GEOPHYSICAL OFFSHORE OIL EXPLORATIONS

and

ASSOCIATED FISHERY PROBLEMS

Robert L. Rulifson

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Robert W. Schoning

INVESTIGATIONAL REPORT NO. 1

FISH COMMISSION OF OREGON

PORTLAND, OREGON

APRIL 1963

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TABLE OF CONTENTS

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

GEOPHYSICAL OFFSHORE OIL EXPLORATIONS
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INTRODUCTION

Conflict in the utilization of natural resources is a problem of long standing. In many instances it is real and serious, while in others there is little justifiable basis for disagreement. Misinformation, hasty generalizations, misunderstandings, and faulty conclusions may contribute to the strife, notwithstanding the fact that all persons involved sincerely believe they are right or are being wronged. There have been honest, sincere, and very strong differences of opinion on oil exploration in offshore waters of Oregon and its actual and potential effect on the fish stocks and fisheries. Opinions vary from the bottom fish will disappear in a very few years, to no significant damage is being done.

Conventional seismic work began in offshore waters of Oregon in 1961, when the State Land Board issued a permit to Shell Oil Company. Permits were issued to Gulf, Union and Standard Oil Companies at the same time for non-explosive type seismic work. As provided in Shell's permit, the licensee paid expenses for a representative of the Oregon Fish Commission to observe company activities and prevent undue damage to the fisheries resource. In 1962 Standard Oil Company as well as Shell conducted conventional seismic work. Union and Superior Oil Companies made studies using non-explosive geophysical apparatus. The Oregon Game Commission supplied an observer for the Standard operations and the Fish Commission continued with Shell.

Several offshore fishermen have developed increasing opposition to the operations, strongly advocating that all offshore seismic exploration be terminated until evidence conclusively demonstrates no damage is being done to marine life.

The Fish Commission feels that lack of information is one of the main reasons for the widely divergent views, and that if all of the pertinent material relating to seismic work were assembled in readily understandable form, there would be little serious disagreement. With this as a premise, Fish Commission personnel have collected and summarized appropriate information. It is sincerely hoped that this report will provide the badly needed missing link so that the fishermen and oil companies can work in harmony, each utilizing a natural resource without jeopardizing the activities or future of the other. If it does, it will have served its purpose well.

HISTORY

The first offshore well in the United States is believed to have been drilled at Summerland, California, in 1896. More than 200 wells were drilled in this area before 1920. Wells were located 1/2 mile from shore in one area (Hortig. 1959). The State of California did not assert its authority over tidelands until 1921, when offshore leasing was permitted. The 1921 law was very restrictive as to drilling locations, contained many special provisions including unqualified forfeiture, and specified small parcels. More lenient legislation was enacted in 1938 and subsequently amended. Texas passed workable tidelands legislation in 1913, and Louisiana authorized leasing of tidelands in 1915 (Krueger, 1958). Large-scale drilling operations for oil did not really begin off the coast of Louisiana and Texas until 1948 when techniques were developed enabling the industry to operate economically (Anon. 1961).

By 1961, oil exploration was underway in shelf regions offshore in the Persian Gulf; Sea of Japan; Gulf of Paria, Venezuela; North Sea, Holland; Nigeria, Africa; and British Columbia, Canada.

Seismic studies are presently being conducted along the coast of the United States by many institutes and by naval research groups to an increasing degree. Oil company explorations comprise the greater portion of offshore studies to date, but this may change in the next few years.

PRINCIPLE AND METHODS OF MARINE OIL EXPLORATION

It is believed that oil is synthesized from organic debris deposited in marine sediments. It is found associated with specific rock formations which may be on the earth's surface or at depths to 40,000 feet. Because drilling is costly and time consuming, more economical and efficient means of determining the possible presence of oil have been developed. Exploration involves searching for folded structures in marine rock, and is easier in water because there are no physical obstructions or rights-of-way involved. The three most common methods used in water are sparker, gas exploder, and conventional seismic. All use the principle of generating shock waves in water which bounce off the layers of dense material underlying the ocean floor and return to the surface where they are recorded on sensitive instruments. The layers underlying the floor can be of mud, rock, or sand. The water depth has little effect on the quality of the seismographic recording.

Correlation of individual reflected seismic waves as well as speed and frequency as recorded on the sonic instrument tapes, can indicate the dip or attitude and to a limited extent the character of the rock layers penetrated to a depth of 15,000 feet under ideal conditions.

Seismic, by definition, relates to earthquakes and the shock waves produced by them, or more literally, shock waves from the earth. In one sense, artificially produced waves would qualify regardless of how they were caused. Underwater oil exploration by means of an explosive is commonly called conventional seismic. Sparker and gas exploder are referred to as non-explosive geophysical work.

The sparker utilizes a high voltage spark at 1/8- to 1/2-second intervals. The spark jumps between electrodes which are suspended near the water surface and towed behind the moving boat. The shock waves are received by sensitive instruments (hydrophones) contained in the seismic cable which are connected to recording devices on the ship. Gas exploder and conventional seismic methods employ the same type of recording equipment. The advantages of this method are the comparative economy ($70 per mile), absence of any damage to marine life or significant disturbance of the water, and a nearly continuous seismic record in great detail. Disadvantages are the relatively small amount of energy produced by the electric arc (equivalent to 1/2 pound of dynamite) which limits penetration of the earth's crust (2,000 to 3,000 feet) mainly because the high sound frequencies produced (over 60 per second) do not penetrate well, and limit the application of the data for petroleum exploration. This method is used extensively for determining near surface structure in sedimentary layers and thickness of unconsolidated recent sediments. A diagrammatic sketch of a sparker layout is shown in Figure 1.

The gas exploder utilizes an explosive mixture of propane and oxygen detonated by a spark plug in an open chamber at a water depth of 15 feet. Energy produced is equivalent to 1 pound of dynamite. The gas gun, which is suspended from the seismic vessel, is exploded every 3 seconds, and the vessel normally travels at 4 knots. The merits of this method include the comparative economy ($100 - $125 per mile), a greater depth of penetration (2,000 to 6,000 feet) than the sparker which is made possible by a more favorable sound frequency range (20 to 60 cycles per second), and the nearly continuous seismographic record obtained. The relatively shallow penetration compared to the conventional seismic method using explosives is the most serious drawback although depth of penetration is primarily dependent upon bottom composition. A sketch of a gas exploder layout is shown in Figure 1.

The most extensively used method of oil exploration, commonly called conventional seismic, is by electrical detonation of various-sized charges of explosives, usually near the water surface. Charges fired near the surface throw a spectacular plume of water into the air, but if submerged 20 feet or

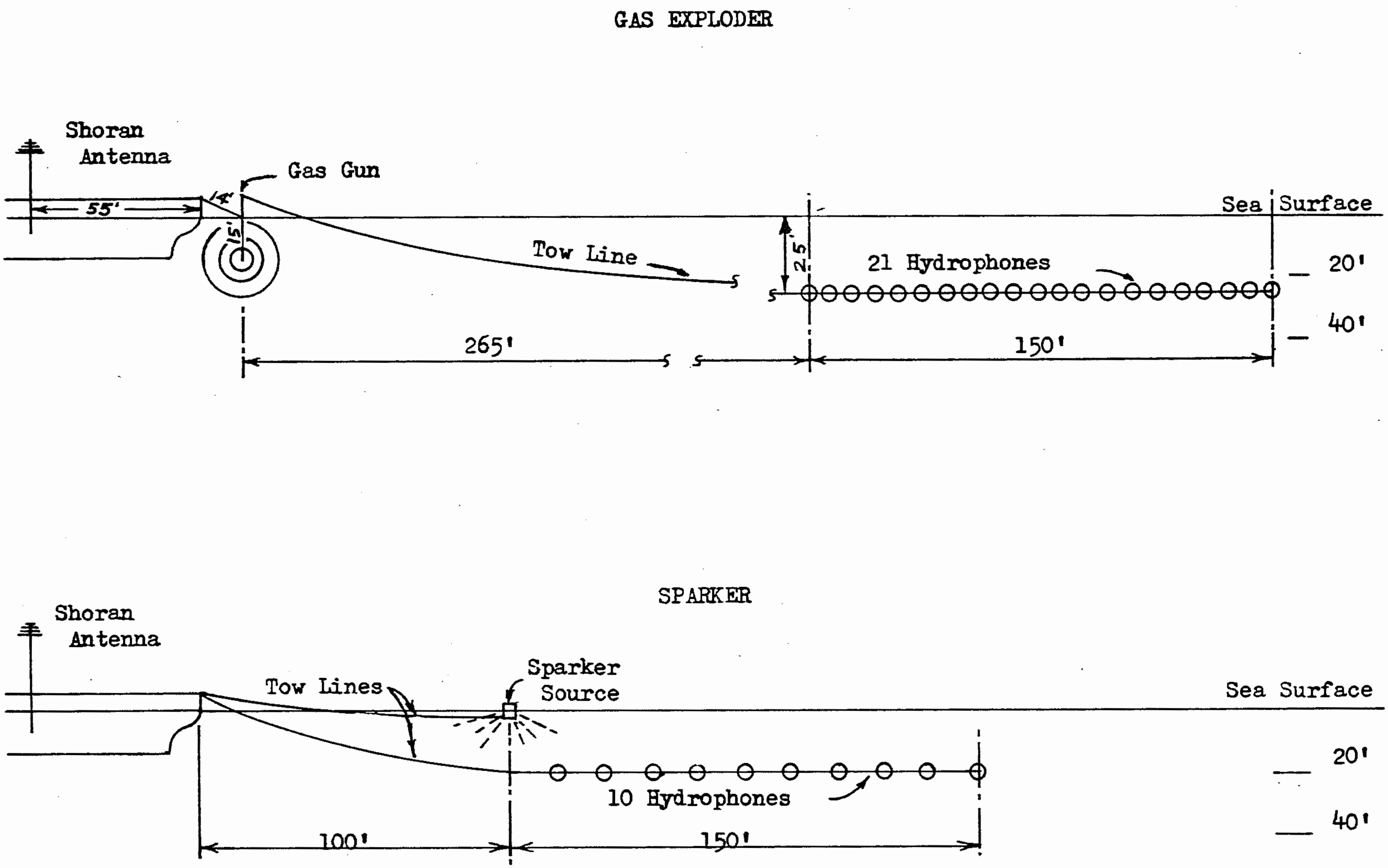

Figure 1. Diagram of Sparker and Gas Exploder Survey Methods.

