

MARINE BIOLUMINESCENCE

James F. Case
Marine Science Institute, University of California,
Santa Barbara, CA 93106
805 893 2913/3639
case@lifesci.ucsb.edu

N00014-89-J-1736

LONG TERM GOALS

Marine bioluminescence has long been studied from isolated perspectives by relatively few investigators. The result has been a fascinating but disconnected and incomplete understanding of the subject, in our view. Our laboratory has worked at several levels of biological organization to attempt to develop a more coherent picture of the processes and significance of bioluminescence in the ocean. The basic concept of our approach has been that the interactions generated by studies at several levels or organization in the same research group is catalytic to the development of new approaches and concepts. An important aspect of the work has been training new PhD level scholars in the subject.

OBJECTIVES

This research program, terminating this year, (but continuing some elements in N00014-97-I-0424) has sought to assist in understanding the adaptive significance and role of bioluminescence in marine ecosystems by conducting studies ranging from cellular, physiological and behavioral mechanisms through oceanographic research. The program built upon this substrate of pure science to develop field instrumentation and variously to contribute to understanding of the impact of bioluminescence upon naval operations.

APPROACH

Laboratory investigations on salient luminescent species from dinoflagellates to fish were carried out and instrumental support was provided for field studies led by Mr. David Lapota at the Space and Naval Warfare Systems Center, San Diego. These latter studies are described in his annual report and in Lapota, et al (1997).

WORK COMPLETED

The mechanisms of excitation of bioluminescence in dinoflagellates are under study using principally *Pyrocystis fusiformis* a very large organism amenable to microscopical - biophysical study. Using confocal microscopy and a low light CCD camera detailed recordings have been made of the activity of individual luminescent sources during local mechanical and chemical excitation.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 30 SEP 1997	2. REPORT TYPE	3. DATES COVERED 00-00-1997 to 00-00-1997			
4. TITLE AND SUBTITLE Marine Bioluminescence		5a. CONTRACT NUMBER			
		5b. GRANT NUMBER			
		5c. PROGRAM ELEMENT NUMBER			
6. AUTHOR(S)		5d. PROJECT NUMBER			
		5e. TASK NUMBER			
		5f. WORK UNIT NUMBER			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of California at Santa Barbara, Marine Science Institute, Santa Barbara, CA, 93106		8. PERFORMING ORGANIZATION REPORT NUMBER			
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)			
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)			
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 3	19a. NAME OF RESPONSIBLE PERSON
a REPORT unclassified	b ABSTRACT unclassified	c THIS PAGE unclassified			

Natural rates of bioluminescence, by which is meant luminescence not known to have been induced by human intervention, have long been disputed owing to uncontrollable instrumentational effects. They are of considerable scientific as well as applied interest since natural luminescence, in the latter instance, might well represent a considerable fraction of the noise signal in bioluminescence-based surveillance. *In situ* diver observations coupled with concurrent phyto- and zooplankton collections gave excellent results in near-surface waters in the Santa Barbara Channel (Haddock and Case, 1997).

Bioluminescence in marine snow was first discovered by our group and has been studied in order to assess its magnitude, sources and implications in respect to material flux in the sea.

Work on counterillumination in the midshipman fish Porichthys has continued with a study of the non-luminous variant from Puget Sound. See N00014-97-I-0424.

RESULTS

Excitation mechanism studies on dinoflagellates thus far have concerned the role of calcium via use of a calcium ionophore and visualization and interruption of the actin cytoskeleton in a study of circadian transport of luminescent microspheres.

In the spontaneous rate of luminescence work, 19 sets of observations gave spontaneous rates varied from >20 to >1000 flashes/cu.m./min., far greater than the maximum predicted by a previous model, and they demonstrate that luminescence is commonly provoked by natural encounters. Thus the data can be used to correlate the natural rate with biomass and to produce realistic models that predict spontaneous luminescence.

Our marine snow bioluminescence work showed that a very substantial fraction of bioluminescent dinoflagellates are trapped in marine snow. We examined bioluminescence of marine aggregates during four cruises in the Santa Barbara Channel in late spring, fall, and winter seasons. Samples representing over 1000 snow particles (>2mm dia) were collected on blue-water dives in the upper 20 meters. Stimulated luminescence, dry weight, *in-situ* particle abundance, and organisms present were measured and compared with values for surrounding particle-free seawater.

Ninety-seven percent of the snow samples were bioluminescent. Aggregates produced several hundred times the light output of an equivalent volume of surrounding water, with more enrichment occurring on larger particles. Although aggregates represented a miniscule fraction of the water column by volume, they contributed 2 to 44% of stimulated luminescence in the water. Luminescence correlated most strongly with the abundance of dinoflagellates ($R^2 \sim 0.8$) although larvacean houses, radiolarians, and copepods such as *Oncaea* were also present. Steady-state luminescence, as might indicate bacterial contribution, was not detected.

The Puget Sound Porichthys investigation has concluded with demonstration that feeding Puget Sound fish with the appropriate luciferin not merely renders the fish luminescent, as we and others have demonstrated, but most remarkably renders them capable of effective counterillumination.

IMPACT

Our natural bioluminescence rate and marine snow work substantially modifies how we interpret near surface bioluminescence and its general significance to marine ecosystem dynamics. Since we and others have shown that there is considerable predation focussed on luminescent sources, accumulation of luminescent cells by marine snow must increase the likelihood of its being consumed by foraging zooplankton. This process would thus be likely to diminish the rate of sinking of organic matter collected in marine snow because the zooplankton consumers tend to maintain station in shallow depths. Although our results support previous findings that in coastal waters light is mainly produced by dinoflagellates, the clumped small-scale distribution we found differs from the general assumption that luminescent sources are distributed homogeneously. Marine aggregates are sites of enhanced bioluminescence, and this may strongly affect how organisms interact with them, in turn altering flux rates.

TRANSITIONS

The long term measurements of coastal bioluminescence described in the accompanying Lapota report together with these studies of details of excitation mechanisms and local distributions define some of the parameters that may become significant in planning and execution of Navy coastal operations.

RELATED PROJECTS

At UCSB we are collaborating with Drs. Alice Alldredge and Sally MacIntyre and share AASERT student, Christy Herren, in a study of luminescence in thin layers. It is anticipated that the collaboration with Mr. David Lapota, SNWSC - San Diego, will continue for at least another year of study of the long-term annual variation of coastal bioluminescence.