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NRL Memorandum Report 1535

FIELD TRIALS WITH THE SSX-1 SUBMARINE AT CHESAPEAKE BAY, NOVEMBER 1962

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May 1964

U. S. NAVAL RESEARCH LABORATORY
Washington, D.C.

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Downgraded at 12 year intervals;
Not automatically declassified.

CONTENTS

ABSTRACT

In order to further an understanding of the changes to the ocean environment indicated by the intrusion of a submarine, tests were conducted in the Chesapeake Bay area. Pigment, turbidity and surface tension were measured in and out of the wake of the SSX-1 submarine. Changes in the parameters are presented and analyzed statistically.

PROBLEM STATUS

This report describes work on a phase of the problem. Work on other phases is continuing.

AUTHORIZATION

NRL Problem 55S01-18

Bureau Projects SF001-03-13-8136 and
RF001-03-44-4065

FIELD TRIALS WITH THE SSX-1 SUBMARINE AT CHESAPEAKE BAY, NOVEMBER 1962

On November 5, 6, 7, and 8, 1962, operations with the SSX-1 submarine were conducted off Kent Island in the Chesapeake Bay (Fig. 1). The purpose was to test further the changes in pigment, turbidity, and surface tension caused by the passage of a submarine. These were the properties of the water which showed the greatest changes during a previous field trip to Block Island, R. I.[1]. Consequently, water samples were collected in and out of the wake and tested a short time later for pigment, turbidity, and surface tension. Also, bacteria were measured on some samples. These tests were made at a temporary laboratory set up on Kent Island, (Fig. 1).

There were 7 runs in all with the submarine running at a speed of about 5 knots at 30 feet depth in each case. One-liter samples were collected from depths of 1/2 inch and 16 inches with a radio-controlled, Dewar-type sampler described previously[2]. Four clustered samplers were first placed with a small boat at a point on the surface above the intended path of the submarine. Then they were actuated one at a time by radio signal, the first before the submarine arrived (to obtain an ambient sample), the second when the submarine was estimated to be directly under the samplers, the third and fourth were actuated 5 and 10 minutes after the submarine passed. The submarine data are shown in Table 1.

After collection, the samples were brought ashore in their Dewars and stored for no longer than a few hours before measurements on them were made. Just prior to the measurements, the sample bottle in each case was shaken. Four drops of the sample were dispensed with a calibrated dropping pipette and measured with a micrometer. A determination of surface tension was made from the drop heights. Next, a turbidity sample was withdrawn from the sample bottle and measured in a Hellige turbidimeter. Subsequently, 100 ml of this same water was filtered through a Millipore type RA membrane filter (1.2 μ pores, 25 mm diam.). Later the filters were examined for pigment at 400 mμ, 550 mμ, and 700 mμ with a Beckman model DK reflectance spectrophotometer. The percent reflectance was measured relative to a MgO reference, and this was converted to percent absorptance by subtraction from 100 percent. For runs 3, 6, and 7, bacteria colony counts were made with cultures incubated 20 hours at 35°C in Millipore monitors with total-count nutrient.

The temperature of the water did not vary by more than a couple of degrees from 52°F over the 4 days of operations. The results of the pigment analysis are shown in Table II for the 7 runs. The means for the 7 runs are plotted in Fig. 2 as a function of time. The result of all pigment measurements shows an increase of 3% absorptance in the wake compared with out. The results of the turbidity analysis are shown in Table III. The mean turbidities for the 7 runs are plotted in Fig. 3 as a function of time. The result of all turbidity measurements shows an increase of 0.3 ppm SiC_2 in the wake compared with out. The results of the surface tension analysis are shown in Table IV with the means plotted in Fig. 4. The result of all surface tension measurements shows no change from in wake to out of wake. The results of the bacteria colony counts are shown in Table V. The 3 runs are averaged and plotted in Fig. 5. The result of all colony counts shows a decrease of 2.9 colonies per ml in the wake compared with out.

One must bear in mind that the results observed in the waters of the Chesapeake Bay using a miniature submarine cannot necessarily be expected to be the same as those observed in the ocean using a full-sized submarine. Statistical analysis of the results showed an 89% confidence coefficient that a difference existed between the pigment content of water in the wake and that of water out of the wake. The confidence coefficient in the case of turbidity was 84%. No statistically significant difference was found in the case of surface tension. The statistical treatment is shown in the appendix. Although the pigments were examined on the spectrophotometer at 3 wavelengths, only the 400 mμ data is presented here since this wavelength was found best toshow differences between the samples. The fact that some data is missing from the tables is in most cases due to malfunction of a sampler buoy so that no sample was obtained. The changes in the wake of all measured variables were not only very small but were in no case much larger than the statistical fluctuation to be expected for the out-of-wake sample.

