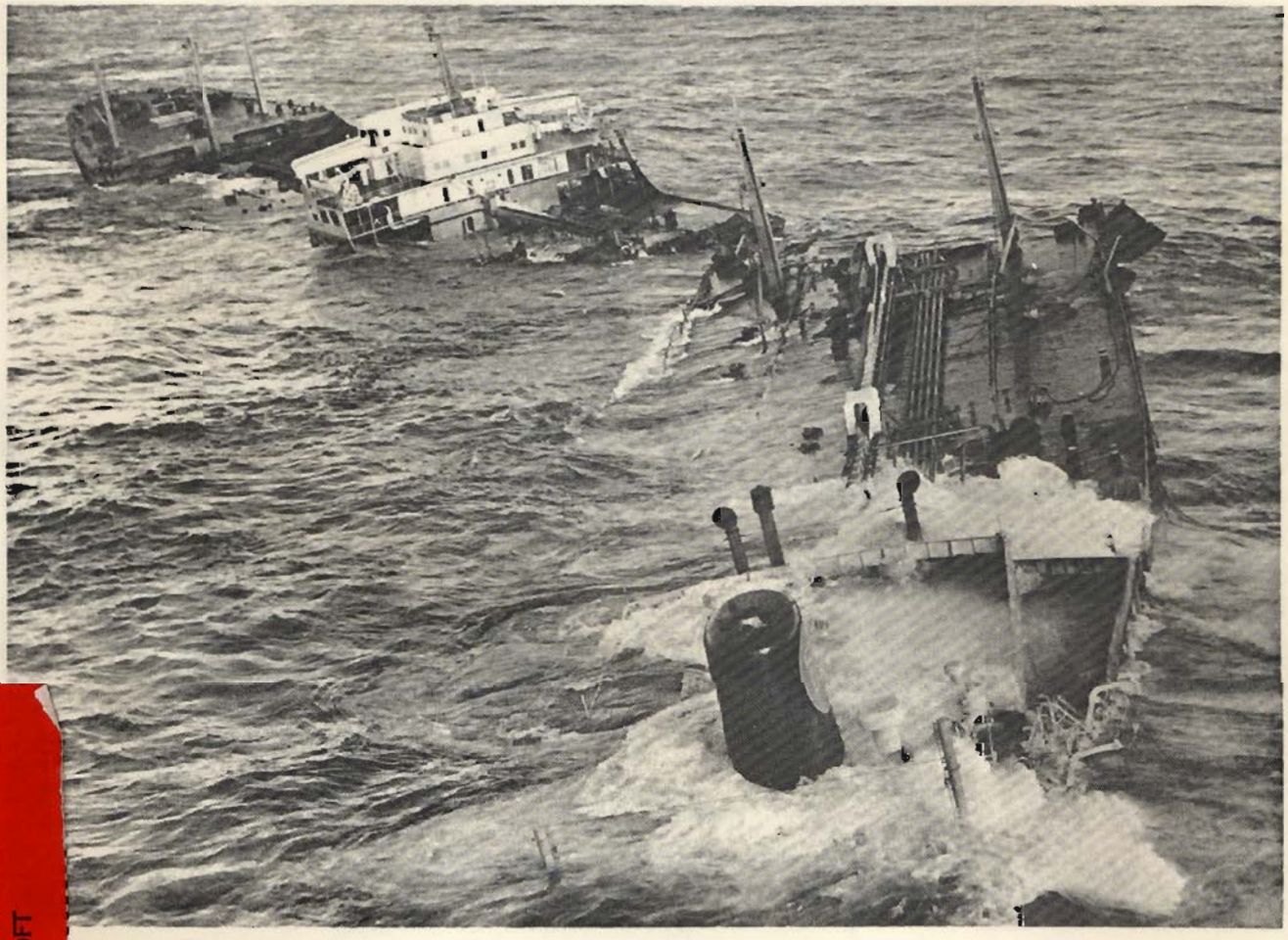
MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

THE TORREY CANYON DISASTER AND FISHERIES



LABORATORY LEAFLET (NEW SERIES) No 18

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BURNHAM ON CROUCH
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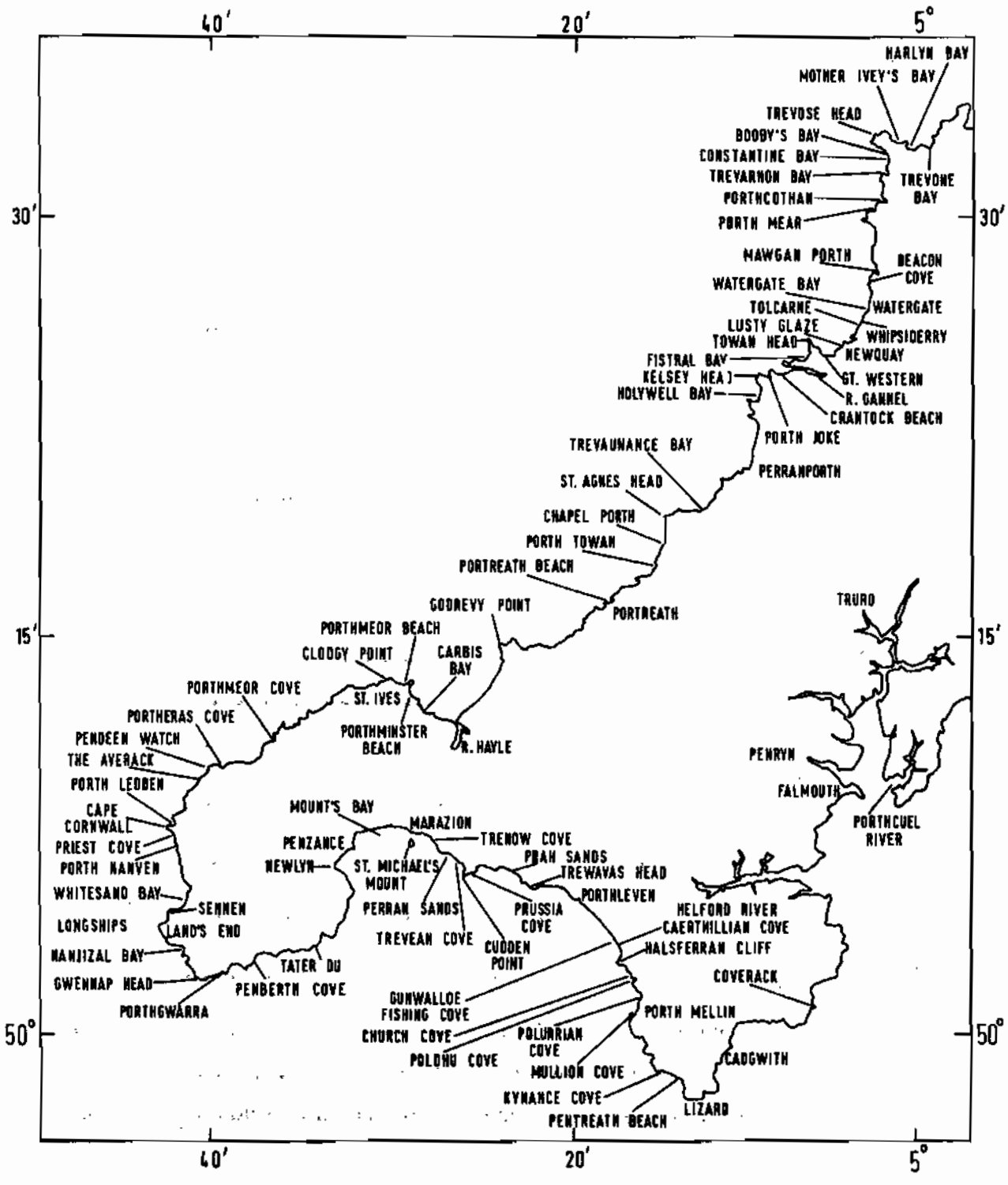
Following the grounding of the "Torrey Canyon" there were fears that fisheries would be affected by the oil and even greater anxiety regarding the possible damage from detergents used at sea and on the beaches. Alarmist reports appeared in the press and controversy raged. In this report Arthur Simpson, in charge of the Fisheries Laboratory, Burnham-on-Crouch, reports on the work done and surveys the damage. It is shown that fisheries have not suffered substantially but in other circumstances heavy damage could have occurred. Further research is urgently needed to increase our effectiveness in dealing with future oil spills.

H. A. Cole
Director of Fishery Research

CONTENTS



Frontispiece: Bays and headlands on the coast of Cornwall referred to in the text and in Table 4.

Laboratory Leaflet (New Series) No. 18

THE TORREY CANYON DISASTER AND FISHERIES

INTRODUCTION

On the morning of 18 March 1967 the tanker "Torrey Canyon", carrying 119 000 tons of crude oil from Kuwait, ran aground on the Seven Stones rocks 16 miles west of Land's End. Some 30 000 tons of oil were released on to the sea at the time of the wreck, and a further 20 000 tons were lost during the next seven days until 26 March when the vessel broke her back, releasing a further 50 000 tons. On 28-30 March the "Torrey Canyon" was bombed and most of the remaining 20 000 tons of oil was destroyed by burning; negligible quantities of oil remained in the tanker after 30 March (Home Office 1967).

As soon as the wreck occurred there was considerable anxiety over the possible harm that might occur to the various fisheries round Cornwall; these include pelagic and demersal fish, coastal shellfisheries, and the important fisheries for oysters in the Fal and Helford estuaries. Members of the fisheries research staff of the Ministry of Agriculture, Fisheries and Food were stationed in Cornwall from 23 March, to investigate the effects of oil and detergents on fish and shellfish, to advise on the protection of the oyster grounds should they be threatened, and to give technical support to the Ministry's District Inspector at Plymouth and the Fishery Officer at Newlyn. The author of the present report was responsible for coordinating the work of the Ministry's scientists in the field and reporting the situation to the Ministry and to the Zuckerman Committee of scientists, of which he and the Director of Fishery Research (Dr. H. A. Cole) were members.

Close liaison was maintained with the Director and staff of the Marine Biological Laboratory, Plymouth, who had initiated a programme of investigation to determine the effects of the oil and detergents on marine life other than the commercial species of fish and shellfish. The results of their investigations are being reported separately.

The following account sets out the background considerations that were taken into account when the M. A. F. F. agreed to the use of the detergents that became the major means of dealing with the oil, and the observations that were made during and after the emergency to follow the effects of the oil and the detergents on fish and shellfish; it also discusses the fisheries aspects of dealing with this and future major oil-spills.

PREVIOUS STUDIES ON THE EFFECTS OF OIL AND OIL-SPILL REMOVERS ON FISHERIES

In 1960 the Warren Spring laboratory of the Department of Scientific and Industrial Research (now Ministry of Technology) at Stevenage began a study of methods for removing oil from beaches and foreshores which had become contaminated as a result of discharges from ships at sea, collisions or accidents, or during the discharging of oil at terminals. These investigations, which covered the use of substances to sink oil, mechanical methods of removing oil from the water surface, mechanical methods to remove tarry residues from beaches, and the use of chemicals to dissolve and emulsify the oil in sea water, are fully reported in two memoranda issued by the Warren Spring laboratory, one in April 1962 (RR/ES/25) and the other in April 1963 (RR/ES/40). In these investigations the solvent/emulsifiers, which could be used on oil on the sea or after it had reached the shore, had proved very successful, and the Fisheries Laboratory at Burnham-on-Crouch (Ministry of Agriculture, Fisheries and Food) undertook the testing of the toxicity of these chemicals to marine life. The testing was done in two ways; the first was devised to simulate the conditions in which solvent/emulsifiers might be used to remove oil from intertidal areas carrying oysters, mussels or cockles, when the chemicals might be applied directly to the shellfish; the second was devised to test the toxicity of the chemicals to shellfish living below low-water mark, which would be bathed in sea water carrying the solvent/emulsifier after a beach or rocks had been treated in the vicinity.

In the first series of tests a variety of solvent/emulsifiers (commercial and experimental) were applied undiluted, and diluted 1:1 and 1:3 with fresh water direct to the shellfish by dipping them for 30 seconds in the solutions. After this the treated shellfish were drained for two hours (as would happen while waiting for the tide to come in), washed clean with sea water and then kept in aerated running sea water for seven days to determine the proportion that had been damaged and failed to recover. The results are shown in Table 1 and it is seen that there were very high mortalities among the cockles and substantial mortalities among the oysters and mussels, though some were able to withstand the chemicals by remaining firmly closed. The winkles became comatose and remained extended from their shells for two-three days before they recovered.

In the second series of tests experiments were done to find out the concentrations of the solvent/emulsifiers in sea water which would cause the death of shellfish if applied for varying periods up to 48 hours. In each test samples of between 20 and 50 animals were subjected to a range of concentrations of the chemicals. The results of some of the early experiments and some done during the emergency are shown in Table 2, where the results are expressed as the concentration of solvent/emulsifier, in parts per million (p.p.m.), required to cause 50 per cent of the sample to die.

It was found that all the chemicals were highly toxic, causing 50 per cent mortality among adult cockles at concentrations of between 10 and 100 p.p.m., and among adult shrimps and shore crabs at concentrations of between 5 and 100 p.p.m. It had also been found in experiments in 1963 that the growth of oyster larvae was reduced at concentrations down to 1 p.p.m.

