CHAPTER 10

SOME LESSONS LEARNT

SUMMARY OF MAIN RESULTS

The investigations reported in the previous chapters of this book have provided us with new information about the movement of oil at sea, about the properties of detergents and their dispersal in the sea, and about the effects that these two pollutants have had upon the animals and plants with which they have come into contact both at sea and on the shore. How can we profit from this information; what advice can we give for dealing with similar problems that arise in the future; and what can we suggest for further lines of research which ought to be put in hand?

Perhaps first it is convenient to refer to some of the more important points which have been discussed and emphasized in earlier chapters.

As regards the oil itself, the formation of emulsions of variable composition with sea water makes it difficult to predict the rate of loss of oil by evaporation. In connection with the drift of oil at sea a simple formula has been given which allows the movement of oil on the sea to be predicted. Pollution by the 'Torrey Canyon' oil was found to have little biological effect apart from the tragic destruction of sea birds.

The detergent used to treat the oil away from the coast was not noticeably injurious to marine life except in the extreme surface layers, where pilchard eggs and some phytoplankton were affected. The direct treatment of polluted shores, however, resulted in the death of a large number of shore organisms of many different kinds, and effects were also observed in the sublittoral zone.

On shores left untreated, evidence has been obtained of removal of the oil by the fauna as well as by other natural agencies. In addition, on sandy beaches microbiological degradation has been occurring unhindered by detergent treatment.

Studies in the laboratory showed that, in addition to the immediate effects observed, longer-term consequences might be expected. It was found that the immediate toxicity of the detergent largely resides in the solvent fraction of the detergents, which is fortunately readily lost by evaporation from sea water, although it is adsorbed on to sand, and may have temporary physical effects upon sandy beaches. In general, treatment has been found to be most successful upon rocky shores; on sandy beaches the use of detergent has been less successful. On both types of shore, however, treatment has led to some degree of secondary pollution owing to

instability of oil–detergent emulsions which allow the oil to re-separate from the emulsion. Methods have been devised for the bioassay of detergents in sea water, and these have been used to follow the dispersion of detergents in the sea after use on the shore. These show that dispersion is largely dependent upon local weather conditions.

POLLUTION

These results have emerged from a study of some of the effects of a major instance of pollution. To be quite clear what we mean, pollution may be defined as 'an event or a continuing circumstance whereby there are introduced into the environments of air, land and water substances that may adversely affect the balance of nature and human well-being'. Pollution of the environment affects everybody. It may carry with it an actual or a potential danger to man's health and to his economy, and it may be damaging to or destructive of features of the natural environment that provide the means of recreation and aesthetic enjoyment. In a modern industrialized society the problems of pollution apply with especial force. They are, moreover, complicated by the fact that some forms of pollution are often permitted in the interest of one requirement but to the detriment of others.

The 'Torrey Canyon' disaster presented these aspects and problems of pollution in such an acute and severe form that it evoked two immediate and significant reactions.

In the first place the unexpected drama of the event, and the magnitude and variety of its possible consequences, showed that when the dangers of pollution are evident there is a widespread public concern for the formulation and development of a nationally conceived policy for dealing with pollution hazards. Secondly, the disaster necessitated the setting up at short notice of administrative arrangements, technological procedures and scientific programmes to asssess and, where possible, to counteract the consequences of the large-scale oil pollution. The 'Torrey Canyon' campaign has thus shown up the strength and weaknesses of a complicated collaborative exercise in ways which, if the lessons are properly learnt, will be of the greatest value in the framing of future procedures and policy for dealing with pollution problems generally.

THE BIOLOGICAL ASPECT

The Plymouth Laboratory was directly concerned with only a small sector of the 'Torrey Canyon' programmes. In association with scientists of the Ministry of Agriculture, Fisheries and Food and of the Nature Conser-

vancy, our primary purpose was to assess the damage done by oil and detergents to marine life and to make recommendations on the measures needed to reduce and alleviate such damage.

