Conventional tagging methods in stock identification: internal and external tags

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Abstract

This paper reviews the feasibility and practical use of conventional tags to identify fish stocks. There are many different types of tags and marks in use, external as well as internal, and many of them are used to estimate stock composition in mixed stocks and to follow their movements between different habitats. To obtain the best estimates, tagging and recovery of the fish must be representative. For the recovery of internally tagged fish, a systematic sampling program is required, whereas external tags can be recovered in sampling programs as well as by commercial fishermen. A tagging program should be carefully planned, taking into consideration effects of capture and handling of the fish, tag types to be used, retention ability of the tags, anaesthesia and recovery. We give examples of tagging studies of three pelagic species, Atlantic salmon, Atlantic mackerel, and Atlantic herring, and one deep-sea species, deep-sea redfish. Results from these studies show that conventional tagging can be used for estimating stock composition. However, there are some limitations. The main problems with the various mark-recapture studies have been the heterogeneity of tagging and recaptures and the lack of simultaneous large-scale marking in the whole distributional area. Such large-scale marking is often difficult due to the nature of the fishing fleet in which the fishery might be limited by national boundaries such that sampling merely reflects the fishing effort in space and time and not biological distribution of the fish.

Keywords: Tagging; internal tags; external tags; stock identification

Introduction

Stock identification is an interdisciplinary field that involves the recognition of self-sustaining components within natural populations. Stock identification remains a central theme in fisheries science and management. Indeed, the reliability of stock assessments and therefore the effectiveness of fishery management are severely limited for many principal fishery resources, because stock structure and delineation are uncertain.

The ICES Stock Identification Methods Working Group (SIMWG) was established to review methodologies of stock identification and develop a protocol for the application of stock identification results. Recently, the Group has compiled a volume of contributions aimed at synthesising the many disciplines involved in stock identification and focusing on the application of results to fishery science and management. The book will be presented at the 2004 ICES Annual Science Conference, "Stock Identification Methods, Applications in Fishery Science". In this book a chapter on "Internal and External Tags" was prepared by the authors and this paper presents an extract of this chapter.

External and internal tags have been used for centuries as markers on marine and freshwater fishes for the purpose of identification and information retrieval. From the earliest application on salmonids and subsequently to most fish species, these markers have been divided into various categories, depending on the authors choices, for example by methods of attachment (external and internal) and design (buttons and disks, dangling, and others) (Jakobsson, 1970; Nielsen, 1992), whether they are natural or artificially made tags (Jones, 1976; McFarlane *et al.*, 1990), their style of identification (style of marking) (Nielsen, 1992), and whether they are applied in mass marking or as individual identifiable tags (Laird & Stott, 1978).

Many studies involving tagging have been described and a scan through the literature show many interesting applications of tagging in relation to stock identification. We focus on the use of conventional tagging methods (i.e., conventional tags and deliberately applied marks) and their applications for identifying stocks, excluding electronic tags and natural marks. A short summary and critique of conventional tagging methods and applications in stock identification is provided. We do not attempt a full review of all aspects of tagging; rather we provide a description of a few case studies where mark-recapture studies have been used for stock identification purposes, concluding with a summary discussion.

The concept of stock identification

Numerous definitions of the stock concept have been proposed throughout the fisheries literature and were recently reviewed by Begg & Waldman (1999). In its present form, the stock concept essentially describes characteristics of a population unit assumed homogeneous for a particular management purpose. Consequently, the working definition of the stock concept consists of semi–discrete groups of fish with some definable attributes of interest to managers (Begg *et al.*, 1999). Begg & Waldman (1999) advocated a holistic approach to fish stock identification, that is, one involving a broad spectrum of complementary techniques, because this would maximize the likelihood of correctly defining fish stocks.

In the management of stocks, it is essential to have some knowledge of the stock structure, including the total extent of the stock (distribution), migration, spawning areas, and temporal and spatial degree of overlap with other stocks. In anadromous fish, stock identification can be used to gather information on, for example spawning stocks, separation of stock components or stock structure (local vs. shared or hatchery vs. wild), determination of stock components in mixed stock fisheries, the extent of escape of farmed fish in areas with fish farms, and management of ranching operations.

