USE AND EFFECT OF EXPLOSIVES IN CALIFORNIA COASTAL WATERS[1]

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Introduction

For many years the discovery of oil deposits in this country has not kept pace with the ever-increasing demands of a mechanical era. World War II hurried the process of depletion of our oil wealth and the outlook for the future is not very bright unless vast new oil fields are discovered and developed. This search for new deposits of oil has taken the oil researchers into the waters off our coast, and the methods employed in the exploration for the oil-bearing geological formations under the sea have resulted in the destruction of various forms of marine life. The total effect of this destruction is not known. In an attempt to throw more light on this problem the Bureau of Marine Fisheries, California Division of Fish and Game, has closely observed the operations of the oil companies engaged in geophysical survey work in our coastal waters. In addition, a limited amount of research has been done on the effect of underwater explosions on some marine animals (Aplin, 1947). The solution of the entire problem does not lie in prohibiting seismic work, but rather in so regulating seismic activities as to hold destruction of our marine resources to a minimum.

Methods

Seismic Operations

Geophysical survey work, as carried on in our coastal waters, entails the setting off of an explosive charge which is destructive to marine life. Most of these operations to date have been carried on between Laguna Beach and Point Conception, from the shore line to five miles offshore. To obtain accurate records, it is necessary for the geophysicists to set off charges of explosives[2] approximately every 250 to 1,000 feet on predetermined lines running north and south and east and west. The sound waves from the explosion travel down through the various strata of rock, and as they bounce back from these strata they are picked up by a number of geophones floated on the surface. An electrical impulse generated by the sound waves then passes from the geophones along a cable to the survey ship, where a permanent record is made on light-sensitized photographic paper. These graphs are later worked out in detail in the offices of the exploring company and anticlinal structures located accurately in various areas of the ocean floor.

The weight of explosive in a single shot has varied from 10 pounds to 160 pounds. In most instances the weight of each individual charge was 40 or 80 pounds for "open" shots and 20 pounds for "jet" shots.

[1] Submitted for publication December, 1947.
[2] Sources of energy, other than explosives, have not as yet been found adaptable to marine seismic operations.

Charges floated a few feet under the surface and exploded from that position are referred to as open shots while those buried under the floor of the ocean by means of a water jet are referred to as jet shots. A third type of shooting, where the charge lies directly on the bottom of the ocean, is also used but not frequently enough to be more than mentioned in passing.

Determination of Destruction

Surface Observations

When an explosion takes place in the water the number of fish killed depends upon the number present in the area. Most of the data collected by the authors concerns only those fish which floated to the surface when killed. Fish which are killed by an explosion, if they are going to float, will come to the surface within 15 minutes. Therefore, surface observations were not made for longer than a 15-minute period after a shot in any one area. The method of determining the number of fish killed and floating in an area was to count a group of 10, 25, 50 or 100 and divide the whole floating mass by inspection into like numerical groups. The above method of counting proved reliable within 10 percent when checked against an actual pickup count.

Weights of the fish killed were determined either by weighing individuals or by picking up 10 to 25 specimens of the small fish, weighing these, obtaining an average weight and applying this average weight to the estimated number of dead fish.

Bottom Samples

During March, 1947, while a geophysical survey was in progress in the Newport-Huntington Beach area and for a week after the cessation of exploratory work, the Bureau of Marine Fisheries received numerous complaints from live bait fishermen that many pounds of dead and rotting fish were taken in their bait hauls. The fishermen attributed this to the seismic operations and insisted that more killed fish sank than floated.

To determine the validity of these complaints attempts were made to find some means of determining the number of fish which were killed and did not float. On April 30, 1947, the Macco Corporation, then operating in the Santa Barbara area, made their survey boat the "Polaris" and a professional diver available for a survey of the bottom where three jet shots had just been made. The "Polaris" was anchored directly over the position where each shot had been fired and the diver searched the bottom for dead fish. The water depth was around 30 feet and there was 100 feet of air hose attached to the diver so the area searched covered about a 75-foot radius around the blast center. At the second position Fitch put on the diving suit and searched the bottom, finding but one small salt-water perch *(Brachyistius frenatus)*. The Macco diver went down immediately after and recovered five perch in the same area. The numbers of fish floating and on the bottom in these three areas are given in Table 7.

Later bottom sampling has been done with the aid of a dredge designed and built by Mr. H. M. Davis of the Kerckhoff Marine Laboratory, Corona del Mar. Most of the work with this dredge has been at depths in excess of 150 feet. The results discussed under "Total Fish Killed" are not conclusive as yet.

Effect on Marine Life

The largest fish observed killed by a shot was a 365-pound black sea-bass *(Stereoleopis gigas)* and the smallest were larval anchovies *(Engraulis mordax)*. The greatest estimated quantity killed as a result of one explosion was approximately two tons of rockfish *(Sebastodes)* but there have been numerous times when not a single fish was killed in a whole day's operation.

Force of an Explosion

The damage that occurs to fish life is, at the present time, thought to be largely limited to those species possessing an air bladder. There is a dearth of factual information on this subject, but what little has been found in the literature confirms our observations. Post mortem examinations of a large number of fish, recovered from both the surface and from the ocean floor, show similar effects. Invariably there is a rupture of the air bladder, and, depending upon the distance and position of the fish in relation to an explosion, other parts of the viscera may be damaged or crushed. In some of the larger fishes the ribs have been broken from the backbone.