We soon found, however, that the need to obtain information on matters essential to our investigations—for example, the composition of detergents, the quantities used in different localities, the movements of oil at sea and its influx on to beaches—involved us intimately in all aspects of the remedial measures. And, in addition, we extended our investigations to the examination of some physical phenomena such as the movements of oil at sea and the stability of detergent-treated beaches which were not originally in our programmes. This has enabled us to view the problems of pollution in a broader perspective than at first we had thought possible. It is therefore thought appropriate to draw on these experiences, as well as on the results of our biological investigations, in commenting on the 'Torrey Canyon' procedures, to make suggestions which may be helpful in the planning of future programmes of work on marine pollution. We omit from our comments, however, reference to matters which are outside our scientific competence; for example, questions bearing on the salvage of the 'Torrey Canyon', the disposal of oil contained within the ship, and the efficacy of mechanical devices designed to prevent the spread of oil and to provide the means of collecting it. These matters are dealt with fully in the Report of the Committee of Scientists on the Scientific and Technological Aspects of the 'Torrey Canyon' Disaster (1967). Our comments are arranged under the following headings: 'Torrey Canyon' programmes and procedures in retrospect; organizational requirements for future emergencies; a final comment.

'Torrey Canyon' programmes and procedures in retrospect

The 'Torrey Canyon' marine pollution was caused by crude oil released on to the surface of the sea and by non-ionic detergents used in the dispersal of the oil. Oil, although it killed several thousand sea birds, was recognized from the outset of the 'Torrey Canyon' operations to be a pollutant mainly destructive of the amenities of shores and beaches; detergents, on the other hand, were known to be destructive of life.

There was therefore built into the operations, from the beginning, a division of effort and of purpose. Almost the entire complex machinery of policy-making, administration and technological procedures were focused on the problem of disposing of the oil, either by getting rid of it at source, by preventing it reaching shores, or if these methods failed by removing it from rocks and beaches. With the preservation of one kind of amenity the primary and most urgent objective of the operations, the biologists' role

was thus essentially to assess the effects of the oil pollution and of the use of detergents. A situation of this kind inevitably means, in a crisis, that the many bodies engaged in the preservation of 'amenity' have this purpose wholly in view and have little occasion to consult biologists for information which could assist them in their purpose. Biologists, on the other hand, must continually seek for information as to what is being done if they are to measure the effects of the pollutants and to recommend (as we were required to do) the measures needed to reduce and to alleviate the damage which they cause.

During the 'Torrey Canyon' operations we were fortunate in finding at Maritime H.Q. liaison personnel who were sympathetic and helpful in answering inquiries. Our work, however, would have been made easier, if from the beginning of the operations, there could have been established an interchange of personnel on a recognized basis between the Plymouth Laboratory, as the centre of biological operations, and Maritime H.Q. This would have needed one or two additional staff at H.Q. who could have spent some time each day at the Laboratory to see at first hand the nature and progress of the research going on and to discuss its implications with members of the staff. A direct contact of this kind would have been of particular value in assessing: the movements of oil at sea; the determination of its quantity in the travelling patches; in advising H.Q. on the routing of air reconnaissance flights; and in alerting authorities in France of the magnitude, rate of travel and direction of approach of oil patches threatening the French coastline.

Within the Laboratory itself our main need, once the programmes of investigation had been formulated, was to ensure (*a*) that we had expert advice available on all matters relevant to the study of pollution problems and (*b*) that the teams of workers in each field should be large enough to cover, in the limited time available, the work that had to be done. Pollution problems required the participation of organic and physical chemists, hydrographers, physiologists, pharmacologists and bacteriologists; and they involve the expertise of ecologists with a special knowledge of planktonic or of benthic organisms. So far as possible it is most important that all should work in a laboratory near the scene of operations. Only in this way can a problem which overlaps many scientific disciplines be fully probed, and the expert in each field be assured of the means of seeing the opportunities offered for study and for developing his investigations in his own way. During the 'Torrey Canyon' investigations we often felt the need for assistance in particular fields (e.g. bacteriology) and we should perhaps have been more active in recruiting it had we always known where to make the approaches.

We may now turn to some of the problems which had to be tackled in examining the biological consequences of the 'Torrey Canyon' pollution, and, in particular, to the effects of the use of detergents.

