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TECHNIQUES FOR MONITORING THE ENVIRONMENTAL EFFECTS OF ROUTINE --ETC(U)
AUG 77 G A YOUNG, R L WILLEY
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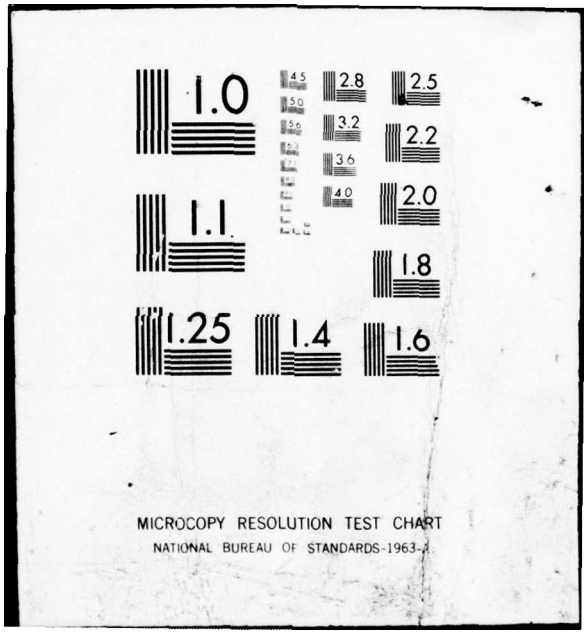
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NSWC/WOL TR 76-161

TECHNIQUES FOR MONITORING THE ENVIRONMENTAL EFFECTS OF ROUTINE UNDERWATER EXPLOSION TESTS

BY GEORGE A. YOUNG
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RESEARCH AND TECHNOLOGY DEPARTMENT

4 AUGUST 1977

NAVAL SURFACE WEAPONS CENTER

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: NSWC/WOL TR-76-161	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): TECHNIQUES FOR MONITORING THE ENVIRONMENTAL EFFECTS OF ROUTINE UNDERWATER EXPLOSION TESTS	5. TYPE OF REPORT & PERIOD COVERED: Final rept. / 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): George A. Young, Richard L. Willey	8. CONTRACT OR GRANT NUMBER(s): F57572, SF57572,391
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Surface Weapons Center, White Oak Laboratory, White Oak, Silver Spring, Maryland 20910	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62765N; F57-572; SF57-572-391; WR18BA;
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: 4 Aug 77 / 13. NUMBER OF PAGES: 43
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 34 p.	15. SECURITY CLASS. (of this report): UNCLASSIFIED / 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Underwater Explosions
Environmental Effects of Explosions
Fish Kill

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Possible techniques for monitoring the biological, chemical, and physical effects of underwater explosion tests are described, and the results of the evaluation of a limited number of possible methods are given. The funds and man-hours required for techniques at different levels of sophistication are estimated. It is concluded that simple inexpensive monitoring techniques are adequate for routine explosion tests. However, an extra person would be needed in the crew in order to accomplish the monitoring without adding appreciably to the time spent in the field.

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SUMMARY

The Navy is required by law to mimimize adverse effects on the environment in all of its activities and to monitor its operations to ensure compliance with applicable standards and regulations.

This report presents the results of part of a continuing study of the environmental effects of underwater explosion testing, and covers the practical aspects of monitoring such tests on a routine basis. In addition, this information will be useful in the planning of all underwater tests and should be particularly helpful for estimating the funding and man-power requirements. The mention of specific commercial equipment and/or brand names does not imply endorsement or recommendation for use.

This work is part of the Ordnance Pollution Abatement Program of the Naval Sea Systems Command and was funded under Program Element 62765N SF57-572-391, the Review and Evaluation Work Unit.

Julius W. Enig

JULIUS W. ENIG
By direction

CONTENTS

TABLES

I. INTRODUCTION

Agencies of the Federal Government are required by law to consider environmental factors during the planning and conduct of all programs and to monitor these activities to assure conformance to accepted standards. This responsibility extends to experimental programs and includes the underwater testing of explosives.

Studies have shown that these tests can be conducted in such a way as to have negligible environmental impact, and procedures are generally followed to reduce the unavoidable effects to an acceptable level.[1] Nevertheless, a need exists for relatively simple procedures that can be followed to monitor the environmental impact on a continuing basis as a routine part of an experimental program. Techniques are needed for biological, physical, and chemical effects.

The procedures can serve the following purposes:

1. to provide an objective basis for a decision to delay or move the tests if fish kill or other effects exceed an acceptable level;

2. to provide statistical data on fish populations and biological effects that can be used for planning purposes;

3. to detect unanticipated effects at an early stage; and,

4. to provide information on new chemical explosives or procedures.

Efforts have been made to evaluate fish kill on Naval Surface Weapons Center explosive test programs at Indian Head and Solomons, Maryland over a period of years, and these observations have been used for guidance and for the preparation of environmental impact assessments. However, the evaluations were strongly dependent on the skill of the observer, and the recorded information was not always consistent from year to year.

During the week of 3-7 May, 1976, a limited number of tests was conducted at the Naval Surface Weapons Center Facility at

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1. Young, G. A., 1973: Guide-Lines for Evaluating the Environmental Effects of Underwater Explosion Tests, NOLTR 72-211, Naval Ordnance Laboratory, White Oak, Maryland.