Marking of fish can be used to infer stock structure. For stock identification purposes, best results occur when putative stocks are marked when they are geographically discrete in order to determine whether they subsequently intermingle (Cushing, 1981). Alternatively, stock mixtures may be marked to find out if fish later separate geographically. The success of mark-recapture for stock identification purposes is dependent on representative tagging and recapture efforts (Begg & Waldman, 1999; Cushing, 1981).

Mark-recapture studies have been used in stock identification applications since the beginning in the 20th century. In many cases stock identification has been a part of tagging studies, either as the primary goal or auxiliary to the objectives.

The practical aspects of tagging

An extensive literature on conventional tags and marks as well as the practical aspects of tagging (i.e., planning, sampling design, capture, types of tags, field techniques, holding, handling, and anesthetics) is available (e.g. Jakobsson, 1970; Jones, 1979; Kohler & Turner, 2001; Laird & Stott, 1978; McFarlane *et al.*, 1990; Nielsen, 1992; Rounsefell & Everhart, 1953; Thorsteinsson, 2002).

The success of tagging experiments depends on many factors, the most important being handling and tagging mortality of the marked individuals, loss of tags and marks, and failure to detect or report marked fish during the recovery process. There have been many attempts to define the perfect mark or tag [see, e.g., Ricker (1956), Laird & Stott (1978), and Nielsen (1992)]. In summary, the ideal mark and marking method would make any fish identifiable to at least a group (preferably individually) to anyone examining it, be permanent on any fish, inexpensive, easy and fast to apply, preferably without the use of anesthetics, and have no effect on growth, mortality, behavior, vulnerability to fishing gear, or the commercial value of the fish. Obviously, it will rarely be possible to obtain a perfect tag or mark meeting all these requirements. For many purposes, one or more of the above requirements are unnecessary, or can be relaxed with little loss of information, depending on the objectives of the study. If the duration of a the study is short, it is obvious that a (cheap) tag or mark with lower retention rate that is easy and fast to apply could be used, and in a closed scientific study, the ease of recognition for untrained people might not be applicable.

<u>Capture</u>: An important part of any marking experiment is the way in which fish are caught and handled. Some fish species are relatively tough and can withstand rough

treatment, such as cod. Other species, especially many small and medium-sized pelagic fish, are quite delicate, and unless precautions are taken, may be severely damaged or killed. Hansen & Jacobsen (2003) and Hartt (1963) noted that the small individuals suffer more from handling during tagging (mainly scale loss) as a result of their vigor compared to larger individuals. Hartt (1963) and Mattson *et al.* (1990) considered descaling most severe compared to other types of damage such as scars. When tagging salmon in the Pacific, Hartt (1963) observed less damage on the fish when using purse seines compared to fish caught with gill nets and long-line. Trawls usually cause more damage to the fish than most other types of gear (Jones, 1979). A newly developed live fish cage (Fish-Lift) attached to the end of the trawl, instead of a cod end, and capable of bringing live fish on deck might improve survival of tagged fish (Holst & McDonald, 2000).

<u>Effects of tagging and handling</u>: In planning tagging procedures, handling time for the fish should be short. This will enhance survival and thus optimize return.

Many tagging methods have been tested by controlled survival and tag retention experiments (e.g. Buckmeier & Irwin, 2000; McAllister *et al.*, 1992; Nakashima & Winters, 1984; Parker *et al.*, 1990; Strand *et al.*, 2002). Mortality due to the tagging process is one of the critical parameters. Mortality due to increased predation of externally tagged fish should also be considered (Parker *et al.*, 1963; Strand *et al.*, 2002), although Maynard *et al.*(1996) reported that the main cause of higher predation of marked fish was trauma associated with tagging itself and not the tag type or attachment. Otterå *et al.*(1998), however, did not find any difference in predation rate of externally tagged small cod and controls.

Increased recovery rates associated with fish size at tagging were observed for sablefish, *Anoplopoma fimbria*, tagged off the west coast of Canada (Saunders *et al.*, 1990), for groundfish species (Atlantic cod, haddock, pollock and American place) in the Northwest Atlantic (Fowler & Stobo, 1999), and for cod in the Northeast Atlantic (Beverton & Bedford, 1963).

