THE OFFICIAL MAGAZINE OF THE OCEANOGRAPHY SOCIETY

Oceanography

CITATION

Phillips, B.T., D.F. Gruber, G. Vasan, V.A. Pieribone, J.S. Sparks, and C.N. Roman. 2016. First evidence of bioluminescence on a "black smoker" hydrothermal chimney. *Oceanography* 29(2):10–11, http://dx.doi.org/10.5670/oceanog.2016.27.

DOI

http://dx.doi.org/10.5670/oceanog.2016.27

First Evidence of Bioluminescence on a "Black Smoker" Hydrothermal Chimney

By Brennan T. Phillips, David F. Gruber, Ganesh Vasan, Vincent A. Pieribone, John S. Sparks, and Christopher N. Roman

Bioluminescence in the deep sea is omnipresent, yet imagery of the phenomenon is scarce. While this dearth in observations can be largely explained by sampling effort, the camera technology available for in situ, low-light imagery is also a limiting factor. Recent work by Phillips et al. (2016) describes the application of a Hamamatsu ORCA Flash2.0 V2 sCMOS camera to detect light-stimulated luminescence in the water column. This system was recently employed to observe bioluminescence on a deep-sea "black smoker" hydrothermal vent.

As part of a multidisciplinary expedition on E/V *Nautilus* aimed at exploring the Galápagos Spreading Center, dive #H1439 on July 1, 2015, used the *Hercules* remotely operated vehicle (ROV) system to take a close look at the Iguanas hydrothermal vent field (Raineault et al., 2016). This vent system was initially discovered in 2006 (Haymon et al., 2008). Outfitted with the low-light camera and two high-power strobes oriented vertically toward the seafloor, the ROV was positioned almost directly over the vent orifice of one of the larger active chimneys at 1,643 m water depth (~1 m altitude, chimney height 11 m). All lights on the ROV system were turned off (including external LED indicators), and closed-loop inertial navigation control was used to maintain vehicle position within <10 cm on all axes. The vehicle hovered over the chimney for approximately 20 minutes while light-stimulation techniques, as performed in Phillips et al. (2016), were used to elicit bioluminescent responses. No light-stimulated bioluminescence was observed, but two recordings made as controls without any strobes detected a weak, mobile luminescent source within 1 m of the vent orifice (Figure 1, supplemental video). The source appears to be moving quickly in one recording, indicating a mobile organism. Review of footage obtained five minutes prior to the low-light recordings revealed a relatively low abundance of macrobiology on and around the chimney, with a few scattered Bythograeid crabs, squat lobsters, and numerous Alvinocarid shrimp. Based on these observations and the behavior of the luminescence, it is likely biologically sourced and could be a free-swimming shrimp. Whether such an organism is a vent-associate or a member of the surrounding midwater community cannot be determined by these observations alone.

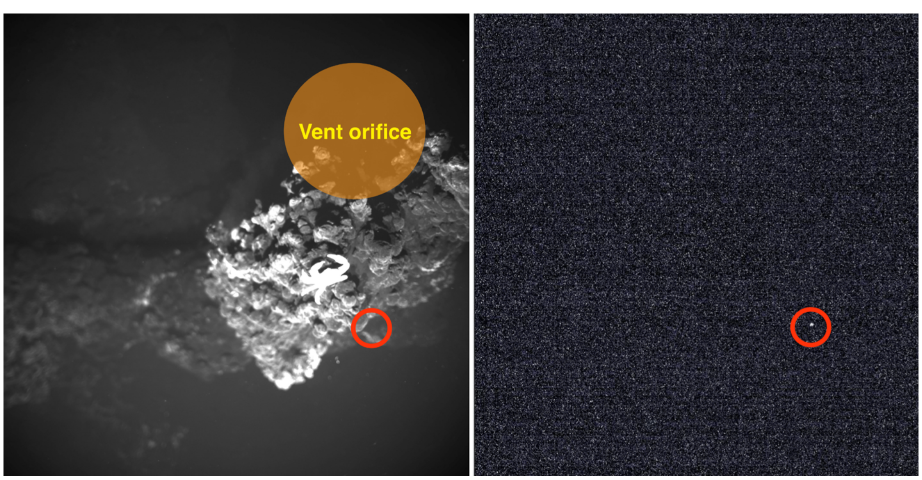

FIGURE 1. (left) Strobe-lit, down-looking view of the active black smoker chimney. (right) Same field of view as the strobe-lit image, with a single bioluminescent source visible in the lower-right corner. The location of the bioluminescent source is circled in red in both images.