more, they barely break the surface. Normally, charges are set at 1/4-mile intervals by manually dropping them from the seismic ship and detonating them by means of a high-frequency radio signal. There are variations in procedure, depending upon the contractor, location, and information desired. Two shooting vessels firing alternately are used in one method. Charges fired at 1-minute intervals by a single boat is another modification. The most favorable aspect of the conventional method is the consistently greater depth of penetration (10,000 to 15,000 feet). The most obvious disadvantage is the potential damage to all forms of sea life within a certain distance. Others include danger to crew members, and the comparatively high cost of the survey ($250 to $400 per mile) -- several times as expensive as either of the other two methods.

The theory of seismic prospecting is explained in Du Pont's Blasters Handbook as follows: "A sudden shock, such as that caused by an explosion, sends out vibrations which radiate in all directions. When these vibrations strike a layer of rock, or other dense material, they divide into three parts. One part is immediately reflected back to the surface. Another travels longitudinally along this layer, at greatly increased speed, and a portion of it also returns to the surface at all points above the travel path. This is known as the refracted energy. The remaining part passes downward through the layer and, if it has sufficient strength, will divide again and again as it hits successive new dense layers." The energy source and the recording instruments are comparatively close together in reflection surveying and farther apart in refraction surveying. A diagram of the two methods is shown in Figure 2.

The size of the charges used in reflection surveying in Oregon ranges from 5 to 25 pounds of nitro-carbo-nitrate. Because of the greater energy required for refraction surveying, 100- to 300-pound charges are necessary.

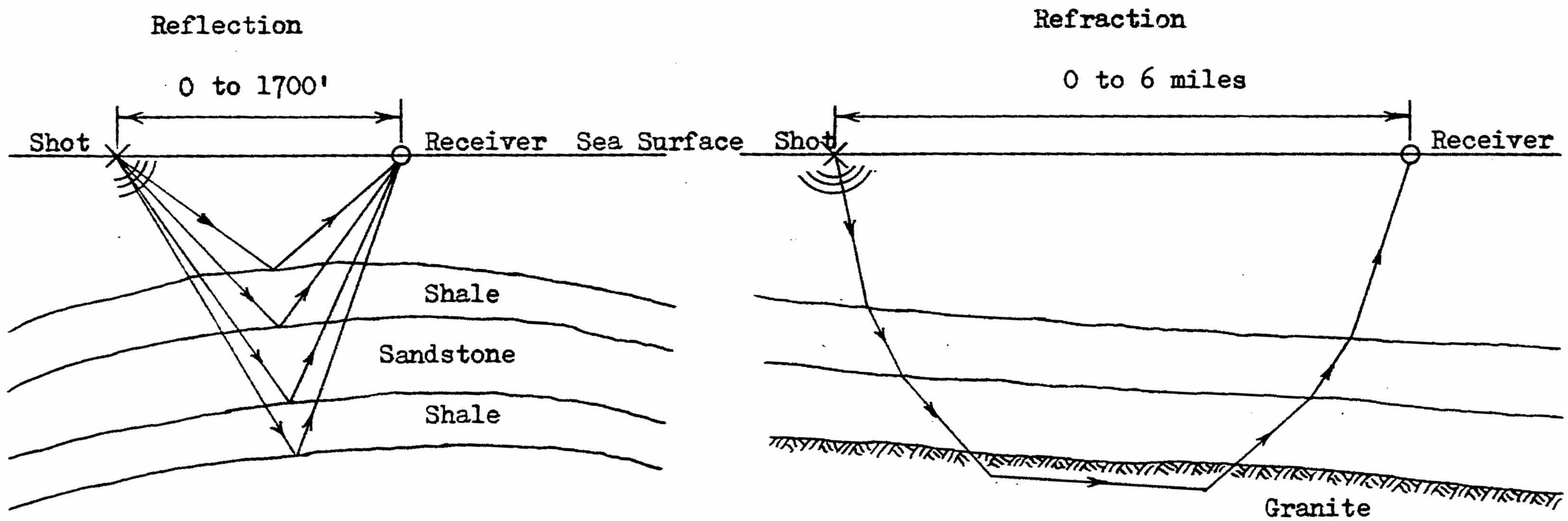

Figure 2. Diagrammatic Illustration of Reflection and Refraction Methods of Seismographic Surveying.

and used only with a special permit. A distance of 4 to 6 miles between the explosive source and the recording instruments is common.

In all three methods of underwater exploration, the shock waves are recorded by a sensitive cable or other instruments towed at a relatively standard depth. These readings are transmitted to a viewing screen on the recording vessel, and a printed record is made simultaneously. An average of about 20 miles per day can be covered by each method, although it varies from about 10 to 60 miles, depending on a number of factors.

In the interest of protecting marine life, it has been asked why gas exploder surveys could not be used to replace conventional seismic surveys. The difference in depth of penetration has already been mentioned. This is important because the deep structural configuration is not always identical to the structures expressed in the shallower sediments. If they were the same, then shallow-type survey methods such as the sparker or gas exploder could be utilized to predict the composition of the deeper structures. However, particularly on the Pacific Coast where subsurface geology is unknown, the deeper structures are often more complex, frequently offset from the shallower structures, and unable to be predicted by any shallow method of surveying. In Figure 3 are demonstrated several of the probable oil-bearing structures whose positions cannot be adequately determined from shallow-mapping techniques. As shown, an exploratory well located on the crest of shallow structures may not encounter the oil-bearing reservoir at depth. Such complete knowledge is necessary not only for successful drilling, but also for intelligent bidding on the offshore tracts.

Oil prospecting is not the only purpose of seismic shooting at sea. It has become an important occupation of physical oceanographers. A research vessel of Columbia University, working in cooperation with other vessels, has gathered more than 200,000 miles of seismic profiles in all the oceans of the world, including the Arctic and Antarctic (Ewing & Engel, 1962).

