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TESTS TO INVESTIGATE EFFECTS OF SEISMIC EXPLOSIONS ON FLATFISH AND CRABS

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TESTS TO INVESTIGATE EFFECTS OF SEISMIC EXPLOSIONS ON FLATFISH AND CRABS

INTRODUCTION

An investigation to obtain further information on the effects of underwater explosions on flatfish and crabs was conducted offshore in coastal marine waters of Oregon on September 6 and 7, 1962. The study was conducted by the Oregon Fish Commission and financed by several companies presently engaged in oil seismic explorations.

The program was divided into two main parts--flatfish off Tillamook Head and crabs off Newport. The first part was further divided into two phases. Live flatfish were placed in test cages and lowered to the bottom in 20 and 38 fathom depths. Maximum amounts of explosives allowed under standard state permits were detonated over some cages while one was placed several hundred yards away from the shot area to serve as a control. The second phase (flatfish shotline test) involved making, along the same line, one-hour tows with a trawl net prior and subsequent to firing a string of explosions.

The second part involved soft and hard-shelled as well as large and small crabs in test pots placed on the bottom in various depths with seismic charges being detonated over them. Control pots were placed in the study area outside any possible lethal range.

Some incidental observations were made during the tests and these are summarized in part III of this report.

It was realized that the studies were restricted in scope and would provide only limited information. The general purpose was to detonate maximum-size charges of nitro-carbonitrate allowed under regular state

permits over caged fish and crabs under controlled conditions to measure possible damage. The conditions were to approximate the more severe expected under normal seismic operations. The trawling before and after a shot operation, likewise, was to see what gross effect this would have on total catch and condition of fish. There was no intention to try to locate fish with the fish detector and deliberately shoot over them to try to kill them. The ability to kill fish close to the point of detonation of certain-sized charges has not been questioned.

If significant damage were to be caused to the fish and shellfish under approximately routine seismic operations, as discovered by the controlled experiments, then a basis would be established for possible modification of procedures.

Oil seismic explorations commenced off the Oregon coast during the summer of 1961. Permits to explore for oil are issued by the Oregon State Land Board. Special conditions of the permits require that a fish-detecting device satisfactory to the Fish and Game Commissions be installed on each seismic vessel and be operated by a competent crew member. Regular permits limit the size of charges of nitro-carbonitrate to be used--5 pound maximum in waters less than 200 feet in depth and 25 pound maximum in waters over 200 feet in depth.

An observer from the Fish or Game Commission must be present whenever explosives are detonated and he has the authority to prohibit any shooting if undue damage to fish and wildlife is anticipated or has occurred. In general this is determined by use of the fish-detecting equipment before shooting and by observing injured or dead fish at the surface following an explosion. Approximately 7 per cent of the shots have been stopped due to

detection of fish within specified ranges of the shot point--150 feet horizontally and 150 feet vertically for a 5-pound charge of nitro-carbonitrate and 500 feet horizontally and 250 feet vertically for a 25-pound charge. Studies of the Scripps Institute of Oceanography on the effects of underwater explosions of nitro-carbonitrate on caged fish indicate that lethal effects to fish life from these charges are largely dissipated within these distances (Hubbs, 1960).

Other investigators have described studies on the effects of explosions on shrimp, oysters, crabs, and various species of fish. (Anon., 1948; Aplin, 1947; Gowanloch and McDougall, 1945, 1946; Hubbs and Rechnitzer, 1952; Rechnitzer and Hubbs, 1954; Hubbs, Schultz, and Wisner, 1960.) No work dealing with the effects of explosions on flatfish or their availability to a commercial trawl fishery following seismic work is known.

METHODS AND RESULTS

Part I - Flatfish Tests

The investigation dealing with flatfish was conducted on September 6, 1962. Vessels used were the chartered trawlers BETTY and TRASK and the seismic shot boat MISS IDA. Trawl work was assigned to the BETTY whereas the TRASK was used as an observation vessel and for recovery of test cages.

Caged Flatfish Test

Four wire cages, each containing live flatfish, were placed on the ocean floor and subjected to charges of nitro-carbonitrate. Three of the cages, all submerged in a line about 100 feet apart in 20 fathoms of water, were subjected to two separate 5-pound charges. Each was detonated 2 feet beneath the surface at a point approximately midway between an outside cage and the

center cage, with the result that the center cage (cage B in Table 1) received a double charge. The fourth experimental cage was placed in 38 fathoms of water and subjected to a 25-pound charge fired 4 feet beneath the surface approximately over the cage.