ACKNOWLEDGMENTS

Thanks are due to Mr. W. B. Nefedov and Mr. R. C. Beckett who obtained the samples and to Mrs. E. F. DuPre who kindly made available, and helped us with the use of, the Beckman spectrophotometer for the pigment measurements.

REFERENCES

(1) Hiller, A. J.; Klee, C. W.; Nefedov, W. B.; "Some Modifications of the Ocean Environment Caused by a Submarine and Surface Craft During Trials in Block Island Sound", NRL Conf Memorandum Report 1464.

(2) Beckett, R. C.; "Ocean Surface Water Sampling Devices", NRL Memorandum Report 1460.

TABLE I Submarine Data

Run	Date	Time Under Buoy	Sub. Depth	Sub. Speed	Sub. Trim
1	11/5/62	1130(approx.)	30 ft	5 kts	3° down
2	11/5/62	1305	30 ft	5 kts	3° down
3	11/6/62	----	----	5 kts	----
4	11/7/62	0956	30 ft	5 kts	1° down
5	11/7/62	1115	30 ft	5 kts	0°
6	11/7/62	1227	30 ft	5 kts	0°
7	11/8/62	1006	25 ft	5 kts	3° down

TABLE II Pigment (% Absorptance)

Run No.	1/2 inch Depth				16 inch Depth			
	Ambient	Time after passage of sub (minutes)			Ambient	Time after passage of sub. (minutes)		
		0	5	10		0	5	10
1	39	40	40	---	---	41	39	45
2	47	---	43	51	---	---	41	44
3	43	49	---	51	---	51	43	44
4	41	---	---	---	41	49	41	---
5	---	39	---	---	41	---	---	36
6	36	---	---	38	35	---	---	38
7	37	---	39	34	35	---	35	36

TABLE III Turbidity (ppm SiO_2)

Run No.	1/2 inch Depth				16 inch Depth			
	Ambient	Time after Passage of sub (minutes)			Ambient	Time after Passage of sub (minutes)		
		0	5	10		0	5	10
1	2.5	3.3	2.3	---	---	3.3	2.5	3.1
2	3.9	---	3.1	3.9	---	---	3.1	3.6
3	3.6	3.8	---	3.6	---	3.6	3.9	3.8
4	2.9	---	---	---	2.8	3.6	2.9	---
5	---	3.4	---	---	3.1	---	---	2.6
6	3.1	---	---	2.9	3.1	---	---	2.9
7	3.1	---	3.1	7.2	3.1	---	2.9	3.6

TABLE IV Surface Tension (dynes/cm)

Run No.	1/2 inch Depth				16 inch Depth			
	Ambient	Time after Passage of Sub (minutes)			Ambient	Time after Passage of Sub. (minutes)		
		0	5	10		0	5	10
1	86	87	84	---	---	80	82	80
2	87	---	78	80	---	---	86	72
3	72	73	---	70	---	73	73	76
4	71	---	---	---	71	71	72	---
5	---	73	---	---	76	---	---	71
6	72	---	---	80	73	---	---	74
7	77	---	72	71	78	---	75	74

TABLE V Bacteria (colonies/ml)

Run No.	1/2 inch Depth				16 inch Depth			
	Ambient	Time after Passage of Sub (minutes)			Ambient	Time after Passage of Sub (minutes)		
		0	5	10		0	5	10
3	4. 1	2. 4	---	5. 0	---	3. 8	2. 6	2. 1
6	3. 5	---	---	3. 0	3. 2	---	---	2. 7
7	15. 2	---	2. 9	---	3. 3	---	2. 3	---

APPENDIX

If water in the wake (x) and water out of the wake (y) are repeatedly sampled with sample sizes of n_x and n_y and in each case the sample means $\bar{x}$ and $\bar{y}$ of some measured parameter are calculated and their difference taken, then these differences will be distributed with a mean $(\mu_x - \mu_y)$ and a standard deviation $\sqrt{\frac{\sigma_x^2}{n_x} + \frac{\sigma_y^2}{n_y}}$ where μ is the true population mean and σ is the true population standard deviation. This distribution, called a sampling distribution of the difference of means, is normal if $\bar{x}$ and $\bar{y}$ are normally and independently distributed. For large samples, say $(n_x + n_y) > 32$, the standard deviation of the sampling distribution can be approximated by

$$\sqrt{\frac{s_x^2}{n_x} + \frac{s_y^2}{n_y}}$$

where s is the sample standard deviation.