The ability of an underwater explosion to inflict damage decreases inversely as the cube of the distance. A fish 10 feet away from an explosion will receive approximately eight times the force from the shock wave as a fish 20 feet from the same explosion. A fish 200 feet from the explosion will receive but one eight-thousandths the shock received by a fish 10 feet distant.

Physical Effect on Fish

The great speed of the shock wave, approximately 4,940 feet per second (Gowanloch and McDougall, 1944), exerts terrific pressure on a fish that presents a broad surface to the direction of wave travel. If the hapless fish is provided with an air bladder, the effect may be fatal. However, when the fish does not possess an air bladder, controlled experiments (Aplin, 1947) showed that there was no noticeable effect. When a fish is either pointed directly toward or directly away from the source of the shock, the pressure exerted will tend to be equal, or very nearly so, on both sides of the fish. Under this condition, recovery from an explosion would tend to be more assured than for fish which are broadside to the path of the shock pressure wave. Fish presenting a broadside are literally plastered up against an incompressible wall of water. The body wall and air spaces within the fish are compressed instantaneously, allowing no opportunity for physiological adjustment to the sudden pressure.

There is, in each species of fish, an inherent resistance to shock pressure. Some species, as the barracuda, kingfish, queenfish and others, possess a tough, heavy-walled air bladder and a body of cylindrical proportions. Such fish appear to have much more resistance to pressure than do laterally compressed fish with a very thin walled air bladder such as the salt-water perch. Jack smelt, although cylindrical in shape, have a thin air bladder and are quite susceptible to blasts. The various rockfishes, which are also quite susceptible, are good examples of fish that have large air bladders with medium thick walls.

Susceptibility Among Mammals

On at least three occasions California sea lions *(Zalophus californianus)* were killed but California grey whales *(Rhachianects glaucus)* observed in the region of a blast were seemingly unaffected and in fact were not even frightened from the area.

The professional diver employed to jet the charges into the bottom by the Macco Corporation was lowered into the water 500 feet from an exploding jetted charge. He stated that he heard a sharp noise in his metal headgear but felt no pain in any part of his body. At a distance of approximately 5,000 feet from an open shot he stated the noise hurt his ears and that he also felt sharp pains in the region of the groin. These pains did not persist or recur.

Susceptibility Among Birds

Among the birds that follow the operations to feed upon the dead fish, the cormorants *(Phalacrocorax)* suffer the heaviest damage because they dive beneath the surface. All appear to be killed if they are below the surface when a charge is exploded. California brown pelicans *(Pelecanus occidentalis californicus)* are frequently killed, but only when they have their heads beneath the surface reaching for a fish. A few gulls *(Larus)* have suffered broken wings after being struck by the column of water which rises in the air when an open shot is exploded. On one occasion a Phalarope *(Phalaropus)* was observed with a broken wing immediately after a shot.

Susceptibility Among Fish

It as been observed many times that not all of the fish within the lethal range of the exploded charge are killed or even outwardly affected by the concussion. Several times in the kelp beds (Santa Barbara area) when a charge was exploded, small perch *(Brachyistius frenatus)* spun and gyrated crazily in the water whereupon kelp bass *(Paralabrax clathratus)*, evidently attracted by these flashing cripples, began feeding upon them and in a few minutes the area was spotted with feeding kelp bass. Succeeding shots in the same area resulted in the death of some of these bass, but, regardless of this, the feeding activities of those unharmed continued.

On another occasion, outside the kelp beds in open water, the observation boat was stopped well within the lethal range of the ensuing explosion. A school of 30 to 40 jack smelt *(Atherinopsis californiensis)* was observed a few feet away from the boat and between it and the charge of explosive. When the blast went off, three, and only three, of this group immediately turned over and floated to the surface. The rest of the school swam off as if nothing had happened.

Similar occurrences have been witnessed often enough to remove any doubt that they may be accidental. However, much more work should be done on the susceptibility of fish to an explosion before drawing any conclusions as to why some are apparently unaffected while others in the same group are killed immediately.

Behavior of Fish

The case of the kelp bass feeding upon the small perch is one example of a case where the fish were not driven from the area by the explosion.

