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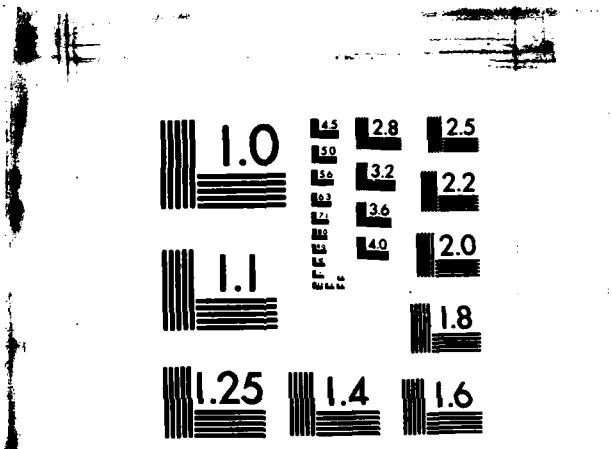

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NRL Report 8776

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Second Analysis of Fleet Reports of Bioluminescence in the Indian Ocean

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Two years of bioluminescence observations and ancillary data from units of the Seventh Fleet stationed in the Indian Ocean are analyzed for geographic and seasonal distributions along with one year of already published data. The results of this analysis are presented in this report. The appearance of characteristic bioluminescent phenomena, including displays, is described.

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CONTENTS

SECOND ANALYSIS OF FLEET REPORTS OF BIOLUMINESCENCE IN THE INDIAN OCEAN

INTRODUCTION

The United States Navy has exhibited a long interest in the phenomenon of marine bioluminescence. With the development of low-light-level image intensifying technology in the past two decades, this interest has intensified. However, to utilize most effectively this new technology, several basic questions must be resolved. One of these questions is the geographic and temporal distribution of bioluminescence. Another related question is whether or not bioluminescence observations correlate with any environmental factors. To collect data bearing on these two questions, the Naval Research Laboratory (NRL) and the Office of Naval Research (ONR) prepared a format for reporting observations of bioluminescence as well as supplemental information and requested the Fleet to report these observations according to this format. The message was directed primarily to the Seventh Fleet, operating in the Indian Ocean, because of the known richness of that area in bioluminescence, although observations from other commands were desired as well. The response has been very positive. In the first year after release of the request, 103 observations were forwarded to NRL and an analysis was published [1]. Two more years have resulted in the receipt of an additional 148 observations. This report contains the results of the analysis of these three years of observations.

METHODS

The sole source of data in this report was the bioluminescence reports from units of the Seventh Fleet. The reporting format, statistical difficulties, and treatment of the data are described by Lynch [1]. No variations in this method have occurred in this report.

RESULTS, DISCUSSION, AND CONCLUSIONS

Seasonal and Geographic Distribution

Figures 1 to 3 show the distribution of reports received from July 1981 through August 1983, grouped by quarters. Observations through June 1981 are included in Lynch [1]. In addition to the observations mapped, two observations were reported from the eastern Pacific Ocean and one from the Tasman Sea. For purposes of comparison, Figs. 1 and 2 are identical to the corresponding figures in Lynch [1]. In the first year, only one observation was reported from an area outside that covered by these two maps.

On a monthly basis, over the two-year period from July 1981 through June 1983, 33 reports were received from August, 21 from February, 20 from September, 18 from November, 13 from March, 12 from October, and 8 or fewer from each of the remaining months. In addition, 5 reports were received from this past August and are included herein. Combined with the first year, these results yield averages of approximately 14/year for November, 12/year for February, 10/year for August and September, 9/year for December, and 7/year or fewer for each of the remaining months. April through July seem especially low. Except for the high figure for November, these numbers are consistent with observations reported in Lynch [1] that bioluminescence peaks follow the end of the monsoon periods (February and August/September). However, the numbers of reports for November and December