Marks, such as the visible implant (VI) and various types of paints and dyes, usually have very little effect on the fish and can be read without use of intrusive methods. They can also be applied on very small fish. Disadvantages include their low visibility to fishermen and their reported shorter retention rate, although recent enhancements of VI marks seem to indicate higher retention rates (Olsen & Voellestad, 2001; Rikardsen *et al.*, 2002).

<u>Tag types and tagging methods</u>: Tags can either be externally or internally attached. The decision on which tag type to use depends on the objectives of the study.

External tags usually have shorter life expectancy than internal tags (McFarlane *et al.*, 1990). Atlantic herring have been recaptured after 15 years carrying an internal CWT (Jakobsson, 1970). For recovery purposes, however, an internal tag is usually not detectable unless a secondary mark/tag is employed, which is often not noted by the fishermen. Therefore, some loss must be expected due to the failure to detect the presence of CWTs (Mattson *et al.*, 1990). Fin clipping of salmon as a secondary tag is not always enough to alert commercial fishermen, although the interested angler might suspect a tagged fish.

If the objective is to tag fish over many years, with expected recapture after one or more years, tags with high retention rates are required, while in a study of short duration (days or weeks) higher tag loss rate may be tolerated without compromising the objectives. However, there is a likelihood of decreased readability due to the possibility of fouling or deterioration of external parts in long-time studies (Henderson-Arzapalo *et al.*, 1999; Mattson *et al.*, 1990; Pepperell, 1990; Thorstad *et al.*, 2001).

It is questionable how long tagged fish should be held prior to release. Some authors recommend releasing the fish once they have been tagged, while others argue for longer periods, from a few hours to several days (Beaumont *et al.*, 2002; Martinelli *et al.*, 1998). This is also dependent on the tagging site, whether on board a vessel or ashore. It might be considered more stressful to keep fish in onboard tanks on vessels in rough weather (Clay, 1990). Simonsen & Treble (2001) found that holding tagged Greenland halibut for 5 hr or more in observation tanks ashore reduced mortality of the released fish significantly.

A detailed list of commonly used anesthetics in fish marking and recommendations for use was given by Thorsteinsson (2002) and should be consulted as part of any tagging project when surgical methods are used.

Case studies – Applications of mark-recapture studies for stock identification

Stock identification of Atlantic salmon

Mark-recapture was used in stock identification of Atlantic salmon (*Salmo salar*) at West Greenland in the late 1960s and early 1970s (Horsted, 1988; Parrish & Horsted, 1980). The commercial exploitation of salmon at west Greenland began in the mid-1960s after local fishermen noticed salmon in abundance. Catches rose quickly with increasing fishing effort as vessels from Norway, Denmark, Sweden, Faroes, as well as Greenland became involved. The general pattern is that salmon from the Northwest Atlantic is mainly confined to the western areas while salmon from the Northeast Atlantic is found in both the eastern and the western part of the Atlantic. Tags applied to salmon smolts leaving home rivers also indicated that the salmon being caught at Greenland originated from Europe and North America (Parrish & Horsted, 1980). Since then, due to the involvement of both European and North American salmon stocks, attention has been focused on estimating the proportions of North American and European Atlantic salmon in commercial catches. These investigations were based on discriminant analyses of scale characters whereby Atlantic salmon could be classified into a western and eastern group with apparently high accuracy (Reddin & Friedland, 1999).

Table 1. Estimated proportions (%) of Atlantic salmon returning to different homewater countries tagged north of the Faroes during three fishing seasons (Winter 1992/1993–1994/1995)[a]

Country of origin	Number recaptured	Tag reporting rate		Exploitation rate		Estimated number recaptured	Simulation		
		min	max	min	max		'-5%	Mean(%)	'+95%
Norway	47	0.40	0.60	0.50	0.80	145	27.2	39.6	51.7
Scotland	12	0.80	1.00	0.10	0.30	67	8.8	19.2	32.5
Russia	6	0.60	0.80	0.10	0.15	69	7.6	18.3	30.5
Canada	4	0.65	0.85	0.15	0.28	25	1.6	6.9	13.6
Ireland	9	0.60	0.80	0.50	0.75	21	2.5	5.7	9.4
Denmark	2	0.40	0.60	0.14	0.34	17	0	4.7	11.8
England	1	0.40	0.60	0.15	0.35	8	0.6	2.3	4.7
Sweden	4	0.55	0.75	0.55	0.90	8	0	2.3	7.1
Spain	1	0.60	0.80	0.55	0.85	2	0	0.6	1.8
Iceland	1	0.80	1.00	0.40	0.60	2	0	0.6	1.7
Total	87					364		100.2	

