Scope of collaboration between
ATLAS and Parallel Works for
ATLAS Deliverable 1.5: Impact of biological parameters on particle spreading
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Abstract

Many ocean bottom dwelling species release their larvae into the water column so that the larvae can both add to the local population and spread far to find other places to colonize. A better understanding of larval pathways and downstream colonization is an important factor informing the design of Marine Protected Areas and ultimately impacts how the marine environment is used. During their transit, larvae exhibit a range of different behaviors for maximizing their immediate survival (finding food and avoiding predation) and their long-term survival (finding a suitable spot to settle). Key strategies are pelagic duration and control of the vertical position in the water column. As part of the ATLAS project, working in the North Atlantic, we try to answer two questions to help identify whether larval behaviors are impacting their long-term spreading: Is there any evidence that any of these behaviors, either alone or combined, cause greater spreading? And, do any of these behaviors cause larvae to follow particular pathways so they settle in specific locations? To answer these questions we use particle tracking with ARIANE within the VIKING20 model of the North Atlantic. Our primary tool will be a factorial experiment simulating a range of larval behaviors to explicitly test the impact of behaviors on spreading and pathways.

The Computational Challenge

Our control dataset will be 9.2 million, 1 year-long particle tracks launched from the 12 ATLAS case study sites, which was completed for ATLAS Deliverable 1.1. In the control run, all particles are purely advective; their movement is entirely dependent on the velocity field. In this and all subsequent cases, the velocity field, an input to the particle simulation, is the 1958-2009 output of the VIKING20 ocean circulation model, a high resolution simulation of the North Atlantic. This time-varying velocity field takes up about 4TB of disk space. The ARIANE particle tracking code is single threaded and the parameters of this simulation are in Table 1, below. Approximately 1/3 of the simulation time is computing the particle trajectories and roughly 2/3 of the simulation time is for reading the velocity field to RAM.

Table 1: Simulation statistics on a Xeon 3.5GHz processor accessing the input data on a local RAID0 disk array (1 Mp = $1x10^6$ particles)

Numbers for scaling	Total usage for a single 50 year, 9.2 Mp run
15 minutes IO time per year	12.5 hours
0.62 minutes compute time per 1 Mp per year	4.8 hours
4 GB RAM per 1 Mp *	49 GB RAM

*Does not include a base RAM usage of about 12 GB (for the velocity field, supporting data, OS)

We have identified 5 key larval behaviors, presented in detail below, that we intend to change in each simulation. Using high and low representative values of each behavior, a sweep of the possible combinations of behaviors results in 2^5 = 32 runs, or about 23 days of continuous single threaded running. This estimate does not include the time necessary for post-processing of the simulation output for efficient visualization.

The power of the cloud with regards to the particle simulation lies primarily with input data duplication. Data duplication in the cloud would allow for several runs to be done at the same time, each touching different disk space, alleviating the IO bottleneck, and thus substantially reducing the total run time. After the simulation is complete, parallelization would be a benefit for speeding up the post-processing, as outlined below.

Scientific Goals

The key larval behaviors that we would like to test are outlined in Figure 1 and Table 2.

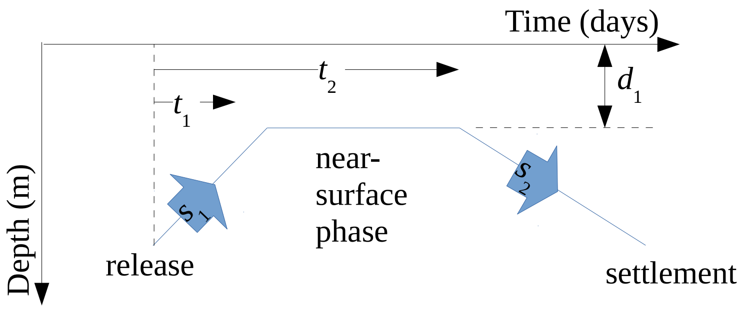

Figure 1: Schematic of key larval behaviors from time of larval release to settlement at the bottom.

Table 2: Key larval behaviors

	Unit	Description	Min	Max
t1	days	time to ramp up to max swimming speed (upward swimming would ramp up linearly over this time)	0	10
t2	days	time after which start swimming downwards	4	42
s1	mm/s	maximum upward swimming speed	0.2	1.0
s2	mm/s	maximum downward swimming speed	0.2	1.0
d1	m	shallowest depth at which hang out (turn off active swimming shallower than this, still allow vertical advection)	12	150

The post-processing and visualization of the larval simulations will proceed in four stages:

1) Split output particle trajectories into subsets specific to each of the ATLAS Case Study regions and to each season of release (DJF, MAM, JJA, SON).

2) Apply a "survival filter" which will use the depth of each particle relative to the bottom of the ocean as well as acceptable ranges for mean bottom temperature and salinity to determine when along each trajectory the larval particle is in a location that it could settle and survive. The result will be a survival rate for each Case Study and each season as a function of time.

3) Quantify the overall spreading of larvae from each Case Study over each season or in aggregate. 2D histograms of particle positions from the particle tracks will be constructed. The spreading will be quantified by the area within the contour enclosing 95% of the particle positions over time and the rate of spreading will be determined by fitting an exponential to each time series. Parallelization will be helpful here as there will be 32 runs x 12 case studies x 4 seasons x 73 time steps = 112,128 histogram and 95% confidence contour operations.

4) Determine whether any combination of behaviors favors specific pathways by using the histograms constructed in step 3, above, to quantify the relative concentration of particles along pathways. Potential automated metrics for particle density along pathways include histogram maxima, the size of histogram maxima, and the slope of the curve relating the value of the confidence contour and the area enclosed by that contour.

Legal implications and requirements

Since ATLAS is funded by the European Union, Parallel Works should not draw profit from the ATLAS work. This project is a test case to potentially showcase Parallel Works' ability to contribute to scientific research and all outputs will remain open access as required by the European Commission. Furthermore, to allow for qualifying the impact of this project, external communications about this project made by ATLAS or Parallel Works will be shared with the other. The ATLAS Principal Investigators request that if Parallel Works want to use results from this collaboration they should check with the ATLAS project office.

The input data to this calculation, output from the VIKING20 model run by GEOMAR, is subject to a contract that requires non-distribution of the data without GEOMAR's permission.

The particle tracking software ARIANE is distributed under the open source CeCILL license, which would allow ARIANE to be used for this collaboration. In particular, the modified ARIANE version used here, if redistributed, must stay open source.

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