For a single pair of samples with difference of means $(\bar{x} - \bar{y})$, one assumes the null hypothesis that this came from a population where $\mu_x - \mu_y = 0$, i. e., no difference existed between in-wake and out-of-wake water, and then one sees if the measurements support this view. This single-sample statistic is converted to standard units by subtracting the mean of its sampling distribution and dividing by the standard deviation of its sampling distribution thusly:

$$z = \frac{(\bar{x} - \bar{y}) - (\mu_x - \mu_y)}{\sqrt{\frac{s_x^2}{n_x} + \frac{s_y^2}{n_y}}}$$

Since it is assumed that $(\mu_x - \mu_y) = 0$, this becomes

$$z = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{s_x^2}{n_x} + \frac{s_y^2}{n_y}}}$$

In this form, the probability that the difference-of-means value, z, will lie between -a and + a is given by the percentage of area under the normal curve bounded by these abscissa values. For example if $a = 1.96$, 95% of the normal-curve area is included and one is 95% sure that z will fall between -1.96 and +1.96. Therefore, if z calculated from the formula above does lie between these values, then one is 95% sure that the difference in means is not significant but is the result of statistical fluctuation in two samples from the same population. On the other hand, if z lies outside the interval from -1.96 to + 1.96 then the null hypothesis is rejected and one is 95% sure that the two samples came from different populations.

Analysis of Pigment Data

The variables had the following values. The unit is precent absorptance of light of 400 mμ wavelength with reference to a MgO standard.

$$\bar{x} = 42.0$$
$$\bar{y} = 39.5$$
$$s_x = 5.06$$
$$s_y = 3.67$$
$$n_x = 24$$
$$n_y = 10$$

Substituting these in the expression for z yields

$$z = \frac{42.0 - 39.5}{\sqrt{\frac{26.0}{24} + \frac{13.7}{10}}} = 1.6$$

This value of z corresponds to an 89% confidence level that a statistically significant difference existed in the pigment content between in-wake and out-of-wake water.

Analysis of Turbidity Data

The variables had the following values. The unit is ppm SiO_2.

$$\bar{x} = 4.1$$
$$\bar{y} = 3.8$$
$$S_x = 0.901$$
$$S_y = 0.371$$
$$n_x = 24$$
$$n_y = 10$$

Substituting these in the expression for z yields

$$z = \frac{4.1 - 3.8}{\sqrt{\frac{0.812}{24} + \frac{0.138}{10}}} = 1.4$$

This value of z corresponds to an 84% confidence level that a statistically significant difference existed in the turbidity between in-wake and out-of-wake water.

Analysis of Surface Tension Data

In this case, $\bar{x} = \bar{y}$ so that no difference existed in the surface tension between in-wake and out-of-wake water.

