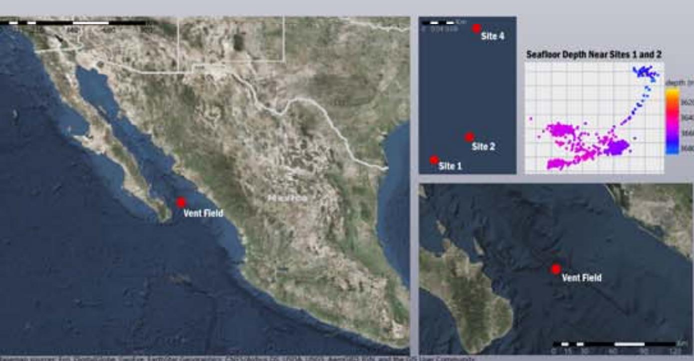
Under Pressure: Ecology at Hydrothermal Vents



Background

Thousands of meters below the surface, far below the reach of sunlight, it is dark, and cold, and crushing. It is not all, however, cold. When seawater seeps through the crust at fissures or thin spots in the Earth's crust, it may be heated by the magma below and rise upward again, emerging at locations called hydrothermal vents. The water issuing from these vents can be over 400°C, and rich in sulfides, organics, and other compounds. The unique chemistry around vents allows chemosynthetic organisms to thrive, which in turn act as a food source for other organisms, providing the basis of a unique food web in a seemingly-inhospitable environment. First discovered in 1977 (Woods Hole Oceanographic Institution, n.d.), hydrothermal vents and their associated fauna are still deeply mysterious.

Data Source

Data were collected October 31, 2017 through November 6, 2017 by researchers from WHOI, MBARI and Universidad Nacional Autónoma de México in the Pescadero Basin in the Gulf of California, Mexico. Measurements and samples were collected from seven sites across the vent field; WHOI data from three of those sites is analyzed here. Sites were identified visually using video feed from the ROV Hercules.

Chemical and temperature measurements were taken at locations of high fluid flow ("bullseye") and approximately 0.50 meters away from the high flow ("away"). Ten minute subsamples of those chemical and temperature data are represented here. Biological samples were also taken at the "bullseye" and "away" locations; both locations were sampled with a suction tube, and the bullseye site was also sampled by "scooping" some of the fauna and sediment by the fluid flow. Biological samples were filtered by size, and sorted by morphology. As samples were subsampled between agencies, the data hererepresent approximate totals for the full biological sample.

Method

Site locations were determined by averaging latitude and longitude for the time period the ROV was at the site, which was determined from video footage. Due to the depth of the vehicle and the method of determining latitude and longitude, location data is accurate to about 10m. Seafloor depth near Sites 1 and 2 was determined by pulling depth and altitude (above seafloor) data from the vehicle, and combining it with coordinate data on a minute-by- minute basis. This yeilded seafloor depth data only through November 1st, attempts to visualize depth for other areas over which the ROV passed is ongoing. All location data was processed in R in decimal degrees, and site locations were visualized in ArcMap.

Chemical data was analyzed for a ten minute subsample of the total chemical measurement, using a timeframe identified from reviewing video footage of data collection. Mean and standard deviation values for H_2, H_2S, CO_2, CH_4 were recieved as an Excel table, and transposed into .csv. Temperature data was taken concurrently to chemical data for all locations except at the Site 4 "bullseye", where it was taken before geological sampling while chemistry was taken after. Summary statistics for the ten temperature data were calculated using base and custom R functions.

Biological data were collated from multiple excel workbooks for sites 1, 2, and 4, for which sample sorting had been completed. Synonymous species were aggregated into single categories; e.g., "Provanna" and "Provannid" were aggregated into "Provannid". Totals per morphogroup for each location were calculated from totals of the size fractions; "away" locations include only suction-collected organisms, while "bullseye" locations include both suction- and scoop-collected organisms. The counts for the top ten most numerous morphogroups, excluding dorvilleids, were visualized as a heatmap. Dorvilleids were excluded because the sheer scale obscured differences between other morphogroups (groups based on pysical traits); one location alone had over 9000 individuals. Species richness was assessed using rarefaction for all sites and samples.

	Site 1 Bullseye	Site 1 Away	Site 2 Bullseye	Site 2 Away	Site 4 Bullseye	Site 4 Away
H_2	8.2+/-3	0.5+/-2	106.4+/-17	-1.2+/-4	34.7+/-6	46.3+/-10
H_2S	2337.2+/-116	505.3+/-154	5238.8+/-509	573.5+/-38	2220.5+/-117	1842.3+/-117
CO_2	273+/-54	-9.5+/-9	5392.8+/-1053	237.9+/-62	222.3+/-61	52.2+/-19
CH_4	38.3+/-30	2.2+/-19	95+/-42	14.4+/-29	-5.3+/-112	-10.8+/-117
max temp	[illegible]	1.97	21.3	6.01	114.44	2.01
min temp	2.48	1.95	12.42	2.24	90.34	1.96
Dirivultids	175		402	1	97	
coiled gastropods	0	12	0	0	0	389
Peltospirids	31	9	296	4	98	0
Neomphalids	5	11	16	100	27	0
bivalves	2	37	0		0	0
Syllids	0	35	1	1	0	1
benthic foraminfera	9	11	1	1	12	4
Oasisia	3	0	22	9	1	0
Polynoids	3	3	0	17	0	4
Amphysamytha	0	0	0	0	0	19

