High-Resolution Measurements of Coastal Bioluminescence

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LONG-TERM GOALS

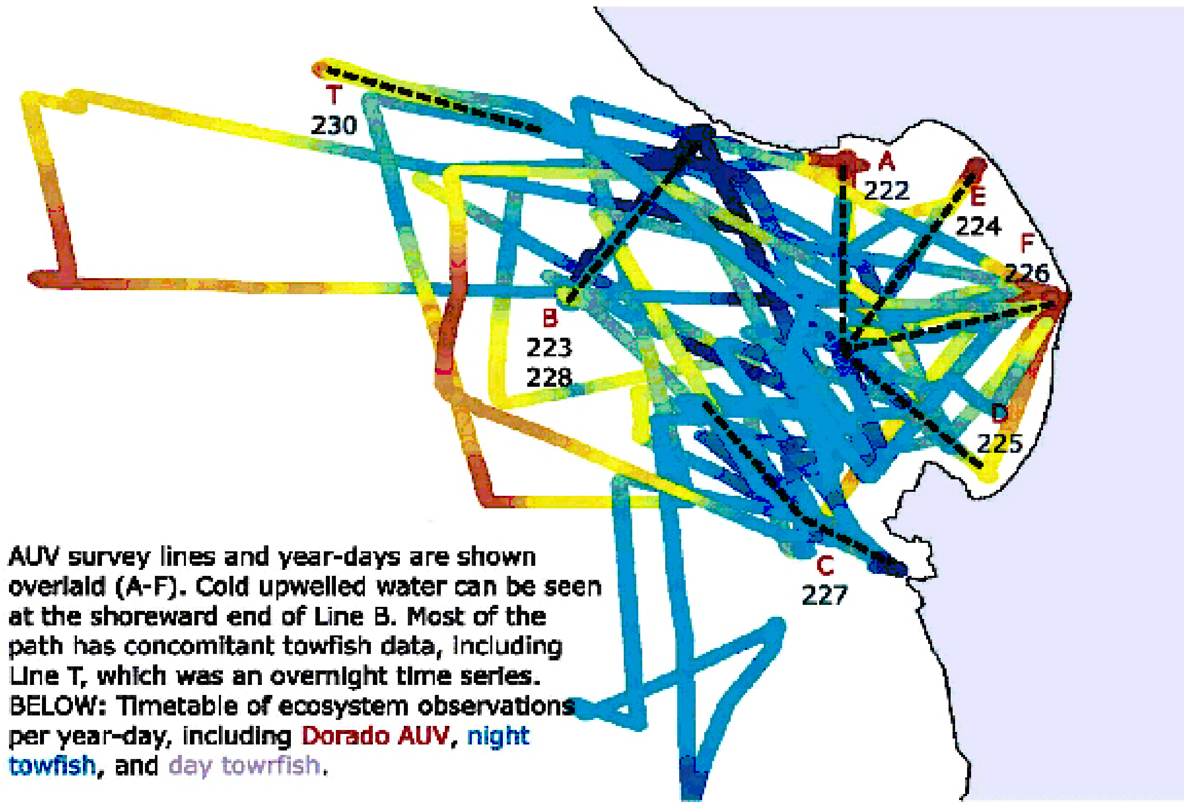
Our long-term goal is to understand and predict the distribution of marine bioluminescence through time, using the most advanced technologyavailable, and coordinating analyses with like-minded modellers. We are especially interested in the organisms that cause luminescence, and their relative contributions to the oceanic light-field.

OBJECTIVES

The objectives of this study are to use our data gathered from autonomous underwater vehicles and other platforms to develop an understanding of the scales (space and time) over which bioluminescence varies in coastal environments. We hope to understand large-scale bioluminescence features in the context of the physics, chemistry, and biology of the environment, and to observe the changes in luminescence distribution through different oceanographic seasons. Because the ultimate sources of bioluminescence are the plankton populations, we are keenly interested in integrating accurate measurements of zoo- and phytoplankton into our otherwise instrument-based programs. Bioluminescence is one of the few ways to sample a fraction of the zooplankton population, and we hope to develop robust predictive methods of relating light measurements back to plankton community composition. Another important objective is to work iteratively with modellers, exchanging data back and forth to improve our ability to predict distributions.

APPROACH

This project involves field measurements of bioluminescence and concurrent sampling of plankton. To collect bioluminescence data, we deploy UCSB-provided bathyphotometers on several moored, towed, profiling, and autonomous platforms. Field work is focused on an intensive two weeks aboard the R/V Point Sur where we collect samples on zooplankton, phytoplankton, chlorophyll, nutrients, pigments for HPLC. These samples are collected along the tracks where high-resolution oceanographic data (CTDO, fluorescence, nutrients, luminescence) are simultaneously being collected. Data are processed, analyzed, and visualized, and these results are distributed for placement into other oceanographic models.



