ICES Theme Session R

Analytical approaches to using telemetry data to assess marine survival of diadromous and other migratory fish species

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A wide range of conventional tagging methods has been used to study the behaviour and survival of fish in the sea in the past, but these approaches are constrained by the need to recapture the marked fish, generally in existing fisheries, and each tagged fish provides only a single recapture event (with time, location and biological data) or very little information at all (if it is not recaptured). Telemetry potentially provides far more information on each tagged fish, and radio and acoustic transmitters are now available that are small enough to be attached to fish of less than 10cm (e.g. the size of salmon smolts) and will transmit for several weeks; larger fish can be tagged with transmitters that will operate for well over a year. Coded tags are now widely used so that large numbers of fish can be individually identified and tags can also transmit information on water depth, temperature and other environmental parameters. Furthermore costs, while still relatively high, have reduced to a level that makes it feasible to tag quite large numbers of individuals. This has led to a rapid expansion in the application of telemetry techniques ranging from localised studies of the behavior of fish in relation to specific problems (e.g. dams) to extensive coastal and ocean investigations of the distribution and behavior of fish populations. Theme Session R focused particularly on approaches for estimating mortality of fish using electronic tags.

The six papers presented to the session addressed both localised and large scale telemetry studies. In the first category, researchers have used direct observations or changes in behaviour to indicate when individual bluefin tuna (*Thunnus thynnus*) had died following catch and release (paper R:03) and when sockeye salmon smolts (*Onchorhyncus nerka*) had been consumed by a predator (paper R:04). The predation studies were enhanced by simultaneous 2D tracking of both the prey and predators and have shown different behaviour being exhibited by different predator species (e.g. smallmouth bass (*Micropterus dolomieu*) and striped bass (*Morone saxitilis*) and possible avoidance behaviour being exhibited by the salmon smolts (paper R:04). Several presentations indicated that rules could be applied to the tracks of tagged fish to identify when they had been consumed by predators, but more reliable data can now be provided by a ‘predation tag’, which has a digestible fuse that causes it to transmit a modified signal after it had been ingested by a predator (paper R:04). Tracking of individual fish with depth recording tags can also indicate their potential vulnerability to marine developments such as tidal stream generating turbines, as illustrated by a study of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) in the Midas Passage in the Bay of Fundy (paper R:03).

In the second category of telemetry studies, papers were presented on the behaviour and population structuring of striped bass around New York Harbour and Hudson Bay (paper R:06) and snook (*Centropomus undecimalis*) along the coast of Florida (paper R:07), and the use of telemetry to estimate the mortality of Atlantic salmon smolts (*Salmo salar*) emigrating from four Canadian rivers entering the Gulf of St Lawrence (papers R:01 and R:05). In the later studies, the use of a sequence of receiver arrays across the migration route of the smolts has allowed the early post-emigration mortality of the smolts to be partitioned in both space and time and variation in the mortality rates between years can be related to environmental changes.

The presentations indicated various potential technical difficulties with deriving information on fish mortality from tag detection rates, for example caused by tag loss, predation, deterioration in tag signals and changes in receiver efficiency. Several papers noted the need to screen data for evidence that receivers were becoming less sensitive and in some cases it was suggested that rules could be applied to the data to do this in a consistent manner. Paper R:05 referred to the use of sentinel tags to monitor the status of receivers over time and identify problems. In discussion it was noted that receivers had also been attached to wave gliders and to predators such as seals, and these had successfully extended the detection of tagged fish.

Most of the papers noted the very large amounts of data that could be generated by telemetry programmes, with some referring to at least 1 million tag detections by up to 50 different receivers. While such studies can now provide detailed descriptions of the behaviour of different populations of a fish species within a given area (e.g. freshwater, estuary and coastal populations of striped bass (paper R:06)), there has been a clear need to develop and apply more sophisticated analytical tools. Paper R:01 described a purpose developed software package, MyTrack, which provides a flexible platform for analysing the detection of 10s or 100s of tags by multiple receivers, while paper R:07 presented the application of Network Theory, using packages such as Unicnet and Netdraw, to analyse the distribution and behaviour of populations of snook on the Florida coast. Papers R:01 and R:05 also described alternative approaches for analysing data on the emigration of tagged salmon smolts , with the latter paper applying a Bayesian Jolly-Seber mark-recapture state-space process model, which provides estimates of the detection efficiencies of the receiver arrays and estimates of losses between the arrays.

It was noted that all the presentations at the Theme Sessions had been based on work undertaken in Canada or USA, and that several of these had highlighted the benefits of cooperation between research groups in order to share tag detection information obtained from different receiver arrays. Such networks have been established in a top-down fashion by such groups as the Ocean Tracking Network (OTN), but speakers also noted real advantages in establishing them in a bottom-up fashion as had been the case with the Atlantic Cooperative Telemetry network (ACT) (paper R:06) and the Florida Atlantic Coast Telemetry network (FACT) (paper R:07). It was felt that there were real opportunities for researchers in Europe to start applying these techniques more widely and that major benefits would be obtained from developing cooperative links between groups working on different species, including diadromous fish, sharks and marine mammals. The session was informed that this was the intention with an international salmon telemetry programme which the North Atlantic Salmon Conservation Organisation (NASCO) has recently agreed to support with the aim of describing the migration pathways of Atlantic salmon in the sea and partitioning the marine mortality of salmon populations from different regions in space and time.

Telemetry studies are not only expanding our knowledge of the biology of a range of marine species but are of great interest to the fisheries managers. The papers presented to Theme Session R described a number of applications of telemetry to practical management problems and the provision of results that fed directly into management actions. The wider application of these methods has potential to greatly enhance our knowledge and the management of marine resources.