As has already been made clear in this report, the decision to use detergents for the dispersal of oil was taken on the view—with which there will be general agreement—that the preservation of coastal recreational amenities was of first priority, and in the hope that the effects of detergents on marine life would not be catastrophic. Let it be said straightway that the effects have not been catastrophic. But it would be wise not to take comfort from the outcome of an action taken largely in ignorance of its possible consequences. It is all the more necessary therefore in the light of our new-found knowledge of the nature and effects of detergents to examine (*a*) by comparison with other possible methods of oil clearance, the efficiency of the detergent method of dispersal, and (*b*) the possibility of the modification of detergents to reduce their toxicity.

Non-ionic detergents have been used for some years by the Navy and by harbour authorities for clearing small oil spills. Though detrimental to marine life if used repeatedly, they have been found to be convenient, efficient when properly applied, and relatively inexpensive to use when only small quantities of detergent (used in an approximate proportion of 1 part by volume of detergent to 2–4 parts of oil) were needed.

The decision to spray at sea the large oil masses which were escaping from the 'Torrey Canyon' was taken on the basis of these experiences. It has been argued that, if complete emulsification of the oil was, in fact, achieved, the 700000 gallons of detergent employed in the sea-spraying operations would have effectively dispersed up to 15000 tons of oil which might otherwise have been carried on to the neighbouring coastline (Committee of Scientists Report, 1967). However, the total cost of the sea operations was probably of the order of £400000 and the question arises as to whether the operation could have been done more cheaply and more effectively.

An alternative method of disposing of oil from the surface of the sea that was tried during the 'Torrey Canyon' operation was the French practice of sprinkling powdered natural chalk (with 1 per cent sodium stearate added) on to the oil. Our information was that 3000 tons of chalk were applied, and we estimate that up to 30000 tons of oil may have been sunk by this method (Chapter 9). Evidently, much more chalk would have been required to sink the same amount of freshly released oil, for the amount of chalk required depends directly upon the density of the oil to be treated; the longer that oil remains at sea the denser it becomes by evaporation of the lighter fractions. The cost of the materials has not been ascertained but it would undoubtedly have been but a small fraction of

the estimated £200 000 spent on sea-sprayed detergents alone in the area of the Seven Stones. Possible disadvantages of the chalk-sinking procedure are that (1) the sunk oil may foul fishing grounds, and (2) the oil may subsequently be washed ashore. All that can be said at present is that there have been no reports that either has happened. There is at least a prima facie case for believing that oil patches moving into the open sea and away from the coast are best dealt with by sprinkling with chalk, or better still, a heavier material rendered unwettable by suitable pretreatment (for example, silicone-treated sand). Such methods might also be as effective as any other in dealing with oil patches driven towards the shore, though under these conditions the danger of sea-bed fouling, adverse to inshore fisheries, might render the chalk treatment undesirable. Nor might it be altogether suitable in shallow areas such as the Thames Estuary or off the Rhine delta. Much depends on how quickly the sunk oil is destroyed by bacteria.

In commenting on the use of detergents for the cleansing of rocky shores and sandy beaches, we fully agree with the point made in the Committee of Scientists Report that every attempt should be made to remove oil from shores and their approaches by mechanical devices and trapping materials, wherever they can be effectively used. It cannot be emphasized too strongly that detergents, at best, can only *disperse*—they do not *destroy* the oil. But where there is a need for the rapid cleansing of a shore the 'Torrey Canyon' operations have shown that detergent treatment can be very effective. There is, however, both for reasons of economy and the preservation of shore life, a need to employ detergents with discrimination.

We were told, at the beginning of the operations, that detergents are only effective in clearing oil from rock surfaces if applied quickly, and before the oil has undergone changes. This has been shown, in the course of 'Torrey Canyon' operations, not to be true. Oil can be cleared effectively from rocks weeks after deposition, provided always that the detergent is applied in a proper manner, and adequate agitation given to the oil–detergent mixture. As therefore a delay in spraying is permissible, the most favourable conditions of wind and tide can and should be selected. It would then not only be possible to consider the optimal conditions for dispersal of the oil, but also to give due regard to the effects of the spraying on the flora and fauna of the affected area. Some places, notably, inaccessible coves should be left undisturbed for, as shown in this report, natural processes including removal of oil by browsing intertidal animals and bacterial decomposition will in the course of a few months bring about a considerable recovery. The nature and time scale of these processes need further investigation. Where rocky shores are needed for holiday recreation there seems, however, to be a case for employing detergent

treatment to the point that they are again acceptable, although this may result in secondary pollution of adjacent sandy areas.

