Linking natural and electronic data records to determine the lifetime movements of North Sea plaice

Cefas

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Problem: Obtaining frequent, repeated estimates of fish location over seasonal time-scales

A full understanding of the spatial dynamics of commercially exploited fish is an important consideration for future sustainable exploitation. Details can be obtained only through frequent, repeated and accurate estimates of individual fish location over annual cycles. This has proved challenging in marine species, especially for sea-bed dwelling fish.

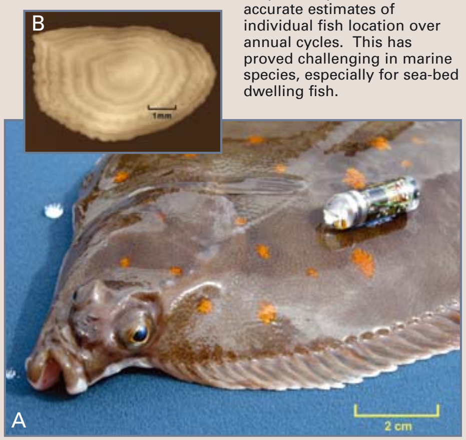

Figure 1: Plaice **A)** tagged with an electronic data storage tag and **B)** otolith.

Data storage tags (DSTs, Figure 1A) allow continuous records to be made of ambient conditions (temperature, depth) experienced by fish in their natural environment for periods of up to 18 months (Figure 2). When tagged-fish rest on the sea-bed for a full tidal cycle (indicated by sequential lower case lettering, Figures 2 and 3), their position can be estimated using the tidal location method. This geolocation system allows reconstruction of the movements of the fish between the time of release and recapture (accurate to within approximately 40 km, Figure 3).

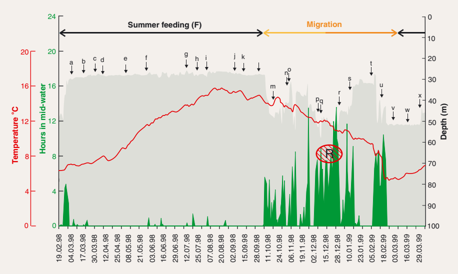

Figure 2: Sea-bed depth, temperature and swimming activity recorded by a DST-tagged, 52 cm female plaice over 411 days. R = reproduction.

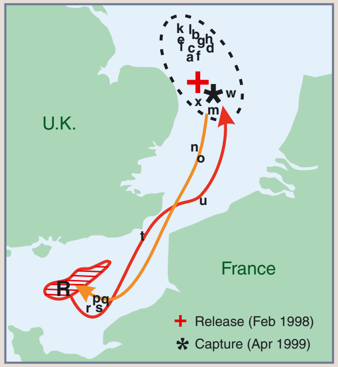

Figure 3: Reconstructed plaice migration route for the data shown in Figure 2.

Plaice (*Pleuronectes platessa*) tagging studies in the North Sea using DSTs has shown that adult female plaice aggregate on three discrete feeding areas during the summer (groups A, B and C, Figure 4). During the winter, the adults disperse, often migrating hundreds of kilometres onto spawning grounds located in the eastern, central and southern North Sea, and the eastern English Channel (shaded areas, Figure 4). In early spring, they return to their feeding locations.

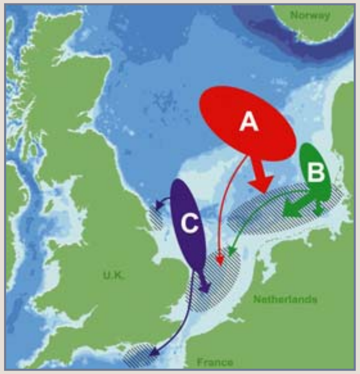

Figure 4: Plaice population structure revealed by DST studies.

Fish earstones ("otoliths", Figure 1B), also indirectly record ambient conditions experienced by fish throughout their lifetimes. Recent studies have demonstrated how the otoliths' chemical composition may reflect the environmental history of individual fish. The success of this technique depends on the variability of environmental conditions experienced. Because migrations often cover hundreds of kilometers in a strictly marine environment, the assessment of spatial dynamics using otolith microchemistry is almost impossible without a priori information on real fish movements.

Linking the two state-of-the-art techniques (DST tagging and otolith microchemistry) should allow accurate retrospective positioning of fish in space and time throughout their lifetimes.