Table 1 The toxicity of solvent/emulsifiers to shellfish from direct application, such as might happen on intertidal shellfish grounds

The sample sizes were: 25 for oysters, mussels and cockles, and 50 for winkles. The water temperature was 10-12°C. The results are shown as the percentage dead after seven days

Solvent/ emulsifier	% of solvent/ emulsifier in fresh water	Oysters (Ostrea edulis)	Mussels (Mytilus edulis)	Cockles (Cardium edule)	Winkles (Littorina littorea)
Polyclens	25	40	88		4
	50	76	100	no test	10
	100	100	100		10
Houghtosolv 108	25	4	8	80	0
	50	32	4	100	0
	100	88	92	100	12
Slix	25	8	8	96	0
	50	16	44	94	0
	100	52	100	100	20
Gamlen	25	24	16	72	0
	50	16	12	80	0
	100	36	28	96	6
Control		0	0	1	0

The results of this second series of toxicity experiments and others done subsequently and during the "Torrey Canyon" incident are summarized in Table 2. The subsequent experiments showed that the solvent/emulsifier BP 1002, which was the chemical used in the largest quantities on the Cornish coast, was in fact slightly more toxic to some marine life (and particularly crustacea) than the other chemicals that had been available and tested previously. No effective solvent/emulsifier was found to be substantially less toxic than the others.

Table 2 The concentrations, in p.p.m., of various solvent/emulsifiers in sea water required to cause 50 per cent mortality in shellfish exposed for 1, 4, 8, 24 and 48 hours (temperature 15°C)

Solvent/ emulsifier	Test animal	Duration of treatment (hours)				
		1	4	8	24	48
Polyclens	Cockle	10 500	3 000	800	70	70
Gamlen	"	12 000	3 500	890		16
Slix	"				20	
Cleanosol	"					19
Essolvene	"					63
BP 1002	"	3 300	1 800	250		81
Polyclens	Brown shrimp	50	20	12		16
Gamlen	"	90	9	7		9
Cleanosol	"					44
Slix	"					115
Essolvene	"					10
BP 1002	"	32	6	3		6
BP 1002	Lobster	200	60	20		45
Polyclens	Shore crab					18
Gamlen	"					20
Cleanosol	"					102
Essolvene	"					18
BP 1002	"					15

In order to make available to the fishing industry, and to those concerned with the administration of inshore fisheries, information on the effects of oil and oil-spill removers on fish and shellfish, a circular on this subject was issued in 1965 and distributed to the Ministry's Inspectorate, the Sea Fisheries Committees, and certain local authorities in whose areas estuaries were considered most likely to be affected. In this circular, which is given as Appendix I to the present report, it was concluded that solvent/emulsifiers have an important place in cleaning up oil-spills, but that where these occur in the vicinity of commercial shellfish grounds the chemicals should only be used after consultation with the fisheries biologists of the Ministry.

Between 1963 and 1967 there were a number of oil-spills in estuaries round the coasts of England and Wales, and the effects of three of the more serious of these (in Milford Haven, Poole harbour and the Medway), in all of which considerable quantities of detergents were applied, were studied by

scientists from the Burnham-on-Crouch laboratory. The consistent experience was that although intertidal animals and plants were killed in the immediate vicinity of the spraying, and some intertidal winkles that had not been killed were tainted, the harm to animals below low-water mark was negligible, due to the very rapid dilution and dispersal of the chemicals. "Polyclens" was the most frequently used solvent/emulsifier on these occasions.

THE DECISION TO USE SOLVENT/EMULSIFIERS IN THE "TORREY CANYON" INCIDENT

When the "Torrey Canyon" was wrecked on the Seven Stones reef, the Warren Spring laboratory was asked for its advice on how to deal with the oil and recommended the use of solvent/emulsifiers, provided that the M. A. F. F. agreed.

The position was examined and the following facts were taken into account. The fisheries adjacent to the coast of Cornwall are for:-

(a) bottom fish - rays, plaice, sole, etc.;

(b) pelagic fish - mackerel and pilchards;

(c) lobsters: although lobsters are predominantly caught on inshore rocky grounds, during the winter they tend to be in slightly deeper water on this exposed coast;

(d) crabs: adult females are in deeper water during winter; males and immature crabs extend from the rocky shores out to deeper water;

(e) crawfish: usually found below 30 ft, and especially where the run of the tide is strong;

(f) oysters: very important oyster fisheries occur in the Fal and Helford estuaries, but they are absent from other estuaries west of Plymouth.

In view of the immense volume of sea off Cornwall, the great tidal mixing that occurs twice a day, and the frequency of rough seas at this time of year, it was concluded that the rate of dilution and dispersal of chemicals would be so great that even if very large quantities were used the chances of serious damage to commercial fish or shellfish would be very small compared with the advantages to the holiday industry in cleaning the beaches. It was fully appreciated that there would be substantial losses among intertidal animals, and probably some deaths locally of crabs and lobsters, but it was felt that these losses could be accepted in the circumstances.

It was therefore considered that the use of chemicals of the solvent/emulsifier type could be accepted on the sea and open coast where damage to fisheries was likely to be very small, provided that the chemicals were not used in estuaries containing shellfisheries and particularly in the Fal estuaries and the Helford River.

However, in view of the unprecedented scale of the pollution and the possibility of unexpected developments it was important that the situation should be closely watched, and members of the Ministry's fisheries research staff were stationed in Cornwall to observe the effects of the use of the chemicals on fish and shellfish, lest serious damage should occur and it became necessary to limit their use.

THE USE OF CHEMICALS ON THE CORNISH COAST

In the "Torrey Canyon" incident, apart from the oil that was burned (about 20 000 tons) and that which was blown over to the French coast (about 50 000 tons), most of the remainder - some 50 000 tons - was dealt with by the use of solvent/emulsifiers on the open sea or after it had reached the shores of Cornwall. It has been estimated that the quantity of oil that came ashore on the Cornish coast was probably about 20 000 tons.

Spraying at sea from large ships started on the day after the wreck occurred and was continued by naval and fishing vessels until 4 April, by which time most of the oil was ashore. Some 500 000 gallons of chemicals* were applied from these boats, during the seventeen days from 19 March to 4 April inclusive. Over 90 per cent of the spraying at sea was done round the wreck and to the east of it, in an area of sea measuring some 35 miles from east to west and some 15 miles from north to south, as shown in Figure 1. A small amount of spraying also extended to the north of the Seven Stones, and to the east of the Lizard, as oil slicks were carried in these directions. Table 3 and Figure 2 show the quantities issued to the boats daily from the bases at Falmouth and Newlyn.

Oil started to come ashore on Easter Saturday, 25 March, and by 30 March most of it was held by westerly winds in the many inaccessible coves along the rocky coastline from St. Ives round Land's End to Gwennap Head, or had been blown across Mount's Bay to come ashore at a number of points between Marazion and the Lizard. Subsequently much of the oil which had been trapped between St. Ives and Land's End was blown and drifted out of the rocky coves, and was spread north-eastwards along the north Cornish coast as far as Trevose Head or brought south to contaminate again the beaches on the eastern side of Mount's Bay.

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*47.0 per cent, BP 1002; 34.4 per cent, Dasic; 8.3 per cent, Gamlen; 10.3 per cent, others.

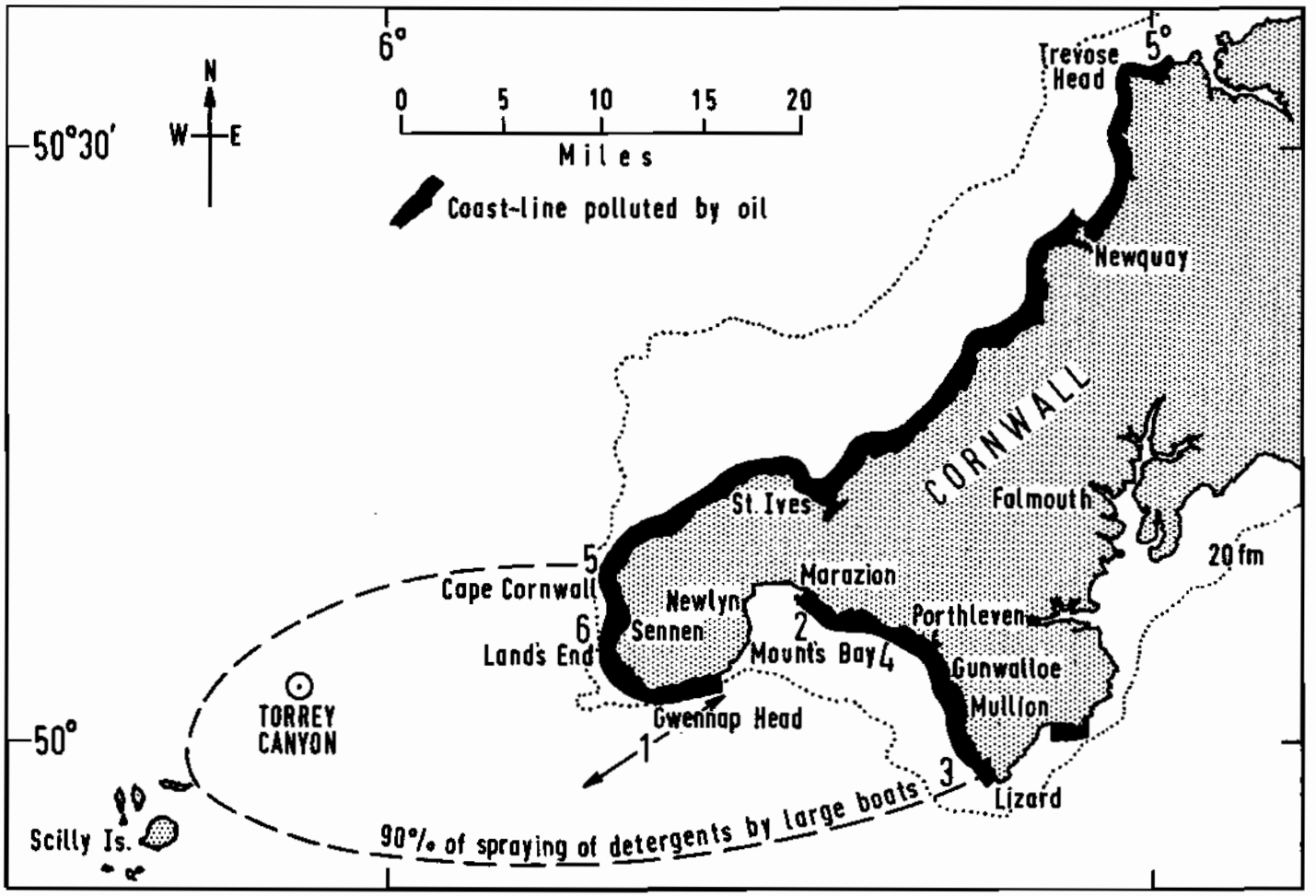

Figure 1 Map showing the position of the wreck of "Torrey Canyon", the area in which most of the spraying of detergents from large boats took place and the extent of the coast of Cornwall that was polluted by oil. The numbers 1-6 show the areas in which trawling was done, 31 March-3 April.

