Informational Leaflet 139

OBSERVATIONS ON THE LETHAL EFFECT OF UNDER ICE DETONATIONS ON FISH

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ALASKA FISH & GAME

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INTRODUCTION

The Sport Fish Division of the Alaska Department of Fish and Game was invited to participate in "Operation Breakup FY '66" to assess effects of underwater detonations on fish in Blair Lake.

"Operation Breakup FY '66" was a joint effort of the U.S. Army Engineer Nuclear Cratering Group (NCG) and the U.S. Army, Alaska (USARAL), conducted in coordination with the Alaska Engineer District, the U.S. Army Cold Region Research and Engineering Laboratory (CRREL), and the Alaska Department of Fish and Game, Sport Fish Division.

"Operation Breakup FY '66" consisted of a series of chemical explosive detonations fired in water to crater overlying sheet ice. The purpose of the operation was to generate information of tactical value for the military who are concerned with aircraft landing strip barriers and denial operations in frozen regions. The information will also be used in civilian application of explosives for clearing ice jams and in erosion control.

This operation afforded the Department the opportunity to test responses of fish to under-ice detonations under controlled conditions.

The operation was conducted in February, 1966, at 542-acre Blair Lake, located 33 miles south-southeast of Fairbanks, Alaska, on government property closed to the public (Figures 1 and 2).

Although Department of Fish and Game participation was on a basis of noninterference with the basic format of the tests, the military did provide the Department with the logistical support necessary to complete its phase of the operation.

Experimental procedures were somewhat hampered by temperatures which remained well below zero during most of the testing period.

Sport Fish biologists participating in this operation were George Van Wyhe, Thomas Nagata, and Eugene Roguski. Sgt. R.E. Kretser, Conservation N.C.O. of Ft. Wainwright, provided valuable assistance to the Department throughout the operation.

OBJECTIVES

The primary purpose of the Department's participation was to acquire information on the lethal effects of under-ice detonations on fish located at various depths and distances from the blasts. This objective required the use of fish held captive at predetermined locations during the detonations. A secondary objective was the determination of possible "excitation" or increased movement of the lake's resident fish as a result of the detonations. An assessment of lethal effects on resident fish in the blast areas was also to be made as far as was practicable.

MATERIALS AND METHODS

To assess lethal effects of the detonations on fish at various depths and distances, hatchery reared yearling king salmon (Oncorhynchus tshawytscha) were utilized as test fish. The yearling king salmon were flown to Blair Lake and placed in a holding pen until utilized. A total of 86 king salmon, ranging in length from 7 to 10 inches with a mean length of 8 inches, was used in these tests.

Cylindrical, 1/4-inch wire mesh cages measuring 8 inches in diameter by 16 inches in length were used to hold the fish. Prior to each detonation, 2 or 3 salmon were placed in each cage. The cages were suspended in the lake at predetermined depths and distances from the center of the various detonations. Cages were brought to the surface after each shot and fish were observed for movement, but were not removed from the cages. Each fish was placed in one