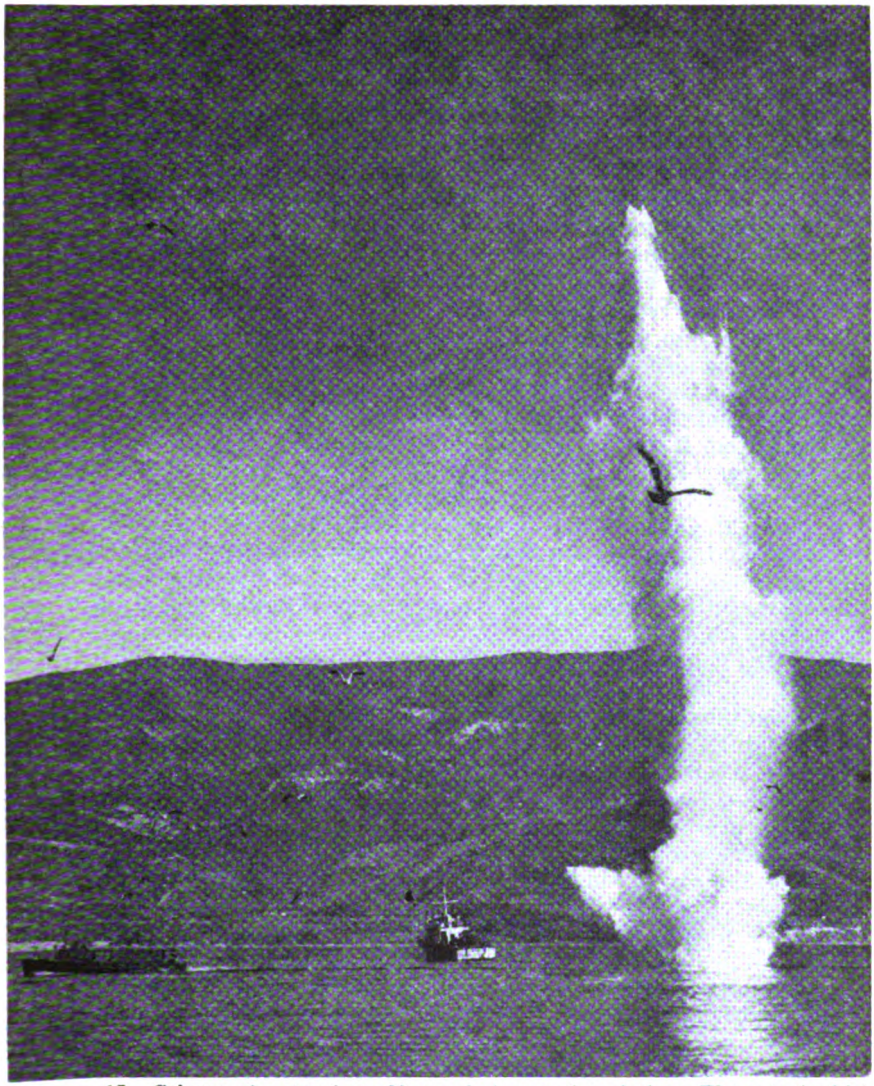

FIGURE 17. Column of water from 80-pound charge of explosives. Water-taxi which set off charge is 43 feet long. *Photograph by John E. Fitch*

The attraction in this instance evidently was food. Aplin (1947) relates an incident concerning a school of anchovies circling the survey ship while blasting was being carried on. The following examples offer further proof that fish are not always driven from an area where dynamite is exploded.

Off Newport on March 25, 1947, shots were fired on the bottom at approximately five minute intervals in one spot marked by an anchored buoy. A few kingfish *(Genyonemus lineatus)* and queenfish *(Seriphus politus)*, both highly susceptible to explosions, were killed with each shot. However, on the eighth shot approximately 350 pounds of barracuda *(Sphyraena argentea)* were killed and floated to the surface. It

will be noted that this was a full 45 minutes or more after the first shot had been fired and not much over five minutes since the preceding explosion.

On one occasion while fishing with hook and line on the bottom in approximately 60 feet of water, two California halibut *(Paralichthys californicus)* and 13 kingfish were caught in 25 minutes succeeding a blast in the identical spot over which the explosion had taken place. Fishing experiments carried on over a period of several days gave even further evidence that the above occurrence was not an accident, as sharks, rays, flatfish and kingfish were caught quite frequently.

It was observed numerous times that when explosions were repeated in an area within a 24-hour period an entirely different group of fishes was killed the second day. Since the fish referred to as killed the second day were for the most part scavengers, it is open to conjecture as to whether or not they had moved into the area to feed on the fish left dead on the bottom from the previous day's operations. One instance of this occurred near Rincon Point on the morning of May 27, 1947, when a charge was fired in the same spot at which a shot the previous afternoon had killed kingfish, queenfish and anchovies. However, besides kingfish, queenfish and anchovies on May 27, approximately two hundred pounds of midshipmen *(Porichthys notatus* and *P. myriaster)* were killed. These had their bellies distended with small kingfish, queenfish and anchovies in various stages of digestion. Since the midshipman is not known to be a schooling fish and since the usual shot kills but one or two midshipmen at the most, it might be assumed they had concentrated in the area to feed upon those fish left dead the day before.

The same thing has happened a number of times where rockfish were killed the second day. Here, too, stomach contents showed all those killed to have been feeding heavily on kingfish, perch, queenfish, sardines and anchovies presumably left dead the previous day. The stomach contents of any large group of rockfish killed in a previously unsurveyed area consisted mainly of small octopi and crabs with empty stomachs predominating.

The extensive observations that have been made during past months give no indication that fish are frightened from an area by a blast. An investigator in Canada (Knight, 1907) observed, "nor could it be said in our experience that pollock *(Pollachus virens)* were frightened away."

Total Fish Killed

Surface Observations

A record of the estimated quantity of fish killed as a result of geophysical survey work conducted on days when an observer from the Bureau of Marine Fisheries was present is given in Tables 1-6. Tables 1, 2 and 3 present data on fish killed by open shots in the Newport Beach region, Santa Barbara region, and Santa Barbara to Gaviota area. Tables 4 and 5 summarize data on fish killed by jet shots in the Newport Beach and Santa Barbara regions. Table 6 contains a summary of all fish killed by all methods.