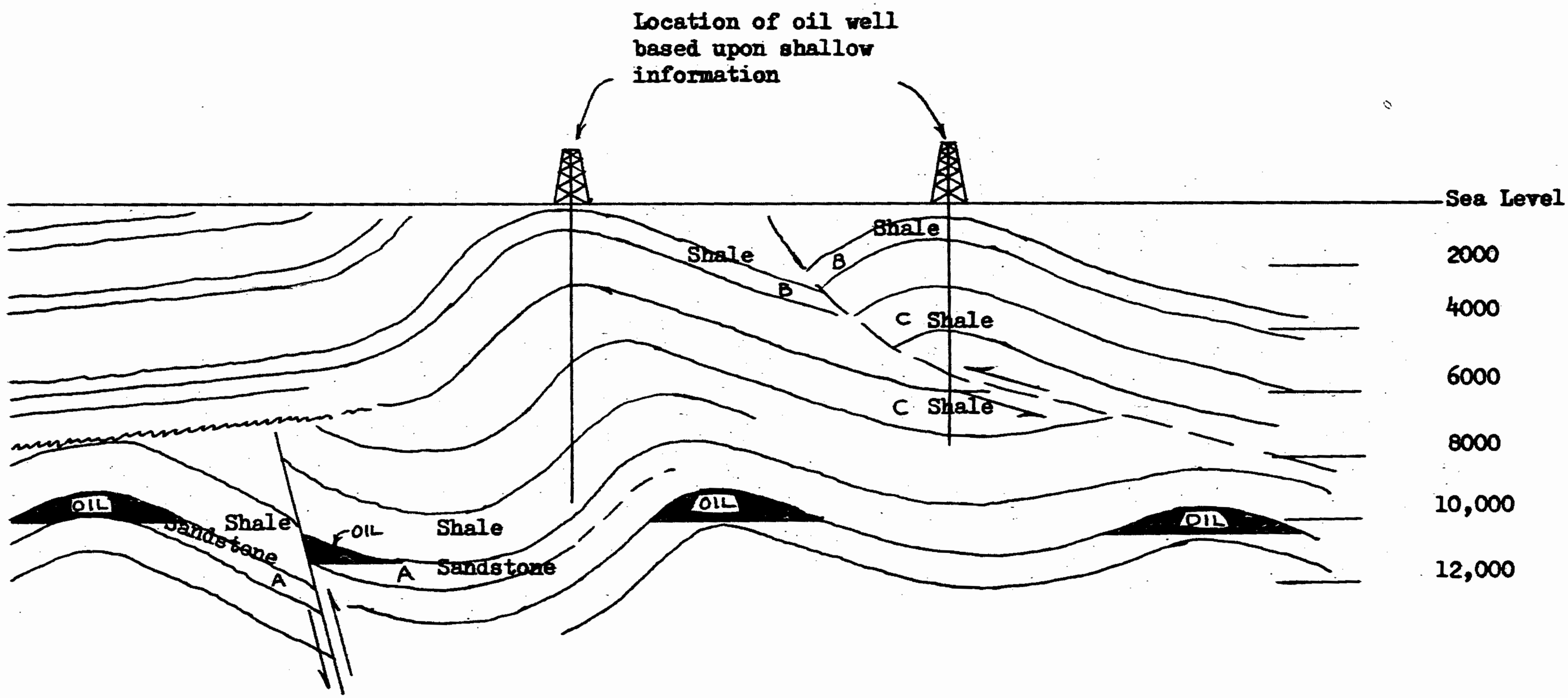

Figure 3. Diagrammatic Cross Section of Probable Oil Bearing Structures Showing the Results of Drilling on the Basis of Shallow Mapping Techniques.

EXPLOSIVES

Classification and Properties

There are many different kinds of explosives which can be divided into three basic groups -- low explosive, high explosive, and blasting agent. Low explosive is black powder which burns progressively for a relatively long period of time and produces a comparatively slow buildup in pressure of the expanding gases. As explained later, this characteristic is responsible for its almost complete lack of damage to fish life. Its detonation speed is 2,000 feet per second. Black powder was used for seismic surveying in California and Alaska, but was discontinued because of the hazard and the poor quality seismographic record obtained. It is not used to any extent for any purpose today, seismic or otherwise, because it is expensive and dangerous to handle and store.

High explosive includes the many grades of dynamite, T.N.T., and numerous other compounds used primarily for military purposes. All burn almost instantly and produce a very fast build-up in pressure of the gases formed by the explosion. The speed of the detonation wave of dynamite ranges from 4,000 to 23,000 feet-per-second, depending on strength, density, and grade. T.N.T. has a velocity of about 20,000 feet-per-second. Dynamite is expensive and dangerous to handle.

A blasting agent alone is not an explosive, but can be made to detonate by use of a high explosive primer. It is composed of ammonium nitrate and is known as nitro-carbo-nitrate (NCN). Several companies manufacture and market the compound under different trade names which have the same primary properties. The velocity of its detonation wave ranges from 8,000 to 16,000 feet-per-second, mid-range of the dynamites. NCN has the principal advantage of being relatively safe to handle, and mainly for this reason, it is almost exclusively used for seismic work today. Cost is considerably less than dynamite.

Lethal Range

The range at which an explosion is capable of killing fish has been a matter of concern to biologists and fishermen. Several tests have been conducted to define the lethal range of black powder and high explosives on various species of fish, crabs, and oysters. Few fish are killed by explosions of black powder, and the damage from even large charges of dynamite is restricted to a radius of 100-200 yards.

When nitro-carbo-nitrate was proposed for use in California, Scripps Institution of Oceanography conducted a series of experiments to determine its killing range. Test fish used were pilchard and anchovies. Both species have air bladders. The findings of their study are summed up by Hubbs, Shultz, Wisner (1960) as follows:

"In the horizontal direction, out through the upper mixed layer of the ocean, the probable lethal range seems to be about 150 feet for 5-pound charges, about 350 feet for 10-pound charges, and about 500 feet for 25-pound charges. Vertically below the shot these limits would seem to be between 100 and 150 feet for 5-pound charges, between 150 and 200 feet for 10-pound charges, and between 200 and 250 feet for 25-pound charges."

Apparently the lethal range to air bladder fish may be extended if the explosions are in an area where the shock waves can be reflected. Hubbs & Rechnitzer (1952) reported on observations of explosions in a submarine canyon. The 50- to 100-pound charges of dynamite were detonated at depths up to 450 feet. Extensive fish kills resulted.

A series of measurements at various distances from an 800-pound dynamite explosion reported by Gowanlock (1950) demonstrates how rapidly pressure is dissipated in water. "A pressure of 1000 units at the shot point fell to the following values:

Pressure in units	Distance in feet
100	50
10	100
4	150
2.5	200
1.9	250
1.5	300
1.4	350
1.1	400
1.0	450

Fish were killed to a distance of 200 feet.

PRINCIPLE OF DAMAGE TO MARINE LIFE

Injuries

Fish and other marine animal life can be injured by explosions in several ways. Severe damage to fish would include tearing of muscle tissue, rupture of the abdominal cavity and internal organs or injury to the nervous system. If the body wall is not burst, the damage may not be visible externally. The main internal organs which can be affected are air bladder, kidney, liver, heart, spleen, and gonads. Less serious injury would range down to slight internal bleeding from blood vessels or organs. It is not known how severe the damage must be before it will kill the fish.

Fish with an air bladder are usually killed or injured if close to an explosion because they cannot adjust to a rapid pressure change resulting in damage to the bladder itself or causing gas bubbles to form in and burst blood vessels. Injured fish usually have damage to areas where blood vessels are concentrated such as the kidney and liver. Anchovies, which have a thin-walled air bladder, are more subject to damage than are rockfish which have a medium thick-walled air bladder. Some of the more common species of fish with air bladders are trout, salmon, anchovies, and rockfish.

Fish without an air bladder are usually not killed or injured unless they are very close to an explosion. Lingcod, halibut, soles, and other bottom-dwelling flatfish do not have air bladders. Fish with a cylindrical body shape are less subject to damage because the pressure is more equalized on all sides of the body.

In the case of plankton, which includes small plant and animal life suspended in the water, the effect of an explosion is difficult to determine. Special equipment is needed to capture the organisms. Most of them are too small to be seen without a microscope. Their bodies are filled with fluid which is incompressible except under extreme pressure. The water pressure increase caused by an explosion is equalized on all sides of the body of an individual plankter, and in theory there is no effect whatsoever. Independent investigations by the Washington Department of Fisheries and Oregon Fish Commission generally concluded that plankton collected from the immediate area of an explosion appeared to be unharmed, but possibly somewhat less active than normal. When examined, the appendages of these fragile microscopic animals were intact.

Biologists have reported no evidence of damage to king crab eggs in Alaska (Bright, 1959) or herring eggs in Canada (Thompson, 1958) as a result of explosions although this does not necessarily mean that none occurred.

Experiments have been conducted in several states to determine the effect of explosions on clams, crabs, oysters, and other invertebrate animals. Except in a comparatively small area immediately adjacent to an explosion, little harmful effect was observed either immediately or after various periods of time. The bodies of these animals are also filled with fluid, thereby preventing them from being crushed by external pressure.

The gases produced by an explosion of nitro-carbo-nitrate are carbon monoxide, nitrous oxide, and nitric oxide. All are poisonous to man and the latter two are soluble in water. It is not known if they could be detected from an area of an explosion with the tremendous dilution in the ocean.

Float or Sink

It is not known precisely why some fish sink and others float when killed or stunned by an explosion, but this is probably dependent on species, condition of the fish, presence or absence of an air bladder, extent of damage, temperature and salinity of the water, and perhaps other factors. The percentage that float is not constant, as various investigators have found a range from 50 to 100%. During an investigation conducted by the Oregon Fish Commission in 1961, a 5-pound charge of Nitromon* suspended 40 feet beneath the surface was fired in a water depth of 24 fathoms. One rockfish was visible in 3 minutes and 159 in 9 minutes. Thirty minutes after the blast only 41 had not recovered and swam away.

California scientists found a ratio of about twelve fish floating after an explosion to one on the bottom (Fitch & Young, 1948). Off Newport, Oregon in 1961, 47 rockfish appeared on the surface following a 5-pound shot of Nitromon suspended 30 feet in 10 fathoms depth. SCUBA divers did not observe any fish on the bottom after the shot but visibility was poor. With good visibility during experiments in 1962 biologist divers observed less than one-third as many dead and injured small smelt on the bottom in 17 fathoms as were observed on the surface following a 5-pound shot submerged 20 feet. It is believed that the ratio would vary with species involved and extent of damage to the fish. Not all fish that rise to the surface are dead, and on some occasions most of them will recover and swim away. It is possible that some will die later. The same thing is probably true of fish that sink to the bottom.

Frighten from Area

It is contended by some fishermen that explosions frighten fish from an area and thereby reduce fishing success. No documented information on this is available to the author. However, there is evidence to the contrary where schools

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*Dupont nitro-carbo-nitrate explosive

of anchovies have been observed in an area both before and after an explosion. California biologists have reported catching salmon with commercial trolling gear almost immediately after and from an area where explosions have been fired (Baldwin, 1954). During 1962, a tuna fisherman off Oregon reported catching 150 albacore during a one-hour period while seismic blasting was being conducted about two miles away. A number of observers have reported that fish are more apt to be killed if several explosions are detonated in the same area. In some cases this may be due to fish moving in to feed on those killed previously.

