Experimental results on sand dollar larvae variation in turbulence response from Bodega Marine Lab in 2014 (Turbulence-spurred settlement project)

Website: https://www.bco-dmo.org/dataset/640454
Data Type: experimental
Version: 2016-03-14

Project
» Turbulence-spurred settlement: Deciphering a newly recognized class of larval response (Turbulence-spurred settlement)

Contributors	Affiliation	Role
Gaylord, Brian	University of California-Davis (UC Davis-BML)	Principal Investigator
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Table of Contents

Dataset Description

The same data were used for Hodin (2015) Royal Society Open Science, Figs 4, 5, 6.

Figure 4. Sand dollar larvae show substantial batch-to-batch variation in the turbulence response across ontogeny. (a) Larval batch A, fertilized 27 May 2014. (b) Larval batch B, fertilized 28 May 2014. Each of the data points in (a) and (b) are results from single runs of 25 larvae, with the exception of the day 9 batch A data, which we replicated once (data points on day 9 in (a) show the mean of the two runs; error bars are s.e.m). (c) Larval batch C, fertilized 22 August 2014. Each of these data points aremeans of four runs at each speed with 20–25 larvae each; error bars are s.e.m. Note that in (a–c), we do not indicate the error along the x-axis in each of the Taylor–Couette cell rotation rates that we employed, which we estimate to be approximately±25 r.p.m. Each graph shows the energy dissipation rates (in W kg−1) on the lower x-axis, and the corresponding rotation rates (spin speeds in r.p.m.) along the upper x-axis. We only tested day 7 larvae from batch A and day 10 larvae from batches A and B.

Figure 5. Precompetent sand dollar larvae showincreasing responsiveness to turbulence as ontogeny proceeds. Shown are themaximal proportion of larvae in each of our three batches (A, B and C; figure 4) that settled on a given daywith the background level of settlement in that batch subtracted out (thus excluding larvae that were nominally competent); error bars are s.e.m. (note that the data from batch A days 10 and 11 and batch B days 9, 10 and 11 were unreplicated, thus show no error bars). This analysis reveals a marked and steady increase in the proportion of nominally precompetent larvae that responded to turbulence as ontogeny proceeds. The estimated slope (±s.e.m.) for the regression is 0.24 (±0.07) maximum proportion settled per age (unpaired t-test: $t_{7.9} = 3.25$, $p<0.02$), and the estimated intercept (±s.e.m.) is−1.90 (±0.74; $t_{7.9}=-2.56$, $p<0.04$).

Figure 6. Precompetent sand dollar larvae show evidence of increasing sensitivity to turbulence as ontogeny proceeds. (a) Shown are the best-fit curves (solid curves)±95% CIs (dashed curves) generated by our best-supported general mixed linear model (see Material and methods for details and comparisons with other models). The lines and symbols (batch A, squares; batch B, circles; batch C, crosses) show the data from day 9 (black) and day 11 (grey). Error bars are s.e.m (note that the data from batch A day 11 and batch B days 9 and 11 were unreplicated, thus show no error bars). The inflection points of the best-fit curves for day 9 (black arrow) and day 11 (grey arrow) are shown along the x-axis and indicated by the black and grey vertical dotted lines, respectively. The shaded areas within the day 9 and day 11 CI curves indicate the range of 95% CIs in our respective inflection point estimates based upon 10 000 non-parametric bootstrap samples. (b) The range of inflection point estimates (and 8.5% overlap) from these bootstrap samples on days 9 and 11. Arrows as in (a).

Note that the y-axis units of density are linearly related to the proportion of bootstrap samples showing a given range of inflection point estimates.

Related Reference:
Hodin J, Ferner MC, Ng G, Lowe CJ, Gaylord B. 2015. Rethinking competence in marine life cycles: ontogenetic changes in the settlement response of sand dollar larvae exposed to turbulence. Royal Society Open Science. 2: 150114. doi: 10.1098/rsos.150114.

Related Datasets:
Turbulence settlement: fig.3
Turbulence settlement: fig.4-6_Batches A & B
Turbulence settlement: fig.6b
Turbulence settlement: fig.7
Turbulence settlement: fig.8
Turbulence settlement: fig.8 bootstrap

Data Processing Description

BCO-DMO Processing:

- added conventional header with dataset name, PI name, version date, reference information
- renamed parameters to BCO-DMO standard
- replaced blank cells with NA ('not applicable')

[table of contents | back to top]

Data Files

File
fig4-6_batch-c.csv(Comma Separated Values (.csv), 2.20 KB) MD5:dbcb6f6819cf69dd949d11fbcb5f07d2 Primary data file for dataset ID 640454

[table of contents | back to top]

Parameters

Parameter	Description	Units
day_develop	age of larvae post-fertilization	days
run	run	unitless
treatment	rotation speed applied to larvae	rotations per minute
replicate	replicate	unitless
min_before_KCl	time before KCl exposure	minutes
num_in_couette	number of larvae in couette	larvae
mins_KCl_exp	duration of KCl exposure	minutes
num_in_KCl	number of larvae in KCl	larvae
recovery_rate	recovery rate (# in KCl / # in couette)	unitless
num_settled_1hr	number of larvae settled in 1 hr	larvae
num_partial_1hr	number of larvae partially settled in 1hr	larvae
num_settled_24hr	number of larvae settled in 24 hr	larvae
proprtn_settled	proportion of larvae settlement (# settled in 24 hr / # in KCl)	unitless
proprtn_settled_tmt	mean proportion of larvae settlement in each treatment	unitless
proprtn_settled_tmt_stderr	standard error of the mean proportion of larvae settlement in each treatment	unitless