During the period of this study jet shots killed an estimated 0.23 pound of fish per pound of explosive used and 4.93 pounds of fish per shot. On the other hand, open shots killed 0.47 pound of fish per pound of explosive, double that of jet shots, and 31.56 pounds of fish per shot,

more than six times that recorded for jet shots. This represents 41,000 pounds of fish killed by open shots and 1,000 pounds killed by jet shots. Jack mackerel comprised over 21,000 pounds or one-half of the total. Next heaviest kill was 6,000 pounds of rockfish, which is about one-fifth of the total poundage. Sardines, kingfish and perch fall in line behind these. Aplin (1947) found in his observations that the kill of fish averaged 200 pounds per shot. Our records show only 32 pounds. The difference between these two figures is possibly due to more stringent regulations by the Division of Fish and Game which now prohibit operations in any area except when the fish population is at a low level.

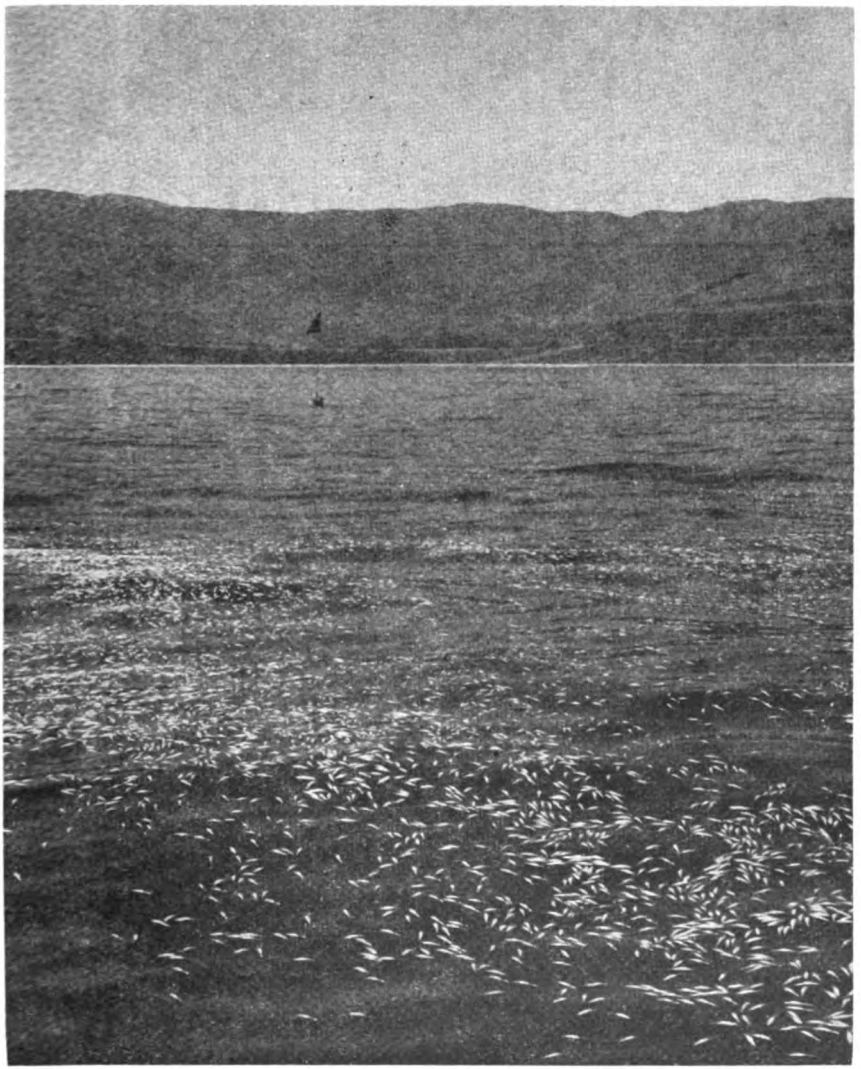

FIGURE 18. Small rockfish (*Sebastodes paucispinis*) floating after a 40-pound charge detonated at four feet beneath the surface. Such destruction is the exception. *Photograph by John E. Fitch.*

TABLE 1

Pounds of Fish Observed Killed by Open Shots in the Region of Newport Beach

Locality and date	Depth of water feet	Number of shots	Total weight of shots pounds	Pounds of fish killed												
				Jack Mackerel	Rock-fish	Sar-dine	King-fish	Perch	Barra-cuda	Pacific Mackerel	White Sea-bass	Queen-fish	Ancho-vy	Jack Smelt	Miscel-laneous	Total
Huntington Pier, March 4, 1947		9	240				1,000					50	50	100		1,200
Off Newport Jetty, March 5, 1947		13	260										5	10		15
Balboa, March 6, 1947		34	870				500					25	20	25		570
Santa Ana River, March 7, 1947		26	420				25			75			10	10		120
Newport, March 10, 1947		2	40				10									10
Newport, March 13, 1947		30	600				20						5	5		30
Newport, March 14, 1947		29	600				25					5				30
Newport, March 15, 1947		16	500													none
Newport, March 17, 1947		no record					10						5			15
Newport, March 18, 1947		no record								50						50
Newport, March 19, 1947		no record														none
Newport, March 20, 1947		32	700													none
Newport, March 21, 1947		1	20													none
Newport, March 22, 1947		10	200				5							10		15
Newport, March 25, 1947	*on* bottom	15	1,080				25		300			10				335
Newport, March 28 and 29		6	120				20					5		10		35
Newport, March 30, 1947		5	100													none
Totals		228	5,750				1,640		300	125		95	95	170		2,425

