THE IMPORTANCE OF INDIVIDUAL BEHAVIOUR FOR SUCCESSFUL SETTLEMENT OF JUVENILE PLAICE – A MODELLING AND FIELD STUDY IN THE EASTERN IRISH SEA

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Introduction

In order to study the transport of plaice eggs and larvae from spawning to nursery grounds in the eastern Irish Sea, we constructed a baroclinic physical model of the region and coupled it to a particle tracking scheme that allowed aspects of larval behaviour to be simulated. Simulations ran from spawning to larval settlement. Starting positions were based upon results from a series of ichthyoplankton surveys and the final positions will be compared with results from a juvenile plaice survey conducted on beaches around the eastern Irish Sea. Despite the relative proximity of spawning and settlement areas (compared to the southern North Sea), we found that circa-tidal vertical swimming behaviour was essential for successful recruitment of plaice to the nursery grounds. If subjected to only passive drift or horizontally directed swimming, the larvae tended to diffuse from the spawning areas and failed to reach nursery grounds in significant numbers. In addition, the development of circa-tidal behaviour caused larvae to accumulate in embayments and estuaries along the coast known to be important nursery areas.

Particle tracking model

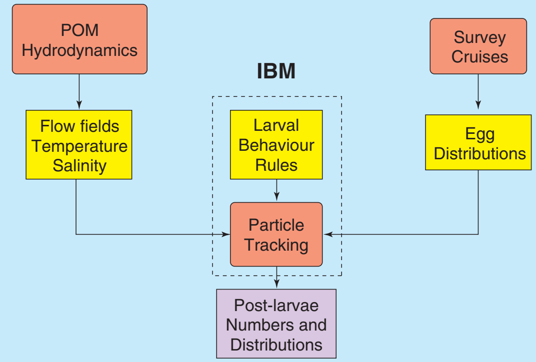
The particle tracking model used for this study is based on that described by Young (1996), and previously employed for the study of haddock larval transport (Dickey-Collas et al., 2003). To keep computer overheads reasonable only a limited number of particles can be tracked, therefore each particle is given a weighting to represent a super-cohort of individuals on which growth and mortality calculations can be performed.

Growth and Mortality

The lifecycle of super-cohorts within the IBM is tracked through egg development stages and after hatching, through larval length. Growth rates in all the lifecycle stages are calculated based on the local temperature field experienced by the super-cohort.

Behaviour

Information in the literature suggests that larvae migrate vertically to take advantage of selective tidal transport. To simulate the vertical movement of larvae within the IBM the following criteria were applied to the super-cohorts.

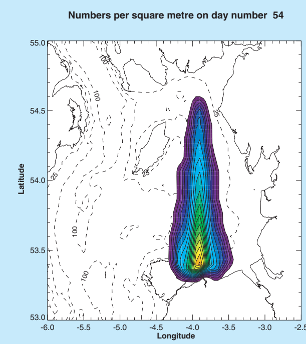


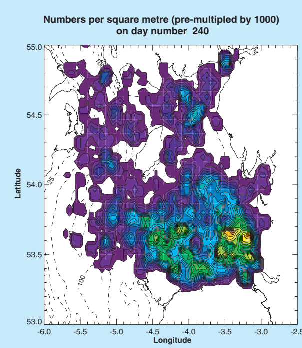
The Rules

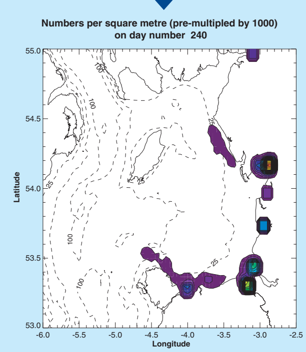
Vertical Migration

7mm-9mm:	Sink during daylight Rise during the night
9mm-10.5mm:	Sink during ebb tide Rise during flood tide
>10.5mm:	Small negative buoyancy

Larvae settle at 11mm





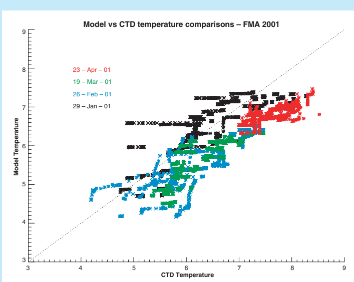


POM model description

- The physical model is a three-dimensional, primitive equation, σ co-ordinate, free-surface model based on the Princeton Ocean Model (Blumberg and Mellor, 1987) with Mellor and Yamada (1982) turbulence closure. The model domain encompasses the Irish and Celtic Seas from 48°N to 56°N (Fig. 1). Details of the model physics are provided in Young (2002). Spatial cell dimensions are 1/20° in longitude and 1/30° in latitude giving a resolution of approximately 3.3 km x 3.7 km.
- Twenty-five sigma layers were used in the vertical, arranged as follows: $\sigma = (0, -0.01, -0.025, -0.05, -0.1, -0.15, -0.2, -0.25, -0.3, -0.35, -0.4, -0.45, -0.5, -0.55, -0.6, -0.65, -0.7, -0.75, -0.8, -0.85, -0.9, -0.95, -0.975, -0.99, -1.0)$. This irregular spacing provides increased resolution in the high-shear surface regions and near-bed layers.
- Model depths were obtained by smoothing a fine resolution (1 km) bathymetry digitized from Admiralty Fair sheets (where available) and Admiralty Charts (UK Hydrographic Office).
- Boundary and initial conditions were taken from the Proudman Oceanographic Laboratory regional scale model (POLCOMS – S12).
- Meteorological forcing was obtained from ECMWF operational dataset.
- River flow data were provided the UK National River Flow Archive and the Irish Environmental Protection Agency

Model Validation

Temperature measurements taken by CTD during four cruises in the early part of 2001 have been compared to model predicted daily average temperatures. The results show fair agreement between predictions and observations with an rms error in the predictions being 0.75°C. There is a general trend of the model under-predicting temperature apart from in the January comparison (which is influenced by the initial temperature conditions imposed on 1st January). There are a number of possible explanations for the under-prediction of temperature such as the influence of river water temperature (which is not modeled), diurnal effects (which are not included in the comparison) and the lack of wetting and drying areas in the model (which are important to the dynamics of the eastern Irish Sea.



Conclusions

Despite the close proximity of plaice spawning and nursery areas in the Irish Sea, the development of tidally selective behaviour by individual larvae appears to be critical to successful settlement into suitable nursery areas. Based on field sampling and historical survey results the major areas of settlement are in bays such as Red Wharf Bay and Morecombe Bay and estuaries such as the Solway. Abundances of settled juvenile plaice along the open coastal regions were considerably lower. We were able to duplicate these distribution patterns using a coupled hydrodynamic-particle tracking model incorporating representations of individual larval behaviour.

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