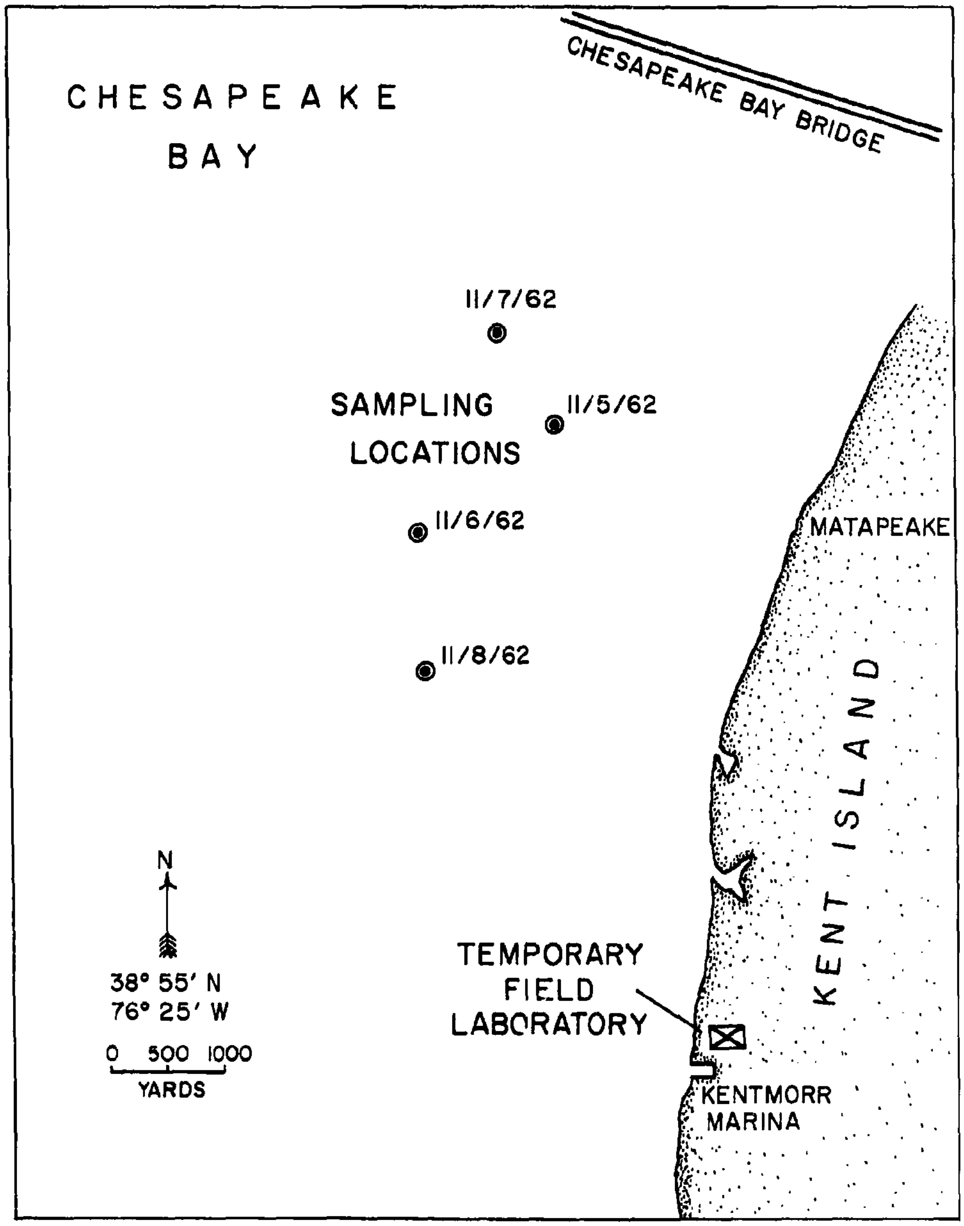

Fig. 1 - Operations Area

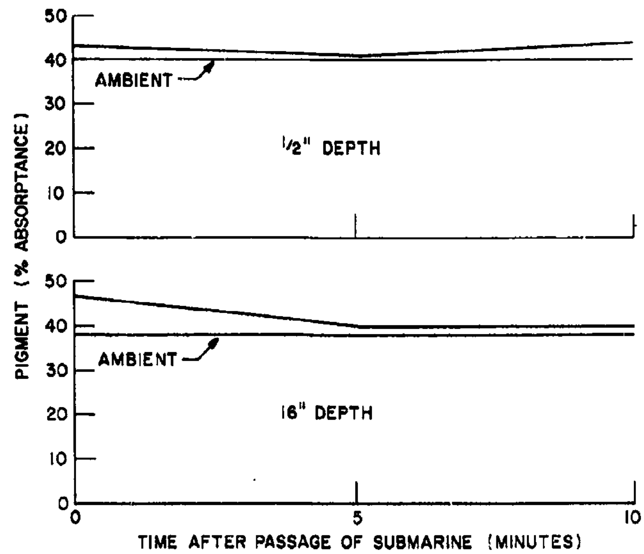

Fig. 2 - Pigment means vs time for all runs

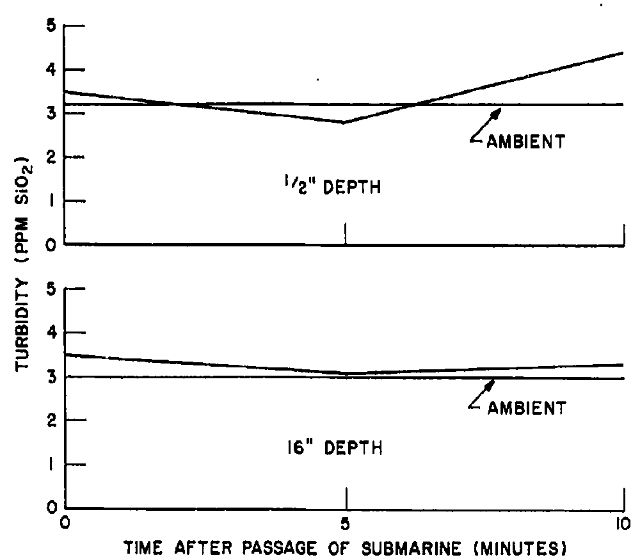

Fig. 3 - Turbidity means vs time for all runs

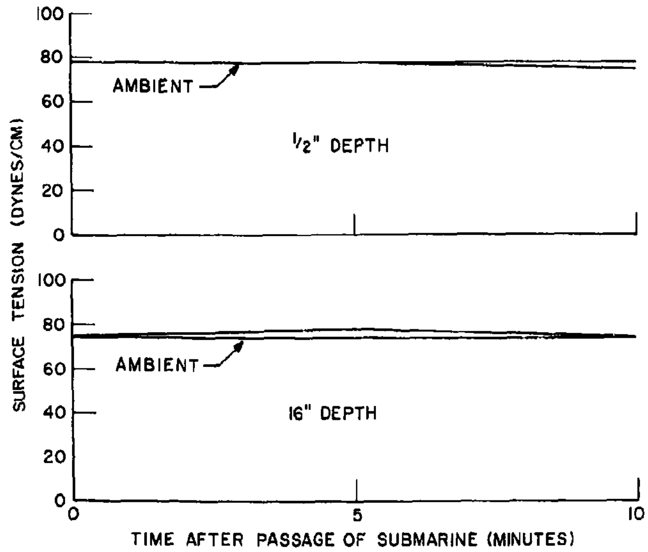

Fig. 4 - Surface tension means vs time for all runs

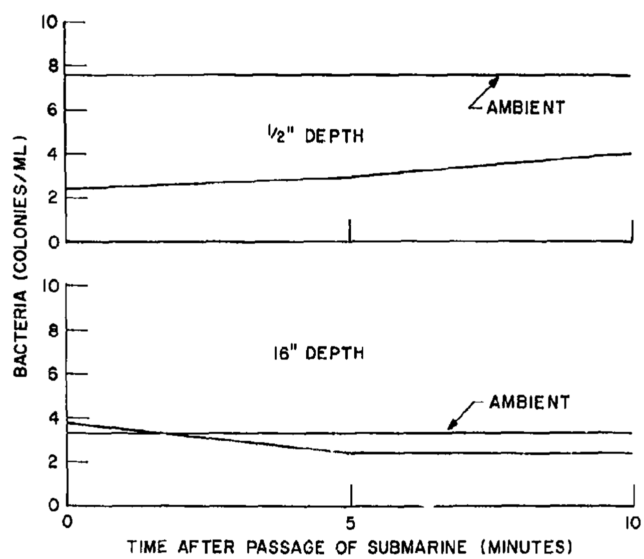

Fig. 5 - Bacteria colony-count means vs time for runs 3, 6, and 7

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Memorandum

7100-101

DATE: 10 September 2003

REPLY TO ATTN OF: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF (A) FOR DECLASSIFICATION

TO: Code 1221.1

REF: (a) "Field Trials with the SSX-1 Submarine at the Chesapeake Bay, November 1962" (U), A.J. Hiller and C.W. Klee, Sound Division, NRL Memo Report 1535, May 1964 (C)

1. Reference (a) describes a series of experiments to determine if the passage of a submarine (SSX-1) changes the pigments, turbidity and the surface tension in and out of the wake. There was some change in the pigmentation and turbidity but no change in the surface tension. More work is required.

2. The technology and equipment of reference (a) have long been superseded. The current value of these papers is historical.

3. Based on the above, it is recommended that reference (a) be declassified and released with no restrictions.

Burton G. Hurdle
BURTON G. HURDLE
NRL Code 7103

CONCUR: Edward R. Franchi 9/11/2003
E.R. Franchi Date
Superintendent, Acoustics Division

CONCUR: Tina Smallwood 9/15/03
Tina Smallwood Date
NRL Code 1221.1