In 1962, off the Columbia River, 2 approximately hour otter trawl tows were made 2 hours apart over nearly the same area. A series of 7 seismic shots were made over the same area between tows. The total fish catch was 1,100 pounds on the first tow and 800 pounds on the one following the explosion. The difference in total weight or species composition was not significant (Anon. 1962b). A few of the bottom fish in the second tow contained internal injuries which could have been attributable to the explosions. None of the fish from the pre-explosion tow were examined.

EXPLORATION PERMITS

Seismic oil exploration is being conducted in Alabama, Alaska, California, Florida, Georgia, Louisiana, Oregon, Texas, and Washington. In all cases permits with various restrictions must be obtained from a state agency. Permits issued by the U. S. Geological Survey are required for all offshore work beyond state waters.

Oregon

Permits for exploration of Oregon coastal waters are issued by the State Land Board for periods not to exceed 2 years under the provisions of Oregon Laws of 1961 Chapter 619. The following oil company activities are specifically permitted:

(a) conventional seismic surveys using uncontained explosives

(b) sparker surveys

(c) gas exploder surveys

(d) gas sniffer surveys

(e) core drilling and sampling

(f) grab sampling on bottom

(g) gravity surveys

(h) magnetic surveys

(i) SCUBA surveys

(j) such other methods of exploration which may from time to time be approved by the State Land Board

Applicants specifically list which one or more of the above activities they wish to engage in for a stated time period. Requirements include a $50 dollar processing fee and a $10,000 bond to cover all proper claims for damage. Renewals of the permits and a change in the type of activity are subject to approval of the Land Board.

A restriction common to all permits states that no surface drilling, exploder surveys, or structures are permitted within the area between high and low tide. Turbulence-producing explorations are not permitted within or adjacent to the mouths of rivers, bays, and inlets at the time of migratory fish runs. Special conditions for protection of fish and marine life which apply only to conventional seismic surveys are summarized as follows:

1. An observer of the Fish or Game Commission shall accompany the seismic crew with authority to stop or slow up operations in order to prevent or determine damage.

2. A separate motor-powered boat and crew for exclusive use of the observer will be furnished. A fish-detecting device must be installed on the exploration and observer boats with a crewman competent in the operation of the communication and fish detection

devices provided. The permittee must provide other equipment needed by the observer for determining damage to marine life and SCUBA observations to determine the extent of fish kill. (No specific provision is made for biological studies.)

3. Shots shall be suspended at a depth no greater than half the distance from the surface to the bottom and in no event nearer to the bottom than 5 feet.

4. Explosives permitted are:

   a. Black powder - 90 lb. maximum

   b. EP-198-B - 45 lb. maximum in water less than 200 feet deep
      90 lb. in water greater than 200 feet deep

   c. Nitro-carbo-nitrate - several brands with 5 lb. maximum in water less than 200 feet deep and 25 lb. in water greater than 200 feet deep.

5. No explosions are allowed within 1/2 mile of any jetty, pier, breakwater, or anchored fishing boat.

No special conditions are listed for other types of surveys. All permits issued through 1962 are listed in Table 1.

Table 1. Permits Issued to Conduct Geophysical Explorations in Oregon Offshore Waters.

Permit Number	Company	Original Date Issued	Type of Activity
SL - 1	Gulf Oil Corporation of California	June 13, 1961	sparker, gas exploder, grab sampling
SL - 2	Shell Oil Company	June 13, 1961	conventional seismic, sparker, core drilling, gas exploder, gas sniffer, grab sampling, gravity, magnetic
SL - 3	Union Oil Company of California	July 6, 1961	gas exploder
SL - 4	Standard Oil Company of California	Aug. 17, 1961	conventional seismic, gas exploder
SL - 5	Superior Oil Company	July 10, 1962	gravity

Other States

The seismic permits of the Gulf Coast states are similar to each other but different from those of the Pacific Coast states. Gulf waters are relatively shallow compared to those on the Pacific shore. Much of the area explored in Alaska has also been comparatively shallow.

Several of the important permit requirements for the states involved are given in Table 2. The only item common to all states is the requirement of an observer or inspector from a state agency, except that Texas requires an inspector only when operations are being conducted in water less than 15 feet deep. Some type of restriction regarding shooting near boats or other objects is in nearly all permits -- 250 feet from an oyster bed (Alabama, Florida); 1,000 feet from a boat without notice so that it may move from the area (Alabama, Louisiana); 1 mile from a shrimping fleet and 3 miles from a major beach resort during May through September (Texas); 1/2 mile of any breakwater, jetty, pier, or anchored fishing boat or barge (Alaska, California, Oregon, and Washington); Alaska includes crab pot, shrimp pot, or halibut set in the previous group.

Table 2. Seismographic Permit Requirements by State and Federal Government

Permit	Gulf States					Pacific States				Federal
Requirements	Ala.	Fla.	Ga.	La.	Tex.	Alsk.	Cal.	Ore.	Wn.	OCS Lands
Geophysical permit issued by Cons. Dept., Lands Comm., or Dept. Geol.	X	X	X		X		X	X		Atlantic Cst. Geophysical permit by stipulations by USGS, all states except La.
Explosives Permit by Fisheries Agency				X		X	X		X	
Observer or inspector	X	X		X	X	X	X	X	X	
Separate observation boat						X	X	X	X	

Table 2. Seismographic Permit Requirements by State and Federal Government (continued)

Permit Requirements	Gulf States Ala.	Fla.	Ga.	La.	Tex.	Pacific States Alsk.	Cal.	Ore.	Wn.	Federal OCS Lands
Fish detection device							X	X	X	Pacific Coast Ratification of regulations of the various states by verbal agreement or ltr. with regulating agency
Pounds of high explosive allowed 1/	50	50	40	50	40	16-2/3	20	25	25	50

1/ All states and the federal government require special permits for charges in excess of these.

Oregon and Washington permits were patterned after California's and are very similar. A difference is that the permit allowing use of explosives is issued by the fisheries agency in the other two states and by the Land Board in Oregon. Oregon alone has two fishery agencies (Fish Commission and Game Commission) responsible for furnishing seismic observers.

An observation vessel and fish-detection device are required in the Pacific states but not in the Gulf. Powder quantities allowed without special permit are also more lenient in the Gulf states. Generally, permits from the Pacific states are more restrictive on the oil companies than those from the Gulf; the observers have more authority to control activities for protection of marine life.

Federal Government

There are separate regulations governing geophysical work on the continental shelf outside of state waters on the Atlantic coast (except Florida). They restrict shot size to 50 pounds without special permit. One provision states that "the exploration party shall employ methods approved by the industry to frighten or drive away the fish and/or marine life which may be in the area where the shot is to be discharged." Other items are for protection of people and property.

The permit provisions of each Pacific Coast state have been accepted by the federal government for use in the respective offshore waters. State observers likewise have been given the same authority for protection of fish life in offshore waters as they have in the inshore state waters within 3 miles of the coast.

OBSERVATIONS OF SEISMIC ACTIVITIES

Oregon

Seismic surveys were conducted off the Oregon coast by Shell Oil Company in 1961 and by Shell and Standard Oil Companies in 1962. An observer of the Oregon Fish Commission accompanied each cruise of Shell during the two years, while Standard activities were observed by an Oregon Game Commission observer.

The basic seismic survey operations of the two companies are similar except that ordinarily two vessels are used by Shell and one by Standard, not including boats used only for fish kill observations. Standard's operation involves towing a 2,400-foot instrument cable and a parallel 1,200-foot lead cable (Figure 4). Charges fastened by a 1-1/2-inch ring to the lead cable slide to the end of it which is suspended 6 to 8 feet beneath the surface by a float. The explosive is held there by a hook until an electrical current from the seismic vessel detonates it. The observation vessel follows about 1,700 to 2,000 feet astern of the seismic boat. Observation of fish kills from a single vessel operation is difficult because the instrument cable being towed prevents turning about or backing up to count or collect the fish. The charge is fired about 1,200 feet astern which further limits observation. Consequently, a separate boat equipped with a fish detector (Simrad) has been used for the observations in all of Standard's work. If fish are detected in advance of the explosion, the shot can be stopped by means of radio contact with the seismic boat. Following the shot the observation boat moves into the shot boil to look for any fish which may have been killed.