A fifth cage (control), also containing flatfish, was placed on bottom in the 38-fathom depth at a distance 600 yards from the fourth pot. Fish in the control cage were subjected to all of the same conditions as fish in the test cages, with the exception that no charge was detonated over them. It was intended that no shot would be fired nearer to the control than 600 yards. However, in starting the second (shotline) part of the study, the initial charge (25 pounds) was detonated inadvertently 150 yards from the control cage buoy.

Fish for the tests were obtained by trawling in 20 and 40 fathoms of water, and in each location, prior to the firing of any shot. All test animals were placed in a holding tank until ready for use. The holding period did not exceed approximately one-half hour. None of the fish was put back into water at a depth varying significantly from where found.

Cages used in all tests were commercial crab pots with the throats wired to prevent fish from escaping. Fish used in the test are listed in Tables 1 and 2.

Table 1. Species and Numbers of Flatfish in Three Cages Submersed to a Depth of 20 Fathoms and Subjected to Two 5-Pound Charges of Nitro-Carbonitrate.

	Flatfish				
Cage	Petrale Sole	English Sole	Sand Dab	Pacific Halibut	Total
A	3	8	1	-	12
B	4	5	-	-	9
C	-	10	-	1	11

Table 2. Species and Numbers of Flatfish in Two Cages Submersed to a Depth of 38 Fathoms, One as a Control (E) and the Other (D) Subjected to a 25-Pound Charge of Nitro-Carbonitrate.

	Sole				
Cage	Petrale	English	Dover	Rex	Total
D	4	5	6	-	15
E	5	4	4	5	18

Divers observed the condition of the fish in cage A immediately subsequent to detonation of the prescribed 5-pound charge. Visibility on the bottom was about 15 feet without artificial light and the water was clear. While swimming along the bottom, the divers observed a skate that swam away when touched. No other dives were made on caged flatfish. All cages were pulled within 1½ hours after being subjected to explosions. Fish in the cages were examined for external signs of damage then placed in plastic bags and iced. Fish from each test cage were kept separate and marked for later identification. Examination for evidence of internal damage was made by biologists when the fish were filleted at the San Juan Fishing and Packing Company in Warrenton on the following day.

All examinations immediately following the detonation of charges may be summarized as follows:

Diver check (20 fathoms)

Cage A -- 2 sole appeared to be dead, all other fish (10) obviously alive.

Surface examination

Cage A -- all 12 fish alive.

" B -- 1 sole dead, rest of fish (8) alive, cause of death unknown.

" C -- 1 sole and 1 halibut dead, rest of fish (9)

alive. It is believed the halibut beat itself to death as it was thrashing violently when submerged. Cause of death to other fish unknown.

Cage D -- all 15 fish alive.

" E (control) -- 3 sole dead, rest of fish (15) alive, cause of death unknown.

Results of the internal examination of all fish when they were filleted on the following day are as follows:

Cage A -- no internal visible damage in any fish.

" B -- no internal visible damage in any fish.

" C -- no internal visible damage in any fish.

" D -- 1 petrale sole with slightly discolored kidney, no break or rupture; 1 dover sole with dark colored kidney, no break or rupture; no visible damage in other fish.

" E -- 1 dover sole with torn peritoneum (probably torn by filleter's knife); no visible damage in other fish.

Fillets from all fish appeared normal with no evidence of hemorrhaging. No sign of external damage to any of the fish was observed.

Flatfish Shotline Test

The second part of the flatfish study was conducted in an area trawled commercially. The plan was to make two trawl tows along the same line, each about one hour in duration, before and after firing a string of seismic shots. The shot phase was accomplished to approximate a normal seismic operation, except that all charges were of maximum size allowed (25 pounds) in the standard permit in water depths over 200 feet. As in normal operations, the firing of shots was stopped whenever fish concentrations were observed on the Simrad echo sounder within the estimated lethal range.

The initial tow in the shotline test lasted 65 minutes and was made by the BETTY in a northerly direction on the 40-fathom curve. The tow began at

Loran* bearing 3343 and ended at bearing 3380 in 39½ fathoms. All Loran bearings given in this report are 2H4.