Solomons to explore improved techniques for the monitoring of fish kill and chemical pollution. This program was helpful in demonstrating some of the practical aspects of this type of work and in showing the time and manpower requirements for monitoring. These tests will be discussed in Chapter III, following a discussion of possible approaches in Chapter II.

II. POSSIBLE MONITORING TECHNIQUES

2.1 Biological

The monitoring of the effects of explosions on marine life should consist of two phases: (1) Pre-shot exploration of the test area to estimate the fish population density and to determine if other forms of marine life are present; and (2) Post-shot evaluation of the area affected by the shot to determine the number killed of each species. There are varying degrees of effort in both of these, and the method employed should be consistent with the nature and magnitude of the tests.

Pre-Shot Exploration

The simplest and most practical method to detect free-swimming fish is to patrol the test area with a small boat containing a commercial fish-finder of the type used by sport fishermen. This should be done shortly before the explosion because of the possible migration of fish into the area between the time of monitoring and the time of the test.

At the present time, commercial fishermen and marine biologists are developing acoustic scanning methods that can be used to study the behavior of fish and to estimate population densities. However, these systems are complex and expensive[2,3,4] and would not be practical for use on routine explosion tests.

Remote sensing of schools of fish from aircraft and satellites is a method also under development at the present time, but this, too, should be considered only if large-scale oceanic tests are contemplated.

Bottom dwelling marine life, such as oysters, clams, and crabs, require trawling for detection. More sophisticated methods

2. Cushing, D., 1973: The Detection of Fish, 200 pp., Pergamon Press
3. Mathisen, O. A., 1975: Three Decades of Hydroacoustic Fish Stock Assessment, MTS Journal, Vol. 9 No. 6, pp. 31 - 34.
4. Peterson, M. L., Clay, C. S., and Brandt, S. B., 1976: Acoustic Estimates of Fish Density and Scattering Function, J. Acoust. Soc. Am., Vol. 60, No. 3, pp. 618 - 622.

include photography of the bottom, and, in some cases, divers with biological training are used. However, areas where these species are found are generally well known because of their commercial importance, and these locations are avoided in explosive test operations.

For planning purposes, some forms of monitoring could be pursued at a test site during a period when explosives are not being detonated. For instance, a plankton net could be used to check for the presence of eggs and fish larvae. This would provide evidence of spawning. Another approach could be the monitoring of water temperature for the occurrence of temperatures that coincide with the initiation of spawning. For example, most spawning of striped bass seems to begin at about 15.5°C.[5]

Post-Shot Evaluation

It is most desirable to know the number, size, weight, and species of the fish or other forms of marine life killed by an explosion. In the past, this has been done by visual observation of the floating dead fish. In cases where the fish kill was high, the fish were netted and weighed.

However, visual estimates are the least reliable and are generally inconsistent because they include only the fish that can be clearly seen floating at the surface. Visibility of floating objects depends on the roughness of the surface, the depth of the object, and the position of the observer. Also, an observer at a distance usually can not estimate the weight reliably, and he cannot always be sure of the species. If several species are present, he must judge the relative numbers of each, which is difficult even in ideal conditions.

The accuracy is doubtless improved if at least two men in a small boat can search the area and pick up all of the floating fish. In this case, the fish can be sorted, measured and weighed, if sufficient time is available. Specimens can be preserved for later identification if necessary. Both methods, of course, do not account for dead fish beneath the surface or on the bottom. In addition, benthic organisms such as crabs and oysters are not accounted for.

When explosive charges are relatively large, it becomes impractical to collect all of the dead fish, and a reliable sampling technique is needed. The following has been proposed by personnel of the Chesapeake Biological Laboratory at Solomons, Maryland:

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5. Raney, E. C., 1952: The Life History of the Striped Bass, Bull. Bingham Oceanogr. Coll. Vol. 14, No. 1, pp. 5-97.

1. The size of the area of visible kill is determined with a range finder from a fixed platform.

2. A surface trawl is towed through the area, collecting a representative sample of floating dead fish. (Ideally, personnel on the tow boat communicate by radio with observers on the fixed platform who record the boat ranges and bearings as a function of time from an elevated position. Times of entry and departure from the kill area, and other significant information, are also recorded. A tape recorder is useful for this purpose.)

3. A bottom trawl is then towed through the area, collecting a representative sample of dead fish that have settled to the bottom and benthic species that may be present. Times, ranges, and bearings are recorded as before.

4. The fish in both trawls are sorted, measured, and weighed.

5. The ratio of volume swept to the total volume is calculated and is used to estimate the total fish kill. (This can be simplified by calculating in terms of the surface and bottom areas and adding the two results.)

This procedure can be expected to be most reliable when the following conditions are met:

1. The area of kill is circular.

2. The radius can be measured accurately.

3. The fish population density is uniform throughout the test site.

4. There are sufficient fish to be statistically significant.

5. There is no current.

6. There is little wind.

7. The dead fish float to the surface or sink to the bottom before trawling begins.

8. The collection efficiency and frontal area of the trawl are known.

9. The path of the boat can be accurately determined.

10. The water is not too deep for effective handling of the bottom trawl.

11. The bottom is level and smooth.

In some cases, fish specimens may be preserved for later dissection by a biologist to determine the nature of physiological damage. When this is done, the distance of the fish from the explosion should be recorded. The damage criteria listed in Table 2.1 have been established for explosive tests and have been used successfully in research programs conducted jointly by the Naval Surface Weapons Center and the Chesapeake Biological Laboratory.[6,7] It is recommended that they be adopted for general use.