Blackbody radiation and visible light have been measured using various methods at several hydrothermal vents (Van Dover et al., 1996; White et al., 2002). While the low-light camera used in this study can detect wavelengths up into the near-infrared spectrum, no patterns were visible in our recordings. This may be attributed to the relatively low temperatures measured at the vent orifice (maximum reading 154.7°C) and the diminished quantum efficiency of the camera in the low infrared wavelength spectrum (800–1,000 nm). Given the absence of any solar radiation from the surface and negative observations of bioluminescence on vents by human observers, it has been hypothesized that blackbody radiation from deep-sea vents may be a signal for vent shrimp to locate and/or avoid heat sources through the use of primitive photoreceptor organs (Pelli and Chamberlain 1989; Van Dover et al., 1989; O'Neill et al., 1995; Nuckley et al., 1996). Given our observations of naturally occurring bioluminescence directly adjacent to an active vent, it may be that such photosensitive capabilities serve more than to simply locate and avoid extreme heat sources. For example, Johnsen et al. (1995) suggest that the measured peak sensitivity of *Rimicaris* sp. shrimp at ~500 nm is more attuned to visible-spectrum light than blackbody radiation, which may be an artifact of their proposed evolution from surface-dwelling bresiliid shrimp (Chamberlain, 2000).

It is our hope that these crude observations will stimulate further interest regarding the role of bioluminescence within and around hydrothermal vent systems, with a possible focus on vent shrimp as potential light-producing animals. The continual improvement of low-light scientific cameras used for in situ imagery, paired with reliable and precise vehicle navigation, makes such endeavors possible.

SUPPLEMENTAL MATERIAL

A link to the video of the hydrothermal chimney collected by camera on ROV *Hercules* can be obtained at http://dx.doi.org/10.5670/oceanog.2016.27.

REFERENCES

Chamberlain, S.C. 2000. Vision in hydrothermal vent shrimp. *Philosophical Transactions of the Royal Society of London B* 355(1401):1,151–1,154, http://dx.doi.org/10.1098/rstb.2000.0657.

Haymon, R.M., S.M. White, E.T. Baker, P.G. Anderson, K.C. Macdonald, and J.A. Resing. 2008. High-resolution surveys along the hot spot-affected Gálapagos Spreading Center: 3. Black smoker discoveries and the implications for geological controls on hydrothermal activity. *Geochemistry, Geophysics, Geosystems* 9, Q12006, http://dx.doi.org/10.1029/2008GC002114.

Johnson, M.L., P.M.J. Shelton, P.J. Herring, and S. Gardner. 1995. Spectral responses from the dorsal organ of a juvenile *Rimicaris exoculata* from the TAG hydrothermal vent site. *BRIDGE Newsletter* 8:38–42.

Nuckley, D.J., R.N. Jinks, B.A. Battelle, E.D. Herzog, L. Kass, G.H. Renninger, and S.C. Chamberlain. 1996. Retinal anatomy of a new species of bresiliid shrimp from a hydrothermal vent field on the Mid-Atlantic Ridge. *The Biological Bulletin* 190(1):98–110.

O'Neill, P.J., R.N. Jinks, E.D. Herzog, B.A. Battelle, L. Kass, G.H. Renninger, and S.C. Chamberlain. 1995. The morphology of the dorsal eye of the hydrothermal vent shrimp, *Rimicaris exoculata*. *Visual Neuroscience* 12(05):861–875, http://dx.doi.org/10.1017/S0952523800009421.