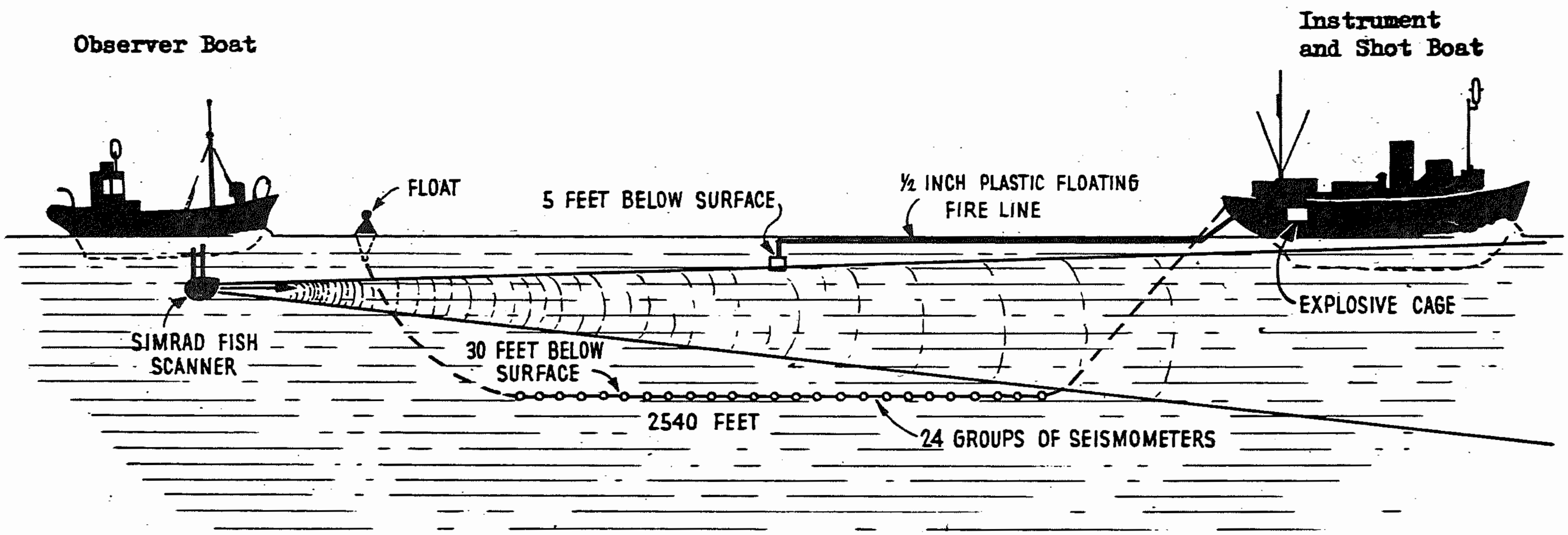

Figure 4. Combination Instrument and Shot Boat with Separate Observer Boat.

In the two vessel operation of Shell, the shot boat follows about 1,700 feet astern of the instrument vessel which tows a 3,600-foot cable submerged 30 feet (Figure 5). Charges suspended 3 to 5 feet beneath an inflated balloon are dropped from the shot boat at 1,300 foot intervals. Both vessels travel at 4 to 5 knots. The charge is detonated about 60 to 100 feet behind the boat by a high frequency radio signal from the instrument vessel. Simrad is located in the wheelhouse of the shot boat and operated at all times during the seismic survey by a qualified crew member. Regardless of the location of the observer -- on the shot vessel or separate observation boat -- the Simrad operator evaluates the readings and makes the decision whether to permit the next shot. The observer is not trained in the operation of the Simrad, so he does not participate in the analysis of the readings. However, whenever shots are stopped, the observer may discuss the details and the effect on future shots with the Simrad operator. Depending on the fish kill from any single shot or series of shots, or other pertinent conditions, the observer has the authority to prevent further shooting in the specific area or on that day. This could include relationship of kill to certain Simrad readings and nearness to other vessels or river mouths. He also controls the size of the shot. When a separate observation vessel is used, contact between the observer and Simrad operator is by radio; with the observer on the shot vessel, it is by intercom. Radio silence is observed by Shell during shooting as a safety precaution.

There was one shakedown cruise of Shell out of Coos Bay before the regular exploration began in July 1961. Two demonstration cruises from Newport were conducted later. Until the end of the second cruise, observations of fish kill were made either from a 17-foot outboard-powered skiff when the weather was favorable, or from the shot vessel. For the last day of the second cruise and five days of the third, a 40-foot troller manned by two fishermen was chartered as an observer vessel. It followed about 1/2 mile astern of the shot boat and the fishermen counted dead and injured fish. At the same time the

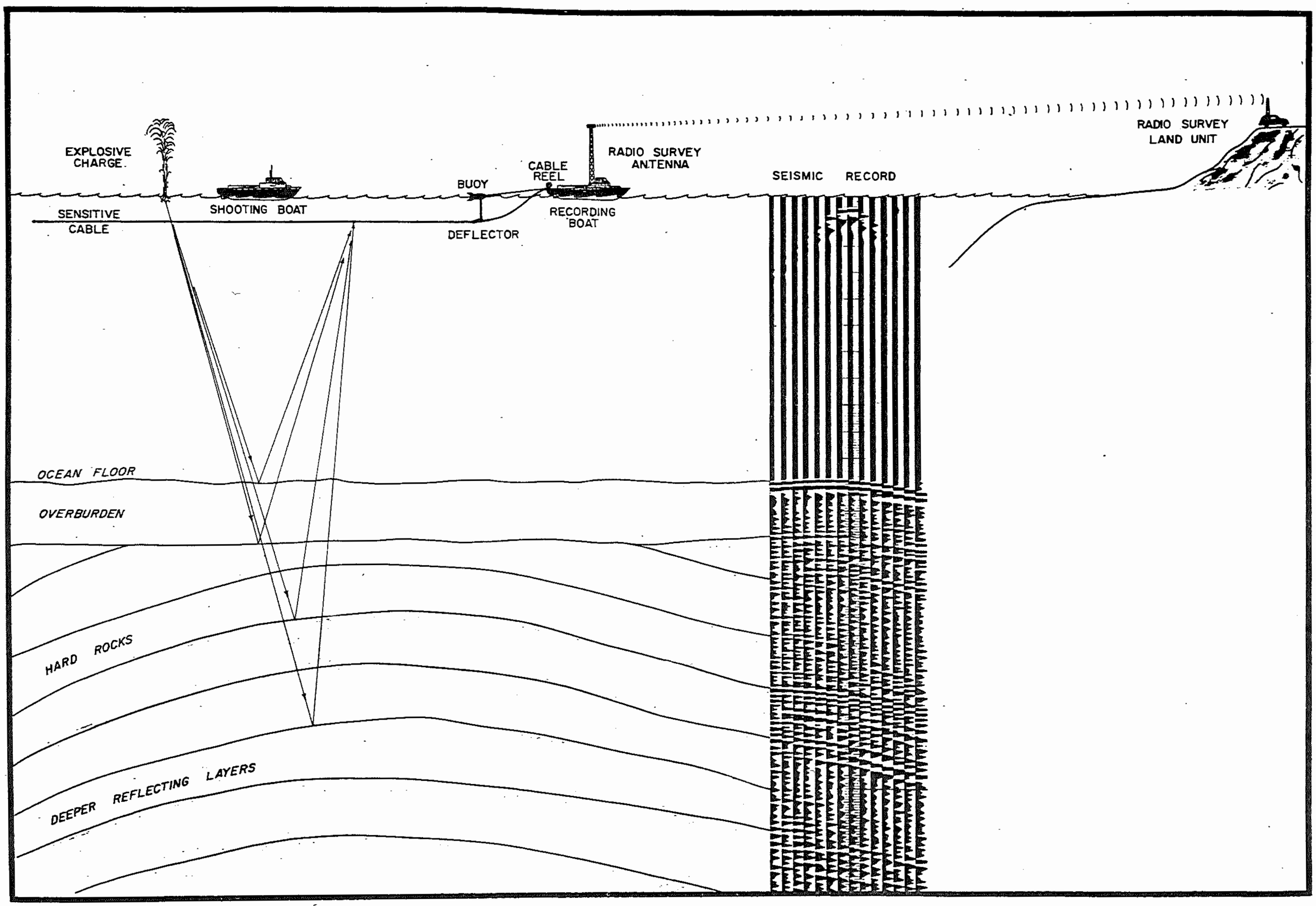

Figure 5. Separate Shooting and Recording Boats Showing One Application of Reflection Surveying and the Type of Seismic Record Produced.

regular observer, stationed aboard the shot vessel, observed through binoculars. He was unable to count the fish, but could determine if there had been a kill. Whenever the troller was functioning, the shot vessel did not stop to measure the kill, although the observer aboard did determine if there was one. This procedure was followed during the six-day period when the troller was utilized. Observation records from the troller and the shot boat for 359 of the shots fired during this period were compared. Kills of 1 to 300 fish were observed on ten of these shots. There was close agreement as to occurrence, but because counts were made from the troller, no duplicate counts were made by the shot boat observer. The observer missed seeing a 27-inch silver salmon counted by the fishermen, the only fish killed on that particular shot. There were no other instances when the observer concluded that no fish were killed, but the fishermen observed some.

The chartered troller abandoned the operation on July 17, 1961, after only six days, causing considerable inconvenience to all concerned. Because the observations from the shot boat and separate boat gave comparable results and an evaluation of the relative merits of the two systems (observe from shot boat or separate vessel), it was decided by the Fish Commission that the best course of action was to locate the observer on the shot boat. This practice was followed during the third cruise. Under this procedure, the observer watched each shot point as long as possible through binoculars from the stern of the shot boat. If any fish appeared, the boat was stopped and backed into the shot boil. An estimated count of dead or injured fish was made before continuing on course.