216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232
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Sea Surface temperature along the R/V Pt. Sur Ship tracks for the 2003 AOSN-II ecosystem surveys

Project team: Christy Herren (postdoc), Jodi Brewster (programmer/grad student), Erica McSwane-Williams (undergraduate), Christy Schnitzler (grad student).
Modeling team: Igor Shulman, Jeff Paduan, Dennis McGillicuddy, Leslie Rosenfeld
Other support: Hans Thomas, Cyril Johnson, James Case, Drew Gashler

WORK COMPLETED

During 2003 we completed a variety of data collection related to the efforts of the AOSN-II ecosystem team (see below). Ship's underway data (surface water properties, ADCP and meteorology) were collected continuously for 10 days. The area of operation covered the entire bay as well as transits farther offshore.

Using the AUV deployed from the R/V Zephyr, we collected seven nights of transects, each ranging from the surface to 100m along approximately 22km for a total of over 150km of data. These high-resolution records include simultaneous measurements of CTDO, OBS, fluorescence, bioluminescence and nutrients. Similar data were collected using a towfish (loaned by Ken Johnson and Luke Coletti of MBARI). The towfish could not operate close to shore, and it went only to 50 meters depth, but it surveyed at double the speed of the AUV so it covered vast tracts of the surface waters. During nine nights and eight days of towing, we gathered approximately 1000 km of towfish data. We also conducted a coordinated survey with the AUV, towfish and WHOI gliders operating in the same location, to compare the efficacy of different glider adaptive-sampling schemes.

Thirty-five stations were occupied with vertical profiles taken along each of the AUV transect lines, along with water and plankton samples to quantify zooplankton, phytoplankton, chlorophyll, nutrients, and HPLC-measured pigments.

Towfish and AUV data were processed as to be immediately made available to AOSN-II modeling groups for assimilation and ground-truthing, and post-processed data has been transferred to the modeling team (Shulman, et al.)

During 2003 we also completed the phyto- and zooplankton counts from 2002 field experiments, and performed more in-depth analyses of the 2002 AUV data. These data processing efforts, including data from 2003, will continue throughout 2004.

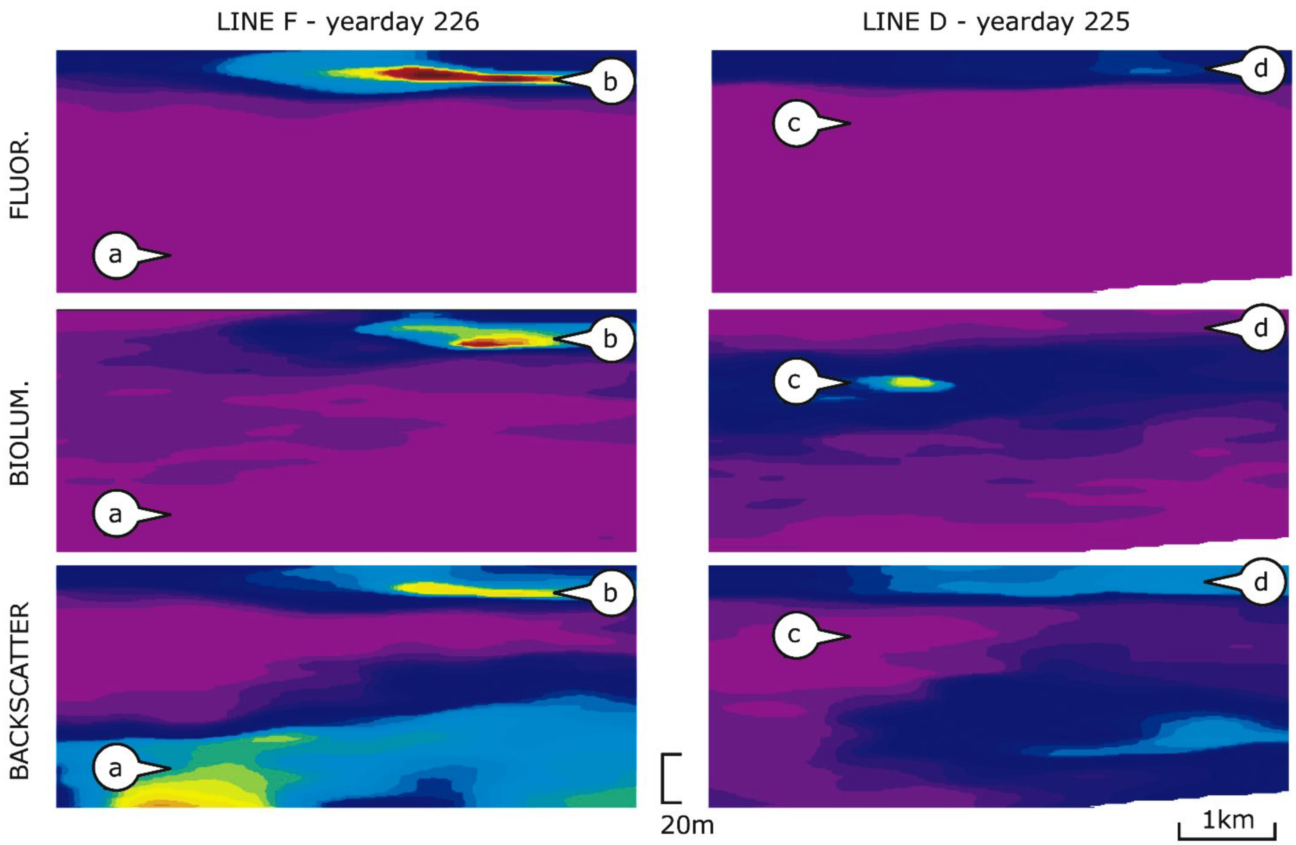
RESULTS

During the 2003 field season we were able to test many of the hypotheses developed during 2002 work. Some of these hypotheses were supported, while others fell victim to the variability which occurs between seasons. For example, during SPOKES 2002 we found persistent and extensive layers of bioluminescence, but for the most part these features were mixed away during the vigorous circulation of 2003. Stratification that had led into the experiment quickly gave way to upwelling conditions as the winds commenced during our early sampling.