Oil on sandy beaches indeed presents an intractable problem. The difficulty here is that detergent-treated oil sinks into sand and may remain there for a considerable time to be uncovered at intervals by wave removal of the cleaner surface deposits. Moreover, oil mixed with sand may sink below low-tide mark and be subsequently washed back on the shore by gales.

The method of bulldozing oil-covered sand to the lower levels of the beach and there treating it with detergents met with some success, but owing to the instability of the oil–detergent emulsion the oil was apt to reappear and be redeposited elsewhere. An alternative method, if places for disposal are readily accessible, would be to remove the oily surface sand mechanically. Open coast beaches often have a sufficient cover to make this practicable without dangerously exposing the backing cliff to erosion, but the method would need to be used only when the conditions for sand removal are favourable.

We now consider the toxicity of detergents, with its attendant problems of (1) when, in their present form, their use would not be desirable, and (2) whether they could be modified to make them less toxic.

It may be supposed that the use of detergents for shore-cleansing becomes undesirable when the preservation of amenities is outweighed by other considerations of which the economic value of fisheries is probably the most important. The more cautious use of detergents by the French reflects the greater economic importance and the more open-shore siting of their shellfish industry. At the outset of the 'Torrey Canyon' operations it was very wisely decided, on the advice of Ministry of Agriculture, Fisheries and Food scientists that detergents should not be used in estuaries where there are commercially important shellfish beds. This should be a continuing directive to which greater point is given by the experiences gained from the 'Torrey Canyon' disaster. If they are protected by booms, estuaries are not likely to be polluted. Should oil enter, in small quantity, our evidence is that it would not kill shellfish, though it would probably make it undesirable for them to be eaten until the oil had been dissipated by natural processes of change and degradation.

The beaches and sea-beds affected by the 'Torrey Canyon' oil, and subjected to detergent treatment, were almost all of the clean, silt-free sand type characteristic of wave-exposed shores. The sand of these beaches is mobile and contains few animals other than minute interstitially living organisms. If, however, the pollution had occurred in a region of more heavily populated sandy muds and muds the high toxicity of the detergents

would have had a catastrophic effect. Oil deposited on the muddy sands and muds of quiet water regions might be very difficult to remove, but use of detergent is not likely to improve the situation.

Our investigations have shown that the toxicity of detergents resides mainly in their volatile aromatic components and we would advise that research is urgently needed to discover whether less toxic materials can be found as substitutes for the presently used solvent fractions. The surfactant components of detergents are much less toxic, but, since they are more persistent in sea water, further biological investigations are required in order to test their possible long-term effects on organisms and their concentration within the terminal organisms of food-chains.

We now comment on our organization of onshore and offshore surveys.

An essential requirement for a scientific analysis of an artificial change of environment on the populations of marine organisms is that the means shall be available for comparing the population changes with any alterations which would have occurred in the course of normal seasonal and other natural changes of the environment. In order to assess the effects of detergents on the populations of intertidal animals it is therefore necessary to have available for collateral study a nearby shore that has not been subject to detergent cleansing. It was a feature of the 'Torrey Canyon' shore-cleansing operations that they left hardly a single locality free from the suspicion of some measure of detergent treatment. If biologists are to report adequately on the effects of a pollution they must be left in possession of a control, and must be consulted before the operations have gone too far on the localities which are to be left untouched. From the few moderately oil-polluted sites that were in fact left untreated, the natural cleansing action of wave, sand, and fauna has become obvious.

A programme of regular surveys will be a continuing requirement if pollution effects are to be adequately assessed in the future. They will also be necessary in the immediate task of assessing the patterns of recolonization of shores following their treatment by detergent. There is therefore, in our opinion, an immediate need to provide by appropriate directives for the reservation of selected localities as 'protected' areas free from avoidable unnatural disturbance.

In carrying out our shore and offshore surveys we had two main purposes in mind: to report, in essentially qualitative terms, on the developing destruction in as many localities as could be visited by our few scientists in the limited time available to them; and to survey more continuously and in greater detail one or two localities which we had examined regularly for many years. The latter aim was only partly achieved because the oil did not reach our home grounds. The detailed survey of the progress of the

destruction of a rich and varied fauna and flora requires a concentrated and sustained attention, which can only be given by large teams working day by day on a shore and with well-prepared objectives, and where detergent-spraying or other treatment is carried out by authorities in collaboration with the scientists. This is a further example of the need for early discussion and collaboration of personnel at Operations H.Q. with the scientists involved in the biological surveys.