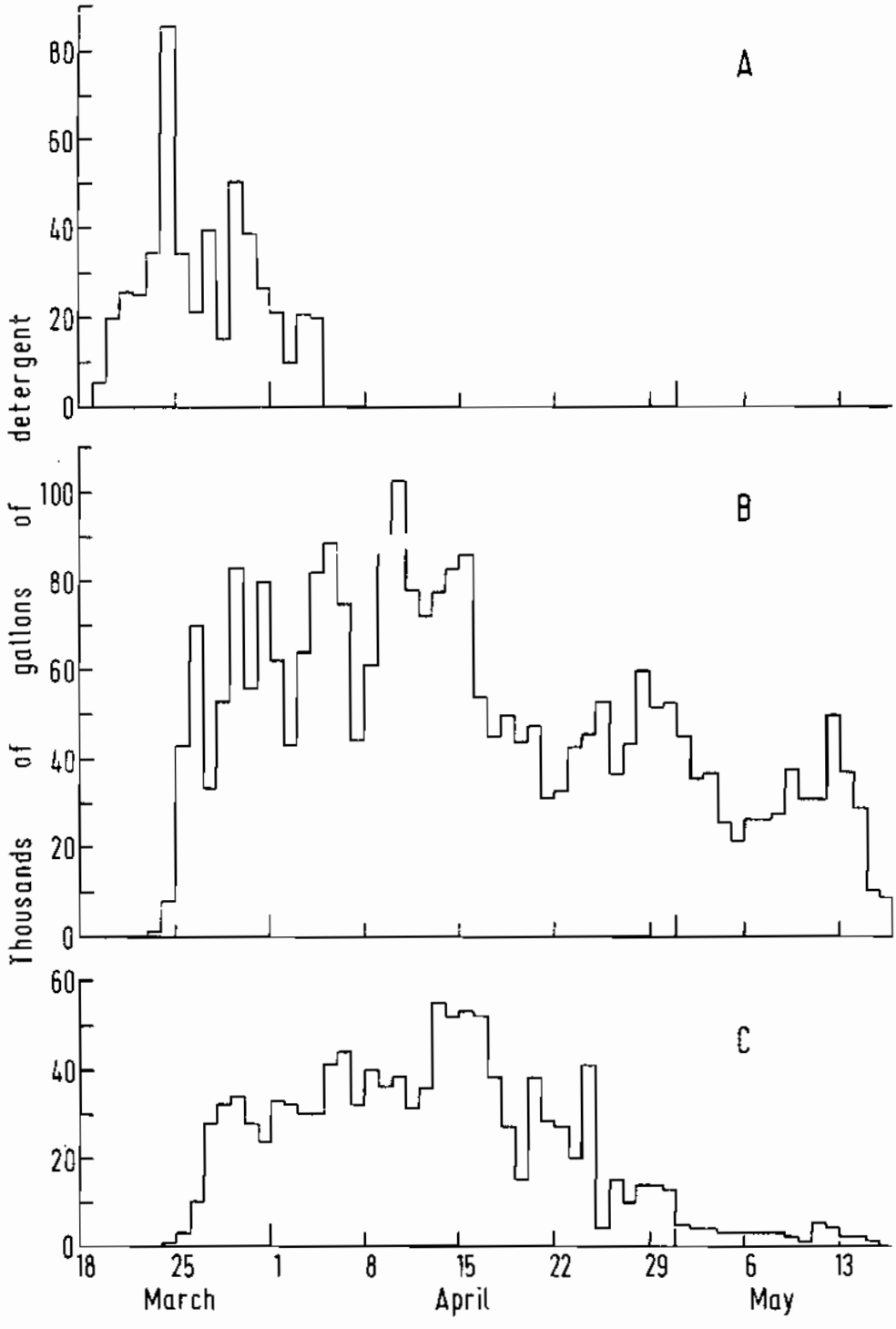

Figure 2 Quantities of detergents, in thousands of gallons, (a) issued daily to large boats and applied by them at sea; (b) issued daily for use from the shore or from small boats; and (c) used daily by local authorities.

Detergents* were supplied to the Army and the local authorities, who used them along the coastline according to the weather and the distribution of the oil, from 25 March to about mid May, though small quantities continued to be used into June. In these operations some 2 million gallons of detergents were used, mostly from the beaches but also to a limited extent from small fishing boats working just offshore.

Information on the exact quantities used each day on each area is not available, but Table 4 shows the quantities of detergents issued to each beach each day through the local authorities. (We are most grateful to them for supplying this information.) Although these figures are correct in giving the quantities used on the different beaches it is not certain whether all the chemicals issued on one day to a beach were used on precisely that day; it is probable that from time to time a number of barrels were held over for a day or two.

There is unfortunately no record of the quantities of detergents used by the Army, but service personnel applied large quantities at Porthleven, Gunwalloe Fishing Cove, around Mullion and at many points along the rocky coastline from Land's End to Hayle. In many areas the Army applied the detergents with care and according to instructions, but in others it was poured on to the rocks and sea in a way which was not only ineffective in emulsifying the oil but also caused avoidable damage to marine life.

Spraying at sea and ashore was done only in daylight, and ashore it was done very largely during the rising tide, to permit the incoming water to emulsify the treated oil and to carry it away. Thus, typically, the shore-based spraying was done on alternate tides, the night tide having the effect of dispersing the oil and detergent before the next application was made. In stormy weather spraying was stopped on the more exposed sites.

Some eight makes of solvent/emulsifier were used from the shores, and these included the following: BP 1002, Dasic, Gamlen, Dutch, Atlas, Petrofina, Basol and Gramos. It is not known what quantities of each were used in each area or in total, but it is believed that BP 1002 comprised more than 50 per cent of the total. It was substantially the cheapest and one of the most effective of those used, though it was at least as toxic to marine life as the others.

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*Footnote: The term "detergent" was very widely used during the incident and is used for convenience in the rest of this report. However, the solvent/emulsifiers used to disperse oil are chemically very different from domestic detergents.

Table 3 Quantities of solvent/emulsifiers (thousands of gallons) used during the "Torrey Canyon" incident

Date		Issued and used on large boats at sea		Issued from naval air bases for use from shore and small boats				Used by local authorities on beaches*
		Falmouth	Newlyn	Culdrose	Penhale	Carnkie	St. Eval	All areas
March	19	5.5						
	20	20.0						
	21	26.0						
	22	25.5						
	23	34.8		1.0				
	24	62.5	24.1	8.0				0.5
	25	4.9	29.4	43.0				3.3
	26	7.6	13.9	25.0	45.0			10.0
	27	23.5	16.7	23.0	10.3			28.3
	28	6.9	8.6	38.0	15.5			32.1
	29	38.0	12.8	60.0	23.2			34.0
	30	17.9	21.8	35.0	21.2			28.0
	31	12.5	14.6	40.0	40.3			24.0
April	1	0	21.5	43.0	19.1			33.0
	2	0.7	9.3	42.0	0.9			32.0
	3	9.4	12.2	44.0	10.1			30.0
	4	7.7	12.8	48.0	34.0			30.3
	5			55.0	34.0			41.1
	6			52.0	23.0			44.3
	7			30.0	14.5			32.0
	8			38.9	22.1			40.0
	9			55.8	32.9			36.0
	10			73.4	29.3			38.1
	11			41.6	36.5			31.4
	12			48.4	23.2			36.2
	13			51.1	27.0			55.0
	14			48.0	34.7			52.0
	15			13.5	72.9			53.0
	16			22.4	31.5			52.4
	17			30.6	14.4			38.0
	18			36.5	13.5			27.0
	19				13.5	30.8		15.0
	20				10.8	37.2		38.1
	21				9.0	21.9		28.0
	22				15.3	17.6		27.0
	23				13.5	29.3		20.0
	24					29.8	16.0	41.0
	25					40.9	12.2	4.0
	26					24.3	12.8	15.0
	27					40.5	3.6	10.0
	28					40.8	19.6	14.0
	29					43.0	8.8	14.0
	30					40.5	12.4	13.1

Table 3 continued

Date		Issued and used on large boats at sea		Issued from naval air bases for use from shore and small boats				Used by local authorities on beaches*
		Falmouth	Newlyn	Culdrose	Penhale	Carnkie	St. Eval	All areas
May	1					34.6	10.6	5.2
	2					35.8	0	4.0
	3					30.1	6.8	4.2
	4					26.2	0	3.0
	5					21.6	0	3.0
	6					26.6	0	3.0
	7					27.5	0	3.0
	8					21.2	6.8	3.4
	9					38.1		2.1
	10					31.1		1.0
	11					31.2		5.0
	12					50.2		4.0
	13					36.6		2.2
	14					28.8		2.2
	15					10.0		1.0
	16					8.6		0
	17					0		0
	18					0.5		0
	19					0		1.0
	20					0		0
	21					0		0
	22					0.5		0
	23					0		0
	24					2.3		0
	25					4.5		0
	26					0.5		0
	27					0		2.0
	28					0		
	29					0		
	30					0		
	31					5.0		
Totals		303.4	197.7	1 047.2	691.2	868.1	109.6	1 150.8
		501.1		2 716.1				

*full details available.

Table 4 Quantities of solvent/emulsifiers (thousands of gallons) used by local authorities each week between Trevose Head and Lizard Point

	March/April						May/June					
	20-26	27-2	3-9	10-16	17-23	24-30	1-7	8-14	15-21	22-28	29-4	5-11
Trevone Bay, Harlyn Bay and Mother Ivey's Bay	0	0	11.0	20.4	9.4	0	0	0	0	0	0	0
TREVOSE HEAD												
Booby's Bay, Constantine Bay and Treyarnon Bay	0	12.0	6.2	14.2	6.1	0	0	0	0	0	0	0
Treyarnon Bay only	0	5.0	1.3	0	0	0	0	0	0	0	0	0
Porthcothan	0	2.0	3.0	8.2	2.0	0	0.9	0	0	0	0	0
Mawgan Porth	0	1.2	9.4	14.0	0.6	5.0	0	0	0	0	0	0
Beacon Cove	0	0	0	8.0	4.0	0	0	0	0	0	0	0
Watergate Bay	0	5.0	3.1	13.0	13.0	27.0	6.3	8.0	0.4	1.2	0	0
Whipsiderry, Tolcarne and Great Western	0	2.2	2.2	10.2	0.5	0	0	0	0	0.1	0	0
Porth and Lusty Glaze	0	7.0	2.0	10.0	9.0	14.4	4.1	2.0	0.2	0.1	0	0
Fistral	0	5.0	2.0	12.0	12.1	23.0	9.0	4.0	0.2	0.2	0	0
River Gannel and Crantock	0	5.0	0.5	0	8.0	7.0	0	0	0	0	0	0
Porth Joke	0	0	1.0	8.0	0.5	7.1	2.0	2.0	0.2	0	0	0
KELSEY HEAD												
Holywell Bay	0	0	0	0	0	8.0	1.1	0	0	0	0	0
Perranporth	0	0	0	0	0	5.1	0.4	0	0	0	0	0
ST. AGNES HEAD												
Chapel Porth	0	0	0	0	0	3.0	0	0	0	0	0	0
Porth Towan	0	0	0	0	0	10.2	2.0	0	0	0	0	0
Portreath Beach	0	1.0	3.1	5.3	1.2	0.9	0	0.3	0.1	0	0	0.3
Carbis Bay	0	0	0	0	1.1	0	0	0	0	0	0	0
St. Ives	0	2.3	10.0	0	0	0	0	0	0	0	0	0
Porthgwidden Beach and Porthmeor Beach	0	33.3	0	0	0	0	0	0	0	0	0	0

Table 4 continued

	March/April						May/June					
	20-26	27-2	3-9	10-16	17-23	24-30	1-7	8-14	15-21	22-28	29-4	5-11
CLODGY POINT												
Porthmeor Cove	0	0	17.0	0	0	0	0	0	0	0	0	0
Portheras Cove	0	0	0	39.0	9.0	0	0	0	0	0	0	0
Pendeen Watch and The Averack	0	0	0	5.0	3.0	0	0	0	0	0	0	0
Porth Ledden	0	0	0	30.0	0	0	0	0	0	0	0	0
Cape Cornwall, Priest Cove and Porth Nanven	0	0	10.0	53.0	37.2	0	0	0	0	0	0	0
Whitesand Bay and Sennen	0	46.0	83.0	19.2	18.2	0	0	0	0	0	0	0
LAND'S END												
Nanjizal Bay	0	0	20.0	0	0	0	0	0	0	0	0	0
Porthgwarra	0	0	5.0	0	0	0	0	0	0	0	0	0
PENZANCE												
Marazion, Trenow Cove, Perran Sands, Trevean Cove, Cudden Point and Prussia Cove	0	42.0	20.0	5.0	24.0	0	0	0	0	0	0	0
Prah Sands	8.0	4.0	0	0	0	0	0	0	0	0	0	0
TREWAVAS HEAD												
Porthleven Harbour	4.0	21.0	18.0	3.0	2.0	0	0	0	0	0	0	0
Porthleven Beach	0	0	0	2.5	0	0	0	4.1	0	0	0	0
Gunwalloe Fishing Cove	0	15.0	7.0	0	0	0	0	0	0	0	0	0
Caerthillian Cove and Halsferran Cliff	0	0	8.0	27.4	8.0	0	0	0	0	0	0	0
Gunwalloe Church Cove and Poldhu Cove	1.4	2.0	10.3	5.0	3.0	0	0	0	0	0	0	0
Polurrian Cove	0.5	0.9	1.0	0	0.7	0	0	0	0	0	0	0
Mullion Cove	0	0.9	0	0	11.0	0	0	0	0	0	0	0
Kynance Cove	0	0	0	2.9	0	0	0	0	0	0	0	0
Pentreath Beach	0	0	0	0.9	0	0	0	0	0	0	0	0
Polpeor	0	0.2	0.2	2.0	5.0	0	0	0	0	0	0	0
THE LIZARD												
Totals	14.0	213.0	254.3	318.2	188.6	110.7	25.8	20.4	1.1	1.6	0	0.3

EFFECTS ON FISH AND SHELLFISH

(a) Trawled fish and mackerel

Oil on the sea is known to have negligible effects on marine life below the surface, and it was anticipated that in this incident the rapid dilution, the evaporation of the lighter fractions, and the dispersion of the chemicals and emulsified oil on the open sea would safeguard the fish from the harmful effects of the detergents. However, nothing could be left to chance, and in order to check the position a Newlyn trawler (M.V. "Pioneer") was chartered to catch fish in the areas in which spraying had been and was still taking place. Fishing was done on 31 March and 1, 3 and 4 April, by which time the spraying at sea was almost at an end. Trawl hauls were made in the following areas, which are shown on Figure 1:-

1. south of Tater-du to east of Wolf Rock
2. inside Mount's Bay and close against St. Michael's Mount
3. west of Lizard Point
4. close to the beach off Prah Sands in 5 fathoms
5. near Pendeen
6. adjacent to the Longships Lighthouse off Land's End.