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6. Gaspin, J. B., 1975: Experimental Investigations of the Effects of Underwater Explosions on Swimbladder Fish, I: 1973 Chesapeake Bay Tests, NSWC/WOL/TR 75-58, Naval Surface Weapons Center, White Oak, Maryland.
7. Gaspin, J. B., Wiley, M. L., and Peters, G. B., 1976: Experimental Investigations of the Effects of Underwater Explosions on Swimbladder Fish, II: 1975 Chesapeake Bay Tests, NSWC/WOL/TR 76-61, Naval Surface Weapons Center, White Oak, Maryland.

TABLE 2.1

CRITERIA FOR DAMAGE TO FISH[8]

(0) No damage

(1) Only light hemorrhaging, principally in the tissues covering the kidney.

(2) Gasbladder intact, but with light hemorrhaging throughout the body cavity with some damage to the kidney.

(3) No external indication of damage but with the gasbladder usually burst. Hemorrhaging and organ disruption less extreme than in (4) and (5) but with gross damage to the kidney.

(4) Incomplete break through the body wall but with bleeding about the anus. The gasbladder is almost invariably broken and the other organs damaged as noted under (5).

(5) Rupture of the body cavity. The break is usually a slit just to the side of the midventral line. Associated with this severe damage is a burst gasbladder and gross damage to other internal organs. The abdominal contents are often completely lost or homogenized.

8. Hubbs, C. L., Shultz, E. P., and Wisner, R. L., 1960: Preliminary Report on Investigations of the Effects on Caged Fishes of Underwater Nitro-Carbonitrate Explosions, University of California, Scripps Institution of Oceanography.

Although biological monitoring procedures should always be conducted with care, and methods can be made rather elaborate if necessary, it must be recognized that a high degree of accuracy is almost never attainable because of the known variability in the resistance of individual members of a species and because it is physically impossible to isolate a portion of an open body of water and count and weigh every organism in it. One problem is the changing location, population, and behavior of all forms of marine life. Also, the frequent occurrence of wind, currents, rough water, irregular bottoms, and other natural obstacles causes operational difficulties. In addition, conditions may change during the monitoring period, which may be as long as one hour.

On the other hand, precision is not needed or expected for the purpose of evaluating biological effects. The effects of explosions must be considered in relation to other variable environmental factors, such as natural fish kills resulting from reduced oxygen content, the importance of a particular species, the magnitude and success of local commercial and sport fishing, and seasonal changes due to spawning and migration.

It may be noted that similar considerations, and operational difficulties, are involved in the investigation of fish kills resulting from the deliberate or accidental spill of a toxic chemical into a body of water.[9]

2.2 Chemical

An underwater explosion deposits a fraction of the chemical products of the explosive reaction in the water. After a brief period, these products can be found in a roughly circular surface pool that moves with the current. This pool disappears quickly unless it is marked with a dye tracer, such as fluorescein. The products of a conventional explosive, such as TNT, are generally harmless to the environment in the concentrations in the pool after the rapid turbulent mixing caused by the explosion has subsided. However, some newer explosives produce products that are possibly harmful, and it may be necessary to collect water samples to determine the amounts present. Another reason for chemical monitoring is that the final composition of the products of any explosion may differ from the values determined on the basis of theory. The theoretical calculations usually end at a stage when the products are at a high temperature and before they cool and mix with the surrounding medium.

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9. Grantham, B. J., 1971: Basic Procedures for Investigating Fish Kills in Streams, pp. 100-104, in Collection of Papers Presented at the Fish Kill Investigation Seminar on 2-4 November 1971, Oklahoma State University, Stillwater, Oklahoma, April, 1972.

A good system would consist of an array or line of samplers, downstream from the explosion, controlled by wire in such a way as to collect contaminated water as it flows past. Another approach would be to traverse the surface pool with electronic probes and recording equipment, such as that developed for monitoring industrial water flows. An alternate procedure would be to measure the concentration of a fluorescent dye tracer, which is directly correlated with the concentration of explosion products. These methods are generally not practical for routine tests because of the cost of equipment and the level of effort required.

A simpler, but satisfactory approach is to dip water samples from the surface pool by hand after the explosion. One-liter polyethylene containers are a good choice. However, certain precautions are needed. First, a dye tracer should be placed in the water directly above the charge. Also, prior to the test, a background sample should be acquired in the vicinity of the charge. A measurement of current speed and direction is recommended.

After the test, a minimum of five samples should be collected at the center of the pool at 20- or 30- second intervals. Times should be recorded. A photographic record can be very helpful. As the contents of the pool may not be thoroughly mixed and uniformly distributed at early times, the measured concentrations may be erratic, but they should be adequate to indicate if a problem exists.

The preparation of samples should be discussed *in advance* with the chemist who will conduct the analysis. For example, it may be necessary to add nitric acid to the sample to reduce the pH level to 2.0 for satisfactory storage without change. Sampling procedures have been discussed thoroughly in a publication by Lai.[10]

In most cases, precise measurements and expensive procedures are not needed. This is particularly true if the measured concentrations are low and are well below hazardous levels. Equipment developed for field analysis of water samples may be adequate in this case. However, if a product is of special concern because of a potential toxic effect, it will then be necessary to obtain a large number of samples and to use whatever means are needed to obtain accurate data.