The MISS IDA fired a shotline of 25-pound charges suspended 4 feet beneath the surface on the 36-fathom curve in a southerly direction. Seven shots approximately 1/4 mile apart were fired and three were skipped because of the presence of fish near the bottom as indicated by the Simrad echo sounder. The TRASK followed the MISS IDA making observations of each shot boil. One injured herring was observed and recovered. No other fish were seen.

The BETTY set her net in 35½ fathoms at Loran bearing 3375 and towed southerly over the course of the shotline after the explosions for 56 minutes, slightly shorter than the first tow, ending at bearing 3343 in 36 fathoms. The catch from each tow was kept separate and examined for species and size composition. On the following day the catch from the post-explosion drag only was examined.

Number and total pounds of each species caught in the two tows are shown in Table 3. Species composition in each catch was approximately the same.

Table 3. Number and Pounds of Flatfish Caught In Trawl Tows Before and After a Shotline.

	Number of Fish		Pounds of Fish	
	Before Explosion	After Explosion	Before Explosion	After Explosion
English Sole	214	170	110	130
Rex Sole	611	507	250	240
Dover Sole	44	11	25	5
Petrale Sole	30	26	20	20
Turbot	10	12	7	15
Sand Dab	155	185	125	100
Herring	1	6	--	1
Rat Fish	23	29	10	30
Skate	34	21	400	200
Ling Cod	2	3	40	25
Crab	50	17	50	20
Halibut	1	3	15	35
Hake	--	2	--	5
Shad	--	1	--	1
Smelt	--	100	--	5
Black Cod	--	1	--	1
Total	1,175	1,094	1,052	833

*Electronic navigational aid used to determine location at sea.

Total weight of the trawl-tow catches before and after the shotline was about 1,000 and 800 pounds, respectively. The difference may be due to normal sampling variation or a shorter second tow.

Cumulative length frequencies of English and rex sole from the two catches are shown in Figure 1. No significant difference is evident in size composition.

Internal and external condition of fish caught in the tow made after the shotline was observed by biologists as they were processed on September 7, 1962. Fish larger than 12 inches were filleted. Of 26 petrale, 24 showed no visible sign of damage. One had a dark kidney while the second showed blood starting to separate from the kidney. Of 56 English sole, 44 showed no sign of damage, 5 had blood starting to separate from the kidney, 1 had bloodshot viscera, 1 had blood on the backbone, 1 had a ruptured kidney, 2 had bloodshot kidneys, and 2 females had a greenish membrane over their ovaries which was not thought to be abnormal. Other fish checked and found normal were: 4 dover sole, 2 rex sole, 2 ling cod, 1 halibut, 3 herring, and 1 shad. Subsequent examination of other flatfish caught by the BETTY with a trawl net showed similar type damage.

Part II - Crab Tests

The crab phase of the investigation was conducted on September 7, 1962, off the Oregon coast north of the Alsea River in an area normally fished for crabs. Vessels used were the ELENA N., an Oregon State Police patrol boat, and the seismic boat, MISS IDA.

Dungeness crabs were obtained for the tests from two sources. Small crabs had been caught in tide pools six weeks previous to the tests. Adult crabs were caught in commercial crab pots in Yaquina Bay a few days prior