The fishing thus covered the main grounds that had received considerable quantities of detergents.

The following observations are those of the scientist aboard (A. R. Margetts) and of the skipper, who was a local full-time fisherman. The fish species caught included:-

Plaice, Pleuronectes platessa L.
Dab, Limanda limanda (L.)
Lemon sole, Microstomus kitt (Walbaum)
Sole, Solea solea (L.)
Brill, Scophthalmus rhombus (L.)
Megrim, Lepidorhombus whiffiagonis (Walbaum)
Cod, Gadus morhua L.
Whiting, Merlangius merlangus (L.)
Haddock, Melanogrammus aeglefinus (L.)
Pollack, Pollachius pollachius (L.)
Saithe, Pollachius virens (L.)
Pout, Trisopterus luscus (L.)
Hake, Merluccius merluccius (L.)
Horse mackerel, Trachurus trachurus L.
Gurnard, Trigla sp.
Red mullet, Mullus surmuletus (L.)
Herring, Clupea harengus L.

Sprat, Sprattus sprattus (L.)
Pilchard, Sardina pilchardus (Walbaum)
Angler, Lophius piscatorius L.
Bream, Pagellus centrodontus (De la Roche)
Blonde ray, Raja brachyura Lafont
Nurse hound, Scyliorhinus stellaris (L.)

The fish were mostly feeding heavily on the available preferred food. All fish were alive and the only unhealthy fish was a very thin megrim with an abnormal gut. The overall impression was one of normality in the type of fish, and in their distribution, quantities and quality. Catches were closely examined and observations made as to liveliness, appearance, odour, gill condition, liver and gut condition, and gut content. Good catches of mixed fish were taken between Tater-du and Wolf Rock, a fine catch of plaice was made to the north-east of Pendeen ($\frac{1}{2}$-1 mile offshore), and a good catch of rays was taken at Longships.

Some of the tows were made close to or among ships spraying detergent and some were near or among broken-up oil patches, but no fish caught carried any signs or odour of oil or detergent. There were no signs of dead fish or other sea animals floating on the surface. Sea birds were seen feeding from shoals of fish swimming near the surface, and many demersal fish were feeding on sand eels and sprats, some of which were taken alive in the trawl.

About 30 stones of unselected fish were landed in the normal manner on Newlyn market on 1 April, and further landings of fish in perfect condition were made on 4 and 5 April and bought by merchants who paid top prices for them.

Following the first two days' fishing the local inshore trawl fishery recommenced and the catches were reported to be at normal levels. The local mackerel fishery started at the same time in the same area, with normal catches. The fisheries for bottom fish and the hand-line fisheries for mackerel and whiting continued and developed normally for this time of year without any reports of dead or damaged fish being seen, in spite of requests for such information. A leaflet (Appendix II) was widely distributed in the following days, to let the fishermen know the current situation and to ask for information on affected fish.

The mackerel fishery in April and May proved to be normal if not above average. This fishery includes fishing with feathers close inshore, and on many occasions a number of boats were fishing so close off St. Ives that they were on the edge of the water which was discoloured by the detergents. No adverse effects to the mackerel have been reported.

In the absence of any observations to the contrary from fishermen or scientists it would appear correct to conclude that there was no direct harm to the fisheries, or so little harm that it was undetectable. Whether there will be any harm to fisheries through destruction of food or of eggs and young stages

cannot be established for several years to come, and, unless substantial, will be inseparable from the normal annual fluctuations in abundance and availability due to changes in environmental conditions and strength of year-classes.

Along the beaches, where detergents were applied in large quantities to oil on the sand, thousands of sand eels remaining in the sand of the beaches must have been killed. Also some conger eels and small plaice, dabs, flounder and mullet were washed up dead or seen dead by divers in the gulleys adjacent to where spraying was being done, but the total numbers of dead seen were to be counted in tens rather than hundreds and probably constituted only a very small proportion of the inshore population at the time.

(b) Shellfish

In order to keep a close watch on the effects on marine life of the chemicals being increasingly applied to the beaches the M. A. F. F. stationed one of their fishery research staff (B. T. Hepper) at Penzance from 28 March-13 April, 21-26 April and 8-18 May, to make regular and frequent visits to the affected areas and to investigate and report on dead fish, shellfish and other marine life. Another member of the research staff (B. Howell), who was familiar with oyster cultivation, was stationed at Truro from 23 March-8 April to advise the oyster industry and others if the oil should enter the oyster-producing estuaries round the Helford, Fal and Porthcuel Rivers, and also to support Mr. Hepper in observations elsewhere. These scientists supplemented the information obtained by the Ministry's Fishery Officer (G. H. Buchanan-Wollaston), who is permanently stationed at Newlyn and is in daily contact with the inshore fishermen.

In addition a group of experienced biologist aqua-lung divers*, who offered their assistance early in the emergency, visited heavily sprayed areas and reported on the condition of the marine life below low tide level. These observations by divers were made during the period 2-8 April and were supplemented by further underwater observations made during the period 9-15 May by the M. A. F. F. divers from the Fisheries Laboratory, Lowestoft (B. H. Holford, M. R. Vince and M. E. Hurst).

The observations made by these people with special reference to inshore fish and shellfish are presented together in chronological order below. Observations on non-commercial species are mentioned only briefly here, as these

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Dr. M. Thurston - British Museum of Natural History.
Mr. G. Harwood - Kodak Limited, Harrow.
Mr. M. R. Vince - M. A. F. F., Lowestoft.

are covered in reports made by the Marine Biological Laboratory at Plymouth, by Drew et al. (1967) and by others (see references).

28-31 March: By the evening of 28 March spraying of oil had been going on for up to four days at several points between Marazion and Gunwalloe on the south coast, and particularly at Porthleven which had received a great deal of oil and was being treated with some 10 000 gallons of detergent per day. By this time some 150 000 gallons of detergents had been applied on the beaches along this stretch of coast, in addition to some 450 000 gallons applied at sea, largely between the wreck and this part of the coast. On the north coast spraying started ashore on 29 March around St. Ives.

In Porthleven harbour, although lugworm, ragworm, sand eels, shore crabs and one conger eel were found dead, many limpets, mussels and shore crabs were still alive. Elsewhere, beaches and rocky areas receiving treatment were examined, but only a few mussels which had received direct spraying were found to have been killed; other intertidal animals appeared to have suffered little harm.

1-10 April: During this period visits were made almost every day to Porthleven and Sennen, at each of which the application of detergents was continuing at a level of some 10 000 gallons a day. Visits were also paid to Porthgwarra, Penberth, Marazion, Prah Sands, Gunwalloe Fishing Cove, Gunwalloe Church Cove, Poldhu Cove and Mullion on the south coast, and Sennen, Cape Cornwall, Pendeen, St. Ives, Hayle, Portreath, Perranporth and Newquay on the north coast.

There were at this time several reports of considerable numbers of dead mackerel, ling and plaice of commercial size being washed ashore, but on visiting the areas concerned exhaustive enquiries showed the rumours to be false. The only authentic records were of one whiting, one mullet (9 inches), one plaice (5 inches), one flounder (5 inches), and two conger eels being washed ashore at Sennen, and three conger eels dead in Porthleven harbour.

A number of dead edible crabs up to commercial size were seen and reported from Gunwalloe Fishing Cove near Mullion, and two lobsters of about 7 inches overall length from the same area. Intertidal mussels had been widely killed, but none of these were of commercial quality, due to the high tidal levels at which they were living.

The detergents had however been killing large numbers of non-commercial species of fish, molluscs and crustacea living in the sand of the beaches, on the intertidal rocks and in the intertidal pools. No attempt was made to make a complete inventory of these species, but dead specimens of the following were recorded:-

Sand eel, Ammodytes spp.
Blenny, Pholis sp.
Rockling, Onos spp.
Topknot, Zeugopterus sp.
Limpet, Patella vulgata
Starfish, Marthasterias sp.
Shore crab, Carcinus maenas
Swimming crab, Portunus sp.
Prawn, Palaemon serratus

The observations from the land indicated that commercial species were not being affected to any extent, and it was to be expected that if there had been heavy losses below low tide level substantial numbers would have been washed ashore, as did happen when lobsters on the north-east coast of England were killed during the 1962/63 cold winter. However, underwater observations by skin divers were made during 2-8 April to examine the situation below low tide level.

At Porthleven dives were made on a line running out to sea, starting at a point 350 feet from the harbour entrance and extending to 2 000 feet from it. At 350 feet and in 6 feet of water sluggish and dead edible crabs were seen, but beyond this, at depths of 12-18 feet, 36, 38 and 40 feet and at distances up to 2 000 feet offshore, all crabs seen were healthy though their numbers were not as great as had been expected. A single large dead lobster was seen at about 12 feet below low water and 400 feet from the shore. The few fish that were seen (plaice, blenny) were all alive.

At Mullion Cove during diving on 6 April, live crabs were seen at the mouth of the harbour, and the fauna just below the low tide mark generally appeared healthy.

At Sennen observations were made in water of 20-35 feet depth from just west of the harbour to about 1 400 feet offshore in a north-westerly direction - away from the Whitesand beach. There was some damage to the more delicate seaweeds down to about 28 feet. There were few living animals to be seen, but some dead sea-urchins, starfish and swimming crabs were found at the bottom of the gulleys, although it was considered that these had fallen or been carried to these positions from nearer the surface. No dead edible crabs, lobsters or fish were seen.

Many of the observations by the team of divers were on non-commercial species and on algae, and these observations have been reported elsewhere (Drew et al. 1967).

On 6-8 April Mr. A. J. O'Sullivan and Miss Alison J. Richardson visited Sennen Cove and Porthgwarra and reported similar findings to those of Mr. Hepper, in that many intertidal animals were killed and some small dead specimens of commercial fish (dab, flounder) were to be found at Sennen, and that some dead crabs were present at both Sennen and Porthgwarra (O'Sullivan

and Richardson 1967). Considerable numbers of dead elvers were found on Hayle beach by the River Authority and also at Porth Mear, near Porthcothan.

Both types of observations (beach and diving) thus indicated that there had been some losses among crabs, and probably to a lesser extent among lobsters, in the immediate vicinity of the heaviest spraying, and there was some indication that fish and crustacea had moved away from close inshore.

In order to test further the possible harmful effects of the detergent on lobsters and crabs, experiments with live lobsters were made at Porthleven and Sennen. At Porthleven, on 3 April, one lobster and three crabs (all with tied claws) were put in each of three lobster pots which had their entrances closed and were placed at approximately 400, 800 and 1 200 yards from the harbour entrance, in depths of 15, 30 and 40 feet respectively. Visible discolouration of the sea water by detergents was seen close to the nearest pot. On 4 April the pot at 1 200 yards was lifted and repositioned at 200 yards from the harbour entrance, in 15 feet depth, the lobsters and crabs being active. The pots were examined on 5 and 7 April, and all were brought ashore on 10 April. All the lobsters and crabs were alive and active on each occasion, being apparently quite unharmed.

The experiment at Sennen was started on 4 April, with one pot at 400 yards (12 feet depth) and two pots at 880 yards (30–40 feet depth) from the shore, 400 yards apart; each contained two lobsters and three crabs. On 5 April one of the offshore pots, in which the lobsters and crabs were normally active, was moved to 200 yards (10 feet depth) from the shore. When the three pots were examined on 7 April the lobsters in the pots at 200 yards and 400 yards appeared a little sluggish compared with those at 880 yards. On 10 April, when the experiment was concluded, the lobsters from the two more inshore pots again appeared somewhat weak, whereas those in the deeper more offshore position were normally active. There had been a considerable swell during this experiment and it is possible that the poorer condition of the lobsters in the shallower water had been aggravated by the pots being moved about by the swell.

The depths given are in all cases approximately those at low water springs; the tidal range is approximately 8 feet at neaps, and 16 feet at springs.

During April the lobster fishermen of Cornwall usually start their season, and fishermen who had just put their pots into the sea for the first time at Newquay brought them ashore and were employed for a time on the spraying of detergents. At Sennen the start of lobster fishing was delayed because the large quantities of oil in this area would have fouled boats and gear. Fishing started at Cadgwith and Coverack, just east of Lizard Point, on 4 April and the lobsters caught were all healthy. The catches were relatively small, as is usual at the

start of the season. As a result of the experiments described above lobster fishermen were advised not to put their "store pots" in shallow water close to areas where there was much spraying, as was practised at Sennen, but to keep them in deeper water away from the spraying.

On 8 April an experiment was done to determine the levels of detergent in the sea where large quantities were being used. During the diving off Porthleven samples of water for detergent analysis were taken at the surface, one meter below the surface, at half depth and just above the bottom, at 120 yards, 300 yards and 600 yards seaward from low-water mark, 200 yards south-east of Porthleven harbour. The analyses were done by the laboratory of the Government Chemist according to the method of Patterson (1966) in which the emulsifying fraction, about 20 per cent of the detergent, is determined. The results are shown in Table 5 below.