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10. Lai, M. G., 1975: A Chemical Monitoring Program of the Explosion Products in Underwater Explosion Tests, NSWC/WOL/TR 75-35, Naval Surface Weapons Center, Silver Spring, Maryland

2.3 Physical

The physical effects of underwater explosions include the following: shock waves, cratering, noise, disturbance of the bottom leading to the suspension of bottom materials, and the possible deposit of metal fragments on the bottom.

Cratering is not of concern unless explosions are near or on the bottom. Craters can be measured with a tape by personnel wading in shallow water, or by probing from a small boat in water up to three meters deep. Deeper water generally requires the services of divers if crater measurements are needed, though a depth-finder can be used in some cases.

However, crater monitoring is probably not needed on a routine basis because the size can be predicted with sufficient accuracy,[1] and tests are normally done over relatively barren bottoms.

Shock waves are generated in water and in air, and the water shock is usually measured as part of the test procedure. The major environmental effect of the underwater shock is the killing of fish. The shock wave in air becomes a sound wave as it travels away from the test site, and it can produce noise at a considerable distance.[1] There is no need to monitor this noise unless relatively large charges are fired at relatively shallow depths. Inexpensive commercial devices are available for this purpose.

The amount of suspended solids in the surface pool can be monitored by using the same water samples collected for the analysis of dissolved chemical products. The solids are mostly particles of sedimentary materials which eventually settle out. However, explosion products such as carbon and aluminum oxide may be present. Methods for the analysis of solid products or for unreacted explosives are described by Lai.[10] The weight of suspended solids can be determined by filtering and weighing and, in some cases, identification and size measurement can be done with an optical microscope. This may be difficult because the suspended particles tend to agglomerate when they are filtered.

III. EXPERIMENTAL PROGRAM - MAY 1976

3.1 Introduction

A limited series of explosion trials was conducted during the first week of May 1976 to test various monitoring techniques under a variety of conditions and to determine the time required. Only the equipment on hand at the time was utilized - no special purchases were made. No data were obtained on shock wave parameters, in order to enable the experimental personnel to devote full time to environmental monitoring. The tests were conducted in the Patuxent River in the vicinity of the Naval Surface Weapons Center Facility at Solomons, Maryland.

An 80-foot (24.4-meter) self-propelled barge was used as the experimental platform and a 17-foot (5.2 meter) boat was used for charge-handling and for monitoring. The barge was equipped with a Ross Fish Finder (Model 200-A Fine Line). Prior to the commencement of the explosion tests, the Ross transducer was mounted for side-scanning as well as for standard vertical soundings, but the lateral survey technique was not successful because the transducer cone angle was too great and multiple signal reflections occurred.

Equipment and supplies on hand also included: a portable fish-finder for use on the boat; a Navy range-finder; a trawl; trawl boards for surface trawling and for bottom trawling; a supply of one-liter plastic bottles; a supply of fluorescein dye; and two-way radios.

Naval Surface Weapons Center personnel were advised and assisted by Mr. Greig Peters of the Chesapeake Biological Laboratory at Solomons. Mr. Peters dissected the fish specimens that were collected and assessed the levels of damage in accordance with the criteria in Table 2.1. The experimental conditions are listed in Table 3.1.

3.2 Shot 1

Shot 1 was a test with a special experimental explosive composition weighing 4.3 kg. The main purpose was to collect water samples and to analyze them for aluminum content. The charge was placed 4.6 meters deep to assure thorough mixing of the explosion products with the water. As the water depth was 24.4 meters, little interaction with the bottom was expected. About 450 grams of fluorescein dye tracer were placed in a flexible plastic container 0.30 meters above the charge.

One water sample was obtained prior to the test and five samples were collected in the surface pool at 30-second intervals from 35 seconds to 155 seconds after the explosion. One-liter plastic bottles were used. The samples were subsequently analyzed at the White Oak Laboratory with a Perkin-Elmer Model 303 atomic absorption spectrophotometer. The background sample and the first three taken in the pool did not contain aluminum at or above the 0.1 mg/l detection limit of the instrumentation. However, the samples collected at 125 and 155 seconds contained 0.2 mg/l of aluminum.

This result indicates that the pool was not thoroughly mixed at early times and that the early samples were taken in relatively clean parts of the pool. The 0.2 mg/l concentration of dissolved aluminum would not be hazardous to marine life.

No dead fish were seen from the experimental platform. However, seagulls were swooping down to pick up fish. A closer inspection from the boat revealed the presence of small numbers of dead

TABLE 3.1

MAY 1976 EXPERIMENTAL PROGRAM

SHOT	DATE	EXPLOSIVE	CHARGE WEIGHT (lb)	CHARGE WEIGHT (kg)	CHARGE DEPTH (ft)	CHARGE DEPTH (m)	WATER DEPTH (ft)	WATER DEPTH (m)
1	4 May	EXPERIMENTAL	9.4	4.3	15	4.6	80	24.4
2	4 May	PENTOLITE	20	9.1	20	6.1	60	18.3
3	5 May	PENTOLITE	20	9.1	10	3.0	20	6.1
4	6 May	TNT	91	41.3	20	6.1	82	25.0
5	6 May	BARATOL	2.5	1.1	5	1.5	82	25.0

juvenile and larval menhaden and blueback herring, averaging about 3.8 cm in length. These were killed out to a range of about 400 feet (122 meters) from surface zero. (In free water the shock wave peak pressure level at 400 feet would be about 60 psi. This alone, however, is not an adequate criterion for estimating the extent of fish kill.[11])

It should be noted that the heavy plastic container of dye did not rupture completely at the time of the explosion, and that dye bled from the package for about two hours. This method proved to be less satisfactory than the technique of placing a mixture of dye and water in a paint can, which has been used successfully in the past.