[a] About 5500 fish were tagged with Carlin tags. Confidence limits (95%) were based on 1000 simulations using Monte Carlo simulation ('@Risk'). Recoveries were adjusted for homewater exploitation rates and tag reporting rates. From Hansen and Jacobsen (2003).

To determine the origin of the Atlantic salmon caught on floating long-lines in the Faroese fishery in the southern Norwegian Sea, a tagging program using external Carlin tags was carried out during the winter season (November–March) from 1992 to 1995 (Hansen & Jacobsen, 2003). The areas north of the Faroes seem to be one of the main feeding areas for Atlantic salmon in the sea (Jacobsen & Hansen, 2000; Jacobsen & Hansen, 2001), and recaptures from this area were returned from most of the regions bordering the North Atlantic. Estimates of the proportions of salmon from their countries of origin are given in Table 1. The recoveries were adjusted for homewater exploitation rates and tag reporting rates. About half of the tags were recovered from Norway and significant numbers were recovered from Scotland and Russia, with less from Ireland, Canada, Sweden, Denmark, England, Spain, and Iceland (Hansen & Jacobsen, 2003). The recapture rates were generally low, with an increasing trend correlated to size of fish, that is 1SW, 2SW, and 3+SW fish (Fig. 1), caused mainly by higher tagging mortality of smaller individuals suffering high scale loss due to increased vigor during the tagging process. Further, the recapture rates of fish with the hook left in when released were significantly higher than of fish where the hook was removed prior to release, which might indicate that active removal of the hook was lethal for some fish. Fish were tagged without use of anesthetics and kept in observation tanks up to 2 hr before release (Hansen & Jacobsen, 2003). Separation of stock components in this area has been used in the assessment of Atlantic salmon by the International Council for the Exploration of the Sea (ICES) in recent years (ICES, 2002).

The main problems with mark-recapture studies of Atlantic salmon have been the heterogeneity of recaptures and the lack of simultaneous large-scale marking in the whole distributional area, which might bias the information gained. Factors like non–reporting of tags, tagging mortality, and low exploitation resulting in low numbers of returns may reduce the power in the derivation of total catches of single stocks using tag recaptures. Further, many countries use CWT while others use external Carlin- or Leatype tags with non–comparable shedding and detection rates, further complicating a quantitative analyses of the data.

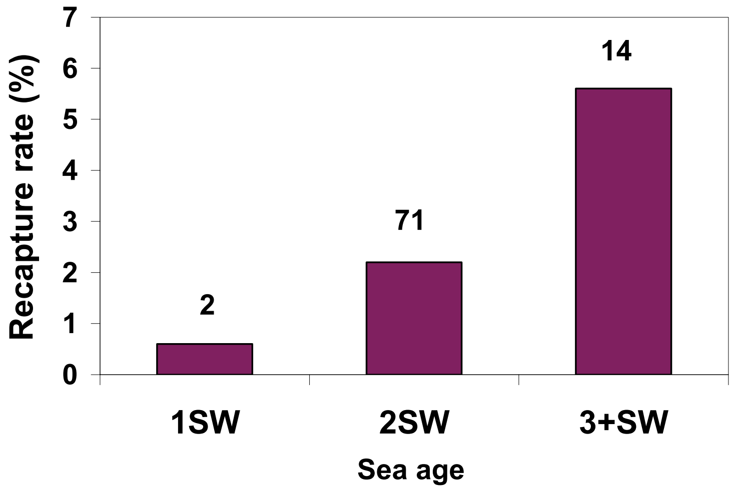

Figure 1. Recapture rates by sea age (size groups) of Atlantic salmon (*Salmo salar*) tagged and released north of the Faroes during 1992/1993–1994/1995. The figures show the number of observations. From Hansen and Jacobsen (2003).