Table 5 The concentrations (p. p. m.) of non-ionic emulsifying agent in the sea off Porthleven on 8 April 1967, 120 yards, 300 yards and 600 yards from low-water mark, in depths of 30 feet, 40-45 feet and 60 feet respectively. The samples were taken during the rising tide

Depth of sample	Position of sample, depth, and type of bottom		
	120 yd, 30 ft sand	300 yd, 40-45 ft rock	600 yd, 60 ft sand, stones
Surface	0.05	0.06	0.05
1 m below surface	0.03	0.05	0.04
$\frac{1}{2}$ depth	0.03	0.03	0.03
bottom	0.02	0.02	0.01

To obtain the concentrations in terms of the original detergents before dilution, it would be necessary to multiply each figure by five; but, as the solvent is more volatile and less persistent than the emulsifier, though more toxic, the calculation would probably give an overestimate of the concentration remaining. The values given in Table 5 do however suggest that at the time of sampling - during the rising tide, when spraying was in progress and during relatively calm weather - the dilution following the spraying on the previous day had resulted in a fairly even distribution of the chemicals out to at least 600 yards offshore, with a tendency for the concentrations at the bottom to be a half to a fifth of those at the surface. However the numbers of observations are too few, and apply only to one area under the weather conditions of the period, and so do not permit generalization.

Another set of water samples for analysis was taken on the same day and tide at Sennen in mid channel between the harbour and the Cowloe Rocks in 35 feet of water, about 100 yards from low-water mark, just west of the breakwater. The concentrations of the non-ionic emulsifier were:-

Surface	0.15 p.p.m.
3 ft	0.15 p.p.m.
bottom (35 ft)	0.08 p.p.m.

The values here were three to four times higher than at Porthleven, but again showed rather lower concentration near the bottom.

22-24 April: Mr. Hepper re-visited the beaches during this period when spraying was continuing very actively - especially at Sennen and Porthmeor - and had started at Newquay. He reported that at Sennen there were no increased findings of dead fish, and good catches of sand eels had been made for bait during a short break in the spraying along Whitesand Beach. At Porthleven, Gunwalloe and Mullion spraying was continuing but no dead fish were seen, and reports from local people indicated only occasional dead fish or crabs being washed up.

Crab and lobster fishing was now starting at most ports and normal yields for the time of year were reported from Trevose Head, though poor catches were reported from Newquay. Merchants buying lobsters and crabs reported that landings of both were generally good for the time of year.

7-17 May: By the second week in May about a million gallons of detergents had been applied along the west and north coast of Cornwall and they were still being applied in considerable quantities in mopping-up operations (see Table 4). Although most of the detergents at this time were being applied to the beaches and those rocky areas where visitors and local people bathed, there was a good deal of anxiety among the fishing and conservation interests, because it was felt that in several areas, such as between Sennen and St. Ives, the chemicals were now being used unnecessarily. A further examination of losses along the beaches and below low-water mark was therefore undertaken by divers. Observations along the beaches and rocky coast showed little change for the worse and in some areas they showed some improvement. Where spraying had been continuing there were few or no animals left at the higher intertidal levels, but towards low-tide level and at quite short distances on each side of the sprayed areas live animals were present. In such areas as Trevaunance Bay, where no detergents had been used, there was no evidence of harm to marine life at any level, although this bay was separated from a heavily treated bay by only a short rocky promontory and a distance of a few hundred yards. Also, where spraying had stopped a new diatom flora had become established and green seaweeds were again showing active growth. Very occasional dead small fish were seen on the beaches.

During this period the M. A. F. F. divers examined a number of areas between Newquay on the north coast and Mullion on the south coast, and the following details are from a report prepared by B. H. Holford who led the team.

Working down to about 25 feet off Old Dane Rock in Newquay Bay on 13 May the fauna was found to be sparse; hermit crabs and plaice were seen alive, but dead Echinocardium and razor shells were found. There had definitely been considerable mortality in this bay and off Fistral Sand, where intense spraying had continued for a long time.

While attempting to retrieve a lost anchor for a local fisherman, the divers encountered oil as a brown viscous layer 2-3 inches thick, 6-7 inches below a layer of clean sand. This occurred in 25 feet of water off Newquay harbour. A sample of the oily sand was brought ashore and it was later noticed that the oil had separated from the sand.

At St. Ives on 12 May dives were made off Porthmeor Beach, the area where the most concentrated detergent spraying had been done, and where the water in the bay was still discoloured from recent spraying. Towards Clodgy Point on a sandy bottom live fish but no dead animals were seen, and towards the east end of the bay, in about 50 feet of water, rocks were well populated with live anemones, spider crabs, starfish, hermit crabs, and some fish; no dead animals were seen. No diving was possible close inshore, due to a heavy swell.

At Sennen, towards Whitesand Bay, where spraying was continuing, dead sea-urchins were common and the effects of spraying were more apparent than elsewhere; therefore an attempt was made to determine how far along the coast to the west the effects of the spraying could be found. Four dives were made directly north and to the west of the breakwater at Sennen, covering an area some 600 yards out from low-tide mark and 800 yards along the coast and centred on the Cowloe reef. The positions of these four dives are marked as A, B, C and D on Figure 3.

Dive A, 11 May, ground covered 300 yards, depth 30-45 feet: The bottom consisted of very large boulders and rocky outcrops, all covered with Laminaria. A few wrasse and anemones and one spider crab were seen alive but the general picture was one devoid of much life, with many dead and dying sea-urchins (broken remains and discoloured shells with spines dropping off).

Dive B, 15 May, ground covered 170 yards, depth 65 feet at south end rising to 20 feet at north: At the deep southern end there were large boulders covered with Laminaria and red weeds; here wrasse, starfish, urchins, anemones and spider crabs were all seen alive, but near the shallow northern end three dead edible crabs and a few dead sea-urchins were found.

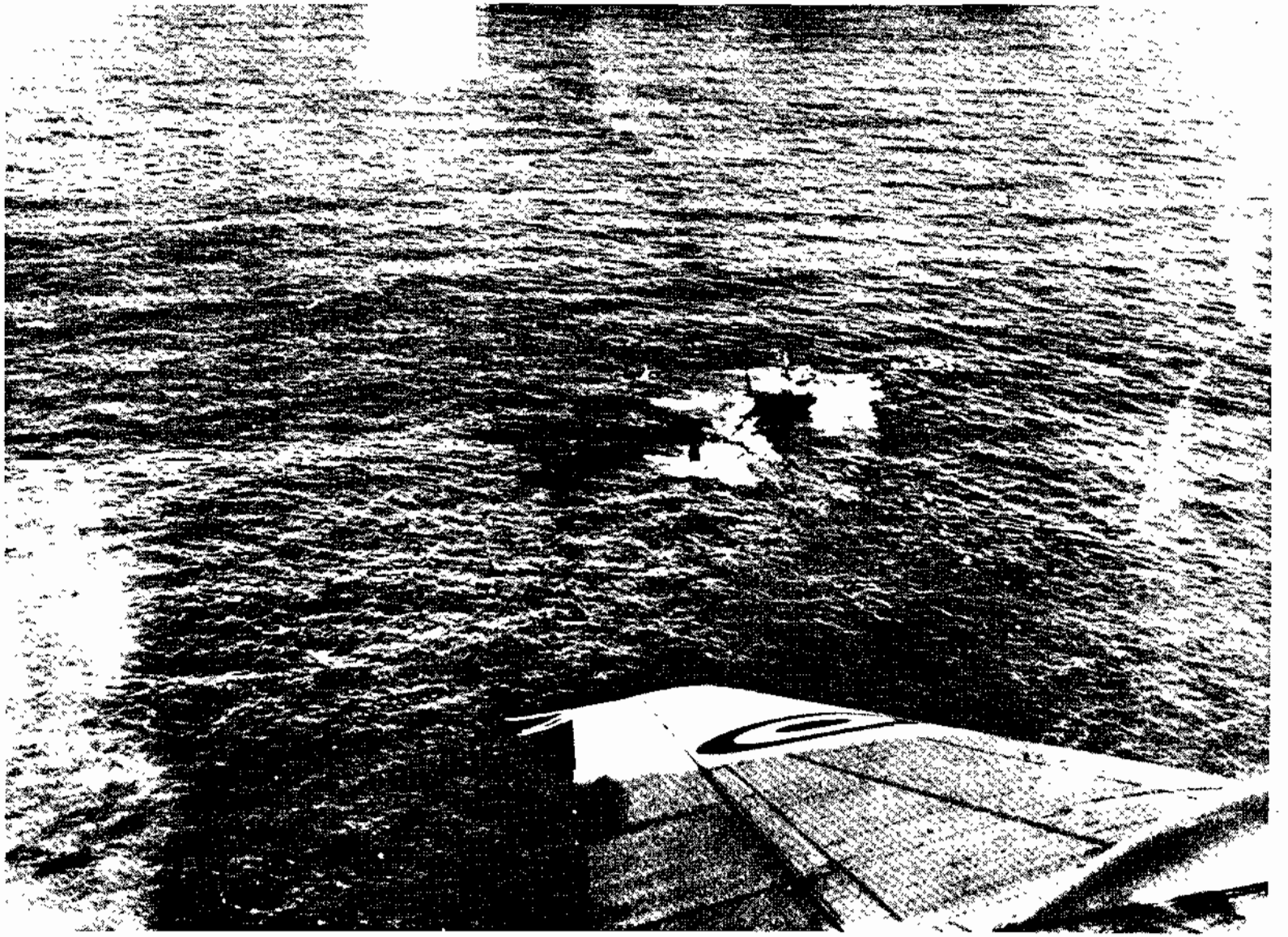

Plate 1 The wreck of the "Torrey Canyon" on 5 April 1967, the day before the remaining tanks were destroyed by bombing. Dark patches of oil are seen drifting from the wreck. The reflection which appears in the photograph is of the interior of the aircraft.

Plate 2 The Sennen Cove end of Whitesand Bay on 5 April 1967, showing extensive oil contamination of the stony foreshore and the sandy beach.

Plate 3 Gunwalloe Fishing Cove, looking towards Porthleven, showing heavy contamination of the beach by oil, and service personnel preparing to treat the oil with detergents as the tide rises, on 5 April 1967.

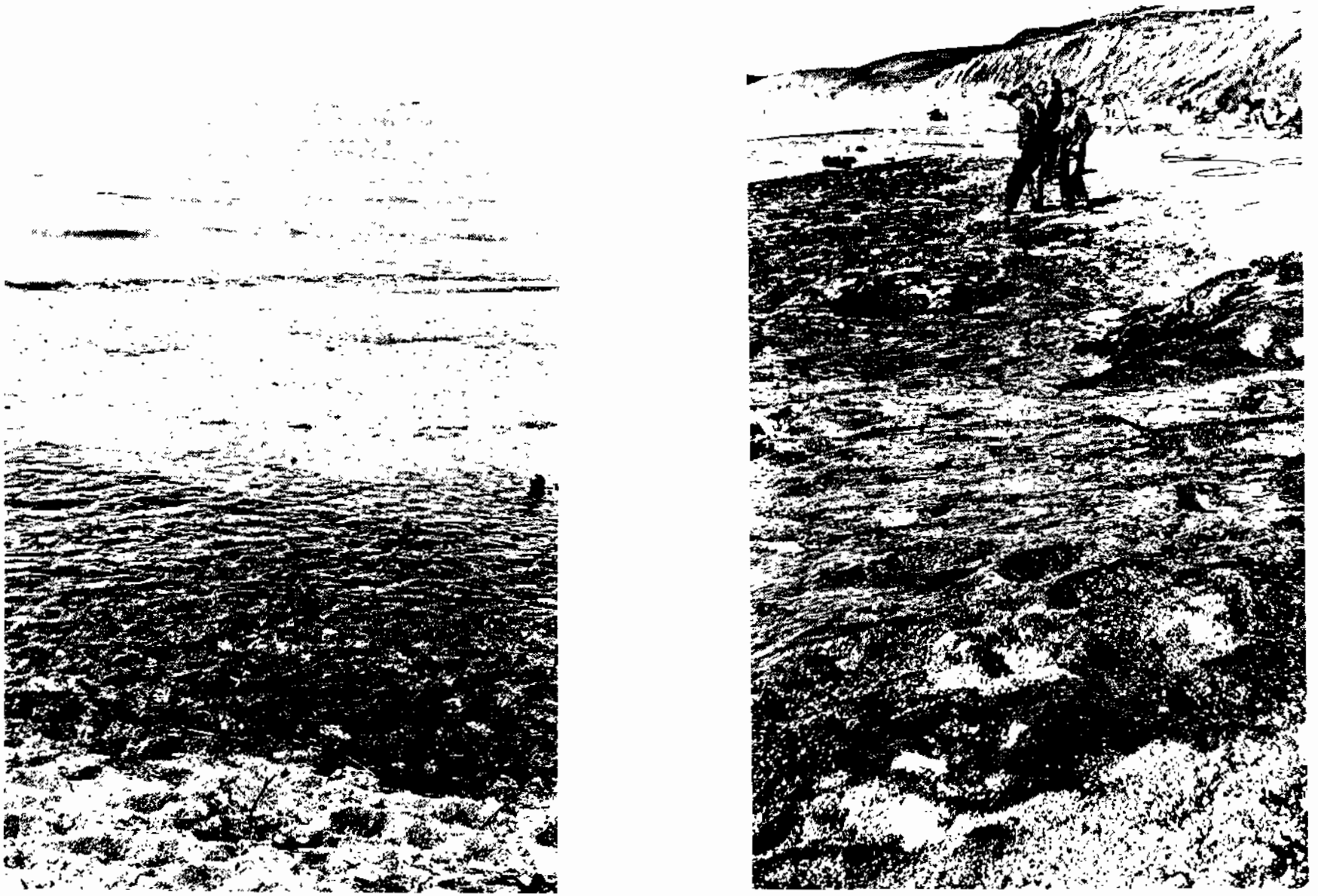

Plate 4 Gunwalloe Fishing Cove, showing (left) oil covering the beach and extending 30–40 feet out to sea; (right) service personnel preparing to treat the oil.