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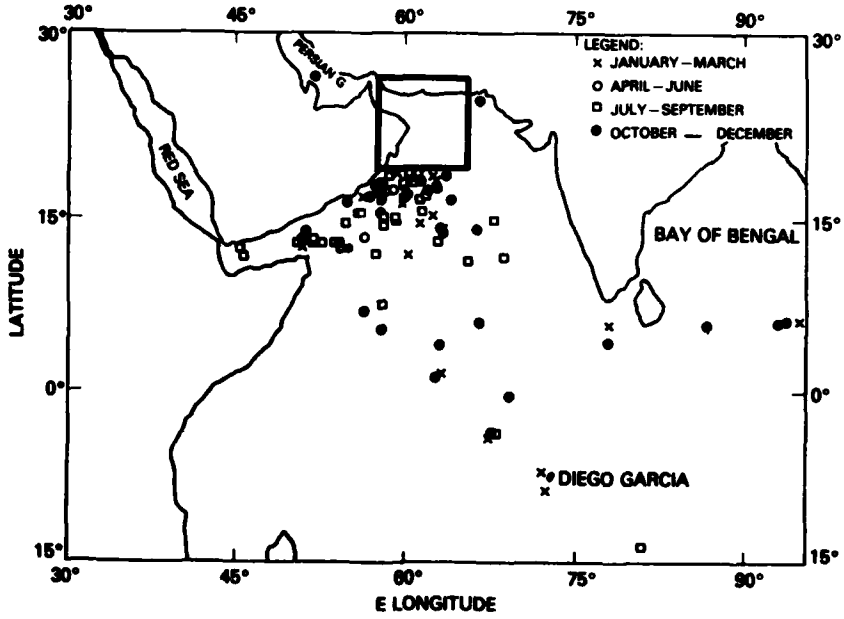

Fig. 1 — Distribution of sightings of bioluminescence by the Seventh Fleet in the Indian Ocean from June 1981 to August 1983. The square indicates the area shown in Fig. 2.

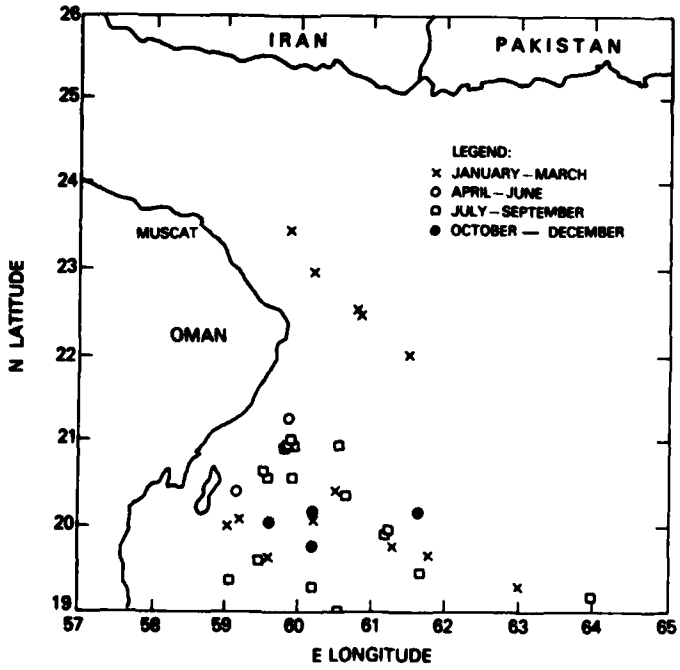

Fig. 2 — Extended map of a portion of the Arabian Sea, showing sightings of bioluminescence by the Seventh Fleet

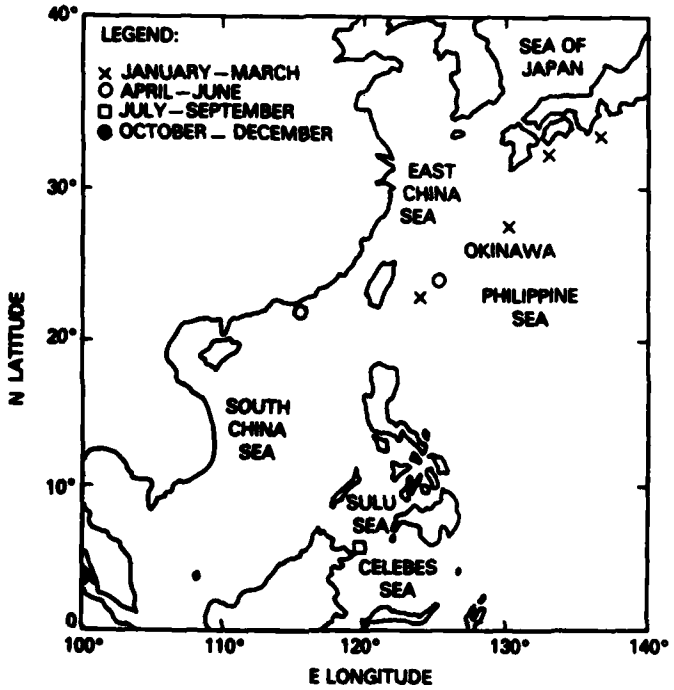

Fig. 3 — Distribution of sightings of bioluminescence by the Seventh Fleet in the western Pacific Ocean from July 1981 to August 1983

support the suggestion of Lynch that much bioluminescence activity occurs outside the peak periods. In light of these three-year averages, however, this suggestion must be modified to apply only to the last quarter of the calendar year; a relatively low level of activity in the second quarter seems confirmed.