3.3 Shot 2

Shot 2 was planned as a fish monitoring experiment. A 9.1 kg Pentolite charge was exploded at a depth of 6.1 meters in 18.3 meters of water about 2.8 km upstream from the Solomons Facility. However, only limited data were obtained because of the small fish-kill. The kill was estimated visually to be less than 100 menhaden, extending to a range of 350 feet (107 meters) from the explosion.

Specimens of floating dead fish were collected from the boat with a dip net up to 11 minutes after the shot. The data are summarized in Table 3.2. The distances from surface zero are visual estimates and are possibly in error by 25%. It is interesting to note that no fish with damage levels (1) or (2) were collected. Although injured, these would continue swimming and would remain in the natural food chain.

Two bottom trawls were attempted but they proved difficult because of the 18.3-meter average water depth and the many changes in depth encountered during the runs. The trawls were run at least 45 meters from surface zero, and the trawl was first placed in the water 19.5 minutes after the shot. This run started 2.25 minutes later, lasting a total of 5.12 minutes, while the second run started 29.75 minutes after the shot, lasting a total of 5 minutes. Only two anchovies about 5 cm long, were collected in the trawl net.

The results were inconclusive because of the deep water, the distance from the location of the explosion, and the small number

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11. "Goertner, J. F., 1977: Dynamical Model for Explosion Injury to Fish, NSWC/WOL/TR 76-155, Naval Surface Weapons Center, White Oak, Maryland.

TABLE 3.2

SHOT 2 DIP NET RECORDS

SAMPLE	FISH			DAMAGE LEVEL	DISTANCE FROM SURFACE ZERO	
	NUMBER	FORK LENGTH	SPECIES			
		(cm)			(m)	(ft)
1	1	12.7	MENHADEN	4	-	-
2	1	13.3	MENHADEN	4	30.5	100
	1	12.1	MENHADEN	3		
3	6	3.8	BLUEBACK HERRING	-	76.2	250
	2	15.2	MENHADEN	3		
4	1	13.3	MENHADEN	3	96.1	315
5	1	19.7	MENHADEN	3	-	-
6	1	15.9	MENHADEN	3	-	-
	1	15.2	MENHADEN	3		
	1	14.0	MENHADEN	3		
	1	11.4	MENHADEN	3		
7	1	30.5	MENHADEN	3	-	-

of fish. It was decided to continue testing in shallower water at the mouth of St. Leonard's Creek, about 6.2 km upstream from Solomons, where fish were known to be more prevalent.

3.4 Shot 3

Shot 3 was also a 9.1 kg Pentolite charge, but it was fired at a depth of three meters in 6.1 meters of water. The shallower water depth, and the location near St. Leonard's Creek, provided a higher fish population density than the site used for Shot 2.

The dead fish were distributed uniformly in the pool after the shot, and samples were collected with a dip net from 60 to 495 seconds after the explosion. The data are summarized in Table 3.3. Distances from surface zero are based on visual estimates and have a possible 25% error. The area of fish kill extended about 320 feet (98 meters) from surface zero.

A bottom trawl was run from about 20 to 29 minutes after the shot. Trawling was difficult because of the 7 m/sec wind speed and the 0.5 m swell. The data are summarized in Table 3.4 and a comparison between the results of the two sampling methods is given in Table 3.5. The times are listed in Table 3.6.

Although the number of fish collected and the times required are comparable in both cases, the percentages at each damage level differ. This may not be significant because of the small number of fish in each collection. It should be noted however, that only a bottom trawl would provide data on crabs and oysters. The trawl, of course, covers only a small fraction of the area of possible fish kill.

During the bottom trawl, ranges and bearings of the boat were recorded from the experimental platform. These readings were not very accurate because the equipment was difficult to handle, but the feasibility of the method was shown. The readings indicated a trawl distance of about 1000 feet (305 meters) and an average trawling speed of about 0.8 m/sec.

3.5 Shot 4

Shot 4 was fired at the deep site as a multi-purpose test. The charge was 39.5 kg of TNT with a 1.8 kg Pentolite booster, which may be treated as 41.3 kg of TNT for the purpose of this report. The charge depth was 6.1 meters and the test took place in water that was 25 meters deep. About 0.9 kg of fluorescein dye was used to assure a clearly visible pool.

Water samples were collected in the pool immediately after the shot and the weight of suspended solids was determined at the White Oak Laboratory. This was done because TNT usually leaves

TABLE 3.3

SHOT 3 DIP NET RECORDS

SAMPLE	TIME	FISH			DAMAGE LEVEL	DISTANCE FROM SURFACE ZERO	
		NUMBER	FORK LENGTH	SPECIES			
	(sec)		(cm)			(m)	(ft)
1	60	3	11.4	MENHADEN	3	91.5	300
		1	12.7	MENHADEN	3		
2	170	1	17.8	WHITE PERCH (MALE)	3	91.5	300
		1	19.0	WHITE PERCH (MALE)	3		
3	-	1	11.4	MENHADEN	3	-	-
		1	12.7	MENHADEN	3		
		1	3.8	MENHADEN (JUVENILE)	-		
4	390	1	10.2	MENHADEN	3-4	15.2	50
		1	11.4	MENHADEN	3-4		
		1	14.0	MENHADEN	3-4		
5	445	2	11.4	MENHADEN	3-4	30.5	100
		1	10.7	MENHADEN	3-4		
		1	5.1	SPOT	3		
6	495	1	12.7	MENHADEN	3	61.0	200
		1	55.9	EEL (LIVE)	3		