Chemical Concentrations (µM): 0 1000 2000 3000 4000 5000
Temperature (°C): 20 40 60 80 100
Organisms (count): 0 100 200 300 400 500

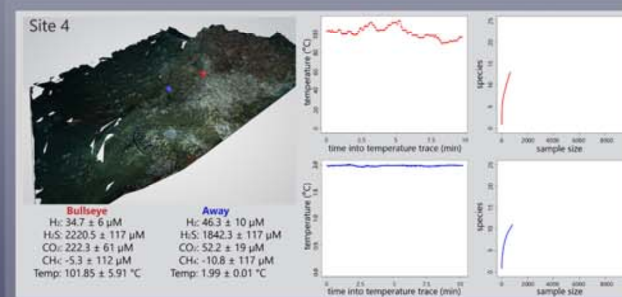
Results

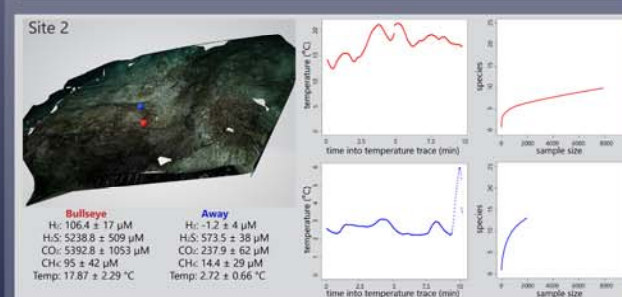
Generally, locations near focused fluid flow —i.e., bullseyes —had greater count totals than locations out of the flow —i.e., "away". Much of this comes from dorvilleids, small segmented worms that were exteremely abundant at bullseye sites. Though present at away locations, they are far more aboundant at bullseye locations. This corresponds to higher temperatures, but not, however, the highest temperatures. At site 4, whiere the mean in-flow temperature was around 100°C, counts of dorvilleids were much lower, decreasing overall counts, suggesting that this is beyond the upper bound at which dorvilleids thrive. Higher temperatures did not generally support much greater numbers of different morphogroups, suggesting similar amounts of diversity at and around areas of venting. Counts of specific species varied between bullseye and away within a single site, and between bullseyes or aways at different sites, indicating possible influence of both temperature and chemistry. For example, counts of peltospirids —a type of snail — and dirivultids —type of crustaceans called copepods —were much higher at locations with higher hydrogen sulfide, and highest at the site 2 bullseye, which correspondingly, had the highest hydrogen sulfide values. It is worth noting, however, that some of the patterns observed in the full data set, particularly the presence-absence data, may be due to some sites getting colonized by chance, and others not, even at such close proximity between venting sites.

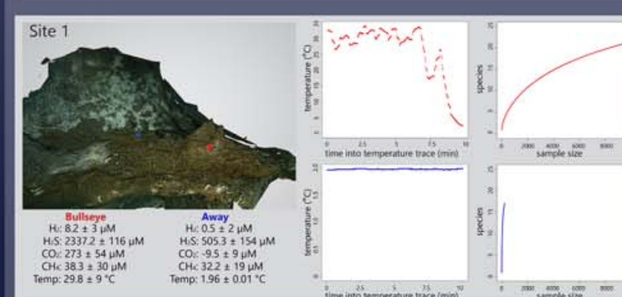
The substantial differences in temperature and chemistry between bullseye and away measurements for a given site attests to how focused the fluid flow at the bullseyes is. The differences between bullseyes and aways at different sites is interesting, given how close these vents are to each other, and suggests differences in substrate, geology, or paths taken by rising fluids over a very short distance.

Relevance

Because hydrothermal vents host flourishing ecosystems in chemical-rich, sunlight-poor environments, they may exemplify environments elsewhere in the solar system that could host life (NOAA, 2013), serving as models of both the conditions and organisms that may exist off of Earth (Barry, 2001). They may also provide insight into the origins of life on Earth, and perhaps assist in discerning the nature of much-debated fossil evidence in the vein of Dickensonia. However, hydrothermal vents often occur on or near large nodules of rare earth minerals like cobalt and manganese. With ongoing or even increasing demand for such resources, the deep sea has become increasingly attractive to mining interests (Letman, 2018). As such, studying hydrothermal vents is important not only for the insights it may yield into life on Earth —and potentially beyond —but also for developing deep sea mining regulations that balance resource demands with environmental impacts.







Citations

- Barry, P. L. (2001, April 13). Life as We Didn't Know It. Retrieved October 9, 2018, from https://science.nasa.gov/science-news/science-at-nasa/2001/ast13apr_1
- National Oceanic and Atmospheric Administration. (2013, June 01). What can the ocean teach us about life on other planets? Retrieved October 9, 2018, from https://oceanservice.noaa.gov/facts/extreme.html
- Letman, J. (2018, August 29). The Race Is On to Mine the Deep Ocean. Retrieved October 9, 2018, from https://www.nationalgeographic.com/environment/2018/08/news-race-to-mine-deep-sea-drones-seafloor-environmental-impact/
- Woods Hole Oceanographic Institution. (n.d.). Hydrothermal Vents. Retrieved October 9, 2018, from https://www.whoi.edu/main/topic/hydrothermal-vents

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