Besides the statistical problems usual to reports of this kind and discussed by Turner [2,3] and Lynch [4,5], and the additional cautions raised by Lynch [1], further cautions must be mentioned here. First, no observations were reported between January and August 1983. It was initially thought that this lack of reports was due to a loss of interest on the part of potential observers—naval messages are said to have an effective lifetime of ~ 2.5 years; but because of the receipt of reports in August 1983, one cannot eliminate the possibility that no bioluminescence was in reality seen during those months. If January 1983 is taken as the effective end of the reporting period, then February through June must be analyzed over 2 years. (July has 3 years because it is the first month of the reporting period.) For April through June this difference means nothing—the number of observations for these months is so low that their rank relative to other months does not change. However, February would replace November as the month with the highest average number of observations, and March also rises in rank. The number of observations made in February 1982 may be anomalous, however. During that month an NRL aircraft made observations of bioluminescence in the Arabian Sea, and a special message to support its mission was sent to the Fleet. An unknown number of February observations may have been due to increased interest resulting from that message.

In addition to the average number of observations, the yearly variation from month to month is important. Most months were fairly consistent in the number of reported observations. December and January 1980 and March 1981 had high numbers of observations compared to the same months in other years, but these numbers can possibly be explained by high interest levels. However,

anomalously different numbers of observations did occur in two months—August and November. More then 80% of all the reported observations in August occurred in one year—1981—whereas no observations at all were reported for November 1982, in contrast to very high numbers of observations for the preceding two Novembers. No explanations can be offered for these variations.

CORRELATION WITH ENVIRONMENTAL DATA

Seasonal and Geographic Distribution

Additional data for two more years support the tentative conclusion in Lynch [1] that there appears to be no correlation between meteorological factors or the phase of the moon and bioluminescence. There was one report of an increase in bioluminescence intensity where the quarter moon emerged from behind cloud cover and one report of an increase in the size and intensity of bioluminescent patches during a rain squall. Since some bioluminescent organisms are known to be stimulated by shock due to a sudden lowering of salinity, this statement may offer an explanation for the latter observation, but no explanation may be offered for the former. There was also one observation of bioluminescence during a sea state 7 condition with winds of approximately 30 knots. These are the most extreme conditions in which bioluminescence is known to have been observed.

Once again insufficient reports of surface temperature or bathythermograph readings were made to attempt correlations with water temperature or salinity or thermocline position.

Characteristic Bioluminescent Phenomena

As before [1], the majority of the bioluminescence observations were examples of Turner's [2,3] "disturbed water luminescence" as modified by Lynch [1]. When a ship was not the disturbing platform, fish schools were identified as the definite disturbance in five instances and the probable disturbance in five others. Once a whale was identified as the disturbing platform. In this instance, the whale was surrounded by a glow outlining its entire body and was trailed by a wake of about 30 yards, the intensity of which was about 25% of the intensity near the body. Localized oscillating globular shapes were seen twice, and localized "spontaneous" scintillations were seen three times. In addition, patches or scintillations were reported as extending to the horizon. Long wakes from ships were occasionally observed, and the intensity was frequently reported as bright enough to cast shadows or read print on the ship's bridge.

Low-light-level devices were rarely used to observe bioluminescence. Once when a low-light-level device was used, the observer reported a great increase in the number of patches that could be seen as well as an increase in their distance from the ship.

Bioluminescent Displays

Twelve reports of "milky seas" were received, seven of these from the month of August. These reports agree with the observation in Staples [6] that milky seas are most common in August and September. Twice, linear features within milky seas were seen. These linear features support the theory that milky seas are caused by luminous bacteria feeding on decaying algae [2,7,8]. However, the fact that no linear features were seen in any other observation suggests some other cause for most milky seas. Other features were also seen. Disturbed water bioluminescence brighter than the milky sea was reported on seven occasions. In three of these cases, the disturbance was due to fish; twice it was due to the ship, and twice to rising and exploding bubbles. These exploding bubbles seem similar to the display described by Lynch [1] rather then the "exploding ball" displays described by Kalle [9,10]. On three other occasions, bright milky seas created the optical illusion of being fog banks and obscured the horizon.

One possible report of a "phosphorescent wheel" was received. However, this report fits only partially the classic description in Kalle [9,10], and it is not certain that it was the same phenomenon. This observation occurred in deep water, in contrast to Kalle's theory that wheels should be seen only in shallow water.

In three years of reporting by the Fleet only two possible observations of phosphorescent wheels have been made. These displays are among the most spectacular bioluminescent events that can be seen and have frequently been reported by merchant vessels. They are said to be most common in the Arabian Sea/Persian Gulf area, the Strait of Malacca, and the South China Sea [6]. Thus, more observations of this phenomenon should have occurred. This dearth of observations cannot be explained.

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