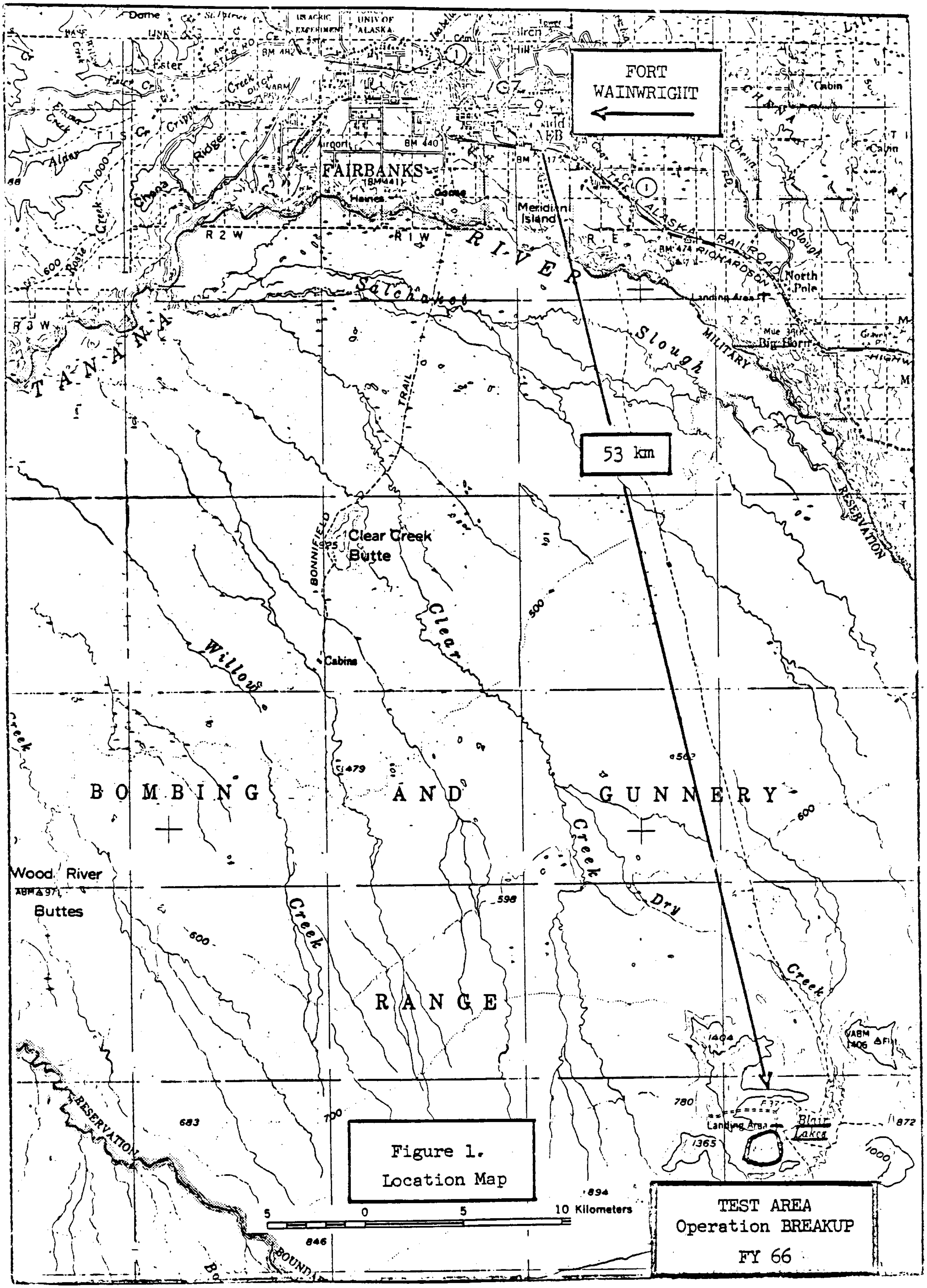


Figure 1.
Location Map

(U.S. Army, Corps of Engineers photo)

Figure 2. Blair Lake test site.

of the three following categories: 1) normal - fish swimming normally; 2) lost equilibrium - fish alive but not swimming normally; 3) dead - no movement. The cages were then lowered to previous depths for subsequent checks at intervals thereafter up to a maximum of 75 hours post shot for delayed mortality.

To evaluate possible mortality induced by the relatively long periods the test fish were confined in the cages, 10 king salmon were suspended in cages at various depths in an area of the lake approximately 2,000 feet from all detonations. These control fish were examined periodically during the confinement period of 99 hours.

All fish used in the tests were frozen upon removal from the water and were taken to the Department laboratory for autopsy.

The known fish population of Blair Lake consists entirely of northern pike (Esox lucius). Two graduated mesh gill nets were employed to determine possible increased movement of these resident fish resulting from the under-ice detonations. These nets are 125' long by 6' deep, of monofilament construction, with mesh sizes ranging from 1/2 inch to 2-1/2 inches square measure.

Attempts to estimate mortalities in the resident fish population caused by the detonations were limited to observing the crater and surrounding area following each detonation for fish floating in the crater or thrown out on the ice. All personnel working in the vicinity of the detonations were asked to report any fish which they had observed.

The nets were set and checked before any blasting activity began. To assess normal fish movements, one net was set at a location remote from the detonation area (approximately 3,000 feet from Shot 1) and the other net was set relatively close to the detonation (approximately 1,100 feet from Shot 1). Shot 1 consisted of 136-1/2 pounds of C-4 explosive1/ and was detonated just below the lower ice surface.

The nets were checked again just prior to the detonation and at intervals following the detonations beginning at two hours post-Shot 1.

1/ "Energy Equivalent Yields. The relative ice cratering effectiveness of C4, ANFO, and TNT ... was based upon the approximate experimental heats of detonation of the explosives. Values of 1.20, 0.94, and 1.10 kcal/g were used for C4, ANFO, and TNT respectively. The use of these values means, for instance, that 100 lb of ANFO is as effective for ice cratering as 78.3 lb of C4 where $\frac{(0.94)}{(1.20)}$ 100 = 78.3 lb." (Kurtz, 1966, pp. 4-17)

Prior to using king salmon in the demolition tests, two northern pike 20 and 21 inches in length, which had been captured unharmed during gill netting operations, were used to investigate the approximate lethal range of the detonations. The pike were placed in weighted burlap bags and suspended 5 feet below the ice at distances of 150 feet and 250 feet from Shot 2. This shot consisted of 135 pounds of C-4 explosive. It was detonated 5 feet below the lower ice surface at a location having a water depth of 44 feet.

RESULTS

Captive Northern Pike

The two northern pike held in burlap bags during Shot 2 (Figure 3) were examined immediately following the detonation. Both fish were dead and had scales missing from both sides of the body. Autopsy of the pike killed at the 150-foot station revealed a badly damaged rib cage and body wall, and ruptured liver, air bladder and kidney. Although damage to the pike killed at the 250-foot station was less severe, the body wall and rib cage were damaged, and the kidney, air bladder and ovaries were ruptured.