TABLE 2

Pounds of Fish Observed Killed by Open Shots in the Santa Barbara Region

Locality and date	Depth of water feet	Number of shots	Total weight of shots pounds	Pounds of fish killed												
				Jack Mackerel	Rock-fish	Sar-dine	King-fish	Perch	Barra-cuda	Pacific Mackerel	White Sea-bass	Queen-fish	Ancho-vy	Jack Smelt	Miscel-laneous	Total
San Augustin, April 16, 1947		4	160		33			396						25	[a]48	502
Naples, May 1, 1947		12	480	870	18	5		440	15					65	47	1,460
Naples, May 14, 1947		2	80		1			1						1		3
Naples, May 15, 1947		15	600	40	10		20	25							5	100
Naples, May 27, 1947		no record					27	2				5				34
Naples, May 28, 1947		no record			1		125	50				25	10		[b]204	415
Isle Vista, June 25, 1947		11	440	521	306		16	39			4			8	26	920
Isle Vista, June 26, 1947		6	140		4		23	3						2	17	49
Tajiguas, July 9, 1947		23	920	195	96		17	158		14				12	29	521
Tajiguas, July 10, 1947	60' av.	9	360		28		10	93						22	36	189
Totals		82	3,180	1,626	497	5	238	1,207	15	14	4	30	10	135	412	4,193

[a] Includes 38 pounds of kelp bass.
[b] Includes 200 pounds of midshipman.

TABLE 3

Pounds of Fish Observed Killed by Open Shots in the Area Between Santa Barbara and Gaviota

Locality and date	Depth of water feet	Number of shots	Total weight of shots pounds	Pounds of fish killed												
				Jack Mackerel	Rock-fish	Sar-dine	King-fish	Perch	Barra-cuda	Pacific Mackerel	White Sea-bass	Queen-fish	Ancho-vy	Jack Smelt	Miscel-laneous	Total
Elwood, September 9, 1947	60 and over	15	680	906	11	1,073	75	67	-------	-------	-------	5	2	173	[c]4	2,316
Hope Ranch Beach, September 10, 1947	"	11	520	110	3	45	10	34	-------	-------	-------	5	-------	10	-------	217
Hope Ranch Beach, September 11, 1947	"	26	1,770	3,152	185	-------	17	236	40	60	180	5	-------	10	-------	3,885
Goleta Point, September 16, 1947	124-192	17	1,440	105	68	15	50	10	-------	-------	-------	-------	10	-------	[d]45	303
Goleta Point, September 17, 1947	115-195	19	1,600	50	509	20	300	25	-------	-------	-------	-------	10	-------	15	929
Goleta Pt. 1 mi. E., September 18, 1947	100-192	26	2,080	108	31	7	122	33	-------	6	-------	6	-------	11	1	325
Goleta Pt. 2 mi. E., September 19, 1947	103-177	23	1,840	822	-------	2,580	1	1	-------	20	-------	-------	-------	-------	-------	3,424
Gaviota, September 23, 1947	25	1	40	-------	-------	-------	1	-------	-------	-------	-------	-------	-------	7	1	9
Gaviota, September 24, 1947	100 and over	13	1,040	1,500	2	75	25	10	-------	-------	-------	-------	-------	-------	-------	1,612
Goleta, September 30, 1947	100-192	32	2,560	139	21	8	3	36	-------	-------	-------	-------	-------	-------	-------	207
Gaviota, October 1, 1947	100-215	41	3,280	2,009	5	25	8	19	-------	-------	-------	-------	-------	-------	-------	2,066
Gaviota, October 2, 1947	100-200	65	5,200	2,606	4	63	135	10	-------	-------	-------	-------	-------	-------	-------	2,818
Gaviota, October 8, 1947	100-200	23	1,840	69	1	1	1	-------	-------	25	-------	-------	-------	-------	[e]10	107
Gaviota, October 9, 1947	100-200	12	960	203	25	58	2	-------	-------	33	-------	-------	-------	-------	3	324
Gaviota, 4 mi. SE., October 10, 1947	100-210	69	5,520	2,428	1,400	349	100	15	-------	-------	-------	-------	-------	-------	-------	4,292
Gaviota, 4 mi. SE., October 16, 1947	100-205	47	3,760	66	120	2	53	45	-------	-------	-------	2	1	-------	6	295
Gaviota, October 17, 1947	100-213	60	4,640	80	10	-------	25	8	-------	-------	-------	-------	-------	-------	1	124
Gaviota, 5 mi. E., October 21, 1947	100-225	70	5,600	31	569	-------	9	33	100	-------	-------	-------	-------	-------	1	743
Gaviota, 5 mi. E., October 22, 1947	100-200	37	2,960	124	103	-------	17	11	-------	-------	-------	-------	-------	-------	-------	255
Gaviota, 5 mi. E., October 30, 1947	100+	44	3,520	181	43	-------	18	-------	-------	-------	-------	-------	-------	-------	1	243
Gaviota, October 31, 1947	210-550	50	4,000	-------	2,202	-------	-------	-------	-------	-------	-------	-------	-------	-------	[c]51	2,253
Goleta, November 6, 1947	100-220	75	6,000	353	50	35	23	87	-------	240	-------	-------	-------	-------	2	790
Goleta, November 7, 1947	100-200	20	1,600	-------	5	-------	-------	40	-------	-------	-------	-------	-------	-------	[f]40	85
Goleta, November 13, 1947	200 and over	37	2,960	2,250	8	250	250	250	-------	-------	-------	-------	-------	-------	4	3,012
Goleta, November 14, 1947	50	2	160	-------	15	-------	-------	10	-------	-------	-------	5	-------	5	1	36
Goleta, November 20, 1947	10-35	8	640	-------	-------	-------	10	80	-------	-------	-------	25	-------	40	-------	155
Hope, November 21, 1947	40	15	1,200	-------	-------	-------	5	110	-------	-------	1	187	10	30	[g]93	436
Gaviota, November 24, 1947	100 and over	55	4,400	908	1	-------	85	5	133	-------	207	-------	2	-------	-------	1,341
Gaviota, 5 mi. E., November 25, 1947	200-550	19	1,520	550	5	-------	-------	-------	-------	-------	-------	-------	-------	-------	[c]10	565
Gaviota, November 26, 1947	100-210	54	4,320	386	105	-------	146	64	328	-------	82	-------	10	-------	1	1,122
Totals	-------	986	77,650	19,136	5,501	4,606	1,491	1,239	601	384	470	240	45	286	290	34,289

