Processed data from Particle Imaging Velocimetry (PIV) observations of Tritia trivittata and Tritia obsoleta behavior in various flow tanks

Website: https://www.bco-dmo.org/dataset/739790
Version: 1
Version Date: 2018-07-12

Project
» Relative Influence of Turbulence and Waves on Larval Behavior (Turbulence and Larval Behavior)

Contributors	Affiliation	Role
Fuchs, Heidi L.	Rutgers University	Principal Investigator, Contact
Christman, Adam J.	Rutgers University	Co-Principal Investigator
Gerbi, Gregory P.	Skidmore College	Co-Principal Investigator
Hunter, Elias J.	Rutgers University	Co-Principal Investigator
Rauch, Shannon	Woods Hole Oceanographic Institution (WHOI BCO-DMO)	BCO-DMO Data Manager

Abstract
Dispersing marine larvae can alter their physical transport by swimming vertically or sinking in response to environmental signals. However, it remains unknown whether any signals could enable larvae to navigate over large scales. We tested whether flow-induced larval behaviors vary with adults' physical environments using congeneric snail larvae from the wavy continental shelf (Tritia trivittata) and from turbulent inlets (Tritia obsoleta). This dataset includes observations of larvae in turbulence, in rotating flows dominated by vorticity or strain rates, and in rectilinear wave oscillations. Larval and water motion were observed using near-infrared particle image velocimetry (IR PIV), and analyses identified threshold signals causing larvae to change their direction or magnitude of propulsive force. The two species reacted similarly to turbulence but differently to waves, and their transport patterns would diverge in wavy, offshore regions. Wave-induced behaviors provide evidence that larvae may detect waves as both motions and sounds useful in navigation.

Table of Contents

Coverage

Spatial Extent: **Lat**:40.479535 **Lon**:-74.437189
Temporal Extent: 2012-06-21 - 2014-07-10

Dataset Description

These data are published in:
Fuchs, H.L., Gerbi, G.P, Hunter, E.J., & Christman, A.J. (2018, in press). Waves cue distinct behaviors and differentiate transport of congeneric snail larvae from sheltered versus wavy habitats. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1804558115

The dataset includes processed data from Particle Imaging Velocimetry (PIV) observations of *Tritia trivittata* and *Tritia obsoleta*. For each experiment, replicates are pooled, and instantaneous observations from larval trajectories are condensed into tabular format. Data were collected from 21 June, 2012 to 10 July, 2014 at Rutgers' Department of Marine and Coastal Sciences.

Methods & Sampling

Larvae were observed in grid-stirred turbulence and in three devices producing simpler flows dominated by strain, vorticity, or acceleration. The three simpler flow devices were operated either vertically or horizontally. In each device, multiple forcing frequencies were used so that larvae experienced a broad range of physical signals with intensities representative of most ocean regions.

In each device, larvae were gently added along with 105 cells mL-1 algae (~18 µm preserved *Thalassiosira weissflogii*; Reed Mariculture) used as flow tracers. Movements of larvae and flow were measured simultaneously using 2-dimensional (2D), infrared particle-image velocimetry (PIV). The PIV system consisted of a 4 megapixel CCD camera (FlowSense, Dantec Dynamics) with a 100 mm lens (Tokina) and a pulsed diode laser (NanoPower 4W or 7W, 808 nm) with a ~2 mm beam width. Image sizes and locations varied among flow tanks (Fig. S1, Fuchs et al. 2018). After an initial 10-20 min acclimation period, larvae were observed in still water for 5 min, and then four or five flow treatments were applied in random order with ≥10 min of no oscillation between successive treatments. Each treatment included a 10 min spin-up period for the flow to become stationary (statistically invariant in time) followed by 5—20 min of recording.

Data Processing Description

Data were processed using DynamicStudio (v.4.10, Dantec) and Matlab (2011b through 2016b, Mathworks). Fluid and larvae move in different directions, so we first separated the PIV images of particles and larvae using techniques for 2-phase flow. Fluid velocities were computed from the particle images with larvae masked out, and larval translational velocities were calculated from larval trajectories. Fluid motion and larval translation differ due to swimming or sinking movement relative to flow outside the larval boundary layer. In the vertical (*z*) dimension, *w*b=*w*o-*w*f, where *w*b is the instantaneous behavioral velocity, *w*f is the instantaneous flow velocity, and *w*o is the instantaneous translational (observed) velocity of an individual larva. The horizontal behavioral velocities were computed similarly for *u*b in the *x* dimension. Trajectories had mean durations of ~2 s in the weakest flow conditions down to ~0.1 s in the strongest flow conditions and were too short to analyze behavioral changes over time.