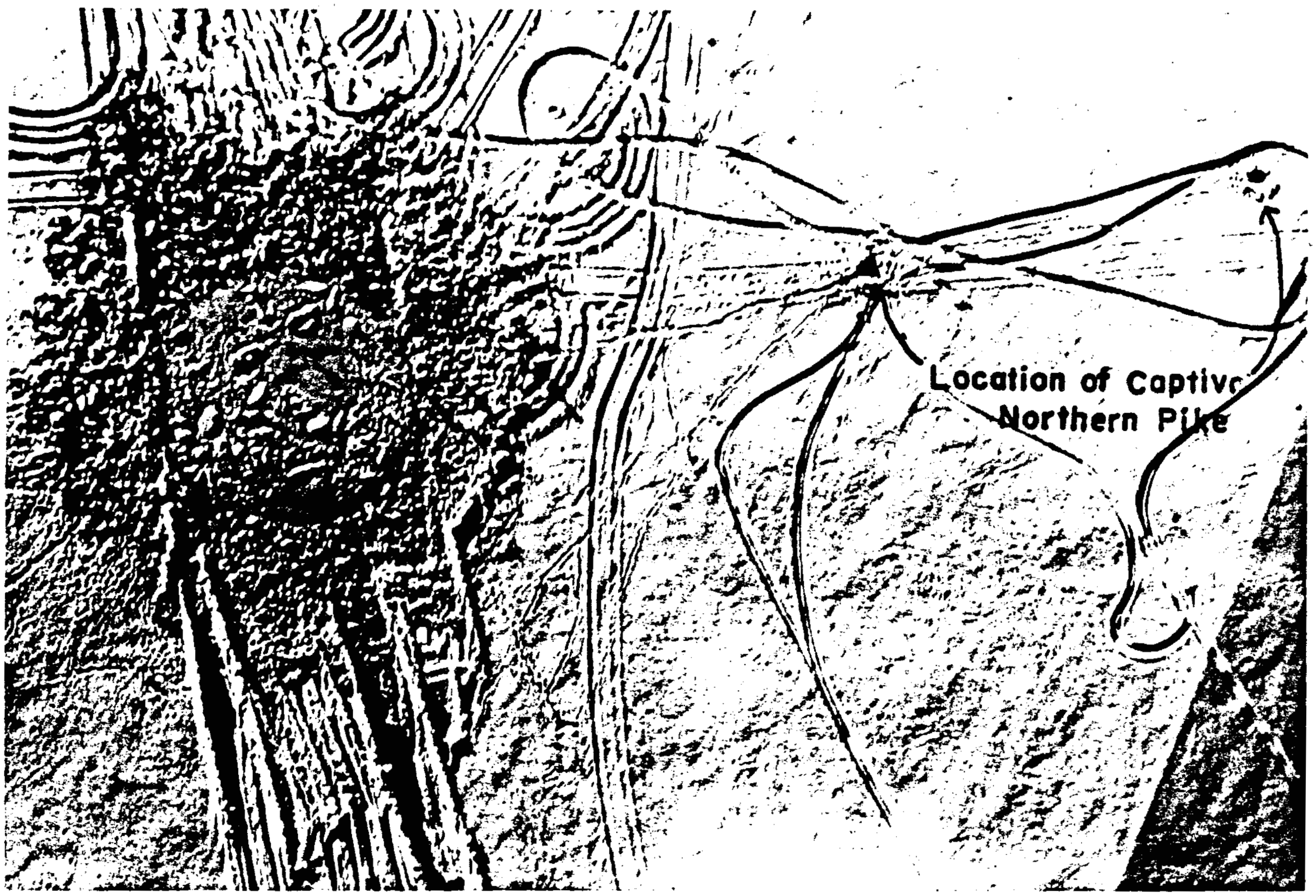
Captive King Salmon

King salmon were subjected to four underwater detonations ranging from 130.5 to 142.5 pounds of C-4 explosive to assess lethal effects of fish placed at various depths and distances, and to test differential effects of charges placed at various depths. In addition to these tests, king salmon were also used to evaluate the range of kill of a larger explosive charge, the 940 pounds of C-4 explosive used in Shot 31 (Figures 4 and 5).

The results of these tests are presented in the order of firing. Shots were pre-numbered by the military and firing order did not necessarily coincide with numerical rank.

