and indicate the expected recovery rates of the electronic tags.

Although there is limited control over the size, or even species, of fish that is caught and the number of tags individual fish may ingest, less traumatic approaches where the fish are tagged underwater e.g. voluntary ingestion of tags should be encouraged. Tagging underwater may eventually become a routine way of avoiding the problems of catching fish with closed swimbladders, although the cost of deploying a team of scuba divers makes it impractical at present.

Effects from traumas experienced in the handling foregoing the tagging may result in deviatic behaviour of the fish thus introducing serious errors in telemetric experiments. The importance of good practices in capture and handling must therefore be emphasised.

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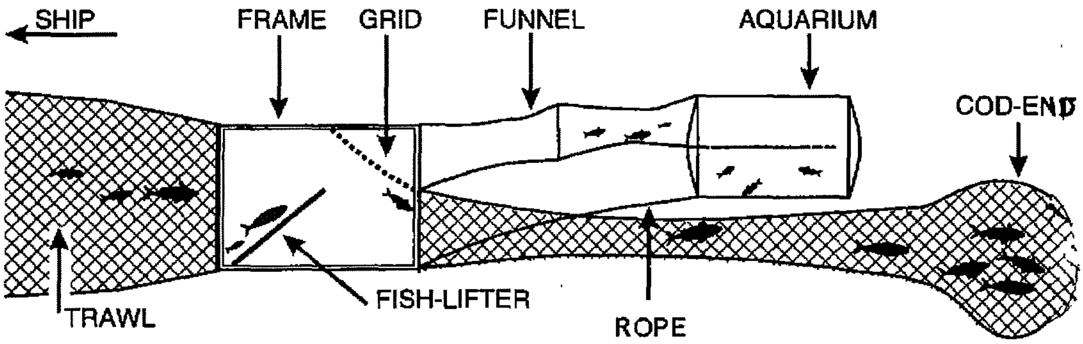
Fig. 1. The "fish LIFT" Mark II. Device for obtaining viable fish from trawling. (Holst and Mac Donald 1999)



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ICES CM 1999/AA:03
Theme Session on Microprocessors
and Things that Swim in the Sea

Capture and handling of fish for electronic tagging- a review and a new non- intrusive capture method.

By
Marianne Holm[1], Geoff P. Arnold[2] Jens Christian Holst[1], and Kjell Ø. Midling[3]

ERRATUM

Page 2, paragr.1, line 9- last words
Reads: Atlantic halibut (H*ippoglossus hippoglossus)*…… **Should read: Greenland halibut (*Rheinhardtius hippoglossoides*)**