[c] Hake.
[d] Includes 30 pounds of herring.
[e] Saury.
[f] Kelp bass.
[g] Includes 60 pounds of black croaker and one 30-pound black sea-bass.

TABLE 4

Pounds of Fish Observed Killed by Jet Shots in the Region of Newport Beach

Locality and date	Depth of water feet	Number of shots	Total weight of shots pounds	Pounds of fish killed												
				Jack Mackerel	Rock-fish	Sar-dine	King-fish	Perch	Barra-cuda	Pacific Mackerel	White Sea-bass	Queen-fish	Ancho-vy	Jack Smelt	Miscel-laneous	Total
Huntington Pier, March 4, 1947	Under 60	5	100				50						5			55
March 5, 1947	"	3	60													none
March 6, 1947	"	9	140										10	5		15
March 7, 1947	"	12	240				5						10		[b]5	20
March 26, 1947	"	35	700				15						10	5	10	40
March 27, 1947	"	33	660													none
March 28, 1947	"	10	200				20					5	20		[1]136	181
March 29, 1947	"	24	480	20			200					5	125	5	20	375
March 30, 1947	"	22	440				5						10			15
March 31, 1947	"	7	140													none
Totals		160	3,160	20			295					10	190	15	171	701

[b] Grunion.
[1] Includes 125 pounds of sunfish.

TABLE 5

Pounds of Fish Observed Killed by Jet Shots in the Region of Santa Barbara

Locality and date	Depth of water feet	Number of shots	Total weight of shots pounds	Pounds of fish killed												
				Jack Mackerel	Rock-fish	Sar-dine	King-fish	Perch	Barra-cuda	Pacific Mackerel	White Sea-bass	Queen-fish	Ancho-vy	Jack Smelt	Miscel-laneous	Total
More, April 30, 1947	Under 60	11	220	.....	9	.....	.....	77	.....	.....	.....	.....	.....	13	14	113
More, May 1, 1947	Under 60	3	60	.....	3	.....	.....	46	.....	.....	.....	.....	.....	2	16	67
Naples, May 27, 1947	Under 60	.....	.....	.....	.....	.....	23	5	.....	.....	.....	6	20	.....	.....	54
Isle Vista, June 25, 1947	Under 60	7	140	.....	2	.....	.....	18	.....	.....	.....	.....	.....	1	7	28
Gaviota, September 23, 1947	25	2	40	.....	.....	.....	.....	15	.....	.....	.....	10	.....	5	.....	30
Goleta, September 25, 1947	100	3	60	.....	.....	.....	.....	19	.....	.....	.....	.....	.....	4	.....	23
Goleta, September 30, 1947	35	5	200	.....	.....	.....	1	1	.....	.....	.....	.....	.....	1	.....	3
Goleta, November 7, 1947	30	3	120	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	negligible
Goleta, November 14, 1947	50	7	280	.....	.....	.....	.....	20	.....	.....	.....	5	.....	11	1	37
Goleta, November 20, 1947	20-30	2	80	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	negligible
Totals	.....	43	1,200	.....	14	.....	24	201	.....	.....	.....	21	20	37	38	355

TABLE 6

Summary of All Fish Killed by All Methods

Region	Number of shots	Weight of shots pounds	Pounds of fish killed												
			Jack Mackerel	Rock-fish	Sar-dine	King-fish	Perch	Barra-cuda	Pacific Mackerel	White Sea-bass	Queen-fish	Ancho-vy	Jack smelt	Miscel-laneous	Total
Table 1, Newport Beach	228	5,750				1,640		300	125		95	95	170		2,425
Table 2, Santa Barbara	82	3,180	1,626	498	5	238	1,206	15	14	4	30	10	135	412	4,193
Table 3, Santa Barbara-Gaviota	986	77,650	19,136	5,501	4,606	1,491	1,239	601	384	470	240	45	286	290	34,289
Totals, Open Shots	1,296	86,580	20,762	5,999	4,611	3,369	2,445	916	523	474	365	150	591	702	40,907
Table 4, Newport Beach	160	3,160	20			295					10	190	15	171	701
Table 5, Santa Barbara	43	1,200		14		24	201				21	20	37	38	355
Totals, Jet Shots	203	4,360	20	14		319	201				31	210	52	209	1,056
Totals, All Methods	1,499	90,940	20,782	6.013	4.611	3.688	2,646	916	523	474	396	360	643	911	41,963

Bottom Observations

Results of the observations made on the bottom during diving operations on April 30, 1947, indicated that the number of fish which do not float is negligible when compared to the number that do float (Table 7). In order to obtain more complete records a dredge has been used in deeper water since November, 1947. In only one instance to date could a direct comparison be made between the number of fish picked up by the dredge, with the number floating. This gave a ratio of about one to one. This is not in accord with the results obtained in the diving operations as shown in Table 7 where the ratio is about twelve floating to one on the bottom. Much more work and experimenting must be done in this line before a true picture can be had of those fish killed which do not float.