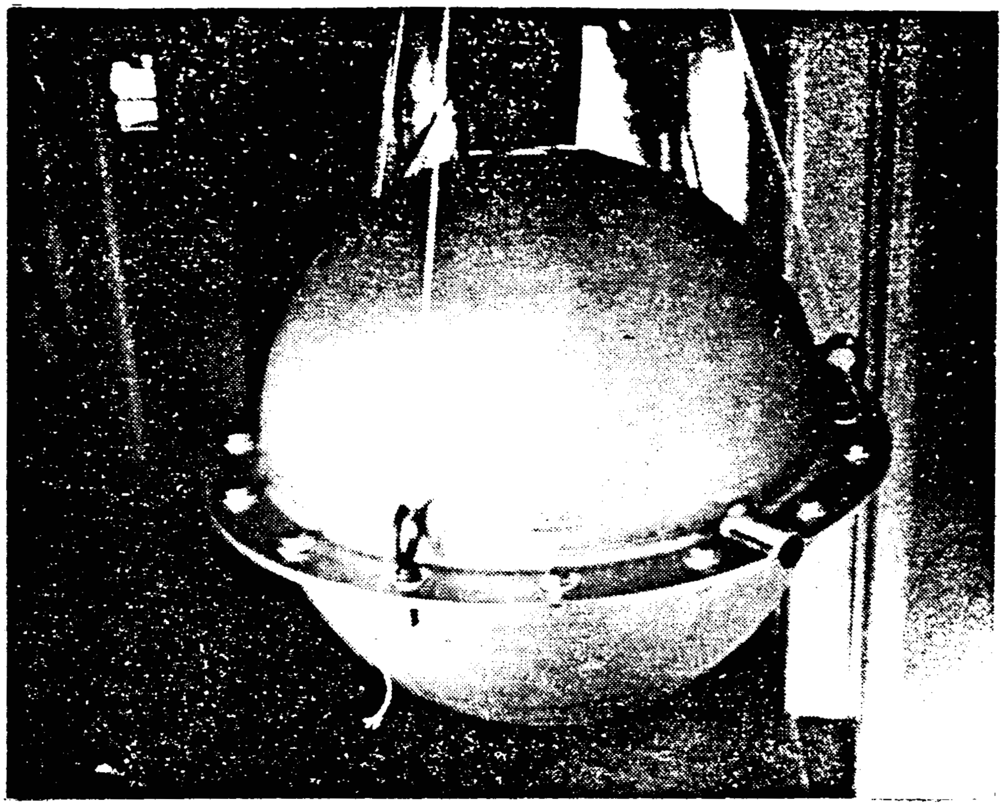
Shot 23

This shot consisted of 135 pounds of C-4. It was detonated 10 feet below the lower ice surface at a location with a water depth of 30 feet and an ice thickness of 33 inches. Because of the severe damage to the northern pike subjected to Shot 2 at distances of 150 and 250 feet, the cages containing



(U.S. Army, Corps of Engineers photo)

Figure 3. Shot 2 - showing location of Northern pike test fish.



(U.S. Army, Corps of Engineers photo)

Figure 4. C-4 charge container.

(U.S. Army, Corps of Engineers photo)

Figure 5. Charge at emplacement hole.

salmon were placed at intervals ranging from 250 to 550 feet (Figures 6a - 6c).

Examination of the cages immediately following the detonation revealed the failure of this charge to cause immediate total mortality to fish confined as close as 250 feet. No effect, either immediate or after a period of 21 hours was demonstrated at 550 feet. Autopsy of the fish which died in cage 5B (450 feet from the charge) revealed a ruptured intestine, but the air bladder and other organs appeared undamaged (see autopsy results appendix Table A). This injury may have resulted from handling, as no other fish experienced this type of injury; thus the lethal range of Shot 23 would be less than 450 feet.

Data on Shot 23 are presented in Table 1.

Shots 21 and 24

Results of these two shots are presented collectively as the cages used in these tests were placed at locations equidistant from both charges. The fish subjected to Shot 21 were left in the cages and also subjected to Shot 24 which was detonated three hours later. Two additional salmon were placed in each cage for Shot 24. These fish were finclipped for identification.

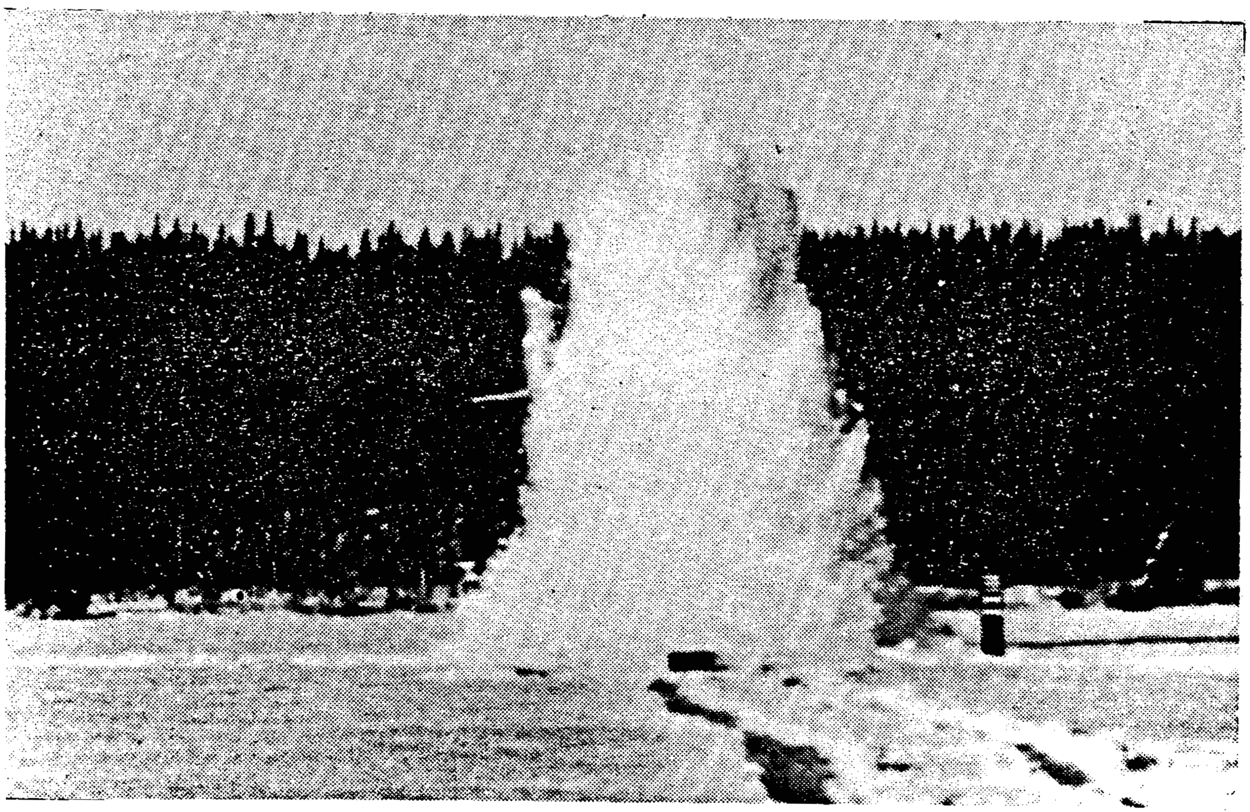
Shot 21 (134.5 pounds C-4) was detonated 15 feet below the lower ice surface in a location with a water depth of 20 feet and an ice thickness of 30 inches. Shot 24 (142.5 pounds C-4) was detonated 20 feet below the lower ice surface in a location with a water depth of 29 feet and an ice thickness of 31 inches (Figure 7).