Dive C, 11 May, ground covered 400 yards, depth 50 feet: At the west end of the dive the fauna was rich and healthy, with spider crabs, shore crabs, many sea-urchins, polyzoa and many fish, including wrasse, pout, whiting and pollack. The fish population decreased towards the east end of the line and dead sea-urchins were seen.

Dive D, 15 May, ground covered 200 yards, depth 50 feet at west end by rock, deepening to 65 feet towards Whitesand Bay, bottom rocky: Local fishermen were keeping their store pots in 65 feet of water at the eastern end of the line. A few dead urchins and one dead edible crab were seen near the store pots, but otherwise the area appeared quite healthy, several wrasse, one large pollack and four spider crabs being noted.

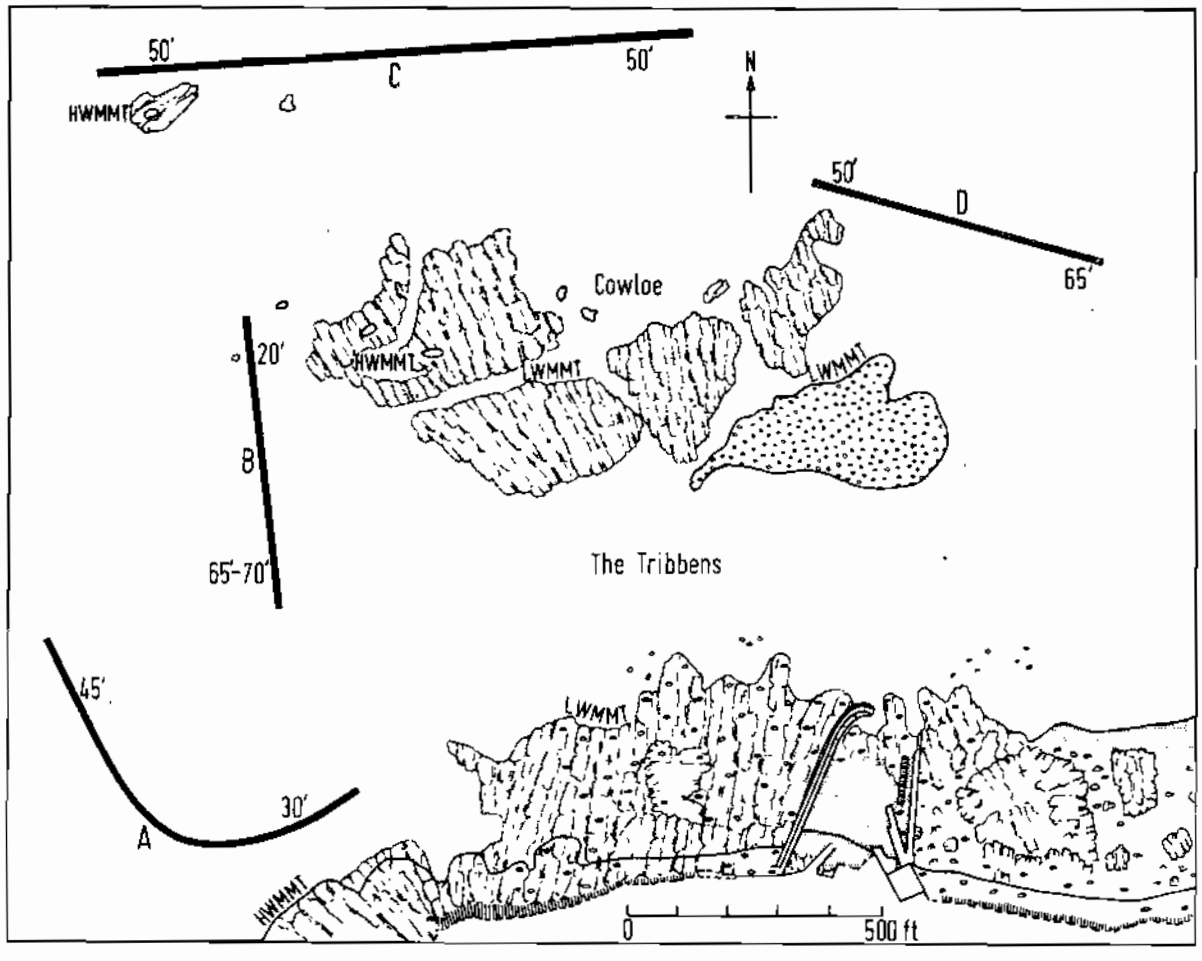

Figure 3 Chart of the coast off Sennen harbour showing the position of dives made on 11 and 15 May 1967.

On several occasions great areas of "milky" water, arising from the detergents being used daily on the beach, rocks and harbour wall, were seen to extend off the shore and to be carried out to the end of the reef. With a southerly tide these areas moved through the gaps in the reef, particularly the inshore gap, and were no doubt responsible for the mortalities there. A stream of milky water would sometimes extend beyond Land's End one and a half miles away, but did not enter the bay just south of Sennen, less than half a mile away, where there had been no spraying. Diving was also done in this bay on 14 May. The bottom, from the shore to a depth of 50 feet, 300 yards out into the bay, where coarse sand was encountered, was of large boulders covered with healthy Laminaria. Many wrasse and pollack were seen, also two plaice and some spider crabs, edible crabs, sea-urchins, starfish and anemones; no dead animals were seen, and it was generally a very healthy-looking area.

Another dive was made on 14 May, this time from the rocks at Land's End out for a distance of 300 yards, where coarse sand was again encountered in 50 feet of water. The rocks and boulders were all covered with healthy Laminaria. Again wrasse, pollack, plaice, spider crabs, edible crabs, urchins, starfish and anemones all appeared to be quite normal. No dead animals were seen.

On the south coast observations by diving were made at Mousehole Island, Porthleven, Gunwalloe Church Cove, and Mullion. The dives, down to 70 feet (at Mousehole Island on 9 May), were made to examine an area, several miles from the nearest point where oil had come ashore or detergent had been used, where commercial divers were collecting sea-urchins. This area had the normal rich fauna of this part of the coast and showed no signs of any harm arising from the oil or detergents. Sea-urchins, spider crabs, edible crabs, ballan wrasse, gobies, anemones, starfish, and shore crabs and Holothuria (on the sand) were recorded.

At Porthleven, where the very great use of detergent had ceased some two days previously, dives were made on 10 May from the rocks at each side of the harbour entrance. On the north-west side the dive extended 400 yards offshore to where the depth was 50 feet. The rocks were covered with Laminaria which appeared healthy; no dead animals were seen, and living animals included sea-urchins, starfish, anemones, prawns, several velvet fiddler crabs, one edible crab, one $1\frac{1}{2}$ lb lobster, wrasse, gobies and whiting. On the south-east side of the harbour entrance the diving observations extended 300 yards offshore and again there was a varied and considerable fauna, including many spider crabs, two edible crabs, fiddler, shore and hermit crabs, polyzoa, a sand eel, several wrasse, gobies and a large sole. On being cooked the lobster and crabs were tainted (see below), but the sole was not.

At Gunwalloe Church Cove, which was investigated by diving on 9 May, a great deal of detergent had been used in early April and there was still some oil being washed out of the sand at the water's edge. The rocks to the north and south of the bay and the sand between were examined. The fauna was scarce, but the animals seen - rockling, anemones, swimming and shore crabs, one edible crab and a starfish - were all healthy. No dead animals were seen. It was not possible to say how much of the scarcity of animals was due to deaths and how much to the fact that this bay is fully exposed to the prevailing south-west winds.

At Porth Mellin (Mullion), on 10 May, dives were made from inside the harbour out to 100 yards beyond the entrance, where at a depth of 40 feet the rocks were replaced by silver sand. The large rocks were all covered with Laminaria, and a small pink alga (not identified) was also present. Two edible crabs, fiddler crabs, large wrasse, gobies, starfish and anemones were recorded, and the life was abundant and healthy. Two divers examined the southern side of Mullion Island and swam westward in 60 feet of water for 150 yards. The fauna was rich and everything appeared healthy.

20-30 May: During this period the quantities of detergents being used were greatly reduced, and spraying ceased in most areas by the end of the month. No further systematic observations were made along the beaches of Cornwall, but records of the catches of crabs, lobsters and crawfish round the Cornish coast have been kept for a number of years, and the continuation of these records should show whether the losses of these crustacea due to the use of the detergent have been great enough to have a significant effect on the yields of the fisheries during the next few years.

(c) Tainting of fish and shellfish

Fish

During April there were several reports of occasional mackerel from both the north coast and Marazion being tainted by detergent when eaten. In these cases it proved most difficult to establish the validity and origin of the tainting, and there is some evidence that the authenticated cases may have arisen by external contamination during the handling of the fish aboard boats or on quays where large quantities of detergents were being used, with inevitable spillage. However, as mentioned elsewhere in this report, active fishing was going on close to some beaches where the sea was already discoloured by detergents, and it is very surprising that there was not considerable tainting of fish in these areas.

Reports of tainted sea-trout were confirmed on fish caught in Mount's Bay in beach seines between 12 and 19 April, soon after spraying had stopped in that area. The tainting is believed to have been due to detergent rather than oil.

A single "strong-alive" plaice caught by an aqua-lung diver off Newquay on 13 May was found on cooking to taste unpleasantly of oil. At no time did tainting of fish become a problem, though it is believed that fear of tainting by consumers caused some sales resistance.

Shellfish

Two series of experiments to determine possible lethal effects of the detergents in the sea on lobsters and crabs were made in early April, and these are described in detail on page 19. The lobsters from these experiments were also used to determine whether the oil and/or detergents were causing tainting. At Porthleven, lobsters and crabs were held in wicker lobster pots for seven days (3-10 April), at distances of 400, 800 and 1 200 yards from the shore, in depths of 15, 30 and 40 feet respectively, at a time when spraying was going on actively in and around the harbour. At Sennen, a further group of lobsters and crabs was also kept in similar pots at 200, 400 and 880 yards from the shore, in depths of 10, 12 and 30-40 feet, for six days (4-10 April) during which a great deal of detergent was being used.

On 10 April all the lobsters and crabs used in the experiments were boiled and the "cream" (digestive gland), tail meat and claw meat tasted for contamination. The crabs were found to be normal but there was some tainting of the flesh of the lobsters, as shown in Table 6, the tainting giving a taste similar to paraffin or white spirit. Thus it was clear that lobsters held in water where detergents were being used to clear oil could become tainted without showing any external signs, and accordingly fishermen were advised to place their store pots well away from sites of oil-cleaning operations.

During the week beginning 8 May a report was received that a lobster had been returned to a merchant by a customer who complained that it was tainted. Following this report catches of lobsters from various ports near oil-cleared areas were examined, and it was noticed that in some cases the eggs of "berried" (egg-carrying) female lobsters when eaten raw were found to be tainted, thus giving a quick method of checking a consignment of lobsters for contamination while still alive. The paraffin taste did not appear until the eggs were actually bitten, indicating that the contaminant was in the eggs and not adhering to the outside. During this week there were also confirmed reports of tainted lobsters from Sennen and Cape Cornwall.

Since all lobsters examined up to 12 May had been held in storage pots for a time, it was still not clear whether the contamination had occurred during storage or whilst the lobsters were still at liberty, but a lobster captured 400 yards off Porthleven in 50 feet of water by a M. A. F. F. diving team on 10 May was found to be tainted, indicating that lobsters could become tainted whilst at liberty. This was confirmed on 15 May, when a batch of lobsters

caught on that day off Sennen and not stored was examined and found to be tainted.

Table 6 Tainting in the cream, tail meat and claw meat of lobsters held in pots off Porthleven (3-10 April) and Sennen (4-10 April)

	Position offshore (yards)	Whether tainted or not		
		Cream	Tail	Claw
Porthleven (1 lobster per pot)	200	no	no	no
	400	yes	yes	no
	800	no	no	no
Sennen (2 lobsters per pot)	200 (a)	yes	yes	no
	(b)	yes	yes	no
	400 (a)	yes	yes	yes
	(b)	yes	no	no
	800 (a)	yes	yes	no
	(b)	yes	no	no

At this time a local merchant put into live storage some 800 lb of lobsters which had been caught in the Sennen-Cape Cornwall area and among which some of the egg-carrying females were tainted, indicating that an unknown proportion of the rest was probably also contaminated. These lobsters could not be sold for fear of affecting the market. The merchant would not accept any further lobsters from part of this area for about three weeks, during which some of the smaller boats stopped fishing.