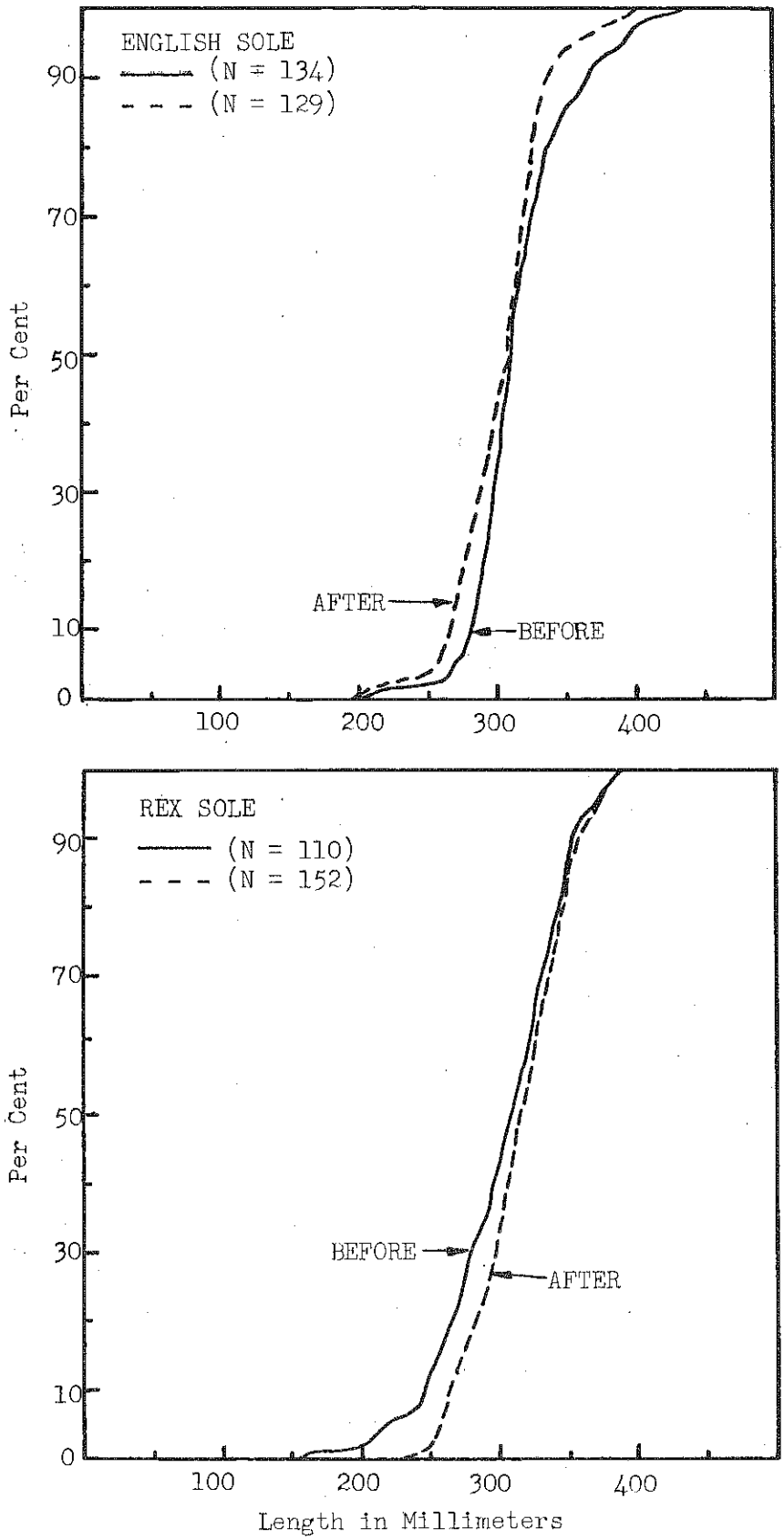

Figure 1. Cumulative Length Frequencies of English Sole and Rex Sole Caught Before and After Seismic Explosions.

to the experiments. All were held in live tanks.

A total of 15 commercial crab pots (12 test, 3 control) was used in the tests. Eight crabs were placed in each of 14 pots--3 large hard shell, 3 large soft shell, and 2 small soft shell to a pot. A similar assortment, excluding 1 large soft shell, was available for the remaining pot. The small crabs in each pot were placed inside a hardware cloth box of 6x6x12-inch dimensions. The chelae (pincerlike claws) of all crabs were tied with rubber bands prior to placement in the pots to prevent damage to each other. Large crabs were over 5 inches (130 mm minimum) and small crabs were less than 3 inches (80 mm maximum) in carapace width.

Two series of tests were conducted. In the first series, one 5-pound charge of nitro-carbonitrate suspended 2 feet beneath the surface was fired between two crab pots placed about 50 feet apart on the bottom at each of two depths--8 and 15 fathoms. A 25-pound charge was exploded at a depth of 4 feet over two additional pots similarly spaced in 35 fathoms of water. In the second series, about one-half mile north of the first series, equivalent-size charges and numbers of pots were used. All other conditions also were similar to the first experiment except that the charges were detonated 20 feet beneath the surface in the 8-and 15-fathom depths and 40 feet in the 35-fathom depth.

One pot was recovered and the crabs examined at each depth in both series within one-half hour after being subjected to shot treatment. The remaining pots were recovered 4 days later. Divers examined the condition of crabs on the bottom at the 8 and 15 fathom depths of both series prior to recovery immediately following the blasts. Results of the divers' observations of seven pots are given in Table 4.

Table 4. Results of Diver Examinations of Crab Pots in 8- and 15-Fathom Depths Following Explosions.