Table 2 depicts results from Shots 21 and 24. Lethal range of Shot 21, detonated at 15 feet, would possibly be greater than indicated if data for a longer period post-shot were available. However, a comparison of immediate effects of Shot 21 and 24 (Table 2) clearly shows a greater mortality at all distances for Shot 24. Since the depth of the cages and the distances from charge and depth of cages were the same for both shots, it appears that the 20-foot depth of Shot 24 was more lethal than the 15-foot depth of Shot 21.

Since most fish from Shot 21 were apparently unharmed, they were also subjected to Shot 24 to assess effects of multiple exposure to charges. Immediate effects of Shot 24 on these fish appeared to be slightly more lethal than to fish not previously exposed to a detonation; however a longer post-shot period (16 hours) negated any differences.

(U.S. Army, Corps of Engineers photo)

Figure 6a. Phase 1 of Surface Motion - Shot 23 at approximately 50 msec - mound height, approximately 5 ft.



(U.S. Army, Corps of Engineers photo)

Figure 6b. Phase 2 of Surface Motion - Shot 23 at approximately 600 msec - mound height, approximately 45 ft.

(U.S. Army, Corps of Engineer photo)

Figure 6c. Phase 3 of Surface Motion - Shot 23 at about 1 second - mound height, 70 ft.

TABLE 1. EFFECTS OF SHOT 23 ON CAPTIVE YEARLING KING SALMON

Cage No.	Cage Depth*	Water Depth*	Distance from Charge	Immediate Effects	Final Effects 21 hrs. Post-Shot
1A	5'	32'	250'	2 L.E.**, 1 dead	3 dead
1B	32'		250'	2 Normal, 1 L.E.	1 Normal, 2 dead
2A	5'	32'	300'	2 L.E.	2 Dead
2B	27'		300'	2 L.E.	2 Dead
3A	5'	31'	350'	2 L.E.	1 Normal, 1 dead
3B	23'		350'	2 Normal	1 Normal, 1 dead
4A	5'	31'	400'	2 L.E.	1 Dead, 1 escape
4B	18'		400'	1 L.E., 1 dead	1 Normal, 1 dead
5A	5'	31'	450'	2 Normal	2 Normal
5B	13'		450'	1 Normal, 1 L.E.	1 Normal, 1 dead
6A	5'	30'	550'	2 Normal	2 Normal
6B	20'		550'	2 Normal	2 Normal

* Measured from lower ice surface
** L.E. = Lost Equilibrium

(U.S. Army, Corps of Engineers photo)

Figure 7. Shot 24 Crater

TABLE 2. EFFECTS OF SHOTS 21 AND 24 ON CAPTIVE YEARLING KING SALMON.

Cage No.	Cage Depth*	Water Depth*	Distance from Charge	Shot 21 Immediate Effect	Shot 24 Immediate Effect (21) Fish from Shot 21 (24) New fish	Final Effect 19 Hrs. Post-Shot 21 16 Hrs. Post-Shot 24
1A	5'	26'	230'	1 Normal, 1 dead	(21) 2 Dead (24) 1 L.E., 1 dead	(21) 2 Dead (24) 2 Dead
1B	21'		230'	2 Normal	(21) 2 Dead (24) 2 Dead	(21) 2 Dead (24) 2 Dead
2A	5'	26'	250'	1 Normal, 1 L.E.	(21) 2 Dead (24) 1 L.E., 1 dead	(21) 2 Dead (24) 2 Dead
2B	21'		250'	2 Normal	(21) 2 Dead (24) 2 Dead	(21) 2 Dead (24) 2 Dead
3A	5'	26'	300'	2 Normal	(21) 1 L.E., 1 dead (24) 2 L.E.	(21) 1 Normal, 1 dead (24) 2 Dead
3B	21'		300'	1 Dead**, 1 normal	(21) 2 Dead (24) 1 L.E., 1 dead	(21) 2 Dead (24) 2 Dead

* Measured from lower ice surface.

** This fish was L.E. prior to the detonation.

Shot 22

The three previous shots failed to cause immediate total mortality to salmon confined as close as 230 feet from the charges.

In an attempt to determine the maximum distance at which an immediate 100 percent kill would occur, test fish for Shot 22 were placed at intervals beginning at 150 feet from the charge.