Stock structure of Northeast Atlantic mackerel

A dispute on stock components of Atlantic mackerel (*Scomber scombrus*) in the Northeast Atlantic has been ongoing for decades. The perception of mackerel migration has changed over time, from the old hypothesis that mackerel undertook relatively short migrations from their spawning grounds off the coast to deeper waters nearby, where they hibernated during winter, to the present recognition of mackerel as a highly migratory species (Iversen, 2002). The current fishery ranges from Gibraltar, along the western continental slope, north into the Norwegian Sea and eastward into the North Sea (ICES, 2003b). It has been debated whether the Northeast Atlantic mackerel consists of two stocks or spawning components, one western and one North Sea component, or three spawning components, named after their main spawning areas: southern, western, and North Sea (Iversen, 2002). The three components are treated as one unit in management, named the Northeast Atlantic mackerel. This is because it is impossible to allocate catches in the Norwegian Sea and North Sea to different components during the second half of the year (ICES, 1995).

Several mark-recapture studies have been applied to answer the question of stock identity, allocation of catches, and other biological issues that have been unresolved since the mid-1950s (Hamre, 1970; Iversen, 2002; Iversen & Skagen, 1989; Uriarte & Lucio, 2001). The most recent studies, in 1997 and 1998, had the objectives of clarifying the migration pattern of adult mackerel from the southern and western areas and determining the spatial recruitment pattern of juveniles from the nursery areas (Uriarte *et al.*, 2001). Adult recoveries show that almost all adult mackerel, regardless of whether tagged in the southern or western areas, follow the same northward migration from the spawning grounds in late spring and summer along the west of the

British Isles to the feeding grounds north of Faroes, the Norwegian Sea, and the northern part of the North Sea (Fig. 2).