Pot Depth (Fathoms)	Pot Number	Condition of Crabs	
		Surface Shot	Submerged Shot
8	1	Two crabs dead (1 with two legs pulled off), 6 crabs alive (lively), no other visible damage.	All crabs (8) alive, no visible damage.
8	2	All crabs (8) alive, one in poor shape with one leg pulled off, no other visible damage.	All crabs (7) alive, no visible damage.
15	1	One crab dead, 7 crabs alive, no visible damage.	All crabs (8) alive, no visible damage.
15	2	All crabs (8) alive, no visible damage.	Not examined.

Three of the original 15 pots were placed on the bottom in the study area on September 7 as controls and were recovered on September 11. After the blast one pot was placed about 100 feet from the remaining test pot at each depth in the first series.

The results of examination of all test and control crabs are given in Table 5. Totals of 37 live undamaged and 11 dead or damaged (including 3 live) crabs were observed in test pots recovered immediately after the explosions. The test pots recovered 4 days later contained 31 live undamaged and 16 dead or damaged (including 5 live) crabs. The control pots (also recovered after 4 days) contained 16 live undamaged and 8 dead or damaged (including 3 live) crabs. No small crabs were found dead or damaged in any group.

The types of damage observed were: holes in carapaces up to 1-inch diameter (underlying tissue not ruptured), cracks in carapaces in various

Table 5. Number of Live Undamaged and Dead or Damaged Crabs from Test and Control Pots Recovered Immediately and After 96 Hours.

Pot Depth (ft.)	Amt. of Expl. (lbs.)	Depth of Expl. (ft.)	Immediate Recovery						Delayed Recovery (96 hrs.)						Control (96 hrs.)					
			Live Undamaged			Dead or Damaged			Live Undamaged			Dead or Damaged			Live Undamaged			Dead or Damaged		
			Lge. Hard	Lge. Soft	Small Soft	Lge. Hard	Lge. Soft	Small Soft	Lge. Hard	Lge. Soft	Small Soft	Lge. Hard	Lge. Soft	Small Soft	Lge. Hard	Lge. Soft	Small Soft	Lge. Hard	Lge. Soft	Small Soft
8	5	2	0	0	2	3	3	0	3	0	2	0	3	0	2	0	2	1	3	0
8	5	20	3	1	2	0	2	0	2	0	2	0	3	0	-	-	-	-	-	-
15	5	2	3	2	2	0	1	0	3	2	2	0	1	0	2	2	2	1	1	0
15	5	20	3	2	2	0	1	0	3	0	2	0	3	0	-	-	-	-	-	-
35	25	4	3	3	2	0	0	0	3	0	2	0	3	0	3	1	2	0	2	0
35	25	40	3	2	2	0	1	0	1	2	2	2	1	0	-	-	-	-	-	-
Total			15	10	12	3	8	0	15	4	12	2	14	0	7	3	6	2	6	0

locations, and one carapace broken in half. Although the chelae of all crabs had been tied, some were able to free themselves and probably inflicted damage on each other. Damage resulted from ends of wires on the pieces of hardware cloth used to cover the inside openings of pot tunnels. One crab had small puncture wounds that matched the ends of wires.

Analysis of variance tests were conducted at the 5 per cent significance level on test data. Calculations and results of the analyses are given in Tables 6,7,8, and 9. The tests were designed to indicate statistically significant differences in mortality and damage in the following groupings: shot versus control groups; 8, 15, and 35-fathom groups; surface versus submerged shots; and 5-pound versus 25-pound shots. No significant difference due to any of the four variables was found.

Part III - Incidental Observations

The BETTY was equipped with an Eko-Lite fish detector which showed concentrations of fish in the identical location and pattern as detected by the Simrad on the MISS IDA when both vessels were traversing the same course. Concentrations assumed to be fish were detected by the Simrad of the MISS IDA prior to 5 shots over crab pots. Dead fish appeared on the surface after 4 of these. It is not known why dead fish were not observed after the fifth shot, although it is possible that jellyfish or something else caused the indication. Fish killed by the explosions included hundreds of small smelt, small anchovies, tom cod, and herring. In addition, two black rockfish were killed by one shot. Autopsies of the rockfish revealed kidneys ruptured, liver completely shattered, heart hemorrhaged, vertebra shattered, and the peritoneal space filled with bloody watery fluid. No external damage was visible. Possibly a fourth as many dead fish, generally of the same species

Table 6. Analysis of Variance Test of the Hypothesis that There is a Significant Difference in Numbers of Crabs Dead or Damaged Between the Shot and Control Groups.