Shot 22 (130.5 pounds C-4) was detonated on the lake bottom at a depth of 20 feet below the lower ice surface. Ice thickness at this location was 31-1/2 inches. Aside from the mortality check immediately following this shot, no subsequent examinations were made until 75 hours post shot because of logistical problems (Figure 8).

Shot 22 failed to cause immediate total mortality to fish confined as close as 150 feet from the detonation, and both fish in cage 2B (200 feet distance, 18 feet depth) appeared normal upon first examination.

Table 3 depicts results of Shot 22.

The 75-hour confinement of these fish prior to final assessment of lethal effects quite possibly contributed to the mortality in cage 2B and 3A, and would thus tend to enhance the actual lethal effects of Shot 22.

Shot 31

This final shot of the test series consisted of 940 pounds of C-4 explosive. It was detonated 19 feet below the lower ice surface in a location with water depth of 45 feet and an ice thickness of 36 inches (Figures 9 and 10).

Cage locations and effects of Shot 31 are presented in Table 4.

Although Shot 31 was approximately seven times larger than the other shots to which king salmon were exposed, its lethal range was not appreciably greater. One fish died in the deep cage 600 feet from Shot 31. However, autopsy revealed no gross internal damage, and other fish closer to the charge were not harmed. If it can be assumed that this fish died from causes other than the blast, the lethal range of Shot 31 appears to be practically identical to that of Shot 23.

(U.S. Army, Corps of Engineers photo)

Figure 8. Shot 22 Crater

TABLE 3. EFFECTS OF SHOT 22 ON CAPTIVE YEARLING KING SALMON.

Cage No.	Cage Depth*	Water Depth*	Distance from Charge	Immediate Effects	Final Effects 75 hrs. Post-Shot
1A	5'	21'	150'	1 L.E., 1 dead	2 Dead
1B	16'		150'	2 L.E.	2 Dead
2A	5'	23'	200'	1 L.E., 1 dead	2 Dead
2B	18'		200'	2 Normal	2 Dead
3A	5'	26'	310'	2 Normal	1 Normal, 1 dead
3B	21'		310'	1 Normal, 1 L.E.	1 Normal, 1 dead

* Measured from lower ice surface

(U.S. Army, Corps of Engineers photo)

Figure 9. Shot 31 Crater

(U.S. Army, Corps of Engineers photo)

Figure 10. Locating Edge of Shot 31 Crater

TABLE 4. EFFECTS OF SHOT 31 ON CAPTIVE YEARLING KING SALMON.

Cage No.	Cage Depth*	Water Depth*	Distance from Charge	Immediate Effects	Effects after 5 hours	Final Effects 21 hours Post-Shot
1A	2'		300'	1 Normal, 2 L.E.	2 Normal, 1 L. E.	1 Normal, 2 dead
1B	17'	39'	300'	2 L.E., 1 dead	1 L.E., 2 dead	3 Dead
1C	37'		300'	2 L.E.	2 L.E.	1 Normal, 1 dead
2A	2'		400'	1 Normal, 1 L.E.	2 Normal	2 Normal
2B	17'	37'	400'	2 L.E.	1 Escaped, 1 dead	1 Dead
2C	35'		400'	2 L.E.	1 Normal, 1 dead	1 Normal, 1 dead
3A	2'		500'	1 Normal, 1 L.E.	2 Normal	2 Normal
3B	15'	35'	500'	1 Normal, 1 L.E.	2 Normal	2 Normal
3C	33'		500'	2 Normal	2 Normal	2 Normal
4A	9'	33'	600'	2 L.E.	2 Normal	1 Normal, 1 dead
4B	22'		600'	1 Normal, 1 L.E.	2 Normal	2 Normal

* Measured from lower ice surface

Summary of test shots

Table 5 compares lethal ranges of the five shots to which king salmon were exposed. Depths listed in the table are measured from the lower ice surface. Lethal ranges, with the exception of Shot 21, are calculated from the final post-shot examinations. Shot 21 data utilizes only immediate mortality figures as these fish were also subjected to Shot 24 three hours after Shot 21. A longer period post-shot would probably increase distances of mortalities somewhat for Shot 21.

Data from the "mid-level" cages of Shot 31 were not utilized in Table 5 as it was felt this data would complicate the table unnecessarily while having little effect on the results depicted.

Shot 31 data indicates a maximum lethal range of 600+ feet for fish near the surface. Although one fish died at 600 feet, no fish died in the cages near the surface at 400 and 500 feet. The death of the fish at 600 feet may have been due to causes other than the detonations; therefore, the actual killing range may have been considerably less than 600 feet.

In several instances cages were not placed at a sufficient distance to adequately measure maximum killing range of the shot. Lethal distance measurements for these shots are followed by a plus (+). In all other cases a lethal effect was observed at one location but not at the farther cage placement and the greater distance is given preceded by a less than (<) sign.

Results of King Salmon Used as Controls

To assess the effects of handling and confinement stress on the king salmon used in these experiments, ten king salmon were placed in cages identical to those employed in the tests. The cages were placed at locations approximately 2,000 feet from any detonations and were checked periodically during a 4-day interval. Table 6 gives the results of this procedure.