A separate observation boat under the Shell procedure permits ready recovery of injured fish and a more accurate determination of fish kill, particularly during rough weather, but may not provide for as close control over the actual shooting as it relates to the presence of fish. Making all the observations from the shot boat causes less delay in the overall operation and the cost of the chartered vessel is eliminated.

Fish killed by a shot usually begin to appear on the surface almost immediately and continuing for at least several minutes. Floating fish can be seen with binoculars for at least two shot points (2,600 feet or about 6 minutes) behind the shot boat. Shot lines on which some dead fish were observed have been re-traversed without seeing many additional fish. It is possible to miss seeing a small number of fish with this system, but it is unlikely that any large kill would be overlooked.

Following the third cruise, the observer recommended observations be maintained solely from the shot boat. Emphasis was continued on prevention of kills by careful operation and interpretation of Simrad traces. This practice was followed for the remainder of the 1961 season, although on several occasions a 17-foot outboard-powered skiff was used as an observation vessel when weather permitted. All observations were made from the shot boat during the 1962 season.

In 1961 a total of 5,900 explosive charges was fired and an estimated 12,000 dead and stunned fish were counted floating on the surface. The 1962 totals for both companies were 13,600 charges (including 62 100-pound and 60 300-pound shots) and 16,355 fish. The species composition for 1962 is listed below. All have air bladders.

Anchovy	12,256
Widow Rockfish	2,840
Pacific Mackerel	465
Red Snapper	281
Silver Smelt	267
Hake	92
Yellowtail Rockfish	60
Herring	54
Saury	36
Silver Salmon (adult)	2
Grouper	1
Shad	1
	16,355

There are several interesting facts concerning these figures. Three shots, all on the same day, accounted for almost half of the total kill observed during the 1962 season. Two of the shots killed 7,000 anchovies and one shot killed 1,000 widow rockfish. All three were 15-pound charges. The first two were fired 5 feet under the surface in water 44 fathoms deep while the third was in 90 fathoms. Anchovies are small fish not over 8 inches in length; widow rockfish are about 16 inches long. Neither species is of commercial importance in Oregon. The schools of anchovies were not detected by the Simrad and must have been near the surface. The rockfish were detected prior to detonation of the shot, but an avoidable error in communications resulted in failure to stop the shot.

In summarizing the activities of both companies in 1962, fish were detected on Simrad 850 times, and 132 shots were stopped because the fish were within the expected lethal range of the charge. Additional shots were stopped because of proximity of fishing craft. Kills ranging from 1 to 3,500 fish were observed on 27 days following 65 shots (4% of the total). Shooting was conducted on 82 days.

During the two seasons no shots were fired in water less than 100 feet deep, and over 99% were outside the 3-mile limit.

The electronic echo-sounder fish finder (modified sonar) on the shot boat or separate observation boat of Standard is in constant operation during the surveys. It is operated by a qualified crew member at settings optimum for the conditions encountered. Settings of the instrument are written on the recording tape which can be examined later. Detection of fish vertically under the boat (echo mode) has been satisfactory, but the equipment used for horizontal detection (Asdic) has not been adequate. The separate observation boat of Standard must use horizontal detection equipment to locate fish prior to a shot. An improvement of the gear for lateral detection would be desirable as a large percentage of the fish killed were near the surface. Interference from signals reflected from the sea surface makes fish detection difficult. The transducer, which sends and receives the sound impulses, is mounted on the bottom of the ship and thus in the echo mode cannot detect vertically in about the top 8 feet of water. During 1962 kills were observed on a greater percentage of the Standard shots than those of Shell which could be explained by the operational difficulties mentioned above. In the Standard operations all of the fish kills resulted from 20 pound charges, and there were no visible positive indications of fish present immediately prior to the detonations.

If the lethal area involved in a single shot is compared with the vast expanse of ocean off the Oregon Coast, it becomes insignificant. When the aspect of time is considered -- a fraction of a second to each explosion and an average of 200 explosions by one crew in a 24 hour period -- the cause for concern becomes even less. Furthermore, the vast majority of marine life is essentially moving all the time so in order to be harmed by seismic explosions a fish would have to be in a very restricted area at a precise moment. The percentage of the fish in the ocean off Oregon which could be affected under such conditions is indeed small.

Other States

The numbers of fish killed under comparable conditions in Washington and Alaska are not greatly different from Oregon. Procedures used for observation in Oregon and Washington are similar, but different from Alaska where conditions are not the same. Much of the Alaskan seismic work has been in shallow water where large tidal fluctuations cause fast currents and hazardous navigation. Alaska Department of Fish and Game believes that a separate observer boat is necessary under these conditions because any fish killed drift away quickly with the tide, and stopping a shot boat would be impractical. A separate boat gives the observer more flexibility in observing shot areas. Electronic fish-finder equipment has not been too satisfactory for some of the same reasons. The Washington Department of Fisheries observed from the shot boat in 1962.

At least during the first year or two of seismic activities, biologists have been used as observers in many of the states involved. After procedures for observing have been worked out, the duties are frequently taken over by non-biologists. California recently assigned this job to law enforcement personnel. The operational procedures relating to qualifications, type, and number of observers, and number and deployment of boats in many of the other states are not known, nor is the reasoning behind the decisions.

Louisiana has had almost 20 years of experience with seismic explorations, and presently has hundreds of seismic crews operating in the state.

Dr. Lyle S. St. Amant, Chief of the Division of Oysters, Water Bottoms, and Seafoods of the Louisiana Wildlife and Fisheries Commission believes that insofar as actual fish kills are concerned, offshore explosions have little effect except in rare cases when they happen to occur in or near a school of fish. They found in Louisiana that charges set directly on the mud bottom caused mud lumps and craters which fouled shrimp gear and other bottom nets. It was corrected by requiring all charges be suspended at mid-water or at a reasonable distance off the bottom. Rarely have they received complaints on offshore operations since this change. By requiring all explosions in shallow water to be set off in drilled holes well below the bottom, most of the argument concerning blast effect on fish and other marine life has been eliminated. There are some conflicts from shooting in shallow water near leased oyster land.

BIOLOGICAL STUDIES OF EFFECT OF EXPLOSIVES ON MARINE LIFE

Many investigations have been made in the United States and other parts of the world to determine the effects of underwater explosions on fish and other forms of aquatic life. The earliest known study was in Canada in 1907 and the latest work was in Oregon in 1962. Most of the available literature on this subject has been examined and is included in the bibliography along with other references. Some of the studies are related to oil seismic explorations while others are concerned with naval ordnance testing of mines, aerial bombs, and intentional killing of fish.

Conditions under which the tests were conducted vary with the purpose of the experiment, locality, and species of fish or other organisms used. Some of the results are applicable to conditions associated with seismic surveys off

Oregon and others are not. The studies can be generally divided into two groups -- black powder and high explosives. The latter is further subdivided into shellfish (oysters, shrimp, and crabs) and finfish.

Black Powder

Permits for oil explorations in southern California were revoked in 1949 after large fish kills had resulted from using dynamite. They were renewed in 1951 for use of black powder after Hubbs and Rechnitzer (1952) conducted a series of tests. Charges of black powder as large as 45 pounds proved to be relatively harmless to fish. This is due to its relatively slow burning quality which produces a less abrupt wave front. Dynamite peak pressures of 40 to 70 pounds per square inch killed fish whereas 124 to 160 pounds per square inch from black powder did not cause mortalities. The faster pressure increase from the dynamite cause death.

In 1952, Fry and Cox (1953) conducted tests which verified the results of Hubbs and Rechnitzer. They state that every observer who was on the spot found the survey operations essentially harmless, but some "observers" who did not get within a mile or two of the operations and some rumor listeners complained to the Fish and Game Commission that the explosion must be killing fish in large numbers. Complaints were probably based on the fact that the earlier dynamite explosions had killed fish and that the black powder explosions threw water about as high and from a distance looked as though they must be just as deadly. Divers observed that several invertebrate forms including sea anemones, sea urchins, and sea cucumbers were undisturbed by a 45-pound charge of black powder. Rockfish were equally abundant before and after the shot and were caught by angling.

Bright 1959 reported on experiments in Alaska using king crabs. Charges of 90 pounds of black powder (Hercules EP 138) were fired over caged crabs in 5 to 56 fathoms of water. No immediate or delayed mortalities were attributed to the blasts.

High Explosives

For convenience of description all aquatic animals which are not finfish are included in this group. This includes oysters, clams, crabs, shrimp, and other invertebrates. Experiments relating to oil seismic surveys, naval ordnance testing, and intertidal ditching with dynamite have been conducted on shellfish. With one exception (Maryland experiments with large charges of TNT) the conclusions are that beyond the immediate influence of an explosion there are no apparent effects on shellfish.

The first known experiments which seem to be applicable to the present situation in Oregon were carried out in Louisiana in 1944 by Gowanloch & McDougall (1944). This study was in connection with the proposed use of heavy explosive charges for refractive seismic exploration for oil in a highly productive shrimp fishing area. A duplicate series of experiments was conducted in which live shrimp, croakers, crabs, and oysters were used. The animals were suspended in 30-inch slotted wooden cages midway between surface and bottom and 50, 100, 150, 200, 300, and 400 feet from the shot point. They were examined immediately before and after the explosions and 24 and 48 hours after firing. One 200-pound and two 800-pound charges of 60% gelatine dynamite were used and results were strikingly similar. These relatively enormous charges, far in excess of anything normally employed, did not harm shrimp at 50 feet, oysters at 50 feet, and fish at 200 feet.