Our offshore surveys were limited in scope by the fact that only a single suitable research vessel was available; the cruise programme had therefore to be devised to cover as many different lines of investigation as possible, and this led to insufficient coverage of some important aspects.

Had our surveys been co-ordinated with other programmes including the aerial surveys, such important tasks as the collection of oil samples at sea to determine the progress of the ageing of the oil and its increase in density (relevant to decisions about the best method of treatment) could have been carried out more efficiently. We also think it important subsequently to follow not only movements of visible oil patches, but also the fate of very finely dispersed oil over the general sea surface.

Finally, some mention should be made of the observations and predictions made by scientists at the Plymouth Laboratory on the movements of oil at sea, the results of which are reported in Chapter 8.

As the laboratory nearest the scene of the wreck we began immediately to collect all the data relating to oil movements that we could lay hands on and we continued to collect records and to study them as a research project. By mid-April we had become seriously concerned that a very large amount of oil had disappeared from the scene, apparently without trace. The predictions shown in Figs. 32–38 were based on calculations from wind velocities and were intended as directives to further observation. Coastal Command of the Royal Air Force gave us most willingly all the assistance that it was in their power to give but their programmes did not allow them to fly the sorties which we needed. Our calculations remained therefore largely theoretical until at a later date oil stranded on the coast of Brittany and we established contact with the French Navy through Professor Courtot of the Faculté des Sciences, Brest.

We feel that the National Institute of Oceanography would have been admirably fitted not only to plot events but actively to advise the British and neighbouring governments on the air reconnaissance necessary for advising on the coasts which were at hazard.

It is, of course, easy to comment after all the facts have been collated and tested, but in any future incident of this kind we strongly urge the National Institute of Oceanography should at once be consulted as expert advisers

on the probable course of events. The Institute is well able to co-ordinate effort with its sister laboratories in neighbouring countries with which it has close contacts. Such international co-ordination was needed but was only slowly achieved.

Organizational requirements for future emergencies

Our commentaries on the lessons learnt from the 'Torrey Canyon' disaster and from the investigation of its biological consequences have included some suggestions and recommendations that may be of value in future emergencies of a similar kind. Oil pollution and the measures necessary to counteract it could, however, occur over any part of the British coastline, and it is appropriate to consider the means by which the investigation of the biological consequences might most effectively be organized on a regional basis.

We have given our reasons for believing that complex investigations of this kind, involving a wide range of scientific disciplines, need to be based on a laboratory with staff and facilities adequate to service these various requirements. It would seem desirable therefore in anticipation of future emergencies to prepare a list of regional centres upon which pollution investigations could be based. Such a centre would ideally be not more than 30–40 miles from the field operations, and would need to be of a size and scientific coverage such as is provided in Britain mainly by marine laboratories and universities. If the co-operation of suitably located universities could be sought in the provision of facilities for the conduct of emergency programmes a substantial part of the British coastline could be covered by a chain of regional centres. Within the framework of the present organization of civil science in the United Kingdom, the Natural Environment Research Council might well be thought to be the body best able to organize the regional arrangements and to provide such advice and assistance as would be needed in preparation for future emergencies.

A final comment

The 'Torrey Canyon' disaster highlighted with an exceptional clarity the unpleasantness (to put its consequences in the least emotive terms) that can arise when materials essential to man's industrialized society escape from the confines of their intended use to foul the environment.

The escape through human error or by unavoidable accident of dangerous or unpleasant pollutant materials are hazards which must be accepted and dealt with as the occasion arises and as best we can. Other forms of pollution are intentional and many are thought to be necessary. If we ask why they are thought to be necessary there can be but one answer: it is because

the easiest and cheapest way of disposing of unwanted materials is to throw them away. If materials so disposed of are harmless and unenduring no one minds very much. But, if they are injurious and persistent, acceptable means of disposing of them must be found even though it may be expensive to find the answer.

We are progressively making a slum of nature and may eventually find that we are enjoying the benefit of science and industry under conditions which no civilized society should tolerate.