Experiments were therefore done to find out more about the distribution of the tainting in lobsters and to determine how long it would last if the lobsters were kept in clean sea water. Nineteen berried female lobsters with tainted eggs were selected on 12 May and four of these were boiled and found to taste strongly of paraffin internally. The remainder were placed in a store box in Newlyn harbour which was free of detergent. The eggs of six of the stored lobsters were tasted again on 13 May and all were still tainted.

On 15 May the eggs were again tasted and the tainting was much less marked. Two lobsters whose eggs tasted now only very slightly were boiled and these had only a faint tainting which was not detected by three of six people who tasted them. On 16 May two more of the stored lobsters were cooked, and both had a slight paraffin flavour. On 17 May the eggs of the

remaining eleven lobsters were tasted and there was no detectable tainting in seven of these: two of those which appeared clear were then cooked and both showed a slight internal tainting. These observations are summarized in Table 7.

Table 7 Tainting of the uncooked eggs and the cooked meat of berried female lobsters held in clean sea water from 12-19 May at a temperature of 49°F (9°C)

Sampling date	Lobster number	Uncooked eggs	Cooked meat			
			Cream	Coral	Tail	Claw
12 May	1	strong	strong	strong	no	no
	2	strong	strong	strong	no	no
	3	strong	strong	strong	slight	no
	4	strong	strong	strong	slight	slight
15 May	5	little	slight	slight	no	no
	6	-	slight	slight	no	no
16 May	7	little	slight	slight	no	no
	8	no	slight	slight	no	no
17 May	9-12	little	not cooked			
	13-17	no	not cooked			
	18	no	little	little	no	no
	19	no	little	little	no	no

In all lobsters the tainting was most marked in the "cream" (digestive gland) and "coral" (ovary). The cream was affected in all tainted lobsters. In some cases the white meat (muscle) of the tail was tainted and in a very few cases the claw meat also. It would therefore seem that in mild cases the cream only is tainted, in more serious cases the cream and the white meat of the tail, and in the worst cases the whole body. In no cases were the eggs of berried females tainted without internal tainting, but some cases of internal tainting without the "berries" being tainted suggested that tasting the eggs is a good but not perfect guide.

From these tests it was clear that lobsters which were heavily tainted at the start of the experiment had lost all of the bad taste from the tail and claw meat after three days, but they had not lost all the tainting of the digestive gland, ovary, or external eggs after five days, though it was much reduced. It may be concluded that under similar temperature conditions it would be advisable to keep lobsters in clean sea water for seven days to be sure of

ridding the white tail and claw meat of heavy tainting, and that fourteen days would be necessary to be sure of eliminating it also from the cream and coral. It has been suggested that feeding the lobsters while keeping them to clear the tainting might reduce the time required, but this has not been tested.

The only reports of tainted crabs were from the divers who cooked and tasted active crabs caught off Porthleven on 10 May. Thus it appears that crabs may become tainted in the same way as lobsters, though tainting of crabs did not become a problem during this incident. During this period very large numbers of crabs were cooked and the meat picked out at Newlyn but none was tainted, although the pickers were keeping a very careful watch for tainted animals.

DISCUSSION

The forecast that the use of large quantities of detergents to deal with the oil on the sea and along the open coast of Cornwall would have an acceptably small adverse effect on fisheries has proved, up to the present, to be correct, despite the fact that considerably greater quantities of chemicals were used than anticipated. Although the damage to intertidal animals and plants was extensive wherever very heavy spraying was done, there was relatively little effect on commercially valuable fish or shellfish. That the damage to commercial fisheries was so small was primarily due to the special conditions prevailing at this season of the year off the Cornish coast. An additional factor of importance was no doubt the volatility of the more toxic fraction of the solvent/emulsifiers, which must have been reduced considerably when these materials were used on the open coastline with much wave action. However, the damage to wild life generally and to edible crabs in shallow water near the shore, and the tainting of lobsters, would certainly have been very much less if more oil had been removed mechanically, using such aids as straw, and if the detergents had been applied with more discretion and at all times in accordance with instructions.

While the experience of the "Torrey Canyon" disaster shows that detergents have an important place in the treatment of major oil-spills as well as minor ones, it must not be deduced that the use of detergents should always be the method of choice. Each incident must be considered on its merits, and the methods chosen should be the most appropriate ones after considering the effects both of oil and of the various available methods of clearance on the local amenities, fisheries and wild life. In each case consultation with fisheries interests is needed before detergent spraying is authorized either at sea or on the shore.

Specific circumstances in which the large-scale use of detergents is likely to be harmful are considered below.

1. Fish nursery grounds

Many important nursery grounds for young fish are in shallow coastal waters, such as along the North Sea coast of Belgium, Holland, Germany and Denmark or in the eastern Irish Sea from North Wales to the Solway Firth. In such areas the young fish are very abundant close in along the shore lines.

In such shallow waters oil itself is unlikely to do the young fish much harm but the massive use of toxic detergents could almost wipe out a whole year-class. In these circumstances the detergents now available should not be used, except perhaps during the winter and on a small scale. Mechanical and physical methods such as the use of straw and absorbent foams along the high-water line would seem to be the most appropriate. If non-toxic solvent/emulsifiers could be developed they would have an important place in clean-up operations.

On shallow nursery grounds tainting of small fish is unlikely to cause trouble, but these grounds are frequently also the site of important shrimp fisheries, and shrimps are particularly susceptible to chemical pollution and to tainting.

2. Oyster, mussel and cockle fisheries

Although oil alone is relatively harmless to marine life, especially after the lighter fractions have evaporated, it can render molluscan shellfish unsaleable if it settles on them. As such shellfish occur mostly in estuaries, the primary method of defence here should be to exclude oil by physical means. For this purpose booms are likely to provide the most useful defence, but further work is needed to establish the most suitable designs, materials and methods of anchorage, combined with the development of methods of removing impounded oil. All existing solvent/emulsifiers are very toxic to marine life and should not be used close to oyster, mussel or cockle grounds, especially in estuaries where dispersion is limited.

Most of the methods suggested for sinking oil at sea and so avoiding pollution of coastlines and estuaries have been only partially successful; a considerable proportion of the oil taken to the sea bed separates from the sinking material and returns to the surface. Moreover, fishing gear towed over grounds where oil has been sunk may become so contaminated that both net and catch have to be destroyed. However, the French apparently used with success a treated calcium carbonate to sink some of the "Torrey Canyon" oil off the Cherbourg Peninsula. Further research is clearly needed in this field to develop really effective methods of sinking and retaining oil on the bottom and

this should be coupled with trawling trials over areas where oil has been sunk, to assess more precisely the risks of contamination.

To summarize - in order to safeguard fisheries in the event of future major oil-spills further research is especially required in the following fields:-

1. the development of physical and mechanical methods of removing oil from beaches, so as to avoid the use of chemicals on fish nursery grounds;
2. the development of less toxic solvent/emulsifiers;
3. the development of booms, and the associated methods of removing impounded oil, for the protection of molluscan shellfish in estuaries;
4. the study of the effects on fishing which might be caused by sinking oil on trawling grounds and of the subsequent fouling of fishing gear and catch.

SUMMARY

1. The studies made during 1961 and 1962 by the Warren Spring laboratory (Stevenage) into the use of detergents for clearing oil-spill, and by the Fisheries Laboratory (Burnham-on-Crouch) into the toxicity of these chemicals are briefly reviewed.
2. The distributing of the oil pollution following the "Torrey Canyon" wreck, around the coast of Cornwall from Trevose Head to the Lizard, is described and details are given of the quantities of solvent/emulsifiers used each day to disperse it.
3. Food fish were found not to have been affected adversely by the oil or chemicals.
4. Edible crabs, and to a much smaller extent lobsters, were killed in the areas immediately adjacent to the three or four centres where the largest quantities of chemicals were applied, but total losses among these species are considered to have been very small compared with the local stocks.
5. Sufficient tainting of lobsters occurred along the coast between Sennen and Cape Cornwall to stop the fishery in this area for two to three weeks, but elsewhere tainting was negligible.
6. Although there was only slight damage to fisheries in Cornwall from chemicals used to disperse the oil, it is considered that there are many areas around Britain where the use of comparable quantities of these chemicals would have been unacceptable because of serious damage to fisheries.

7. The most appropriate methods for dealing with massive oil-spills to minimize damage to fisheries are considered, and some recommendations on lines of further research are given.

ACKNOWLEDGEMENTS

This report has drawn very extensively on the notes made by members of the M. A. F. F. staff who were making observations in the field, and I wish to acknowledge particularly the reports and help given by: Mr. B. T. Hepper of the Fisheries Experiment Station, Conway, who made most of the shore observations and those on tainting; Mr. B. H. Holford of the Fisheries Laboratory, Lowestoft, who led the Ministry's diving team; Mr. A. R. Margetts, also of the Fisheries Laboratory, Lowestoft, who was in charge of the trawling observations under very bad weather conditions from 31 March to 4 April; and Mr. B. Howell, of the Fisheries Laboratory, Burnham-on-Crouch. I am also grateful to Dr. Lythgoe and his team of divers, who made the very useful underwater observations early in the emergency. I have also drawn on information obtained from Mr. W. H. Williams, the Ministry's District Inspector of Fisheries at Plymouth, and Mr. G. H. Buchanan-Wollaston, his Fishery Officer at Newlyn. For help with the problem of the tainted lobsters I am indebted to Mr. J. Horne of the Torry Research Station of the Ministry of Technology. I wish to acknowledge also the assistance of all those local authorities who supplied me with information on the quantities of detergents used on the various parts of the coastlines within their districts.

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APPENDIX I: OIL POLLUTION AND SHELLFISH

1. Introduction

Oil on the sea or washed ashore is a menace to bird life, and a serious trouble to holiday makers, as well as being extremely unsightly along beautiful parts of our coastline. Active measures are being taken by Governments and shipping companies to prevent the pollution of the sea by oil, but some pollution, at least through accidents, is certain to continue. Local authorities and other bodies will therefore wish to take any measures open to them to prevent the coastline from becoming contaminated or to dispose of the oil when pollution does occur.

Some methods now available for dealing with oilspill, including those recently developed by the D.S.I.R., are very effective and in most circumstances can be used without harm to fishing interests. However, as all the chemicals at present available for removing oil by dissolving it and then emulsifying it in sea water are highly toxic to marine life, there are times when they should not be used.

This memorandum sets out the conditions when damage may occur to inshore fisheries by oil, or by the chemicals used to deal with it, so that the most suitable methods can be used when fishing interests might be affected.

2. Oil

Oil which is carried ashore by wind or tide may settle on organisms living at any level between the high and low tide marks, but can only cause damage to them if it comes into contact with their soft parts. However, many of these organisms, including the commercial shellfish (mussels, winkles, cockles and Portuguese oysters) are able to retract their soft parts, or close their shells, so that oil rarely does any harm to them.

Oil adhering to the shells of shellfish, while doing little harm to the animals within, can however render them quite unsaleable due to the smell and tainting that occurs. Small oil particles in the water can also be taken in by the filter feeders (oysters, mussels and cockles) and so cause tainting. A few years ago mussels on the west coast were so tainted by oil that they could not be sold and in 1961 considerable quantities of winkles in Poole harbour were rendered unsaleable due to oil on their shells.

There is as yet no evidence that fish, plankton or animals living on the bottom below low water mark are likely to be affected by oilspill except where they occur in enclosed water, such as docks.

3. Sinking oil to the sea bed

Clay, sand, powdered clinker and proprietary materials have been proposed for sinking oil before it reaches the coast. The use of these materials is only partially successful, with the result that some oil fails to sink and some rises to the surface again, finally to be carried ashore. It takes several days for the sunk oil to harden and any fishing gear that is inadvertently dragged through it is liable to become contaminated and may have to be destroyed. Sunk oil adhering to a trawl is liable to come into contact with the fish caught and may cause sufficient tainting to render at least part of the catch unsaleable.

Oil sunk on to oyster or mussel grounds below low water level, or on to shellfish in the intertidal zone, would be liable to cause tainting and the dredges used could become so contaminated as to be unsuitable for further use until cleaned; the dredge bag may have to be replaced.

Oil should therefore not be sunk on much frequented trawling, seining or dredging grounds or within at least two miles of exploited mussel, oyster or cockle grounds.

4. Chemical cleansers

All chemicals at present on the market capable of dissolving and emulsifying oil are highly toxic to marine life and the use of these may affect shellfish in two ways: by the direct application of the chemicals, concentrated or partially diluted, to shellfish which have become contaminated, and by their being bathed in a suspension of the chemicals carrying oil after its use in the vicinity of shellfish grounds. These cases will be considered separately.

(a) Cleaning oil from contaminated shellfish

If any of the chemicals at present available, even diluted 1 : 1 with water, are applied direct to shellfish which have become contaminated by oil, and this is most likely to occur to mussels and winkles and more rarely to cockles or Portuguese oysters, they are likely to cause up to 100 per cent mortality of the shellfish so treated.

Winkles are rather more resistant to these chemicals than are cockles, mussels or oysters, but the winkles take several days to recover and, as they are sluggish during this period, they would be very vulnerable to their enemies.