TABLE 3.4

SHOT 3 BOTTOM TRAWL RECORDS

FISH			
NUMBER	FORK LENGTH	SPECIES	DAMAGE LEVEL
3	-	MALE BLUE CRABS	0
2	-	FEMALE BLUE CRABS	0
1	-	OYSTER	0
1	10.2	MENHADEN	3
2	11.4	MENHADEN	3 (SWIMMING)
4	11.4	MENHADEN	3
1	11.4	MENHADEN	4
3	11.9	MENHADEN	3
1	12.7	MENHADEN	3 (SWIMMING)
1	13.2	MENHADEN	3
1	13.2	MENHADEN	4
1	18.5	WHITE PERCH (FEMALE)	3

TABLE 3.5

SHOT 3 COMPARISON OF RESULTS

SAMPLING METHOD	NUMBER OF FISH	DAMAGE PERCENTAGE	
		LEVEL 3	LEVEL 4
DIP NET	16	62.5	37.5
BOTTOM TRAWL	15	86.7	13.3

TABLE 3.6

SHOT 3 SEQUENCE OF EVENTS

EVENT	TIME (MIN:SEC)
FIRST DIP NET SAMPLE	1:00
LAST DIP NET SAMPLE	8:15
TRAWL IN WATER	20:30
END OF TRAWL	28:20
TRAWL PICKED UP	29:15

a residue of carbon floating on the water, which is unsightly though not harmful to the environment. The results are shown in Table 3.7. The weights are probably accurate to ± 10% or better. However, as in the evaluation of chemical concentrations, the major problem is one of obtaining representative samples when the distribution in the pool, and also in the ambient water, is not uniform.

Visual examination in a microscope showed the presence of sediment in the background sample and both sediment and carbon in the pool samples. Although the water was relatively deep, sediment was present because of the proximity of shallow water and the relatively strong current in the river. At 50 and 70 seconds carbon particles with diameters up to about 260 microns were present. At 90 seconds, the largest observed were about 130 microns, and, at 110 seconds, the largest were about 45 microns in diameter. However, by this time, the majority were of the order of 5 microns. The last sample, taken at 130 seconds after the shot was predominantly sediment with only fine (<5 microns) carbon particles remaining. There was a tendency for sediment and carbon to agglomerate into clusters.

The extent of fish kill could not be determined visually from the barge, but gulls were observed feeding about 300 meters from the shot point. Observers in the boat stated that about 1000 fish were slowly floating up to the surface. The surface trawl was placed in the water about 8 minutes after the shot and was towed through the dye patch. The patch, including the dead fish, moved away from the barge at about 0.4 m/sec, and the trawl was towed at about 1 m/sec. The trawl was in the water for 12 minutes, but the time in the dye was only about 5.5 minutes. It was noted that the fish were in patches in the pool of dye.

About 1.2 kg of menhaden were collected in the first trawl. The levels of damage are shown in Table 3.8.

Following the first trawl, a series of samples was taken with a dip net. The data are summarized in Table 3.9. The distances shown were determined with a range-finder. However, they represent the locations of fish after transport by the current. The original positions are not known.

It was noted that fish were still floating to the surface, and a second surface trawl was started 65 minutes after the shot and was terminated 9 minutes later. The boat was too far away from the barge for accurate tracking with the equipment available. The trawl net collected 0.77 kg of menhaden; the data are shown in Table 3.10.

Table 3.11 presents a comparison of the overall results of the three sampling efforts. In terms of percentage, the differences are minor, though more specimens were collected with the dip net.

TABLE 3.7

SHOT 4 WATER SAMPLE RECORDS

SAMPLE	SAMPLE TIME	WEIGHT OF SOLIDS
	(sec)	(mg/l)
1	BACKGROUND	127.8
2	50	812.2
3	70	530.3
4	90	707.7
5	110	134.1
6	130	104.6

TABLE 3.8

SHOT 4 FIRST SURFACE TRAWL RECORDS

	FISH		DAMAGE LEVEL
NUMBER	FORK LENGTH	SPECIES	
	(cm)		
1	25.4	MENHADEN	2
1	17.0	MENHADEN	3
7	11.4 - 14.0	MENHADEN	3
17	11.4 - 14.0	MENHADEN	4

TABLE 3.9

SHOT 4 DIP NET RECORDS

SAMPLE	TIME	FISH			DAMAGE LEVEL	DISTANCE FROM SURFACE ZERO	
		NUMBER	FORK LENGTH	SPECIES			
	(min.sec)		(cm)			(m)	(ft)
1	22:30	6	11.9-14.0	MENHADEN	3	460	1510
2	25:20	12	11.4-12.7	MENHADEN	3	427	1400
3	29:45	1	11.9-14.5	MENHADEN	3	390	1280
		2	11.9-14.5	MENHADEN	4(WITH INTACT BLADDER)		
		30	11.9-14.5	MENHADEN	4		
		65	11.9-14.5	MENHADEN	NOT DISSECTED		
4	33:50	6	11.9-13.2	MENHADEN	3	436	1430
		1	16.5	MENHADEN	3		
		32	11.9-13.2	MENHADEN	4		
5	36:40	1	17.8	MENHADEN	2(WITH SEVERE HEMORRHAGING)	393	1290
		1	27.4	MENHADEN	2(WITH SEVERE HEMORRHAGING)		
		2	12.7	MENHADEN	3		
		2	26.7	MENHADEN	3		
6	40:30	3	17.8-19.0	MENHADEN	3	227	744
7	45:30	1	53.3	EEL	3	32	105