TABLE 7

Numbers of Fish Found Floating on Surface Compared With Numbers Found on Bottom

Position	Dead and floating	Dead, recovered from bottom
1	1 Midshipman 3 Saltwater perch 2 Jack smelt 50 small fish taken by gulls — 56 Total	6 Saltwater perch — 6 Total
2	3 Rockfish 6 Saltwater perch 1 Kelp blenny 75 small fish taken by gulls — 85 Total	6 Saltwater perch — 6 Total
3	1 Kelp bass 20 Saltwater perch 1 Rockfish 2 Pipefish 2 Kelp blenny 200 small fish taken by gulls — 226	17 Saltwater perch 2 Kelp blenny — 19

Common and Scientific Names of Fish Killed

1. Anchovy, deep-bodied, *Anchoa compressa*
2. Anchovy, northern, *Engraulis mordax*
3. Barracuda, *Sphyraena argentea*
4. Bass, kelp, *Paralabrax clathratus*
5. Bass, sand, *Paralabrax nebulifer*
6. Blacksmith, *Chromis punctipinnis*
7. Corbina, California, *Menticirrhus undulatus*
8. Croaker, black, *Sciaena saturna*
9. Croaker, spotfin, *Roncador stearnsii*
10. Croaker, yellowfin, *Umbrina roncador*
11. Cusk eel, *Otophidium scrippsi*
12. Cusk eel, *Otophidium taylori*
13. Grunion, *Leuresthes tenuis*
14. Hake, *Merluccius productus*
15. Herring, Pacific, *Culpea pallasii*
16. Kelp blenny, *Heterostichus rostratus*
17. Kingfish, *Genyonemus lineatus*
18. Mackerel, jack, *Trachurus symmetricus*
19. Mackerel, Pacific, *Pneumatophorus diego*
20. Midshipman, *Porichthys myriaster*
21. Midshipman, *Porichthys notatus*
22. Mullet, *Mugil cephalus*
23. Opal-eye, *Girella nigricans*
24. Perch, black, *Embiotoca jacksoni*
25. Perch, fork-tailed, *Damalichthys vacca*
26. Perch, Pacific white, *Phanerodon furcatus*
27. Perch, rainbow, *Hypsurus caryi*
28. Perch, rubberlip, *Rhacochilus toxotes*
29. Perch, wall-eyed, *Hyperprosopon argenteum*
30. Perch, *Brachyistius frenatus*
31. Perch, *Cymatogaster aggregatus*
32. Perch, *Micrometrus minimus*
33. Perch, *Zalembius rosaceus*
34. Pipefish, *Syngnathus californiensis*
35. Queenfish, *Seriphus politus*
36. Rockfish, bocaccio, *Sebastodes paucispinis*
37. Rockfish, chili-pepper, *Sebastodes goodei*
38. Rockfish, green spotted, *Sebastodes chlorostictus*
39. Rockfish, starry, *Sebastodes constellatus*
40. Rockfish, striped, *Sebastodes elongatus*
41. Rockfish, yellow-tailed, *Sebastodes flavidus*
42. Rockfish, *Sebastodes miniatus*
43. Rockfish, *Sebastodes rastrelliger*
44. Rockfish, *Sebastodes rubrivinctus*
45. Sardine, *Sardinops caerulea*
46. Sargo, *Anisotremus davidsonii*
47. Saury, Pacific, *Cololabis saira*
48. Sea-bass, black, *Stereolepis gigas*
49. Sea-bass, white, *Cynoscion nobilis*
50. Shad, *Alosa sapidissima*
51. Sheepshead, California, *Pimelometopon pulchrum*
52. Smelt, bay, *Atherinops affinis*
53. Smelt, jack, *Atherinopsis californiensis*
54. Stickleback, *Aulorhynchus flavidus*
55. Sunfish, ocean, *Mola mola*
56. Whitefish, ocean, *Caulolatilus princeps*

REGULATIONS GOVERNING SEISMIC OPERATIONS

Rules and Regulations

The following rules and regulations were adopted by the California Fish and Game Commission at the meeting on August 22, 1947, and became a part of the Fish and Game Code effective September 19, 1947.

As provided by Section 480, the following are the regulations under which permits are granted to use explosives in the waters of this State inhabited by fish, insofar as such explosives may be used for seismic exploration:

(a) Permits shall be issued for such areas and seasons as will result in a minimum of destruction to marine life and fisheries.

(b) No blasts shall be set off in waters of less than one hundred feet (100′) (seventeen (17) fathoms), except as they are placed below the surface of the ocean floor, unless prevented from so doing by rock formations.

(c) An employee of the Division of Fish and Game shall be permitted to accompany the boat or crew which is conducting the exploratory work, as an observer to determine if any damage is done to the fisheries. This observer shall have the authority to stop operations in any given area if damage to marine life seems too great. A boat and boat crew shall be made available to this observer to check the area after each individual blast, and this boat shall carry, and the crew shall help operate, such gear and equipment as the observer shall furnish, and permittee shall meet any expense of gear rental or operation that may be incurred.