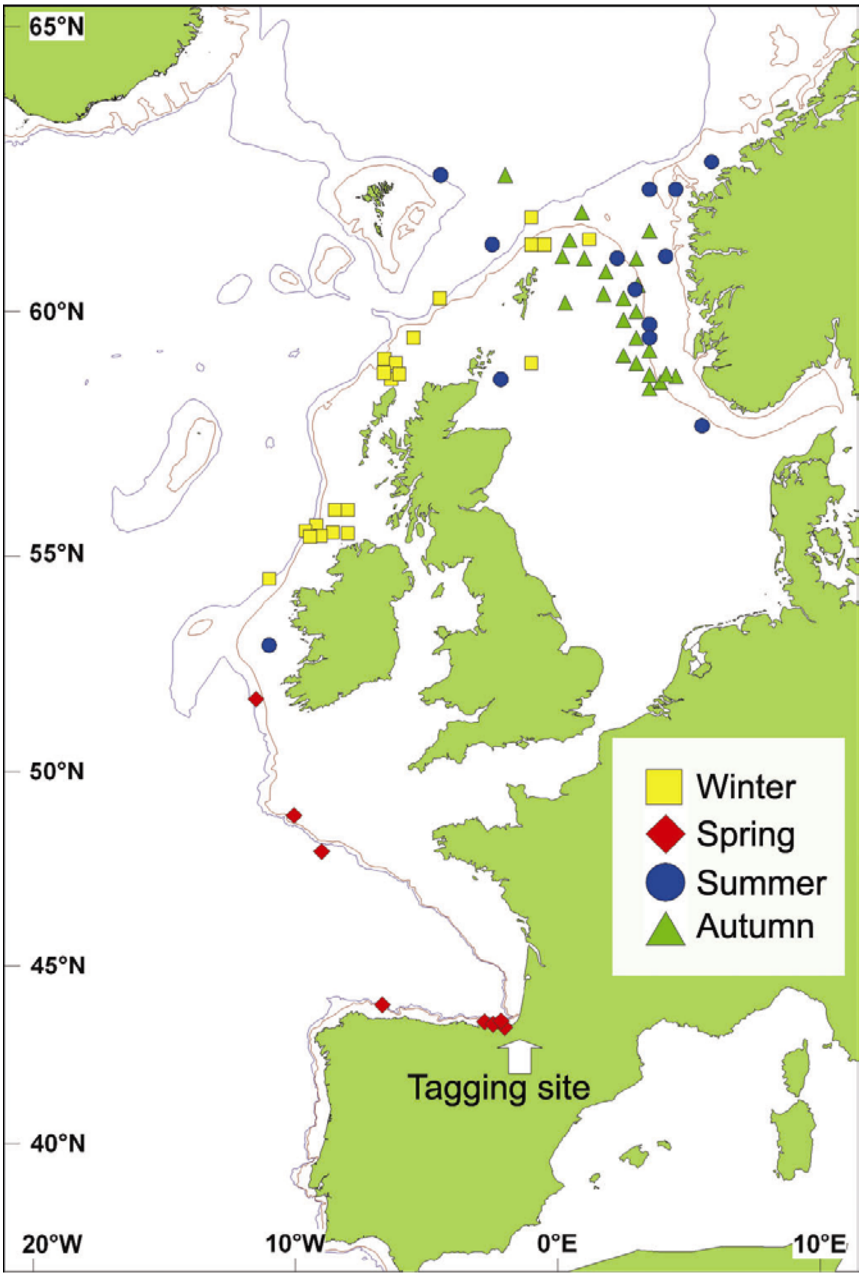

Figure 2. Recaptures of adult Atlantic mackerel (*Scomber scombrus*) in the Northeast Atlantic from tagging in 1994 (white arrow) in the Bay of Biscay [redrawn from Uriarte and Lucio, (2001)]. Recaptures grouped into seasons, winter (12/21–3/31), spring (3/21–6/21), summer (6/21–9/21), and autumn (9/21–12/21).

Recaptures of juveniles suggested, that in general, they remain close to the areas where they are tagged (Uriarte *et al.*, 2001). Further, the presence of adult mackerel of the southern component on the western spawning grounds during spring questioned the present assumption of separate spawning components in these areas (Uriarte *et al.*, 2001). Unfortunately, no tagging was done at the summer feeding grounds in the oceanic part of the distribution areas further north. Also, the use of two different tag types, one internal and one external, complicated the subsequent analysis. Further, the heterogeneity of the recaptures, with no or little fishery and, hence, recaptures in some of the nursery areas, excluded an unbiased analysis of the origin and migration in these areas. However, it is clear from recent studies, that the main issue in management of mackerel today, that is, whether the southern and western components are separate stock units, still remains to be solved. Genetic analysis seems to indicate that there is a separate southern component (Nesbø *et al.*, 2000).

Stock structure of herring

Results from the tagging of Atlantic herring (*Clupea harengus*) in the Northeast Atlantic (Dragesund *et al.*, 1980; Hamre, 1989; Jakobsson, 1970) provide an example of long-distance fish migrations and stock identification. The term *Atlanto-Scandian herring* was used as a common name for three stocks: Norwegian spring spawners, Icelandic spring spawners, and Icelandic summer spawners, with a small component of spring spawners on the eastern banks of the Faroes (Friðriksson & Aasen, 1950; Jakobsson, 1970). The objective was to test if at least part of the stock of herring caught during summer off the north coast of Iceland was identical to the Norwegian winter herring. Jakobsson (1970) reviewed these tagging experiments and stated that the main findings supported the original view that they originated from the same stock.

Schweigert *et al.*(2001) recently applied coded wire tagging technology in Pacific herring (*Clupea pallasi*) to investigate stock structure and migration (Fig. 3). Since the 1930s tagging of Pacific herring using internal metal tags and external Floy tags has been carried out in British Columbia to understand stock structure and mixing rates of populations. Unfortunately, uncertainty in some tag recovery locations and low rates of tag return limited the utility of these studies. In 1999, a new tagging program was initiated employing coded wire microtags to mark Pacific herring on the spawning grounds in order to monitor the movement and mixture of fish interannually Schweigert *et al.* (2001). Tank experiments indicated high rates of survival and low tag-shedding rates, and field trials indicated the feasibility of cost-effective application of large numbers of tags during the short spawning season (250,000 tags applied over 28 days). A detailed description of methodologies for capturing, holding, tagging, and releasing tagged herring was developed (Schweigert *et al.*, 2001). Tag recovery rates of 1–2% in 2000 from the 1999 releases greatly exceeded the returns from previous tagging programs and indicated a high degree of homing or fidelity to the area of release, but also produced a number of remarkable strays (Schweigert *et al.*, 2001). The automated coded wire tagging technology appears to provide a useful tool for large-scale marking experiments on smaller pelagic species for stock identification purposes.