We used the PIV data to analyze larval swimming mechanics as a response to the instantaneous flow environments around individual larvae (Fuchs et al. 2013, 2015a, 2015b). The relevant hydrodynamic signals are the dissipation rate ε, strain rate γ, horizontal component of vorticity ξ, and fluid acceleration α. We calculated 2D approximations of these signals from fluid velocities and their gradients, interpolated in space and time to the larval observations.

Approximations for ε varied among flow tanks (Fuchs et al. 2013, 2015b). We also calculated the instantaneous fluid forces on individual larvae. The product of larval mass and acceleration is balanced by a vector sum of forces, including gravity, buoyancy, drag, Basset history forces, fluid acceleration, and the force that larvae exert to propel themselves (see Appendix of Fuchs et al. 2015b). Assuming larvae to be spherical, we computed all terms except propulsive force from measured velocities, larval size, and density (Fuchs et al. 2013), then solved the force balance equation for the propulsive force vector Fv, which indicates the magnitude and Cartesian direction of larval swimming effort. The propulsion direction was corrected to larval coordinates by estimating the vorticity-induced larval tilt angle ϕ (Fuchs 2013), and larvae were classified as "swimming" or "sinking/diving" if their propulsive force was directed upward (velum direction) or downward (shell direction), respectively, relative to the body axis.

[table of contents | back to top]

Data Files

File
PIV_snail_larvae.csv (Comma Separated Values (.csv), 61.56 MB) MD5:b17b9ea3986996aebc3575d5ed7fa54f Primary data file for dataset ID 739790

[table of contents | back to top]

Related Publications

Fuchs, H. L., Christman, A. J., Gerbi, G. P., Hunter, E. J., & Diez, F. J. (2015). Directional flow sensing by passively stable larvae. Journal of Experimental Biology, 218(17), 2782–2792. doi:10.1242/jeb.125096
Methods

Fuchs, H. L., Gerbi, G. P., Hunter, E. J., & Christman, A. J. (2018). Waves cue distinct behaviors and differentiate transport of congeneric snail larvae from sheltered versus wavy habitats. Proceedings of the National Academy of Sciences, 115(32). https://doi.org/10.1073/pnas.1804558115
Results

Fuchs, H. L., Gerbi, G. P., Hunter, E. J., Christman, A. J., & Diez, F. J. (2015). Hydrodynamic sensing and behavior by oyster larvae in turbulence and waves. Journal of Experimental Biology, 218(9), 1419–1432. doi:10.1242/jeb.118562
Methods

[table of contents | back to top]

Parameters

Parameter	Description	Units
file_name	Original name of csv file	unitless
larval_stage	Larval stage: Precomp = precompetent larvae; Comp = competent larvae	unitless
species	Name of species: T_trivittata = Tritia trivittata; T_obsoleta = Tritia obsoleta	unitless
flow_tank	Type of flow tank: turb = grid-stirred turbulence tank; couette = Couette device; rotate = rotating cylinder; accel = shaker flask	unitless
direction	Direction (axis of rotation for Couette device and rotating cylinder, direction of oscillation for shaker flask): H = horizontal; V: vertical	unitless
x	x	centimeters (cm)
z	y	centimeters (cm)
uf	uf	centimeters per second (cm/s)
wf	wf	centimeters per second (cm/s)
ub	ub	centimeters per second (cm/s)
wb	wb	centimeters per second (cm/s)
larval_axial_rotation_ang	Larval axial rotation angle	radians
larval_propulsive_force	Larval propulsive force magnitude	N
propulsion_direction	Propulsion direction relative to larval axis	radians
dissipation_rate	Dissipation rate at larval location	m^2 s^-3
horizontal_comp_of_vorticity	horizontal component of vorticity at larval location	s^-1
acceleration	acceleration at larval location	meters per second (m s^-2)
strain_rate	strain rate at larval location	s^-1

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	near-infrared (IR) particle image velocimeter (IR PIV)
Generic Instrument Name	Particle Image Velocimetry (PIV) system
Dataset-specific Description	Larval behavior and flow were observed simultaneously using near-infrared (IR) particle image velocimeter (IR PIV). The PIV system consisted of a 4 megapixel CCD camera (FlowSense, Dantec Dynamics) with a 100 mm lens (Tokina) and a pulsed diode laser (NanoPower 4W or 7W, 808 nm) with a ~2 mm beam width.
Generic Instrument Description	Measures 2D velocity flow fields, usually by scanning particles with a laser beam and capturing images of the illuminated particles.