(d) All fish of edible size which may be killed shall be picked up by the operating crew, and arangements made for their free disposal to charitable institutions or agencies.

(e) Anyone holding a permit shall notify the Division of Fish and Game in writing before beginning operations. For operations in San Luis Obispo County and southward, the Terminal Island Office shall be notified; for operations in Monterey County and northward, the San Francisco Office shall be notified.

(f) On the fifteenth and last day of each month of operation, the permittee shall submit a report of dates, location, and number of detonations made in the preceding period. A report shall be submitted for each permit for each half-month period whether operations were actually conducted or not. The report shall include the species and weight of edible fish disposed of, as provided in paragraph (d), and the name of the recipient.

(g) No permit shall be issued for more than ninety (90) days, and no applicant shall be issued more than one permit at a time.

(h) In order to subject the fish life to a minimum of disturbance, no permit shall be issued to any applicant after October 1, 1948, for any area until twelve (12) months after the last previous issuance of a permit for that area to the same or any other applicant, providing such permit was exercised. The provisions of this paragraph do not prohibit the setting of recheck shots not to exceed ten (10) percent in number of those actually fired during the life of the permit. The approval of the commission must be obtained before such recheck shots are fired.

(i) Any permit granted by the Fish and Game Commission to conduct seismic operations grants permission only insofar as the Fish and

Game Commission is concerned. No permit is valid nor shall be exercised unless at the time thereof the permittee has in force and effect a permit covering such operations issued by the State Lands Commission of the State of California.

(j) All permits shall be subject to revocation at any time.

Form of Permit

The following form has been adopted for use in issuing permits by the California Division of Fish and Game to the various companies desiring to do geophysical survey work in California waters:

TO WHOM IT MAY CONCERN:

Permission is hereby granted, insofar as the Division of Fish and Game is concerned, to (*name, address*) to use explosives for seismic work from (*date*) to (*date*), inclusive, from (*location*) to (*location*).

It is understood in this permit that no blasts shall be set off in waters of less than one hundred feet (100′) (seventeen (17) fathoms), except as they are placed below the surface of the ocean floor, unless prevented from so doing by rock formations.

It is further understood that an employee of the Division of Fish and Game shall be permitted to accompany the boat or crew which is conducting the exploratory work, as an observer to determine if any damage is done to the fisheries. This observer shall have authority to stop operations in any given area if damage to marine life seems too great. A boat and boat crew shall be made available to this observer to check the area after each individual blast, and this boat shall carry, and the crew shall help operate such gear and equipment as the observer shall furnish, and permittee shall meet any expense of gear rental or operation that may be incurred.

It is further understood that all fish of edible size which may be killed shall be picked up by the operating crew, and arrangements made for their free disposal to charitable institutions or agencies.

Permittee shall notify the Bureau of Patrol and Law Enforcement, Division of Fish and Game, Terminal Island, California, in writing before beginning operations.

On the fifteenth and last day of each month of operation, the permittee shall submit a report of dates, location, and number of detonations made in the preceding period. A report shall be submitted for each half-month period whether operations were actually conducted or not. The report shall include the species and weight of edible fish disposed of, as provided in paragraph four above, and the name of the recipient.

This permit grants permission to conduct seismic operations only insofar as the Fish and Game Commission is concerned. The permit is not valid and shall not be exercised unless at the time thereof permittee has in force and effect a permit covering such operations issued by the State Lands Commission of the State of California.

This permit is subject to revocation at any time.

Disposal of Fish Killed

To prevent waste of fish, regulations were set up requiring that all edible fish be picked up and turned over to charitable institutions. Although this scheme was considered to be most favorable by all concerned, it did not prove practical since charitable agencies do not have facilities to handle quantities of fish at irregular intervals. As a substitute, all edible fish are disposed of through normal commercial channels. Money from the sale of these fish is being held in trust until enough is accumulated to warrant transfer to charitable agencies. The handling of fish by the commercial establishments has been rotated periodically among the companies willing to handle such material. The amount of fish sold from September 18 to November 27, 1947, comprised 4,110 pounds which realized $218.04 (Table 8).

TABLE 8

Pounds and Value of Fish Sold

Date	Rockfish		Jack & Pacific Makerel		Barracuda		White Sea-bass	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1947								
September 18	171	$8 55						
September 23	379	18 95	81	$4 05				
September 25			657	19 71				
October 8	74	2 96						
October 9	35	1 40	69	2 76				
October 22	218	7 63						
October 23	113	3 96						
October 31	1,552	54 32						
November 19			25	75	78	$11 70	30	$4 50
November 24			145	4 35	84	12 60	201	30 15
November 27					198	29 70		
Totals	2,542	$97 77	977	$31 62	360	$54 00	231	$34 65

Conclusions

Constant observations should be continued in order to determine damage to marine life and to improve methods of keeping this destruction to a minimum.

Jetting of shots will substantially reduce destruction. During the period of this study, jet shots killed an estimated 0.23 pound of fish per pound of explosive or 4.93 pounds of fish per shot, whereas open shots killed 0.47 pound of fish per pound of explosive or 31.83 pounds of fish per shot.

Not all fish killed by an explosion float. Some method of determining the number which sink should be devised.

Not all fish susceptible to an explosion and within lethal range of a shot are killed or injured.

Certain birds and mammals are killed by underwater explosions under some conditions.

Fish are not driven from a particular area by underwater explosions.

References

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