(b) The effect of diluted cleansers on shellfish

Experiments have shown that suspension of these chemicals down to 10 parts per million (10 p.p.m.) can cause the death of shellfish if immersed in them for 24 hours. Also the growth rate of larval oysters has been reduced by suspensions down to 1 p.p.m. While the evidence

shows that these chemicals are highly toxic, even in substantial dilution, the quantities of chemicals likely to be used are small compared with the great quantities of sea water moved up and down estuaries by the tide. It would therefore be unreasonable to advocate the complete avoidance of these chemicals in any estuary which has shellfish and it is considered adequate protection - by dilution - if they are only used on beaches more than 440 yards ($\frac{1}{4}$ mile) from the nearest shellfish beds below low tide level. A greater margin of safety would be advisable where the beds are exposed on the shore and in the direct path of the tidal stream carrying water from an area being treated.

While there is little doubt that these chemicals cause considerable damage to the smaller planktonic organisms which are present in the water to which they have been added, it is not considered that the effect on the food supply to the larger bottom-living organisms, including commercial shellfish, would be sufficiently lasting to have a significant effect on the growth, etc. of the adult shellfish.

No work has yet been done nor evidence collected to determine whether the large-scale removal of oil from beaches etc. by using chemicals causes tainting to shellfish in the area. It is intended that the research which is continuing in this whole field will include this specific problem.

5. Summary and conclusions

(a) Oil

1. Oil settling on shellfish between the tides is unlikely to damage them but will cause tainting. Oil may in this way render shellfish unsaleable for a considerable time.

2. Oil will not harm fish and shellfish below low water mark.

(b) Sinking oil

1. This is not a very effective method of dealing with oil. It certainly should not be used in the vicinity of much frequented trawling, seining or dredging grounds nor in estuaries where shellfish are exploited, for the sunk oil can still contaminate gear and cause tainting of shellfish with which it comes into contact.

(c) Chemical cleansers

1. All such chemicals at present available are highly toxic substances and should not be used for removing oil which has settled on shellfish between tidemarks. It is better to leave these oily patches to weather, than to risk killing the shellfish by chemicals.

2. These chemical cleansers should not be used in the immediate vicinity of shellfish living below low water mark. The quantity of water in an estuary is however very great compared with the quantity of chemical that is likely to be used in clearing oilspill. Therefore, if used more than $\frac{1}{4}$ mile from the nearest commercially exploited shellfish living below low water mark, these chemicals are not likely to do significant harm. Temporary tainting could however occur and might affect sales if gathering for market is being done at the time that oilspill in the vicinity is being treated with these chemicals.

1965

Ministry of Agriculture, Fisheries and Food
Fisheries Laboratory
BURNHAM-ON-CROUCH
Essex.

APPENDIX II: "TORREY CANYON" OIL AND FISHERIES

As this note is being written (31 March) all the oil is out of the tanker and large areas of sea off Cornwall are becoming free from oil.

The following information is given to help the fishing industry to use the fish that are clear of oil and to assist the inshore industry and authorities to take the appropriate precautions and action where oil pollution is present along the shore.

Whitefish

The oil alone can have no damaging effect on fish in the open sea, it is inert and stays on the surface.

The emulsifier/solvent mixtures, the so called detergents, used to disperse the oil are toxic to fish, but even in quite shallow waters they are so diluted when only a few fathoms below the surface that there is extremely little risk to fish living on or near the bottom.

Even if the emulsified oil gets near the bottom it will be so dispersed that the chances of any tainting will also be small.

There is however a risk of clean fish becoming tainted if the trawl becomes fouled with oil during shooting or hauling. This risk should be avoided by not shooting or hauling where oil is present, even as a fine but visible layer. It would be unwise to spoil the market by landing contaminated fish which, although harmless, might be unpalatable.

Mackerel and pilchards

There is more risk to fish near the surface but in spite of thousands of gallons of detergent having been applied by spraying to the offshore and inshore waters off Cornwall during the last ten days there have been no reports of dead fish. As there are some pelagic fish in this area, it would appear that the concentrations have been too low to cause trouble. Examination of planktonic organisms in the area of spraying has not shown any evidence of appreciable damage to these more delicate organisms.

It is possible that pilchard or mackerel which have been swimming through water in which the oil has been dispersed might become tainted, but there is no information to suggest that this has in fact happened.

There is however a greater risk of tainting of fish from oil which has got on to the net during shooting or hauling. It is therefore recommended that fishing should not be done where the nets are likely to get fouled when brought through the surface waters. Hand-lines should not be used through visibly oily waters as the fish lifted through the oil might be tainted.

Risks of eating affected fish

It is quite certain that fish would become tainted and would smell of oil or detergent and be unpalatable long before they became in any way harmful if eaten. Thus if fish caught and landed appear healthy and do not smell of oil or detergent they are quite safe for human consumption.

Shellfish

Crawfish. Crawfish live in deeper water and usually where there is a strong run of tide; it is most unlikely that they will be affected by oil or detergent at all.

Scallops are largely away from the coast and unlikely to be affected.

Crabs. The egg-carrying female crabs go to the softer offshore grounds during the winter and will be well away from the effects of oil or detergent. The proportion of crabs close inshore in March and April is small and it is not expected that a significant number will be affected by even large-scale use of detergents along the open coastline.

Lobsters. Some lobsters tend to remain in the inshore waters in winter and are more likely to be affected by the detergents than the above shellfish. However they are on the rocky ground and it is expected that the heaviest doses of detergent will be along the sandy beaches. It is possible that there will be some loss of lobsters on rocky ground adjacent to beaches which receive a great deal of detergent. But compared with the total stock of lobsters in any mile of coast losses that may occur are likely to be small and local.

There is risk of lobsters and crabs being tainted if pots are hauled through oil on the water surface. If oil is present, pots should be left down until the oil has cleared from the immediate area.

Oysters. Those oysters that are above low water mark of spring tides are vulnerable to direct contamination by oil and should be removed to pits or relaid in deeper water.

Owing to the enclosed nature of the estuaries and inlets where oysters are cultivated any detergents used there are much less diluted than on the open coast and are more likely to cause damage. Detergents should not be used in these areas and the oil should be kept out by booms and removed by mechanical means.

Mussels, cockles and winkles. Mussels below low water mark of spring tides are safe from direct contamination by oil. Intertidal mussels, cockles and winkles are liable to direct contamination and oil should be kept off commercially useful grounds by booms. Detergents should not be used in estuaries containing commercially useful mussels, cockles or winkles.

In no circumstances should detergents be used to clean oil contaminated shellfish - it is likely to kill them.

The Ministry of Housing and Local Government, who are concerned with priorities for the allocation of assistance for booms, have been advised that priority should be given to the following areas on fishery grounds:-

South coast of England

Helford River
Porthcawl River
Fal estuary, including Penryn River
Teign estuary
Exe estuary
Poole harbour
Beaulieu River
Newtown River (Isle of Wight)
Marchwood area of Southampton Water
Emsworth Channel.

Between Lands End and Milford Haven

Taw and Torridge
Burry Inlet (South Wales)
Taf, Twyi rivers (South Wales).

After the emergency and when no more oil is coming ashore, detergents could safely be used in small quantities in these areas after consultation with the local District Inspectors of Fisheries and the M. A. F. F. scientific staff.

If you require further information or have found dead fish or shellfish, please contact your local M. A F. F. fisheries officer.

Plymouth	District Fisheries Office (W. H. Williams) Citadel Hill Plymouth.	Tel. Plymouth 63804
Newlyn	Fisheries Office (G. H. B. Wollaston) The Quay Newlyn.	Tel. Penzance 2805

Hastings	District Fishery Office (Commander J. Quicke) 97a All Saints Street Hastings	Tel. Hastings 4109
Poole	Fishery Office (J. R. Aldous) Crown Offices Civic Centre Park Road Poole.	Tel. Parkstone 5880
Milford Haven	District Fishery Office (V. A. Lees) Fish Docks Milford Haven.	Tel. Milford Haven 3412

31 March 1967

Ministry of Agriculture, Fisheries and Food (Fisheries Division)
issued from
District Fisheries Office
Plymouth
Devon.

APPENDIX III: METHOD OF CLEANING A BEACH CONTAMINATED BY LIQUID OIL

1. This note gives details of the recommended procedure for removing liquid oil contamination by treatment with an emulsifier/solvent mixture, including methods of preparing the cleaning mixture and precautions to be taken.

Preparation of cleaning mixture

2. If proprietary cleaners are used any directions given by the makers should be followed. If one of the formulations recommended in the main report is preferred it is suggested that the mixture be made up to 40 or 50 gallon drums. This is a convenient size in which to have the solvent delivered and also for handling the cleanser after mixing. A quantity of 4 or 5 gallons of solvent (depending upon the size of drum) should be drawn from a full drum and replaced by 4 or 5 gallons of emulsifier. (Although sold by weight, the recommended emulsifiers are viscous liquids.) The bung of the drum should then be replaced and the contents mixed by rolling the drum up and down for about 5 minutes.

Method of application

3. The amount of cleaning mixture required will be roughly 50 per cent of the volume of oil to be removed. The amount of oil actually present on a beach can, of course, only be estimated approximately, but one gallon per square yard would be a very heavy deposit. This would require treatment with cleanser at a rate of half a gallon per square yard. Complete removal of the oil pollution is, in fact, not generally obtained if it is treated with less than 25 per cent by volume of cleanser, but little benefit is gained by applying more than 50 per cent. As a general guide an application of a quarter gallon per square yard is recommended.

4. Although many types of applicator can be used, varying from watering cans to pressure sprayers, it is suggested that for the greatest economy a multi-nozzle spray lance should be used, this will enable the mixture to be applied uniformly over a reasonable width of beach. Owing to the large quantities which have to be used if the contamination is heavy, it is suggested that the spray lance should be fed through a long pressure hose from a vehicle on the nearest promenade or road. At this point a motor driven pump can be used to draw the mixture from the drums in which it has been delivered or prepared. This method also simplifies the problem of moving between ABD around groynes and other beach obstructions as the hose can be readily lifted over them.

5. The cleaning fluid should be applied not less than 30 minutes and not more than 2 hours before the tide reaches the area to allow sufficient time for the fluid to penetrate the oil but not long enough for the solvent to evaporate. Washing of the beach can be left to the action of the tide, particularly if a high sea is running, but since decontamination is only completely effective if the oil can be dispersed quickly into a large volume of water, it is strongly recommended that the area be hosed down with fresh or sea water as the tide approaches. Hosing down the beach when the tide is out will be ineffective and may lead to an extension of the pollution.

6. Very viscous oils may require several treatments before cleaning is complete since the mixture tends to run off such oil rather than penetrate and mix with it. Light or mobile oil may sink into a shingle beach beyond the reach of cleaning fluid. In such cases vigorous disturbance of the beach surface by hosing with a high pressure water jet will help to achieve complete cleaning.

7. It has been found that if the water-table is high, i.e. if a shallow hole dug in the beach quickly fills with water, the emulsified oil does not readily wash away with the tide and may be brought to the surface by subsequent tides. In this case only complete removal of contaminated material will provide a permanent solution to the problem.

Precautions which must be taken

8. The emulsifier/solvent mixtures are, without exception, flammable and all the normal precautions which should be taken when handling paraffin or kerosene must be observed. They also have a very strongly detergent action on the hands so that care must be taken to see that operators do not work for prolonged periods with their hands wetted by the mixture. Barrier creams should always be used and, preferably, PVC coated gloves should be worn. Splashes should be avoided and if there is any danger of getting spray in the eyes, goggles must be worn. Since these cleaning mixtures are poisonous to shellfish etc., consideration should be given to the amount of cleaning mixture which will be discharged into the sea in the proximity of fishing grounds or beds of oysters or other shellfish. Special difficulties may arise if the beach to be cleaned forms part of an estuary or other location where movement of the sea may be restricted. If a rocky beach is being sprayed it is almost inevitable that all the marine fauna in rock pools will be killed.

Spraying equipment

9. A convenient spraying lance would consist of a horizontal boom of 3/8 inch diameter brass tubing, 4 feet 6 inches long fitted at 14-inch intervals with 5 ceramic spray nozzles each capable of delivering 60 gallons of liquid per hour. This will give an even spray pattern over a total width of 6 feet

when held about 1 foot above the ground. The boom should be fitted with a handle and an "On/Off" tap and be attached to a shoulder harness worn by the operator. A clip on the harness between the shoulders will enable the weight of the hose to be carried by the body instead of by the handle. The lance should be attached to the pump by the requisite length of oil and petrol resistant hose.

NOTE: In the equipment used by Warren Spring Laboratory in its beach trials and demonstrations, the emulsifer/solvent mixture was pumped from a 50 gallon drum by a "Mono" positive Liwu Liquid displacement pump, type CD 42, fitted with an oil resistant stator and driven by a 4-stroke Villiers petrol engine and with an output of 300 gallons per hour at 75 lb/inch. A half-inch bore, double-braided, oil-resistant hose was used and the ceramic tipped nozzles on the spray lance were size no. 7 supplied by Messrs. Cooper Pegler, Ltd. of Burgess Hill, Sussex.

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