Moores & Winters (1984) reported on the migration patterns of Atlantic herring in western Newfoundland waters elucidated from eight tagging experiments from 1975 to 1980 involving both spring and autumn spawners. A total of 43,700 external tags were applied from which 1062 recaptures were reported to the end of 1981. The spatial and temporal distribution of the returns indicated that the western Newfoundland herring populations are discrete from stocks in adjacent areas, although extensive mixing occurs during part of the year, particularly outside the spawning season. The Strait of Belle Isle appeared to be an important summer feeding area for the western Newfoundland herring populations and, to a lesser degree, for herring from northeastern Newfoundland and the southern Gulf of St. Lawrence. These results were utilized in establishing the boundaries for management of the western Newfoundland stock complex. These boundaries were considered appropriate for the current herring fisheries which exploit both spring and autumn spawners (Moores & Winters, 1984).

Figure 3. The central nape (neck) tag site and brass needle support are shown as a herring (*Clupea harengus*) is about to have the needle inserted prior to tag insertion. From Schweigert *et al.* (2001).

<u>Assessment of Atlantic salmon</u>

In the management of Atlantic salmon (*Salmo salar*) in the North Atlantic the stock composition needs to be known to estimate the contribution to the fishery from various regions. The present assessment model provides catch advice to fisheries managers based on a forecast of pre–fishery abundance (ICES, 2002). CWT and Carlin tag studies have been extensively used and form the basis for estimating the exploitation rate of various European salmon stocks using the run-reconstruction model (Lassen *et al.*, 1988; Potter & Dunkley, 1993; Rago *et al.*, 1993). This approach has been developed for estimating levels of exploitation of Atlantic salmon stocks in sequential fisheries. The run-reconstruction model back–calculates the stock size at the beginning of a fishery, taking the number of returning spawners as the starting point. Mainly CWT and Carlin tag studies are used to estimate the number of fish removed by fisheries and hence the levels of exploitation of the extant stock. However, the method is limited to stocks from closely monitored rivers because of the need to know the total numbers of tagged fish returning to home rivers.

<u>*In situ* tagging of deep-sea redfish (*Sebastes* Spp.)</u>

Stock identification of redfish stock complex in the Irminger Sea and its adjacent waters is one important unresolved issue within the NEAFC (North-East Atlantic Fisheries Commission). Many nations fish on various stocks or stock components in the area without knowing the stock boundaries of the different components (ICES, 2003a). For tagging of fish *in situ*, a newly developed Underwater Tagging Equipment (UTE, Fig. 4) by Star-Oddi in collaboration with the Marine Research Institute in Reykjavik (http://www.star-oddi.com, Iceland) is expected to bring a new dimension to the research of deepwater species in general, and results from tagging of deep-sea redfish with the new system may help resolve the stock identification issue in the near future.

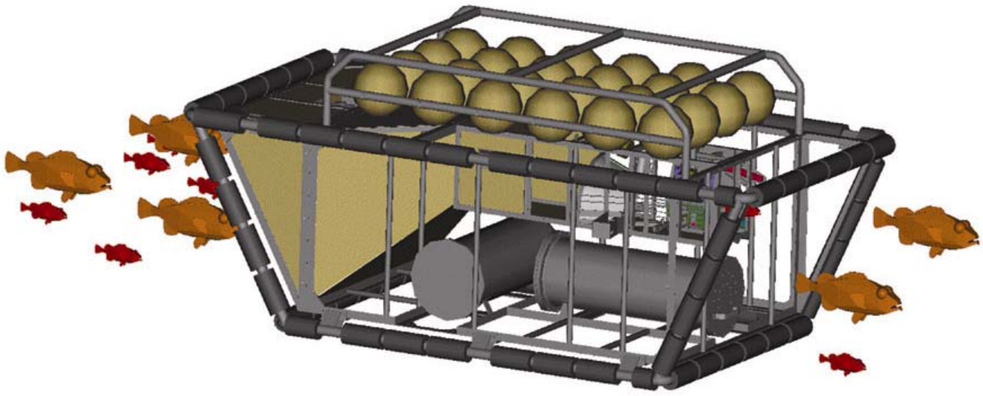

Figure 4. The newly developed Underwater Tagging Equipment (UTE) for tagging of fish *in situ*, by Star-Oddi (http://www.star-oddi.com, Iceland).