TABLE 3.10

SHOT 4 SECOND SURFACE TRAWL RECORDS

	FISH		DAMAGE
NUMBER	FORK LENGTH (cm)	SPECIES	LEVEL
5	11.4-14.0	MENHADEN	3
1	24.1	MENHADEN	3
14	11.4-14.0	MENHADEN	4
1	16.5	MENHADEN	4
1	18.3	MENHADEN	4

TABLE 3.11

SHOT 4 COMPARISON OF RESULTS

SAMPLING METHOD	NUMBER OF FISH	DAMAGE PERCENTAGE		
		LEVEL 2	LEVEL 3	LEVEL 4
SURFACE TRAWL 1	26	3.8	30.8	65.4
DIP NET	99	2.0	33.3	64.7
SURFACE TRAWL 2	22	-	27.3	72.7

TABLE 3.12

SHOT 4 SEQUENCE OF EVENTS

EVENT	TIME (MIN:SEC)
FIRST WATER SAMPLE	0:50
LAST WATER SAMPLE	2:10
TRAWL IN WATER	8:00
START OF TRAWL	10:25
TRAWL IN DYE POOL	13:30
END OF TRAWL	19:05
TRAWL PICKED UP	20:00
FIRST DIP NET SAMPLE	22:30
LAST DIP NET SAMPLE	45:30
TRAWL IN WATER	65:20
TRAWL PICKED UP	74:00

The trawls probably collected smaller numbers of fish because the fish were floating in patches. Also, the boat towing the trawl may have pushed fish aside, thereby reducing the number collected by this method.

Table 3.12 summarizes the times of the Shot 4 monitoring efforts.

3.6 Shot 5

Shot 5 was fired to check on the presence of barium in the river following the detonation of a 1.1-kg charge of Baratol at a depth of 1.5 meters in water 25 meters deep. Baratol is a mixture of $BaNO_3$ and TNT in a ratio of 73/27.

Five water samples were collected in the surface pool, which was marked with fluorescein dye. The times were 30, 50, 70, 90, and 120 seconds after the explosion. When analyzed in the atomic absorption spectrophotometer, the barium concentrations were found to be below the limits of detection (0.5 mg/l).

The estimated visible fish-kill was 50 menhaden.

IV CONCLUSIONS

4.1 Time and Cost of Monitoring

When explosion tests are conducted on a routine basis in the same locality over a period of time, some degree of monitoring should be established that is acceptable in terms of both economics and environmental protection. The May 1976 program provided useful information in this regard, and Table 4.1 provides guidance as to the number of man-hours required for biological monitoring at increasing levels of effort.

The costs of supplies are approximate. As a minimum, they include the purchase of a vertical echo-sounder for fish detection and books or color charts for the identification of fish for use on all procedures. The maximum effort of Procedure VII also requires the purchase of at least two trawls, about 60 meters of tow line for each, glass jars for specimens, and formalin for use as a preservative. As the costs are not excessive, and the supplies are readily available, it is clear that the major expense involved in biological monitoring is the cost of labor. An expense that is more difficult to evaluate is the effect of the added time of monitoring on the total time required to complete an experimental program. For example, if four tests can be done in one day without monitoring, and only two with extensive monitoring, the time in the field could be doubled, thereby increasing the total cost by a considerable amount.

TABLE 4.1 BIOLOGICAL MONITORING

(ROUTINE TESTS - UP TO 1000 -LB EXPLOSIVE)

	MONITORING PROCEDURE	PERSONNEL AT SITE	TIME PER TEST	LABORATORY PERSONNEL	*TIME PER SPECIMEN	COST OF SUPPLIES
I	Visual Observation - Species, Number, Weight, Lateral Extent	2 in boat	15 min in boat	0	-	$300
II	Dip Net - Sorting and Weighing all fish	2 in boat	20 min in boat +30 min on platform	0	-	$400
III	Dip Net - Sorting and Weighing all fish Specimens preserved in bottles	2 in boat	20 min in boat +60 min on platform	1	15 min	$500
IV	Surface Trawl - Sorting and Weighing all fish	2 in boat 2 tracking on barge	30 min in boat +30 min on platform	0	-	$500
V	Surface Trawl - Sorting and Weighing all fish Specimens preserved in bottles	"	30 min in boat +60 min on platform	1	15 min	$600
VI	Surface and Bottom Trawls - Sorting and Weighing all fish	"	60 min in boat +60 min on platform	0	-	$750
VII	Surface and Bottom Trawls - Sorting and Weighing all fish Specimens preserved in bottles	"	60 min in boat +90 min on platform	1	15 min	$850

*Not including set-up time.

The cost of the dissection of specimens and evaluation of physiological damage is more difficult to evaluate, but it should not be excessive if a fully equipped biological laboratory and a biologist familiar with the procedure are available. The 15 minutes per specimen shown in Table 4.1 is a rough average that includes the recording of results.

In the case of chemical monitoring, as outlined in Table 4.2, Item I involves the least effort in the field and also provides good quality data. Items II and III require more work in the field and provide less accurate data, but can give results the same day as the test and require less costly instrumentation than that used in a laboratory.

