Images, porewater pressure, O2 data from lab experiments of lugworm Arenicola marina in different sediment types; conducted at Wadden Sea Station Sylt, Germany in 2007 (Infaunal Hydraulics project)

Website: https://www.bco-dmo.org/dataset/3950
Version: 1
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Project
» Linking infaunal hydraulic activities, porewater flow and biogeochemical processes in marine sediments (Infaunal Hydraulics)

Contributors	Affiliation	Role
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Dataset Description

This dataset includes results from experiments investigating the hydraulic activities of the lugworm, *Arenicola marina*, in different sediment types. Porewater pressure sensing, time-lapse photography, and planar optode imaging methods were used. MP4 movies and NetCDF files are avialable for download. Each file contains 7.5 h of porewater pressure data and nikon images or oxygen planar optode images.

Quick-look files are MP4 movies (with H264 codec) that incorporate simultaneous visible light and optode imagery and pressure records. The movie files provide a "quick look" of what exactly can be found in the NetCDF files.

Netcdf optode files include optode imagery as time-resolved matrices, and a time series of pressure records. Oxygen images are matrices of percent air saturation values. All times are in unix format (seconds since 1970-01-01). Data are in 2.5 hour blocks.

Netcdf Nikon files include visible light imagery as time-resolved matrices and a time series pressure records. Nikon images are matrices of 24 bit RGB values. All times are in unix format (seconds since 1970-01-01). Data are in 2.5 hour blocks.

Methods & Sampling

Experimental set-up and sediment characteristics:
internal tank dimensions: 40 cm wide, 30 cm high, 1.2 cm deep,

30 cm x 20 cm sediment,
3 cm overlying water,
overlying water flow rate: 10 mL min-1
pressure sensors: 15 deep in the sediment in the center of aquarium, for dataset 070601 data from 3 pressure sensors are provided (all 15 cm deep).

Experiments were conducted at the Alfred Wegener Institute for Polar and Marine Research in the Helmholtz Association, Wadden Sea Station Sylt, Hafenstrasse 43, 25992 List, Germany.

Planar Optode Imaging:
The lifetime imaging system is modified after Holst and Grunwald (2001). It comprises a cooled CCD camera (pco.1600MOD, PCO AG, Donaupark 11, 93309 Kelheim, Germany), a pulse delay generator (T560, Highland Technology, 18 Otis St, San Francisco CA), an array of blue-light emitting diodes (LEDs; lambda max = 455 nm, LXHL-LR5C, Philips Lumileds, 370 W Trimble Rd, San Jose, CA) attached to a heat sink (~5×5×2.5 cm), and a custom-made power supply. The camera accumulates multiple exposures with a programmable modulation time. By using the output of the exposure synchronization of the camera as a trigger for the pulse delay generator and subsequently the LED light pulse, any jitter between the camera exposure time and the preceding light flash can be avoided. The timing parameters is chosen as follows. After the LED pulse of 20 µs duration and a given delay, delta, the electronic shutter for camera exposure opens for D = 10 µs. The delays of delta_1 = 1 µs and delta_2 = 11 µs are applied for the accumulation of the first (I1) and second (I2) intensity window images (gates), respectively, which are acquired sequentially. Summing up all times to 41 µs for the longest delay reveals the minimum time interval for the accumulations of single exposures. Typically an interval of 44 µs is chosen, corresponding to a repetition rate of almost 23 kHz. Using the first and second intensity window images, the luminescence lifetime image is calculated as t = D/ln(I1/I2) (Holst and Grunwald 2001). The peak current through the LEDs (typically 200–300 mA) and the integration time during which both intensity windows are accumulated (typically 250–1000 ms) are adjusted to optimize image quality. The control of the camera and image acquisition through the IEEE 1394 (firewire) interface, and of the delay pulse generator through the RS232 (serial) interface, are done by a laptop computer using software developed by Lubos Polercky (Microsensors Group, Max Planck Institute for Marine Microbiology, Bremen, 28359, Germany) and Uli Henne (German Aerospace Center, Institute of Aerodynamics and Flow Technology, Göttingen, 37073, Germany) in Borland Delphi and C++. Optodes were calibrated using the lifetime values measured in the anoxic sediment and in the air-saturated overlying water. For details see Matsui, GY et al. 2011.

Porewater Pressure Sensing:
The differential pressure sensors (Honeywell 27PC) are piezoresistive bridges that provide a differential voltage proportional to the pressure difference between the 2 sides of the sensor. While one side of the sensor is indirect contact with the sediment porewater (gage pressure), the ambient (hydrostatic) pressure isdetected within a water-filled space within the PVC channels (plenum) that is in direct contact with the overlying water and isolated from the porewater. Data are typically collected at 200 Hz using autonomous 8-channel 16-bit data loggers (CF2, Persistor Instruments, 153-A Lovells Lane, Marston Mills MA). Amplifiers on the boards allow adjustment of the dynamic range of the sensors. Sensors are calibrated by varying the water heights on both sides of the sensors, i.e. the plenum and sediment side. Twelve positive and negative pressures are typically applied to each sensor, and the linear calibration between the gauge pressure and measured voltage has typically R2 > 0.95. The 200 Hz raw data are downscaled to 1Hz by taking the median of all values in each 1-second interval. The median of each 60 minute block was calculated, and linearly interpolated values of this median time series was subtracted from each 1Hz data value to remove long term drift from the signals.