Calculations				
	Treatment			Total
	Control	Immediate	Delay	
	.500	.750	.375	1.625
	.250	.375	.125	0.750
	.250	.000	.375	0.625
	--	.250	.429	0.679
	--	.125	.375	0.500
	--	.125	.375	0.500
T	1.000	1.625	2.054	G=4.679
n	3	6	6	Σn= 15
$\bar{y}$	0.333	0.271	0.342	
			$\Sigma T^2/n$=1.477	
			Σy^2 =1.934	

Analysis of Variance

Variation due to:	Sum of Squares	Degrees Freedom	Mean Square	F	Remarks
Control vs. Test	0.0017	1	0.0017	0.04	Not Significant
Residual	0.0153	1			
Error	0.4570	12	0.0381		
Total	0.4740	14			

F.05=4.75 with 1 and 12 d.f.

Conclusion: No significant difference in the mortalities or damage between the test and control groups.

Table 7. Analysis of Variance Test of the Hypothesis that There is a Significant Difference in Numbers of Crabs Dead or Damaged with Pots placed at Different Depths

	Calculations			
	Depth	Live Boxes		Total
	8 fathom	15 f	35 f	
	.750	.375	.000	1.125
	.375	.125	.375	0.875
	.250	.125	.125	0.500
	.429	.375	.375	1.179
T	1.804	1.000	0.875	G=3.679
n	4	4	4	n= 12
$\bar{y}$	0.451	0.250	0.219	
			T^2/n	1.255
			y^2	1.559

Analysis of Variance

Variation due to:	Sum of Squares	Degrees Freedom	Mean Square	F	Remarks
Regression	0.1070	1	0.1070	3.17	Not Significant
Deviation Linearity	0.0201	1	0.0201	0.59	Not Significant
Error	0.3040	9	0.0338		
Total	0.4311	11			

F.05=5.12 with 1 and 9 d.f.

Conclusion: No significant difference in mortalities or damage with the crab pots placed at different depths.

Table 8. Analysis of Variance Test of the Hypothesis that There is a Significant Difference in Numbers of Crabs Dead or Damaged Between Surface and Submerged Explosions.

Calculations		
Depth of Shot		Total
Surface	Submerg.	
.750	.250	1.000
.375	.429	0.804
.375	.125	0.500
.125	.375	0.500
.000	.125	0.125
.375	.375	0.750
T 2.000	1.679	G +3.679
n 6	6	$\Sigma n = 12$
$\bar{y}$ 0.333	0.280	
	$\Sigma T^2/n = 1.136$	
	$\Sigma y^2 = 1.559$	

Analysis of Variance

Variation	Sum of	DF	Mean Square	F	Remarks
Depth	0.0081	1	0.0081	0.19	Not
Error	0.4230	10	0.0423		Significant
Total	0.4311	11			

$F.05 = 4.96$ with 1 and 10 d.f.

Conclusion: No significant difference in numbers of mortalities or damage between surface & submerged shots.

Table 9. Analysis of Variance Test of the Hypothesis that There is a Significant Difference in Numbers of Crabs Dead or Damaged Between 5-Pound and 25-Pound Charges of Nitro-carbonitrate.

	Calculations		
	Size of Shot		Total
	5	25	
	.750	.000	0.750
	.375	.375	0.750
	.375	.125	0.500
	.125	.375	0.500
	.250	--	0.250
	.429	--	0.429
	.125	--	0.125
	.375	--	0.375
T	2.804	0.875	G=3.679
n	8	4	Σn= 12
$\bar{y}$	0.350	0.219	
		$\Sigma T^2/n$= 1.174	
		Σy^2 = 1.559	

Analysis of Variance

Variation Due to:	Sum of Squares	D.F.	Mean Square	F.	Remarks
Size of Shot	0.0461	1	0.0461	1.20	Not Significant
Error	0.3850	10	0.0385		
Total	0.4311	11			

F.05=4.96 with 1 and 10 d.f.

Conclusion: No significant difference in numbers of crabs dead or damaged between 5 and 25-pound charges.

composition, were found on the bottom as on the surface.

Because the purpose of these five shots was to determine their effect on caged crabs at a specific location, indications of fish on Simrad were disregarded. Consequently, it was expected that substantial numbers of fish would be killed. However, it should be remembered that under normal operations, readings of this type would have resulted in prohibiting the shots.