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	
Generic Instrument Name	Taylor-Couette system
Dataset-specific Description	To generate turbulence intensities (quantified in terms of the energy dissipation rate, in units ofWkg−1) ranging from those found in open ocean waters to those arising on wave-battered coasts, we employed a Taylor–Couette cell [29], an apparatus composed of two vertically oriented, coaxial cylinders separated by a 3.5mm gap that contains seawater (described in greater detail in [1]). We held the stationary inner cylinder, and thus the water in the gap, at 19–21◦C by means of a circulating water stream from a temperature-controlled water bath passing through the cylinder's interior. During operation, the outer cylinder rotated at a prescribed speed causing relative motion between the cylinders and thereby shearing the seawater between them. At rotation speeds employed for testing sand dollar larvae, the sheared flow was turbulent [1]. [1]Gaylord B, Hodin J, Ferner MC. 2013 Turbulent shear spurs settlement in larval sea urchins. Proc. Natl Acad. Sci. USA 110, 6901–6906. (doi:10.1073/pnas. 1220680110)
Generic Instrument Description	An apparatus composed of two vertically oriented, coaxial cylinders separated by a gap that contains seawater. During operation, the outer cylinder rotates at a prescribed speed causing relative motion between the cylinders and thereby shearing the seawater between them.

[table of contents | back to top]

Deployments

Gaylord_Turb-Settlement

Website	https://www.bco-dmo.org/deployment/640417
Platform	lab Bodega Marine Laboratory
Start Date	2014-06-01
End Date	2014-08-31
Description	sand dollar settlement studies

[table of contents | back to top]

Project Information

Turbulence-spurred settlement: Deciphering a newly recognized class of larval response (Turbulence-spurred settlement)

Coverage: Northeast Pacific

Description from NSF award abstract:
With this award the investigators will explore a habitat-scale oceanographic process that has the potential to integrate studies of larval delivery with an understanding of how larvae respond to substrate-associated cues. This work will build on published and preliminary data indicating that turbulent shear characteristic of high-energy near shore environments primes larvae to initiate settlement and to transform into the juvenile stage. These prior findings suggest that: 1) Because turbulence intensity varies predictably as a function of the strength of wave breaking and other factors, turbulence could operate as an indicator for larvae of their approach to suitable habitat, providing a link between larger-scale dispersal phenomena, and near-bottom search and selection behaviors; and 2) The larval response to turbulence acts in an unprecedented fashion. In contrast to typical cues, turbulence does not induce settlement directly, but rather spurs otherwise "pre-competent" larvae that are refractory to chemical cues to become "competent", thereby causing them to acquire responsiveness to such cues and undergo settlement. The interdisciplinary team has combined expertise in larval biology, sensory ecology, and organism-flow interactions necessary to address this topic. They will employ a phylogenetically robust approach to explore the scope and adaptive significance of the turbulence response in a widespread and ecologically important class of organisms (echinoids; sea urchins and their relatives), and will determine whether the response is aligned with environmental conditions characteristic of these organisms' adult habitat. They will also test for ecologically important functional consequences of precocious, turbulence-induced settlement. This work will provide a detailed look at an entirely new class of settlement inducer, one with strong potential for changing current conceptualizations of dispersing larval stages, their ability to detect signatures of habitat across multiple scales, and the ways in which organism-level traits might influence population connectivity.

How organisms with dispersing life stages find their way back to adult habitat is a fundamental question in marine ecology. Considerable research has explored links between transport, delivery, settlement, and recruitment, with important advances in knowledge. However, a complete understanding of the larval recruitment process remains elusive. Standard tools for estimating dispersal (e.g., numerical circulation models) have limited spatial resolution, which prevents them from predicting at scales below a few hundred meters how larvae will interact with the shore. Studies investigating larval attachment have focused on chemical, tactile, or near-bottom hydrodynamic cues active across microns to centimeters. The novelty of the present project is that it will focus on processes at habitat scales -- between transport and settlement -- where there is a gap in the understanding of processes.

This project will provide a framework for integrating key concepts of propagule dispersal and settlement, two fundamental but largely disjunct themes in marine science. The understanding that will come from this study will provide key information for ecosystem based management of coastal marine resources. The investigators will develop a "Surfing to Settlement" virtual lab activity based on their research that will be incorporated into the VirtualUrchin web platform, a widely exploited educational resource at Stanford that gets thousands of unique users per month. Through connections to the San Francisco Bay National Estuarine Research Reserve, they will integrate the "Surfing to Settlement" activity into one of NERRs professional development workshops for central California educators, thus disseminating this resource to and gaining valuable feedback from dozens of teachers and thousands of students.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1356966
NSF Division of Ocean Sciences (NSF OCE)	OCE-1357033
NSF Division of Ocean Sciences (NSF OCE)	OCE-1357077

[table of contents | back to top]