Time-lapse photography:
Images of the tanks are taken with digital SLR cameras (Nikon D200 and D300) using flash, triggered by time-lapse controllers (Digi-Snap, Harbortronics) or by a digital delay generator (T560 Highland Technology). Images are typically taken at 15 to 30 s intervals.

Related files and references:
Optode system:
Matsui, GY, N Volkenborn, L Polerecky, U Henne, DS Wethey, CR Lovell, SA Woodin. 2011. Mechanical imitation of bidirectional bioadvection in aquatic sediments. Limnology and Oceanography: Methods 9: 84-96. DOI: [10.4319/lom.2011.9.84](10.4319/lom.2011.9.84)

These data are related to Figures 2 and 4 in the following paper:
Volkenborn N., Polerecky L., Wethey D.S, Woodin S.A (2010) Oscillatory porewater bioadvection in marine sediments induced by hydraulic activities of Arenicola marina. Limnology and Oceanography 55(3), 2010, 1231–1247. DOI: [10.4319/lo.2010.55.3.1231](10.4319/lo.2010.55.3.1231)

Data Processing Description

Data Processing:
Programs in R statistics language that were used to make the netcdf files:
parms_070520_Sylt_h1_ch2_arenicola.r
parms_070522_Sylt_h1_ch2_arenicola.r
parms_070524_Sylt_h1_ch2_arenicola.r
parms_070525_Sylt_h1_ch2_arenicola.r
parms_070530_Sylt_h1_ch2_arenicola.r
parms_070601_Sylt_h1_ch2_arenicola.r
plot_optode_nikon_pressure_2_ncdf_avi_readparms_070520_arenicola.r
plot_optode_nikon_pressure_2_ncdf_avi_readparms_070522_arenicola.r
plot_optode_nikon_pressure_2_ncdf_avi_readparms_070524_arenicola.r
plot_optode_nikon_pressure_2_ncdf_avi_readparms_070525_arenicola.r
plot_optode_nikon_pressure_2_ncdf_avi_readparms_070530_arenicola.r
plot_optode_nikon_pressure_2_ncdf_avi_readparms_070601_arenicola.r

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Data Files

File
arenicola_hydraulics.csv (Comma Separated Values (.csv), 9.70 KB) MD5:59ecb314d9f7797a639572af1c006ec6

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Parameters

Parameter	Description	Units
species	Name of the species.	text
date	Date of the experiment.	mmddYYYY
weight	Weight of the worm, in grams.	grams
press_sensor	Identification of the pressure sensor.	text
sediment_permeability	Permeability of the sediment in the experimental tank (m^2).	meters squared
sediment_porosity	Sediment porosity.	volume fraction
tot_org_matter	% weight total organic matter.	% weight
O2_consump_rate	O2 consumption rate (umol cm-3 h-1).	micromoles per cubic centimeter per hour

movie_url	URL	unitless
movie_text	text of the link	unitless
movie	Link to the movie (mp4) file. Movies provide a "quick look" of what is in the NetCDF files, incorporating simultaneous visible light and optode imagery and pressure records. The vertical red line marks the time point in the 20 min pressure record that corresponds to the images.	dimensionless
nikon_NetCDF_files_url	URL	unitless
nikon_NetCDF_files_text	text of the link	unitless
nikon_NetCDF_files	Link to the Nikon NetCDF files (.zip). Nikon NetCDF files include visible light imagery as time-resolved matrices, and a time series of pressure records. 10 hour time series were split in four 2.5 h blocks. Nikon images are matrices of 24 bit RGB values. All times are in unix format (seconds since 1970-01-01).	dimensionless
O2_NetCDF_files_url	URL	unitless
O2_NetCDF_files_text	text of the link	unitless
O2_NetCDF_files	Link to the NetCDF optode files, which include optode imagery as time-resolved matrices, and a time series of pressure records. Oxygen images are matrices of percent air saturation values. 10 hour time series were split in four 2.5 hour blocks. All times are in unix format (seconds since 1970-01-01).	dimensionless
R_files_url	URL	unitless
R_files_text	text of the link	unitless
R_files	Link to R files, which show how the NetCDF files were created.	dimensionless

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Instruments

Dataset-specific Instrument Name	Camera
Generic Instrument Name	Camera
Dataset-specific Description	Images of the tanks are taken with digital SLR cameras (Nikon D200 and D300) using flash, triggered by time-lapse controllers (Digi-Snap, Harbortronics) or by a digital delay generator (T560 Highland Technology).
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

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Deployments

lab_AWI_Wadden_2007

Website	https://www.bco-dmo.org/deployment/59036
Platform	Wadden Sea Station Sylt
Start Date	2007-05-20
End Date	2007-06-12
Description	Experiments were conducted at the Alfred Wegener Institute for Polar and Marine Research in the Helmholtz Association, Wadden Sea Station Sylt, Hafenstrasse 43, 25992 List, Germany for the project, "Linking infaunal hydraulic activities, porewater flow and biogeochemical processes in marine sediments" during May and June 2007.