The observed 10 percent mortality after 22 hours and 30 percent mortality after 99 hours confinement could not be correlated either with depth of cages (5 feet and 25 feet) or number of fish per cage (2 or 3) and thus may reflect the mortality which could be expected in the experimental fish when confined a considerable time post-shot (refer to Shot 22 confinement period of 75 hours).

Lethal Effects of Detonations on Resident Fish

Following each shot a search of the blast area was conducted in an

TABLE 5. LETHAL EFFECTS OF UNDERWATER DETONATIONS ON CAPTIVE YEARLING KING SALMON.

Shot Number & Size of Charge	Depth of Charge*	Water Depth*	DISTANCE OF FISH FROM DETONATION					
			100% Mortality		50% Mortality		Maximum Distance any Mortality Occurred	
			Fish near Surface	Fish near Bottom	Fish near Surface	Fish near Bottom	Fish near Surface	Fish near Bottom
23 (135#)	10'	30'	<350'	<250'	<450'	<550'	<450'	<550'
21** (134.5#)	15'	20'	<230'	<230'	<250'	<230'	<300'	<230'
24 (142.5#)	20'	29'	<300'	300'+	300'+	300'+	300'+	300'+
22 (130.5#)	20'	20'	<310'	<310'	310'+	310'+	310'+	310'+
31 (940#)	19'	46'	<300'	<300'	<400'	<500'	600'+	<500'

* Measured from lower ice surface.
** Shot 21 data is for immediate effects only.
< Greater distance than observed lethal effect.
+ Lethal distance measurement.

TABLE 6. MORTALITY OF CAPTIVE YEARLING KING SALMON USED AS CONTROLS

Cage No.	Cage Depth*	4 Hours in Cage	22 Hours in Cage	99 Hours in Cage
1A	5'	2 Normal	2 Normal	2 Normal
1B	25'	2 Normal	1 Normal, 1 dead	1 Normal, 1 dead
2A	5'	3 Normal	3 Normal	1 Normal, 2 dead
2B	25'	3 Normal	3 Normal	3 Normal
			10% Mortality	30% Mortality

* Measured from lower ice surface.

attempt to locate any fish that had been thrown out on the ice or were floating in the crater. However, a 20-inch layer of snow plus ice ejecta and other debris surrounding and floating in the craters made accurate observation difficult.

Although many personnel were in the blast areas making observations after each shot, no northern pike were observed throughout the entire test series.

"Excitation" of Resident Northern Pike

The two gill nets used in an attempt to determine any unusual movement of resident fish that could be correlated with the under-ice detonations produced the following:

> The net set at a location remote from the first two detonations was fished for a period of 39 hours to Shot 1. Three northern pike were captured. The net set nearer the detonations was fished for 18 hours prior to Shot 1 and captured no fish.
>
> A check of the nets two hours after Shot 1 revealed one northern pike in the near net and no fish in the remote net. A check four hours later (two hours after Shot 2) produced one northern pike in the remote net and no fish in the near net.
>
> The nets were fished overnight and checked the following morning. The near net contained one northern pike and the remote net contained two northern pike.
>
> The nets were removed at that time because of failure to show any catch data which could be correlated with the detonations.

Autopsy of Test Salmon

All salmon used in these tests were examined in the laboratory to determine internal damage. Autopsy findings for the 56 salmon that died during the tests are tabulated in the appendix.

The three salmon that died while confined as controls and all salmon alive at the conclusion of the tests were also autopsied; however, no evidence of internal injury was found in any of these fish.

Damage to fish killed relatively near the detonations was generally more severe than damage to more distant fish; however, degree of damage often varied considerably between fish from the same cage. In some instances, one of a caged pair recovered unharmed while the others died from extensive internal damage.

The most frequent injury, occurring to 45 fish, was rupture of the air bladder. Thirty-three fish also had kidney damage, either rupture or hemorrhage.

Damage to nine fish could not be determined.

DISCUSSION

Table 5 reveals no appreciable differences in final lethal effect on king salmon of charges detonated at depths between 10 and 20 feet below the lower ice surface.

Great variation in damage to fish in the same cages was often noted (see autopsy results in appendix Table A). In several instances one of a captive pair of salmon suffered no apparent damage while the other was killed or died later of injuries. The reasons for this variation can only be surmised. However, it seems quite possible that, because of differences in position between the pair at the time of burst, one fish may have absorbed much more of the energy of the shock wave, or the shock wave may have caused the cage to collide with one fish but not the other. However, no evidence of external damage to the fish was noted that would substantiate the latter theory.

Although data comparing blast effects on the fish of different sizes are meager and not strictly open to comparison, they do tend to indicate that larger fish (20-inch pike) may sustain greater damage from under-ice detonations than smaller fish (8-inch salmon). (Compare results of pike used in Shot 2 with Shots 23, 21, 24, and 22, in which salmon were placed 150 to 250 feet from the charge).

A possible interpretation may be that fish having a larger surface area absorb more of the energy of the blast than smaller fish and thus sustain relatively greater injuries. This difference, however, may only be due to differences in propagation of shock waves of charges fired at different depths (5 feet in the case of the pike and 10 feet or more in experiments using salmon).