[table of contents | back to top]

Project Information

Relative Influence of Turbulence and Waves on Larval Behavior (Turbulence and Larval Behavior)

Website:
http://marine.rutgers.edu/~hfuchs/Rutgers_site/Research/Entries/2010/12/17_Larval_responses_to_turbulence_and_waves.html

Coverage: Coastal New Jersey

This study will investigate how snail larvae from distinct habitats respond to fluid mechanical cues in turbulence and surface gravity waves. Turbulence and waves are common features of coastal flows and may provide larvae with behavior cues that aid transport toward specific flow regimes or habitats. Turbulence induces some mollusk larvae to sink more frequently, but the detection mechanism and the response to waves are unknown. Larvae may sense spatial velocity gradients (strain rate and vorticity) or acceleration. Larvalscale flows are affected differently by turbulence and waves, because turbulence can generate larger strain rates and vorticity but waves can generate larger accelerations. Larvae that sense multiple flow characteristics may be able to distinguish between turbulence-dominated coastal embayments and wave-dominated regions of the continental shelf. In this study, larval behaviors will be quantified in several devices that generate steady strain rates and vorticity, simple acceleration, homogeneous turbulence, and complex flow with turbulence plus waves. Data will be used to develop stochastic models of larval behavior as a function of hydrodynamics and to test hypotheses about ecological and size-based controls on behavior.

The proposed research addresses several fundamental aspects of larval behavior and the ecological impacts of turbulence and waves:

- **Novel approaches for insights on behavioral signaling:** Two-phase infrared particle-image velocimetry techniques will be applied in multiple flow tanks to study effects of both turbulence and waves at the larval scale. Statistical protocols will be developed for converting behavior observations into empirical models, laying the groundwork for careful integration of more complex behaviors with physical circulation models. Results will identify the key fluid characteristics affecting behavior in species from intertidal and shelf habitats.
- **Impact of waves on behavior:** Many habitats are influenced or even dominated by waves, yet the potential for waves to provide a larval behavioral signal is unexplored. To our knowledge, this will be the first study of how larvae respond to the large accelerations present only in waves.
- **Role of behavior in dispersal:** Benthic recruitment variability arises partly from vagaries of dispersal that result from larval responses to the physical environment. Turbulence and waves vary spatially and also temporally due to stratification, water depth, tides, and winds. Small-scale symptoms of turbulence and waves could elicit larval behaviors that contribute to differences in dispersal trajectories. This study will describe larval responses to hydromechanical cues that ultimately could explain considerable uncertainty in dispersal and recruitment.
- **Adaptation to physical environments:** Shears and acceleration are potential behavior signals that could be enhanced or dampened by human impacts such as boating, shoreline modification, or increased storms. If behaviors are tuned to specific flow regimes, larvae may have difficulty adapting to changing marine environments. This work will be instrumental in assessing the potential ecological impacts of changing physical processes on larval behavior and dispersal.

In addition to the data contributed to BCO-DMO, addtional data resources include:

1. Particle image velocimetry data: Metadata for digital image data will be archived on the project web page hosted by Rutgers Institute of Marine and Coastal Sciences. Image data will be made available on request after publication of results. The Rutgers library system is implementing a data archiving system, and project metadata will also be stored on that system when it becomes available.

2. Biological Data: Adult snails will be collected from the intertidal zone and from the continental shelf offshore of Tuckerton, New Jersey. Shelf samples will be collected by beam trawling from the R/V Arabella. Two 1-day cruises will be scheduled in 2012 or later. Snails will be cultured and used for spawning stock to produce larvae. Type specimens of all snails collected will be preserved in ethanol and stored at Rutgers. Metadata for snail collections will be posted on the project web page.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1060622

[table of contents | back to top]