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Project Information

Linking infaunal hydraulic activities, porewater flow and biogeochemical processes in marine sediments (Infaunal Hydraulics)

Coverage: Friday Harbor, Washington; Newport, Oregon; Georgetown, South Carolina; Manukau Harbour, Tauranga Harbour, North Island, New Zealand; Sylt, Germany; Tvarminne, Finland

This research project is funded under the American Recovery and Reinvestment Act (ARRA) of 2009 (Public Law 111-5). In addition to being funded as part of the NSF Biological and Chemical Oceanography programs, the research is also related to the Ocean Drilling Program (ODP) and the Integrative Computing Education and Research (ICER) initiative.

Most of the oceanic seafloor is pervaded by burrows and tubes of infauna. Activities of these animals, such as burrowing, feeding, and defecation, are of fundamental importance to biogeochemical processes as these activities are associated with movement of sediment porewater. These bio-advective processes increase benthic-pelagic coupling and microbial activity, but the underlying mechanisms by which infaunal activities drive biogeochemical cycling through bio-advection are very poorly understood. Recent work has demonstrated that bio-advection is the result of behavior specific, hydraulically generated pressure fields with changing directions and radial extent from the burrow of 50 cm or more. These results force a re-evaluation of sediments as habitats with transient conditions predominant to the depth of biotic activity. This project addresses (a) which types of infauna contribute significantly to these bio-advective processes, (b) what behaviors generate porewater fluxes, how frequently and under what conditions, (c) what is the impact on oxygen availability within the sediment and how transient is this availability, (d) what is the impact on biogeochemical rates and microbial community structure, and (e) what are the direct effects and feedbacks on biological processes, such as primary productivity and recruitment?

The general goals are to determine the influence of large, numerically dominant polychaetes, bivalves, and crustaceans on bio-advective porewater flow and its consequences for biogeochemical cycling and feedbacks on the benthic community. First, using a combination of field and laboratory measurements, the research will analyze the diversity of hydraulic activities by important large infauna to determine which types of infauna contribute most significantly to these bio-advective processes and what behaviors are the most important to porewater flux. Second, laboratory experiments will link species-specific hydraulic activities to chemocline dynamics using live animals and biomimetic 'robolugs' to produce controlled porewater flows. For selected hydraulic behaviors the impact on microbial activity and diversity will be analyzed. Finally, feedback mechanisms on benthic communities in habitats that they partly create will be analyzed using a combination of large laboratory aquaria and field deployed robolugs.

This research challenges the traditional view that most sediments are primarily steady-state, diffusion-dominated systems. The research will be transformative to the fields of benthic ecology, microbial ecology, and biogeochemistry as it makes obvious the central role played by infaunal animals in driving changes in the chemical and physical properties of sediments.

Publications resulting from this research:

Woodin, SA; Wethey, DS; Volkenborn, N. "Infaunal Hydraulic Ecosystem Engineers: Cast of Characters and Impacts," INTEGRATIVE AND COMPARATIVE BIOLOGY, v.50, 2010, p. 176. DOI: 10.1093/icb/icq031

Volkenborn, N; Polerecky, L; Wethey, DS; Woodin, SA. "Oscillatory porewater bioadvection in marine sediments induced by hydraulic activities of Arenicola marina," LIMNOLOGY AND OCEANOGRAPHY, v.55, 2010, p. 1231. DOI: 10.4319/lo.2010.55.3.1231

Matsui G; Volkenborn N; Polerecky L; Henne U; Wethey D; Lovell CR; Woodin SA.. "Mechanical imitation of bidirectional bioadvection in aquatic sediments.," Limnology and Oceanography Methods, v.9, 2011, p. 84. DOI: 10.4319/lom.2011.9.84

Volkenborn, N, L Polerecky, DS Wethey, TH DeWitt, SA Woodin. "Oxic-anoxic oscillations around complex burrow structures caused by hydraulic activities of the ghost shrimp Neotrypaea californiensis.," Marine Ecology Progress Series, v.455, 2012, p. 141. DOI: 10.3354/meps09645

Woodin, SA, DS Wethey, JE Hewitt, SF Thrush. "Small scale terrestrial clay deposits on intertidal sand flats: behavioral changes and productivity reduction.," Journal of Experimental Marine Biology and Ecology, v.413, 2012, p. 184. DOI: 10.1016/j.jembe.2011.12.010

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-0928002

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