Method IV can also provide data at early times, though the set-up, operation, and pick-up of equipment is relatively time-consuming. Method V would require less time of field personnel. Methods VI and VII produce the most data and eliminate the problems of collecting representative samples by hand. Method VII is doubtless the most expensive. However, in general, the cost of chemical monitoring is greater than the cost of biological monitoring.

The time for the laboratory analysis of a sample obviously depends on the nature of the procedure followed. The time of one hour in Table 4.2 is only a rough average and actual costs should be determined on a per case basis.

The use of Chemical Monitoring Methods such as IV, V, VI, and VII require the design and construction of special equipment. Methods VI and VII would possibly require electronic engineers for field operations and for the interpretation of records.

If both biological and chemical monitoring are required on the same tests, this can be done with the same crew if Methods I, II, or III are followed in both cases. Chemical sampling should be done first. If Method IV or V is used for chemical monitoring, it would be difficult to operate a trawl unless trawling could be delayed until the pool (and floating fish) had been carried downstream beyond the farthest sampler or until the array had been hauled in. It would probably be impossible to use Method VI or VII for chemical monitoring and also trawl for specimens of marine life on the same test.

4.2 Recommendations

The actual extent of monitoring should be related to the nature of the test; i.e., a test involving possibly harmful chemical products should receive more attention than a TNT explosion; and a large explosion near an important fishery should be planned and monitored more extensively than a series of 2-kg explosions in a barren environment. Also, on large-scale tests, more environmental

TABLE 4.2 CHEMICAL MONITORING

	MONITORING PROCEDURE	PERSONNEL AT SITE	TIME	LABORATORY PERSONNEL	*TIME PER SAMPLE	COST OF FIELD EQUIPMENT
I	Collection by Hand in Surface Pool - Retention of Samples for Laboratory Analysis	2 in boat	15 min	1	1 hour	$ 100
II	Collection by Hand in Surface Pool - Analysis of Samples at Site with Fluorometer	2 in boat 1 on barge	15 min +30 min	0	-	$ 500
III	Collection by Hand in Surface Pool - Analysis of Samples at Site with Field Techniques	2 in boat 1 on barge	15 min +30 min	0	-	$ 1,000
IV	Collection by Wire-Controlled Samplers on Floats Analysis of Samples at Site with Field Techniques	2 for set-up and collection 1 on barge	90 min +30 min	0	-	$21,000
V	Collection by Wire-Controlled Samplers on Floats Retention of Samples for Laboratory Analysis	2 for set-up and collection	90 min	1	1 hour	$20,000
VI	Traversal of Pool with Recording in-situ Fluorometer	2 on boat 2 tracking on barge	30 min	0	-	$50,000
VII	Traversal of Pool with Electronic Chemical Analysis Probes	2 on boat 2 tracking on barge	30 min	0	-	$100,000

*Not including set-up time.

specialists, including biologists and chemists, should be involved, and more attention should be given to the selection of the site and the time of the year.

It is not clear at the present time how reliable a particular monitoring method would be. Consider for example, Shot 4 in the 1976 series. A rough estimate was made of 1000 fish killed within a radius of 300 meters. The first trawl collected 26 fish, or 2.6% of the estimated total.

It was estimated that the actual trawl width when under tow is about 1.8 meters. The trawl was towed about 450 meters, resulting in a sweep of 8100 square meters of surface. Using the estimated fish-kill radius of 300 meters gives a circular surface area of 283,000 square meters. The swept area was 2.9% of the estimated kill area, which is consistent with the percentage of fish collected. This is doubtless fortuitous, as the fish distribution was patchy and the radius of fish kill was a rough estimate.

The most reliable count would be one based on the collection of every floating fish. However, the question of the number of dead fish on the bottom has not been answered. There is no simple rule-of-thumb that can be employed, as fish that are negatively buoyant sink to the bottom and those that are positively buoyant float when killed. With the passage of time, the fish that have fallen to the bottom decompose and rise to the surface. On a practical basis, an accuracy better than $\pm$ 50% should probably not be expected.

The accuracy of chemical analysis of a sample can be better than $\pm$ 1% in laboratory work and probably better than $\pm$ 10% with field procedures. However, the overall reliability depends highly on the number of samples and the locations and times of sampling. Because of the nature of the turbulent motions in the environment and in the surface pools, an individual sample could easily be taken in a spot where the concentration is considerably above or below average. If an accuracy better than $\pm$ 50% is required, it is necessary to traverse an explosion pool with probes and acquire continuous recordings of each traversal.

In the case of relatively small-scale routine testing, such as that done by the Naval Surface Weapons Center in the Potomac River, Patuxent River, and Chesapeake Bay with a crew of four to five men, a continuing monitoring program, including Procedures such as II or III in Table 4.1 and an occasional chemical monitoring with Procedure I in Table 4.2 seems to be the maximum practicable effort. However, even this would require the addition of one man to the field crew. A member of the regular experimental group could operate the boat, and the additional man could be responsible for the collection, sorting, weighing, and identification of fish specimens and the collection of water samples. When the collection

has been completed, the sorting, weighing, and recording could be done while other personnel are engaged in other duties, such as preparing for the next explosive test. When not engaged in monitoring activities, the extra man could have other assignments in connection with the experimental program.

The use of more elaborate (and costly) procedures on routine tests would not be justified. However, they should be seriously considered if large-scale tests with greater potential for ecological damage are contemplated.

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