The UTE is located at the end of the belly section of a trawl net (both bottom and pelagic) and performs the whole tagging operation underwater, from the surface down to more than 1000 m. Since UTE prevents the need for hauling the fish to the surface for tagging and release (most deepwater species do not survive being brought to the surface), the handling time for each fish is short. By tagging the fish in its natural environment, stress factors such as changes in pressure and temperature can be avoided, reducing tagging mortality. The fish to be tagged is enclosed by a grid that diverts the fish into the tagging place. The fish is viewed through an onboard video camera, and the tagging gun is moved into position. A knife makes a small incision into the skin of the fish and the tag is pressed into its body cavity. Both data storage tags and anchor tags can be used. A small plastic tube hangs outside to allow for identification (Fig. 5). After tagging, the fish is released into open water. The whole process takes less than 30 sec after the fish enters the device.

The device has been tested in tank experiments on cod without damaging their health, and successful tagging has recently been made on deep-sea redfish *in situ*, but survival of the tagged fish was not examined. About 750 deep-sea redfish have been tagged at 500-800 m depth on at the Reykjanes ridge, south off Iceland, in October 2003 and June 2004, with the purpose to investigate if there is mixing between Pelagic deep sea redfish on the Reykjanes ridge, Oceanic redfish and the demersal deep-sea redfish closer to the shore. To date seven tagged redfish have been recaptured (Star-Oddi).

Figure 5. Deep-sea redfish (*Sebastes* sp.) tagged *in situ*. A small plastic tube hangs outside the fish to allow its identification (Star-Oddi, http://www.star-oddi.com, Iceland).

Long-term studies are needed to verify the success of the method, especially regarding long-term tagging mortality and shedding of tags, since the incision wound is not closed after tagging. Wagner *et al.* (2000) found that insertion of dummy radio transmitters in rainbow trout, when compared to sham-operated controls, had negative effects on healing incisions, probably because of increased pressure on the wound from the tag, thus, increasing the chance that the tag eventually migrates out through the wound since the wound is not closed as part of the tagging process.

Summary discussion

Identification of fish stocks is necessary for a number of reasons including allocation of catch among competing fisheries (nationally or internationally), management of highly migratory stocks, recognition and protection of nursery and spawning areas, and development of optimal harvest and monitoring strategies.

Tagging is one of several techniques that have been used to analyze stock composition, separation, and identity in time and space, providing the basis for subsequent regulation and management, and the examples given here show that conventional tagging has been and can still be used for stock identification of fish. However, there are some limitations. The main problems with the various mark-recapture studies have been the heterogeneity of tagging and recaptures and the lack of simultaneous large-scale marking in the whole distributional area. Such large-scale marking is often difficult due to the nature of the fishing fleet in which the fishery might be limited by national boundaries such that sampling merely reflects the fishing effort in space and time and not biological distribution of the fish.

For stock identification the use of internal tags requires the setup of a screening program, whereas external tags can be recovered in dedicated sampling programs and by commercial and recreational fishermen. The choice of tag and tagging method should be decided based on the purpose of the investigation, the species to be tagged, size, and costs.

Hilborn *et al.* (1990) argue that marking will play an important role in meeting the current challenges of fisheries management. Stock identification is a multidisciplinary field and encompasses many techniques (Begg & Waldman, 1999; Cadrin & Friedland, 1999; Waldman *et al.*, 1997). It continues to evolve along with fisheries management and conservation requirements (Begg *et al.*, 1999). Because a large proportion of world fisheries occur on mixed stocks, it is essential to continuously develop new tagging technologies to quantify the various stock components that comprise these fisheries. Fish marking, in combination with other state-of-the-art techniques, continues to be one means of obtaining such information, if well designed.

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