After a second series of experiments (Gowanlock and McDougall, 1945), the following conclusion is stated: "It is, therefore, on this basis of careful experimental work that we can now conclude that seismographic exploration of oil can be carried out adequately without harming our valuable aquatic resources. This is not a matter of surmise and not a matter of wishful thinking, but is a matter of carefully planned experiments adequately controlled and providing these revealing, valuable results." In answer to criticism on the use of wooden-slotted cages to hold test animals, a later report states: "The most careful consultation was conducted with physicists to establish that these confining cages, constructed with extremely small slats, could not possibly cushion any explosive impact" (Gowanloch, 1950).

General disbelief in the results of the first two series of Louisiana experiments was expressed by fishermen. Members of the legislature, representatives of fishing interests, representatives of coastal police juries, and other interested parties were invited to witness a third series. A quotation from the Second Biennial Report, 1946-47, on the third series states: "It is perhaps sufficient here to say that although in these experiments fish were killed at a range of two hundred feet, nevertheless the experiments did accord in pattern with the two previous series. The shrimp were completely unharmed at a distance of only fifty feet, while the crabs that were killed by the explosion were found to be individuals that had already bred and would soon normally die. Healthy crabs survived even at a distance of fifty feet from the eight hundred pound charge in spite of the fact that the force of the explosion was so great that it threw the fifty-two gallon drums, used to suspend the charges, three hundred and fifty feet in the air and violently shook boats over one-half mile away. It is significant to note that representatives of the interested groups, fishery industries, police jurors, and legislators who had previously been so greatly alarmed about the probable damage wrought by the use of dynamite in seismographic exploration for oil voluntarily came to the commissioner with the statement that they were now convinced of the correctness of the conclusions, reached in all of these series of experiments, namely that even dynamite charges of great magnitude never permitted near any oyster resources, caused negligible damage to fisheries."

Maryland experiments (Anon., 1948) with oysters, blue crabs, and finfish concerning naval ordnance testing were somewhat inconclusive. Results reported are that approximately 2% of the oysters exposed in bags on the bottom within 100 feet of a 30-pound charge of TNT and within 200 feet of a 300-pound charge were killed at once. Incomplete data indicate that fatal injury to approximately 5% of the oysters occurred within the same radius. Data from crabs are somewhat erratic but indicate that lethal damage was limited to a radius of approximately 150 feet. The detonation wave of TNT is faster than most dynamites and could be responsible for the greater damage in these experiments.

Aplin (1947) reports that lobsters 50 feet from a 20-pound charge of petrogel (dynamite) were not killed or injured. There is a possibility that abalone were damaged.

Tollefson and Marriage (1949) reported that clams, crabs, and oysters were not damaged farther than 30 feet from the center of an intertidal blast of dynamite. Four cases of dynamite were buried 3 feet beneath the bottom in a 95-foot string. Test animals were in a line at right angles to the charges. Seiling (1954) found that oysters 40 feet from a blast were not affected, and that after 8 months those oysters 20 to 250 feet away showed no effect.

Bright (1959) reported that 2 out of 18 female king crabs subjected to a 16-2/3 pound charge of Nitramon at 25 fathoms distance died within two weeks. This was thought to be from handling and live box conditions. One of 9 crabs in a control pot also died. Eyed eggs on the crabs showed no signs of damage.

Dungeness crabs held in commercial wire-mesh crab pots at depths of 8, 15, and 35 fathoms were subjected to explosions off Oregon (Anon. 1962) in a test of the most severe conditions expected in seismic surveys. Charges of 5 and 25 pounds of Nitramon were fired 2, 20, and 40 feet beneath the surface. Large and small as well as hard and soft crabs were used in the tests. Handling damage was great, but there was no statistical difference in numbers of dead and damaged adult crabs between the test lots and those handled in the same manner but not exposed to explosives. No small crabs were damaged in either lot. Similar lack of mortality had been found in previous California tests. During the Oregon tests divers observed many small, live animals including 1-inch sole, 1 to 2-inch shrimp, 1/2 to 3/4-inch dungeness crabs, and hermit crabs at several locations on the bottom adjacent to the cages subsequent to the explosions. No dead animals were found.

A greater number of experiments has been conducted on the effects of underwater explosions on finfish than on shellfish, while several are concerned with both. Some of the reports are primarily of surface observations following explosions while others are well-controlled tests in which valid conclusions are reached. Some of the species of fish used in the tests are different than those found in Oregon, but many are the same. Results reported from most of the experiments are directly applicable to conditions in Oregon.

Many investigators have attempted to learn the killing range of explosives. Generally, it can be stated that the affected radius is 100-200 yards even from detonations of up to 1,200 pounds of high explosive. For smaller amounts there is universal agreement with the results obtained by Hubbs, Shultz, and Wisner (1960) which are given on page 11. The explosive agent tested was nitro-carbo-nitrate which is commonly used in 5, 10, and 16-2/3 pound amounts in oil seismic work in Alaska, California, Oregon, and Washington.

Of considerable current interest is the fact that without exception the many authors reported that only fishes containing air bladders were killed by explosions. It has been previously mentioned that the soles are among the group of fish without air bladders. Aplin (1947) was the first to report the use of fish from this group in tests. A 20-pound charge of dynamite at a depth of 4 feet was fired 50 feet away horizontally from caged fish. Two opal-eyed perch which have air bladders were killed and their viscera reduced to a pulp, but four sculpins and a cabezone of about a pound each -- without air bladders -- which were in the cage at the same time, were unhurt. They were intentionally killed six days later and their viscera showed no signs of damage. In the same group of experiments 3 California halibut, which are bladderless flatfish, were exposed to a 20-pound charge of dynamite fired 4 feet below the surface and 55 feet from them. They were not killed by the crabs at several locations on the bottom adjacent to the cages subsequent to the explosions. No dead animals were found.

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The tremendous explosion of 2,750,000 pounds of high explosive used to remove Ripple Rock, a navigation hazard in Canada, killed rockfish but did not kill lingcod in cages 1/2 mile away (Thompson, 1958). Rockfish have air bladders, lingcod do not.

Several species of sole were subjected to explosions of nitro-carbo-nitrate in Oregon experiments (Anon., 1962). It appeared that handling caused the equal numbers of mortalities observed in experimental and control groups. All the fish were examined for evidence of external or internal damage. Discolored kidneys found in 2 of the total of 47 fish subjected to blasts could have been caused by explosions. No other damage was evident in these fish.

On one occasion a fisherman reported a catch of several thousand pounds of dead and damaged bottomfish following a series of seismic explosions off Destruction Island, Washington. None of the fish were examined by biologists or agency personnel to establish condition or cause of death to see if it could be seismic related. One bottomfish buyer has indicated part of one or more loads purchased by him has contained fish with internal injuries. It has not been determined if the reported injuries were different from or in greater amount than normally occur in otter trawl catches.

Another fisherman has stated his belief that just as many if not more bottomfish are discarded dead under normal otter trawling as are killed by all the seismic work. He felt damage to larval marine life and plankton was potentially more serious.

OPERATIONAL DIFFICULTIES

There are a number of basic problems inherent in the present observation procedures of conventional seismic exploration which prevent the collection of data with the necessary accuracy. Observations of fish kill at best are limited to the fish which surface within a few minutes after the blast. The shooting vessels move on, and lingering in the area on the chance that more fish may subsequently surface is not practical. Most of the fish which surface can be collected, but no effort has been made to develop and use gear to adequately sample at various depths from the surface to the bottom to catch uninjured, injured, and dead fish and animal life following an explosion. This might well be the area which needs the greatest amount of study and could be the most productive and useful. The picture will not be complete until this is done, although there is limited information on this subject. The effectiveness of the various collecting methods must be known and measured, and the results must lend themselves to extrapolation to obtain a quantitative measure of the complete kill. Additional studies on the relationship of immediate and delayed injury and mortality might be helpful.

CONCERN BY FISHERMEN

There is sincere concern by some fishermen for the future of the bottomfish fishery if seismic exploration in offshore waters is permitted to continue. Their apprehension stems from several points, the most important of which are mentioned below. The Fishermens Marketing Association of Oregon, Inc. submitted a resolution to the Fish Commission November 10, 1962, "..... against any further offshore seismic operations using present type explosives until the fishing industry is fully protected and the Fish Commission of the State of Oregon take advantage of the provisions in the contracts with the oil companies to see that the policing and research be carried out to the satisfaction of the fishing industry."

Very little written material about the effects of seismic exploration on marine life in Oregon and elsewhere in the United States has been available to them, and based on their own contact with oil company activities, they feel that the explosions are seriously damaging marine life. The extensive compilation of the vast majority of the known studies related to this matter which are contained in this report should resolve the difficulty and provide a sound basis for evaluation of the problem. Others feel that much of the material they have seen is from other parts of the country and does not apply to Oregon. There are certain principles of damage which apply to various groups of fish regardless of where they are found. Consequently, many of the studies referred to are directly applicable to Oregon and others are qualified accordingly.

