

Modelling the dispersal of plaice eggs and larvae in the southern North Sea

1. Background and aims

Recent studies on dispersal of marine fish eggs and larvae have highlighted the importance of growth and behaviour characteristics for the ability of propagules to reach nursery grounds. We are developing a new Individual-Based Model (IBM), linked to the General Estuarine Transport Model (GETM), to simulate such characteristics and their influence on dispersal, and here present the first results. Our aims were to:

- Develop a general, flexible toolbox for fish early life styles
- Add this toolbox to an existing particle tracking code and improve the link with GETM
- Apply the new model to a semi-realistic, well-studied example: plaice in the southern North Sea

2. Model structure



3. Hydrodynamics

- GETM (Burchard & Bolding, 2002)
- 3 Dimensional, general vertical coordinates
- Forcing: tides, meteorology, density
- Turbulence: variety of schemes available
- Flooding and drying: realistic modelling of shallow coastal areas
- Parallel computing: fast computations

4. Particles: IBM

- Particle tracking (after Wolk, 2003):
 - Advection: semi-analytical solution
 - Diffusion: random walk
 - Horizontal: constant
 - Vertical: from GETM turbulence
- Biology (after Fox *et al.*, 2006; Van der Molen *et al.*, 2007) variety of schemes for:
 - Egg and larvae growth
 - Mortality
 - Vertical migration behaviour

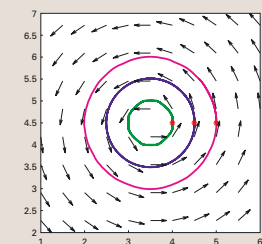
5. Species definition: design from standard components

The species life cycle is split up into stages. For each stage, development and behaviour characteristics are defined. The table gives the structure and settings used here for plaice.

	A	B	C	D	E	F	G	H	I	J	K
1 egg_diam	1.9										
2 l_hatch	7										
3 l_settle	12.5										
4 n_egg_stages	6										
5 n_larvae_stages	4										
6 n_behav	1										
7 dev_timestep	3600										
8 particle stage	1	2	3	4	5	6	7	8	9	10	
9 bio_type	1	1	1	1	1	1	2	2	2	2	
10 stage_start_crit	0	0.47	1.39	2.85	5.14	7.68	10.5	7.5	9.0	12.4	
11 dev_type	1	1	1	1	1	1	2	2	2	2	
12 a_dev	5.188	8.002	12.819	25.398	29.88	43.853	150.0	150.0	150.0	150.0	
13 b_dev	-1.612	-2.54	-4.098	-8.076	-9.313	-14.427	0.092	0.092	0.092	0.092	
14 mort_type	2	2	2	2	2	2	1	1	1	1	
15 a_mort	0.03	0.03	0.03	0.03	0.03	0.03	0.048	0.048	0.048	0.048	
16 b_mort	0.18	0.18	0.18	0.18	0.18	0.18	0	0	0	0	
17 behaviour_type	3	3	3	3	3	3	0	3	3	3	
18 w_migr_mode	1	1	1	1	1	1	0	1	1	1	
19 consmode	1	1	1	1	1	1	0	0	0	0	
20 diurnalmode	0	0	0	0	0	0	0	2	0	0	
21 tidemode	0	0	0	0	0	0	0	0	1	0	
22 andmode	0	0	0	0	0	0	0	0	0	0	
23 wp_up	0.001	0.001	0.001	0.001	0.001	0.001	0	0.005	0.003	0	
24 wp_down	0	0	0	0	0	0	0	-0.005	-0.006	-0.01	
25 part_dens_up	0	0	0	0	0	0	0	0	0	0	
26 part_dens_down	0	0	0	0	0	0	0	0	0	0	
27 diurnal_depth_top	0	0	0	0	0	0	0	0	0	0	
28 diurnal_depth_bottom	0	0	0	0	0	0	0	0	0	0	
29 tidal_depth_top	0	0	0	0	0	0	0	0	0	0	
30 tidal_depth_bottom	0	0	0	0	0	0	0	0	0	0	
31 hor_swim_mode	0	0	0	0	0	0	0	0	0	0	
32 up	0	0	0	0	0	0	0	0	0	0	

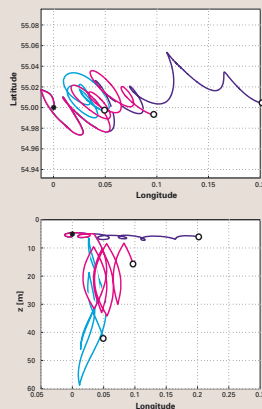
6. Test: advection in circular velocity field

- Three passive particles
- Result: closed particle tracks



7. Illustration: influence of behaviour on dispersal

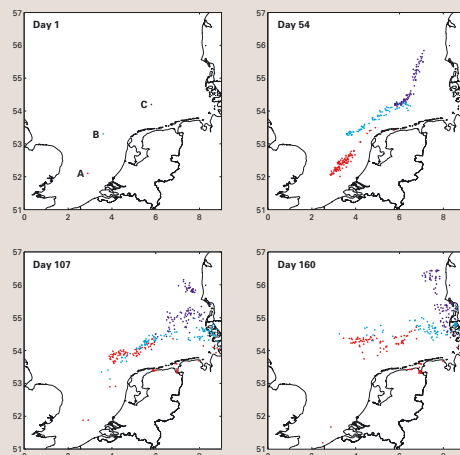
- Advection in 3D hydrodynamics in southern North Sea
- Run duration: 4 days
- Behaviours:
 - Passive (dark blue)
 - Passive, then diurnal vertical migration (light blue)
 - Passive, then tidally cued vertical migration (pink)
 - Both vertical migration modes: fixed upward or downward velocity (5 mm/s)
- Result: contrasting final positions due to differences in time spent near surface where currents are strongest



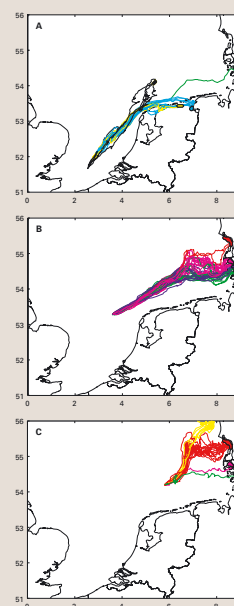
8. Application: plaice in the southern North Sea

- Year: 2001
- Resolution: 2 nautical miles, 26 layers
- 3 spawning sites (at centres of general spawning distributions following Simpson, 1959), 100 particles per site
- Release: normal distribution in time, $\sigma=14$ days, peaks 30 January (Southern Bight - A), 15 February (Frisian Front - B and Heiligoland - C), (following Simpson, 1959)
- Development and behaviour as in table (above)
- Horizontal and vertical diffusion
- Results: many particles congregate in shallow coastal areas mainly because of tidally cued vertical migration, in agreement with earlier results by De Graaf *et al.* (2004)

Particle positions



Particle tracks per spawning site to areas of congregation



9. Future developments:

- More realistic spatial and temporal distribution of spawning
- Larger geographical domain
- Validation with plankton survey data
- Improve and expand larvae growth and behaviour schemes
- Apply to other fish species

References

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