The divers observed many small, live animals including 1-inch sole, 1-2-inch shrimp, 1/2-3/4-inch crabs, and hermit crabs at several locations on the bottom subsequent to explosions over caged crabs. Larger live forms also observed included ling cod, cabezon, and skate, none of which have an air bladder. It is obvious from these on the spot observations that both large and small fish present on the bottom adjacent to the pots within ten minutes of the blast survived with no readily apparent injury. During descents to the bottom the divers observed a 20-foot-thick layer of small, white jellyfish and numbers of large, red jellyfish. A layer was evident on the Simrad trace in the same location.

SUMMARY AND CONCLUSIONS

Oil companies began seismic exploration off the Oregon coast during the summer of 1961 under permits issued by the Oregon State Land Board. A fisheries observer and electronic fish finder equipment on exploration vessels are among the special requirements of the permits.

The Oregon Fish Commission conducted an investigation in coastal marine waters of Oregon on September 6 and 7, 1962 to test effects of seismic explosions on flatfish and crabs. Specific objectives included: (1) determinatin of death or injury to caged flatfish and crabs placed on the ocean floor and subjected to explosions in a manner similar to actual seismic operation; and (2) comparison of flatfish availability to a commercial trawl

net before and after a series of seismic explosions.

The chartered trawlers BETTY and TRASK and the seismic boat, MISS IDA, were used in the flatfish investigation. A total of 47 live fish taken from trawl net catches was placed on the bottom in cages in 20 and 40-fathom depths. Explosive charges of 5 and 25 pounds, respectively, of nitro-carbonitrate were fired over them. A control group of 18 fish (handled in the same manner as test lots but out of the lethal range of explosions) was used in the 40-fathom depth. Divers, while examining fish in one cage in the 20-fathom depth immediately after a test shot was fired, observed 2 sole which appeared to be dead. When the cage was brought to the surface all 12 fish were found to be alive. Four other cages, including one control, contained from 0 to 3 dead fish each (total of 6). All other fish were alive. One of the cages, which was subjected to a 25-pound explosion, contained all (18) live fish. Subsequent internal examination revealed discolored kidneys in 2 of these fish. The 6 (3 experimental and 3 control) fish killed in the cages were examined internally. No physical injury was apparent and the cause of death was undetermined.

A trawl tow of slightly more than 1 hour in duration was made on the 40-fathom depth curve. Total catch of flatfish amounted to approximately 1,100 pounds. Seven 25-pound charges suspended 4 feet beneath the surface were fired approximately 1/4-mile apart on the 36-fathom depth curve. A trawl tow of slightly less than 1 hour in duration, made immediately over the same course, produced a catch of flatfish of about 800 pounds. The difference in size of the two catches could be due to normal sampling variation or a shorter second tow. No marked differences were evident in species or size composition. Unfortunately the catch from the pre-explosion tow was not examined for injury. However, internal examination was made of 95 fish

caught in the post explosion tow. There was observed in 12 (13%) of these fish some type of damage, primarily to the kidneys, which may have resulted from explosions. It is not uncommon to find somewhat similar injuries in fish from regular trawl landings not affected by seismic work, but the amount under such conditions is not known.

Explosions were made over test pots containing crabs placed in 8, 15, and 35-fathom depths. One of two pots placed in each location was recovered immediately. The second pot was recovered 96 hours later. One control pot (not subjected to explosions but handled in the same manner as test pots) was placed at each depth and also recovered 96 hours later. Divers examined the condition of crabs in test pots in the 8 and 15-fathom depths immediately after the explosions. Live, dead, and damaged crabs were found in both test and control pots. Statistical analyses showed no significant difference in numbers of dead and damaged crabs due to depth of crab pots, depth of shot, size of shot, or between test and control groups of pots.

Observations showed that fish and jellyfish were detected by Simrad (electronic fish finder) prior and close to shot points over crab pots. Hundreds of small fish were killed by such explosions and observed on the surface and bottom. At the same time, divers observed many small live crabs, shrimp, and fish on the bottom. Shots were made with the expectation that fish might be killed because the objective was to determine the shot effect on caged crabs under specific conditions irrespective of whether fish were present.

The limited studies provided valuable information on the effect of underwater explosions on crabs and flatfish under certain conditions and indicate a need for additional investigation.

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