The gill netting operations, which failed to discover any unusual amount of movement of resident fish due to the blasting, were limited and terminated early in the operation. Thus, they may have failed to reveal some "excitement" caused by multiple charges, larger charges, or possible "cumulative effects" of the series. However, off-duty military personnel who tried fishing in the lake caught a number of pike throughout the operation. This may indicate that there was no long-term disruption of the feeding pattern due to "excitement".

Besides poor visibility due to a heavy snow layer and large amounts of ice ejecta, another plausible reason for failure to find any pike may have been the damage to the fish. It is relatively certain that any pike near enough to the charge to be thrown out of the crater would have sustained a ruptured air bladder and thus would have sunk if it had fallen back in the water. Pike killed with lesser injuries at greater distances may have floated up, but of course would not be found under the ice.

The kill radius for northern pike is probably at least equal to that for the salmon, that is, a 100 percent kill range of less than 300 feet and a maximum kill range of less than 550 feet.

CONCLUSIONS

1. Under-ice detonation of 130.5 to 142.5-pound charges of C-4 explosive in water depths of 10 to 20 feet had a 100 percent mortality radius of approximately 300 feet and a maximum lethal radius of approximately 550 feet on 8-inch king salmon.

2. An explosive charge seven times as large (940 pounds of C-4) had little or no additional lethal range under these conditions.

3. Charges in water depths of 10 and 20 feet had little difference in effect; however, a charge at an intermediate depth of 15 feet appeared to have a somewhat shorter lethal range.

4. Unknown factors, possibly orientation of fish at time of blast, caused marked variations in kill at any given location (depth and distance).

5. The blasts caused no measurable "excitement" movements in the resident northern pike population.

6. Assessment of mortality to resident fish by observations in the blast vicinity was not feasible, due partly to heavy snow cover and ice ejecta and debris in and around the blast crater.

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APPENDIX TABLE A. AUTOPSY OF KING SALMON KILLED IN "OPERATION BREAKUP FY '66"

Shot 23

Cage 1A	1)	Hemorrhaging from vent, ribs broken, ruptured kidney and air bladder.
	2)	Ruptured kidney and air bladder
	3)	Ruptured kidney and air bladder
Cage 1B	1)	Ruptured kidney and air bladder
	2)	Ruptured kidney and air bladder
Cage 2A	1)	Ruptured kidney, air bladder and stomach, ribs broken
	2)	Ruptured kidney and air bladder
Cage 2B	1)	Ruptured air bladder
	2)	Ruptured air bladder
Cage 3A	1)	Ruptured kidney and air bladder, ribs broken, hemorrhaging from vent
Cage 3B	1)	Ruptured air bladder
Cage 4A	1)	Ruptured kidney, liver and air bladder
Cage 4B	1)	Ruptured air bladder
Cage 5B	1)	Ruptured intestine

Shot 21 (Fish also exposed to Shot 24)

Cage 1A	1)	Kidney, liver and air bladder ruptured, body wall hemorrhaged
	2)	Liver and air bladder ruptured
Cage 1B	1)	Air bladder ruptured

Shot 21 (Continued)

	2)	Air bladder and kidney ruptured
Cage 2A	1)	Air bladder and kidney ruptured
	2)	Air bladder ruptured, kidney badly damaged
Cage 2B	1)	Kidney and air bladder ruptured
	2)	Kidney and air bladder ruptured
Cage 3A	1)	Kidney and air bladder ruptured
Cage 3B	1)	Air bladder ruptured
	2)	Undetermined injuries

Shot 24

Cage 1A	1)	Air bladder and kidney badly ruptured, hemorrhaging from vent
	2)	Air bladder and kidney badly ruptured, body wall and ribs damaged
Cage 1B	1)	Kidney and air bladder badly damaged
	2)	Kidney and air bladder ruptured, body wall and rib cage damaged
Cage 2A	1)	Kidney and air bladder badly ruptured
	2)	Kidney and air bladder ruptured
Cage 2B	1)	Kidney and air bladder ruptured
	2)	Kidney and air bladder badly damaged, body wall hemorrhaged
Cage 3A	1)	Undetermined injuries
	2)	Air bladder ruptured

Shot 24 (Continued)

Cage 3B	1)	Kidney hemorrhaged and air bladder ruptured
	2)	Air bladder ruptured, intestine hemorrhaged

Shot 22

Cage 1A	1)	Kidney and air bladder ruptured, body wall hemorrhaged, rib cage broken
	2)	Air bladder and kidney badly ruptured
Cage 1B	1)	Hemorrhaging around heart
	2)	Undetermined injuries
Cage 2A	1)	Air bladder and kidney badly ruptured, body wall hemorrhaged
	2)	Air bladder ruptured, kidney hemorrhaged
Cage 2B	1)	Undetermined injuries
	2)	Undetermined injuries
Cage 3A	1)	Air bladder ruptured
Cage 3B	1)	Air bladder ruptured

Shot 31

Cage 1A	1)	Undetermined injuries
	2)	Undetermined injuries
Cage 1B	1)	Air bladder ruptured, kidney hemorrhaged
	2)	Air bladder ruptured, kidney hemorrhaged
	3)	Air bladder and kidney ruptured, ribs broken

Shot 31 (Continued)

Cage 1C	1)	Air bladder ruptured
Cage 2B	1)	Kidney and air bladder ruptured, hemorrhaging from vent
Cage 2C	1)	Undetermined injuries
Cage 4A	1)	Undetermined injuries