Matching Otolith Microchemistry with DST data

To identify migration-linked patterns of variation in otolith composition, trace element (Ca, Sr, Ba, Cu, Ni, Pb, Zn, As, Cd), and stable isotope (δ18O, δ13C) composition was analysed for eight plaice (TL = 38-52 cm, age = 5-9 years) with 4 distinct migratory behaviours (Figure 5).

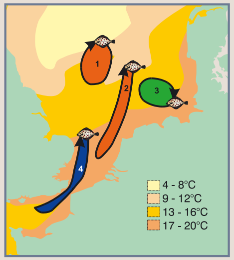

Figure 5: Four distinct plaice migration patterns shown in relation to average summer sea-bed temperature.

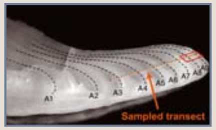

Figure 6: Section illustrating the plaice otolith transect analysed. The red box defines the area with the corresponding DST data record.

Using laser-ablation inductively-coupled plasma mass-spectrometry, sequential seasonal samples (2-3 months) were taken from the area corresponding to the third summer of life to the outer edge of the otolith (Figure 6). These provided data from before and after sexual maturity (which occurs at age 3 to 4).

Otolith Sr:Ca ratio

Our initial observations suggest that Sr:Ca ratios partly reflect migratory behaviour. Intra-annual variation occurred irrespective of life stage or behaviour type (Figure 7). However, long annual migrations (type 1 and 3, Figure 5), were associated with a doubling of the annual variability of the Sr:Ca ratio between the juvenile and adult stages (Figure 7). Only a weak increase was observed with short migrations (type 2 and 4, Figure 5), suggesting that the Sr:Ca ratios may gauge the extent of individual migration (Figure 7).

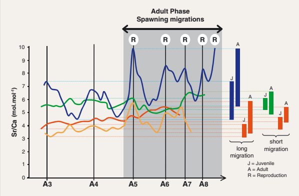

Figure 7: Annual variation of Sr/Ca ratios in plaice otoliths.

For both type 1 migrations (feeding in the southern North Sea and spawning in the eastern English Channel, Figure 5), the annual Sr:Ca ratio variability increased dramatically between ages 4 and 5 (Figure 8). From age 5 onwards, the increase was observed from late summer to late winter (translucent zone) with a decrease from early spring to mid-summer (opaque zone), indicating a change in Sr:Ca deposition linked to sexual maturity and migration (Figure 8). The repeated pattern supports previous observations of repeated annual migration routes from the DST data.

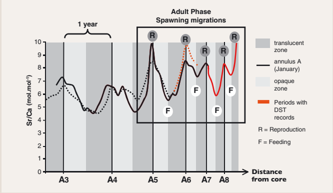

Figure 8: Intra-annual fluctuations of plaice Sr/Ca ratios before and after sexual maturity.

Relationship between temperature and otolith $\delta^{18}O$

The oxygen stable isotope ratio (δ18O) values measured from the otoliths were matched with the temperatures recorded by the DSTs during corresponding time-periods to establish the relationship between sea water temperature and otolith δ18O (Figure 9). This relationship depends on the water δ18O, estimated from North Sea salinity data using the equation:

δ18O W = 0.524 x salinity - 18.38

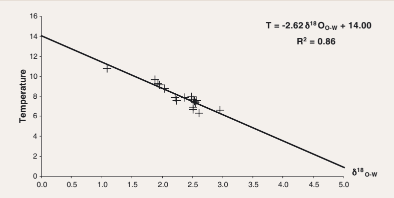

Figure 9: Relationship between sea-water temperature and otolith δ18O.

The differences in sea water temperatures experienced by the 3 sub-groups during the summer (Figure 5) also allowed discrimination based on the otolith summer δ18O values (Figure 10).

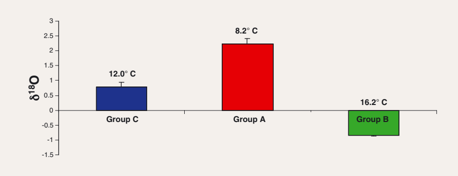

Figure 10: Estimated δ18O values of otoliths based on DST summer temperature.

Conclusion

Although in its early stages, this work may for the first time allow interpretation of the migration history of plaice prior to tagging, and determination of the time and source of recruitment, thereby linking studies of pre- and post recruitment fish behaviour by using otoliths as natural "DSTs".

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