Theme session O
Advances in studying spatial distribution

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Introduction

In the description of the session emphasis was put on:

1) Tags where recapture was not required and what they can tell us.
2) Estimates and reduction of tagging mortality
3) Inference about location from measurements registered in tags.
4) How to utilize sequence of spatial locations from the same individual in tuning of the models.

A large part of the lectures described experiments with acoustic tags where a fish is tagged by acoustic transmitter, and a grid or line of acoustic receivers is set out.

Description of presentations

Sara Iverson started with a description of the global ocean tracking network (OTN) (O:12).

Damian Lidgard described the interactions between Grey Seals carrying receivers for acoustic signals and cod and salmon carrying transmitters (O:16).

Steven Degraer descibed behaviour of cod around and close to a wind farm, using acoustic telemetry (O:03).

Douglas Zemeckis used acoustic telemetry to show spawning site fidelity of cod in the gulf of Maine but also migration to more than one spawning site in the same spawning season (O:07).

Mike Stokesbury showed how to use acoustic telemetry to estimate the number of sturgeons entering and leaving the Minas basin. The project was related to effect of tidal current power station on the sturgeons. The area, in the Bay of Fundy has one of strongest tidal currents in the world, causing lot of problems in detection of acoustic signals (O:02).

Laurie Baker described described a study estimating the range of the Vemco mobile reiceivers and which factors affect the range, a very important study for quantifying results from those tags (O:14).

Johannes Sturlaugsson described an experiments where wolffish was tagged with acoustic tags in a fjord in western Iceland. A number of acoustic receivers had been placed in the fjord, the density enough to detect most of the fishes leaving the fjord (O:18).

Greg DeCelles described use of acoustic telemetry in inferring about the stock structure of cod in Pacentia Bay in Newfoundland (O:01).

Papers O:01, O:18, O:03, O:07 and O:02 all described experiments involving relatively dense grid of receivers, either a line or a small area. Fish crossing the line or entering the area did therefore have a very high probability of being detected.

Paper O:16 described different philosopy where the receivers were put on a potential predators, but O:12 a large "umbrella" project including subproject that do both i.e. placing receivers in a dense grid or line, or on predators.

Acoustic tags have the nice property of giving multiple locations if the grid of receivers is dense enough in the area inhabited by the fish. Outside this area no information will be obtained. With a range 400m the area covered by a receiver is only 0.125 km2 so to cover an area like the Icelandic continental shelf (200 000 km2) is out of the question. Experiments could be designed with a coarse grid (20x20 miles) but in this case each fish would only "hit" a receiver approximately twice a year on the average, still with 160 receivers. Doubling the range will increase the number of "hits" by a factor of four in an experiment with coarse grid but this kind of setup is necessary if the spatial distribution of fish stocks throughout the year is to be estimated. Using acoustic tags to identify migration routes of widely migrating stocks is even more difficult except the range of the receivers will increase substantially something that might be physically impossible.

Pop-up tags are designed to pop up to the surface after certain time and send to a satellite information about location and data stored inside them. These tags are not dependent on recapture or acoustic receivers so they have the same probability of giving position wherever they are. They are on the other hand expensive, large and each tag will only give one location.

Johannes Sturlaugsson described an experiment where pop-up tags were put on 8 large Icelandic cod on a spawning site. (Paper O:17). The recaptures were widely distributed and all the cod gave "valid" recaptures, something to take into account when looking at the price of these tags. The price per recapture is perhaps not so high.

Traditional archival tags that need to be recaptured are also useful, especially for stocks that are heavily fished. Comparison of these tags with other kinds of tags will have to be based on cost per recaptured fish and the information they give. Archival tags can give information about location via measured variables.

- For demersal fish, tidal signals can be identified from depth measurements and related to a tidal model.
- For animals close to the surface light measurements give information about longitude.
- Temperature and depth can be related to hydrographic measurements or satellite measurements for animals close to the surface.
- Magnetic directions can be integrated.

Many questions are at the moment best answered by a combination of techniques as shown in the paper describing distribution of juvenile bluefin tunas in North Atlantic (O:16). Here distributions from pop-up tags and light base geolocations from internal and pop-up archival tags were compared. The internal tags gave more precise light based locations but recapture was a problem there.