On the other hand, we gathered strong support for the relationship between the relative vertical distribution of bioluminescence and of the chlorophyll maxima. Typically, the subsurface chlorophyll max (SCM) co-occurs with the BL max close to shore, but the BL max is consistently below the SCM offshore. Additional variability was sampled in the form of a dusk-to-dawn series of transects to observe the circadian onset and decay of bioluminescence.

Similar to previous years, the plankton sampling and ship-board plankton isolation indicated that the major contributors to bioluminescence were the dinoflagellates *Protoperidinium* spp., the copepod *Metridia*, and larvacean *Oikopleura*.

Another unique sample set which was collected during these surveys was the simultaneous capture of plankton samples with the Schindler, and the filtering of the effluent from the profiling bathyphotometers. Thus, we have an exact physical record of the plankton which were being sampled by the instruments during their profiles, and we can compare our predicted plankton distributions with the samples themselves. These plankton samples are critical to developing an ability to predict zooplankton populations from bathyphotometer data.



Correlation between features in 2003 AUV Survey Data. In our data, it has not possible to generalize about the spatial relationship between chlorophyll fluorescence, bioluminescence, and optical backscatter across the entire survey domain. (a) Optical backscatter indicates the presence of sediment, lacking fluorescence or bioluminescence, but at times high values (b) of all three measurements may co-occur. We believe these instances indicate dinoflagellate bioluminescence. (c) High bioluminescence may also occur in areas with no detectable particles, either fluorescent or not, and in certain water masses, (d) high fluorescence and backscatter occur in a layer above the region of high bioluminescence.

IMPACT/APPLICATIONS

Surveys done here provide a comprehensive view the bioluminescence and plankton distributions in Monterey Bay. In addition, the data provided ground-truthing, initialization, and near-complete ecosystem coverage for the AOSN-II experiment.

RELATED PROJECTS

Field experiments this year were integrated with the AOSN-II experiment (Bellingham and Robinson) and most of the participating groups. Igor Shulman, Jeff Paduan, and Dennis McGillicuddy continue to integrate our data into instructive physical models of the Monterey Bay.We also worked closely with the ONR-supported projects of Mark Moline, James Case, Yi Chao, and Margaret McManus.

PUBLICATIONS

Haddock, S.H.D. (in review) A golden age of gelata: past and future research on planktonic cnidarians and ctenophores. *Hydrobiologia*.

Gasca, R. and S.H.D. Haddock. (in review) Associations between gelatinous zooplankton and hyperiid amphipods (Crustacea: Peracarida) in the Gulf of California. *Hydrobiologia*.

Robison, B.R., K.R. Reisenbichler, J.C. Hunt, and S.H.D. Haddock (in press) Light production by the arm tips of the deep-sea cephalopod *Vampyroteuthis infernalis*. *Biol. Bull*

Mills, C.E. and S.H.D. Haddock. (still in press) Key to the Ctenophora. For Light and Smith's Manual: Intertidal invertebrates of the central California coast. J.T. Carlton, ed.

Herren, C.M., et al. (in press) [Bioluminescence in thin-layers].

Shulman, I., S.H.D. Haddock, D.J. McGillicuddy, Jr., J.D. Paduan, and P.W. Bissett (2003) Numerical modeling of bioluminescence distributions in the coastal ocean. J. Atmospheric and Oceanic Technol. 20:1060-1068.

Cairns, S.D., D.R. Calder, A. Brinckmann-Voss, C.B. Castro, D.G. Fautin, P.R. Pugh, C.E. Mills, W.C. Jaap, M.N. Arai, S.H.D. Haddock and D.M. Opresko, (2002). Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Cnidaria and Ctenophora. Second Edition. American Fisheries Society Special Publication #28, Bethesda, Maryland, 115 pp.

Chapter Author: "Marine Bioluminescence" Digital Photobiology Compendium — peer-reviewed web-based textbook

PATENTS

Provisional patent submitted: Long-wavelength fluorescent proteins, (Haddock, Schnitzler, Keenan, McCord) August 2003

HONORS/AWARDS/PRIZES

Advisory Board, Content & Photographs- GLOW - museum exhibit on bioluminescence

Invited Member, Editorial Board of the journal *Luminescence*, 2003-2006

Invited Plenary speaker: 7th International Conference on Coelenterate Biology

Elected Councillor, International Society for Bioluminescence and Chemiluminescence: 2002-06