Pelli, D.G., and S.C. Chamberlain. 1989. The visibility of 350°C black-body radiation by the shrimp *Rimicaris exoculata* and man. *Nature* 337(6206):460–461, http://dx.doi.org/10.1038/337460a0.

Phillips, B.T., D.F. Gruber, G. Vasan, C.N. Roman, V.A. Pieribone, and J.S. Sparks. 2016. Observations of in situ deep-sea marine bioluminescence with a high-speed, high-resolution sCMOS camera. *Deep Sea Research Part I* 111:102–109, http://dx.doi.org/10.1016/j.dsr.2016.02.012.

Raineault, N.A., R.D. Ballard, L. Mayer, C.R. Fisher, S. Carey, L. Marsh, R. Kane, S. Tüzün, T.M. Shank, and C. Smart. 2016. Exploration of hydrothermal vents along the Galápagos Spreading Center. Pp. 35–37 in *New Frontiers in Ocean Exploration: The E/V* Nautilus *and NOAA Ship* Okeanos Explorer *2015 Field Season*. K.L.C. Bell, M.L. Brennan, J. Flanders, N.A. Raineault, and K. Wagner, eds. *Oceanography* 29(1), supplement, http://dx.doi.org/10.5670/oceanog.2016.supplement.01.

Van Dover, C.L., E.Z. Szuts, S.C. Chamberlain, and J.R. Cann. 1989. A novel eye in 'eyeless' shrimp from hydrothermal vents of the Mid-Atlantic Ridge. *Nature* 337(6206):458–460, http://dx.doi.org/10.1038/337458a0.

Van Dover, C.L., G.T. Reynolds, A.D. Chave, and J.A. Tyson. 1996. Light at deep-sea hydrothermal vents. *Geophysical Research Letters* 23(16):2,049–2,052, http://dx.doi.org/10.1029/96GL02151.

White, S.N., A.D. Chave, G.T. Reynolds, and C.L. Van Dover. 2002. Ambient light emission from hydrothermal vents on the Mid-Atlantic Ridge. *Geophysical Research Letters* 29(15), http://dx.doi.org/10.1029/2002GL014977.

ACKNOWLEDGMENTS

This research used data provided by the *Nautilus* Exploration Program, Expedition #NA064. The authors wish to thank the E/V *Nautilus* crew and the ROV team for their expertise and technical support, the Inner Space Center at the University of Rhode Island, and Chuck Fisher for facilitating this research. This work was conducted under research permit #PC-45-15, and the authors thank the Galápagos National Park directorate and the Charles Darwin Research Station for their collaboration. Sheri White, Cindy Van Dover, and one anonymous reviewer contributed constructive comments that greatly enhanced this article. This work was funded in part by the Ray and Barbara Dalio Family Foundation and NSF grant DEB-1257555 to JSS.

AUTHORS

Brennan T. Phillips (brennanphillips@my.uri.edu) is PhD Candidate, University of Rhode Island, Graduate School of Oceanography, Narragansett, RI, USA. **David F. Gruber** is Associate Professor, City University of New York, Baruch College, New York, NY, USA. **Ganesh Vasan** is Postdoctoral Associate, The John B. Pierce Laboratory, New Haven, CT, USA. **Vincent A. Pieribone** is Fellow, The John B. Pierce Laboratory, New Haven, CT, USA, and Professor, Cellular and Molecular Physiology & Neurobiology, Yale University School of Medicine, New Haven, CT, USA. **John S. Sparks** is Curator-in-Charge, American Museum of Natural History, New York, NY, USA. **Christopher N. Roman** is Assistant Professor, University of Rhode Island, Graduate School of Oceanography, Narragansett, RI, USA.

ARTICLE CITATION

Phillips, B.T., D.F. Gruber, G. Vasan, V.A. Pieribone, J.S. Sparks, and C.N. Roman. 2016. First evidence of bioluminescence on a "black smoker" hydrothermal chimney. *Oceanography* 29(2):10–11, http://dx.doi.org/10.5670/oceanog.2016.27.