The paper on spatial distribution of European Seabass presented by Helene de Pontual (O:05) describes the use of a mixture of dst/archival tags and acoustic telemetry. The fishes are widely migrating so acoustic telemetry only is out of the question. The fishes are tagged in a spawning area where acoustic receivers are located. The DST tags used register temperature, depth and direction. Inference about location is done by hidden Markov models using these measurements.

Tagging mortality is a major factor of disturbance, both for price and precision of results from tagging experiments. This factor depends on depth, speed of hauling and treatment of fish. The experiment described in paper O:17 with pop-up tags show that with careful choice of tagged fishes all of them survive. At greater depth mortality might still be a problem and underwater tagging become a necessity. Paper O:13 describes the experience of using first version of an underwater tagging equipment. The experiments described involve tagging of a sensitive fish with very low fishing mortality. To infer about the usefulness of the device comparison must be made with traditional tagging by tagging the same species in the same area.

Acoustic tags give chance for inferring about tagging mortality by tagging fishes in an area with dense grid of acoustic receivers, noting how the number of recaptures changes.

Use of otolith chemistry to infer about nursery areas and spatial distribution is describe in papers O:06 (goliath grouper) and O:09 (albacore). Otolith chemistry is sometimes a useful method to infer about spatial distribution of fishes. Results sgiwb in the two papers were not too convincing, for the Albacore number of samples was low and the goliath grouper case did even look more suitable for acoustic telemetry.

Two of the papers presented describe modelling migration. Paper O:15 presented by Pederson described a combination of a movement and observation model. The movement model is based on Brownian model and the observation model takes into account the detection rate of the acoustic receiver as function of distance. The model does seem most useful where the grid of receivers is relatively dense. In the other paper (O:04) the recovery of migration routes of depleted and recovered fish stocks is discussed. Linkage to estimation of distribution of fish stocks in not clear.

Summary

Most of the presentations in this session were rather interesting to listen to. Making an interesting lecture from a well-designed tagging experiment is much easier that doing it about some detail in stock assessment model or some other technical detail. The latter lecture will only be understood by few persons working exactly in the same field while the tagging experiment in nearly a material for newspaper article.

It is only when we want to use the tagging experiments for quantitative evaluation that we need to include all the details on estimation of tag loss, tagging mortality, detection range of receivers, statistics of recaptures, movement and observation model etc. The experiments described in these sections are hardly of the scale to be of much help in inference about spatial distribution of fish stocks that migrate over large areas (100-500 thous. square kilometers). Experiments involving 200+ acoustic recevivers would be required for the kind results that are nessecary for understanding multispecies interactions. Those kinds of experiments could be linked to "super individual models" that are commonly used in fisheries research.

Using predators as receivers instead of having receivers at fixed locations is another way to learn about multispecies interactions. These experiments easily lead to biased results if not interpreted correctly. Large experiments where significant number of transmitters will be eaten by receivers would give valuable important on predation but for this to happen the experiment would in most cases have to be extremely large. Situations like that observed in presentation O:17 where a sperm whale ate one of eight cod tagged should not be expected except sperm whale ate substantial proportion of Icelandic cod. One question that arises is if the relatively large tag placed on

the cod attracted the sperm whale somehow but by strong reflection of acoustic signal.

Future development

Acoustic telemetry seems to have the potential for leading to revolution in understanding of distributions of fish stocks. For that to happen the tags must reduce in size of price but the development cost must indirectly be paid by research institutes around the world by buying the current generation of tags. For inference about spatial distribution on whole contiental shelfs or in the open sea range of the receivers must increase, for. The future will have to show to what extent that is possible.

Further development will to some extent be dependent on more than one company developing the tags. As the cost of setting out a grid of receivers will always be rather high, standardising the frequency and form of the signals will be essential. Some fish stocks are known not to respect areas of juridiction and operating with receivers in one area that cannot listen to the tags used in other area will limit the usefulness acoustic tags. Transboundary migrations could be one of the biggest selling points for manufacturers of tags.

The largest potential for development will be in the tags put in the fishes, currently transmitters. Among features that might be included are.

- They can be receivers most of the time only acting as transmitters when they hear from a transmitter. Good for battery life?
- They can be DST tags sending their information when they hear from a transmitter, like pop-up tags do today.

Pop-up tags have not been mentioned in this final part but if size and price of the tags decrease their use will increase, especially if they become small enough to be used on widely migrating pelagic species like. Transboundary problems with different types of signals will at least not be a problem when popup tags are used. .

As may be seen the future could be exciting but development will not continue if everyone waits for improved equipment to appear on the market.