Concern has been expressed that the observer was not a graduate biologist. In other states with much more experience in this field than Oregon, non-biologists are used. Experience has shown that observation duties and responsibilities can be adequately discharged by persons without formal college training in fisheries. Competence in this job comes with actual field experience. Biologists, who are in short supply, can be used for assignments requiring more formal training.

Methods of observing fish kills have come under fire. The Land Board permit provides for a separate observer boat but it was used only a relatively short time in 1961 and not at all in 1962 with Shell Oil Company operations. Standard Oil Company provided one in 1962. Both methods (with and without a separate boat) have been tried and a decision was made to observe Shell operations from the shot boat. There are advantages to both systems, and further evaluation and comparison seem in order.

There have been serious misgivings about the effectiveness of the fish-detection equipment as presently used. Some operational and interpretation problems have cropped up, but they are being resolved with experience.

Fish Commission statements about fish kill have been misunderstood. There is no doubt that fish can be killed by an explosion if close enough to it and other conditions are satisfied. The department has always acknowledgedthat some fish may be killed in normal seismic operations, and that many more could be killed if precautions were not observed. The operational procedure is to determine by fish-detecting devices if fish are present within the lethal range of the explosives used, and if so, the shots are not fired.

The department believes that the stipulations in the Land Board permit provide adequate protection to the fishery resources and if the operations are properly supervised, damage will be at a minimum. Known losses to date have been insignificant. When results indicate the need for an operational change, appropriate steps will be taken.

Some fishermen have advocated additional study under oil company financing. The permit does require the company to finance biological research _per se_. On the other hand, oil companies have indicated a willingness to participate in studies which appear necessary, worthwhile, and to have reasonable assurance of success. However, until all of the available information has been compiled and analyzed, it is difficult to tell what studies are needed. This report may reveal areas in need of further investigation.

There are fishermen who sincerely believe that the seismic explosions are killing significant amounts of plankton and larval fish and animal forms. The limited studies to date indicate little if any damage. It is possible that some planned studies would shed some light on this particular point.

OIL COMPANY PLANS

There are a number of factors which determine the extent of exploratory work necessary. It is the general practice to divide the offshore waters into 10-mile grids in each direction. Shots are run at regular intervals along these imaginary lines. Depending on the findings, the frequency may be increased or decreased, and some areas may be skipped entirely while others are subjected to a more intensive pattern. Results from seismic, sparker, and bottom sampling are correlated to influence this decision.

There is no set depth to which the drilling must be conducted. The presence of oil relates to geologic horizons, the rock layers of which may be at varying depths below the ocean floor. In the shallow waters of the Gulf of Mexico drilling has been conducted as far as 80 miles from shore. Present equipment is capable of working in water depth of 1,000 feet, but this has not yet been done. Holes can be successfully drilled to a depth as great as 19,000 feet.

Weather is a major factor when conducting offshore exploration in northern California, Oregon, and Washington. Its unpredictable nature, particularly in the winter, prevents extensive work programs during these months. Operations must be carefully planned and scheduled in advance; however, intermittent bad weather causes expensive interruptions. In rough weather the so-called "sea noise" of the turbulent water near the surface affects the fidelity of the seismic records. The safety of the crews is always an important factor.

Oil companies are very anxious to collect the basic information as soon as possible to permit them to nominate parcels of land for competitive oil lease bidding. Certain information is a prerequisite for submitting an intelligent bid.

If there are complications such as fish or fishing boats in an area where seismic work is being done, occasional shots can be eliminated without serious effect on the operations, or if the area is large enough and indicates promise, the crew can return at a later date to complete the series.

Although future plans of the oil companies are carefully guarded, there are indications that seismic exploration off Oregon may continue for several years.

SUMMARY

The purpose of the report is to present an objective summary of the available information concerning offshore exploration for oil and its possible adverse effects on fish and other marine life with the hope that it will resolve present differences among the various interested parties.

The first offshore well in the United States is believed to have been drilled at Summerland, California, in 1896. Oil exploration is now conducted offshore from at least nine states and in many other parts of the world.

It is believed that oil is synthesized from organic debris depositied in marine sediments, and is found associated with specific rock formations. The oil geologist "looks" for these structures by causing shock waves, which are partly reflected from each of the underlying layers of rock to a depth up to 15,000 feet. Returning vibrations are recorded on sensitive instruments. The three methods used in water are sparker, gas exploder, and conventional seismic. The first utilizes an electric spark, the second a propane-oxygen mixture, and the third an explosive to produce the shock. The latter is most commonly used, despite the fact that it costs several times as much as the other two methods, because it gives consistently greater penetration into the earth and allows a better seismographic record. It has the drawback of being the only method with a potential for killing fish.

There are three basic groups of explosives -- low explosive, high explosive, and blasting agent. All have been used in seismographic work. Black powder (low explosive) is relatively harmless to fish but hazardous to handle and is no longer used. Dynamite and other high explosives are expensive and dangerous to handle and were replaced by the lower cost blasting agent nitro-carbo-nitrate which is relatively safe to handle.

Salmon, anchovies, and other fish with air bladders are killed if they are close to an explosion. Halibut, soles, and other fish without air bladders are

not killed even when quite close to a blast. The only apparent effect on plankton is a possible slowing of activity. Crabs, clams, and other invertebrate animals are harmed only within a short distance of the explosion.

Few fish are killed by explosions of black powder, and the damage from even large charges of dynamite is restricted to a radius of 100-200 yards. The maximum lethal range of nitro-carbo-nitrate on pilchard and anchovies (with an air bladder) appears to be 150, 350, and 500 feet horizontally from 5, 10, and 25-pound charges, respectively. Vertically, the distances are 150, 200, and 250 feet for the same respective charges. There is universal agreement with these findings. Of the fish killed or injured by an explosion, 50 to 100% may float. There is little evidence to indicate fish are driven from an area by explosions.

Seismic exploration is being conducted in nine states, and permits are required in all cases. Generally the permits from the Pacific Coast states, which are similar to each other, are more restrictive on the oil companies than those from the Gulf states. Separate federal regulations govern Atlantic geophysical work, but state provisions are adapted for Pacific offshore waters.

Observers of seismic activities in Oregon saw 12,000 dead fish from 5,900 charges in 1961 and 16,355 dead fish from 13,600 charges in 1962. Fish were detected on the Simrad 850 times, and 132 shots were stopped because fish were within the expected lethal range. When the number of shots, time, and lethal area are considered in respect to the vast amount of water and numbers of fish therein, the effect of seismic exploration off Oregon on the fisheries resources is indeed small. No shots were fired in water less than 100 feet deep, and over 99% were outside the 3-mile limit.

Fish kill observation procedures vary among states and to some extent within Oregon. Louisiana has several hundred seismic crews operating with few fish-oriented problems.

Many biological studies have been conducted throughout the country to determine the effects of underwater explosions on marine life. Various size charges of different explosives have been exploded under varying conditions and the effect on marine life determined. The results of the individual studies are reported. The findings under comparable conditions are substantially in agreement.

There appears to be a need for better methods of evaluating immediate and delayed mortality, and adequately sampling at various depths to recover marine life following explosions.

Some fishermen have expressed serious concern with various aspects of the overall program of offshore seismic exploration and the effect on fish. Their apprehension involves the absence of written reports on the subject, application of findings to Oregon, qualifications and use of observers, conduct of field work, evaluation of biological data, and the impact of the explosions on the fishery and perpetuation of the resource.

The offshore waters are systematically explored by means of conventional seismic, sparker, gas exploder surveys, and bottom sampling to obtain information essential to bidding on oil leases. There are indications that seismic exploration off Oregon may continue for several years.

CONCLUSIONS

Concern for a natural resource by persons with a direct interest in its harvest is natural and expected. When a potential threat to its existence or perpetuation appears, opposition is generated until the threat is eliminated or determined to be harmless. Seismic exploration for oil in offshore waters of Oregon initially qualified as such a threat. The reaction of a segment of industry was normal -- prohibit it or at least delay operations until absolute proof was available that no damage to the fish or fisheries would result. This is exactly what happened in other states such as California and Louisiana. After conducting conclusive biological studies designed to answer specific questions, and controlled closely supervised seismic exploration activities were permitted and observed, the opposition largely disappeared. Acceptance and even support followed. In Oregon the opposition still exists, primarily because extensive information on the subject has not been made available to the persons concerned. This report contains the highlights of most of the important work done on this subject in the United States.

Extensive studies have been conducted by a number of states over a period of years. Many species of fish and shellfish were subjected to numerous explosives in different quantities under varying conditions. A few results are inconclusive or at some variance with others, but most are reliable and in substantial agreement.

It has been clearly shown that fish and invertebrates can be killed if close enough to the explosions, but are not significantly affected if outside the lethal range. For fish with air bladders this is between 150 and 500 feet, depending on explosive. Fish without air bladders and all invertebrates are much more resistant to damage from underwater explosions. There is some evidence to show that seismic explosions as presently conducted do not adversely affect fishing in the immediate area. The percentage of the ocean off Oregon which is affected by the seismic shots is extremely small.

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