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MARINE OIL SPILLS
A Selected Bibliography

by

D.E. Hurley

NEW ZEALAND OCEANOGRAPHIC INSTITUTE
D.S.I.R.

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CONTENTS

Introduction

THE PROBLEM

Since the *Torrey Canyon* disaster off the coast of England in 1967 brought home the dangers of oil pollution at sea, there has been a steady increase in the number of large and small spills with accompanying disturbances of the marine environment and nearby shores. Most of these incidents have been short-lived but a few, notably that at Santa Barbara, have been chronic long-term situations and, until recently, the introduction every year of still larger tankers has brought with it the likelihood of ever more catastrophic spills.

Over recent years, some degree of general agreement has emerged on the most satisfactory method of tackling oil spills. Salvage at sea if at all possible is the first priority and here the United States Coastguard ADAPTS system offers most promise. If oil is likely to drift ashore, treatment at sea with one of the second-generation, lower toxicity dispersants is recommended. Once oil is ashore, mechanical treatment methods are still the best and straw is still the first choice as absorbent. On sandy beaches, mechanical removal is better than dispersant cleaning which is best reserved for use when there are over-riding amenity considerations. (Papers listed in this bibliography give considerable guidance on the most effective means of using dispersants.) The design and use of booms leaves something to be desired but they can be effective in protecting sheltered waters if properly constructed and used. Rocky beaches are best left uncleaned to let nature take care of the oil, but, if jetties and concrete structures need cleaning, steam-cleaning or hosing with dispersants, followed immediately by high-pressure water cleaning are, as yet, the most practical methods.

More recently, it has been realised that oil persists in sediments much longer than the surface appearance would suggest and, contrary to earlier beliefs, does not necessarily lose toxicity by evaporation of volatile elements immediately after spillage. There is more encouraging news regarding oiled birds where recent research gives some hope of salvage if the right measures are taken.

In the New Zealand situation, the increase in tankers along the coast and the development of the Maui offshore field bring new potential hazards not considered when the New Zealand Committee on Pollution of the Sea by Oil was first established. In a field in which human error is still statistically more dangerous than mechanical failure or act of God, the record of offshore oil operations elsewhere, spillages at terminals and single buoy tanker moorings, not to mention the recent incidence of tanker mishaps, do not inspire confidence that it can never happen here but if we do have spills it is essential to have some idea of the precautions which are necessary to minimise their effects.

Even before the *Torrey Canyon*, a surprising number of papers had already been published on aspects of oil pollution but *Torrey Canyon* stands as a landmark for several reasons, not least the way it captured the public imagination. More important, it dramatically drew the attention of the scientific community to the dangers of large-scale spills and their wide-spread ecological ramifications and, most important of all, occurred fortuitously near the Laboratory of the United Kingdom Marine Biological Association at Plymouth. Here, as well as a team of skilled investigators immediately available to monitor the effects of the disaster, there were baselines from previous research. For that reason, *Torrey Canyon* papers feature prominently in any listing of work on oil pollution. Less well-known, but now equally well documented scientifically by Canadian workers, is the 1970 "Arrow" spill of Chedabucto Bay, Nova Scotia.

THE LITERATURE

This list does not pretend to be a complete bibliography. It was intended as an introduction to recent literature to give layman or scientist a quick entry to some of the more significant papers and the more useful general ones. It does not attempt to cover the very large field of fringe literature - toxicity testing of dispersants, for instance - and it omits some papers which largely repeat what has already been said elsewhere. Any selection of this kind is necessarily arbitrary but, generally speaking, papers have been chosen because they introduce or highlight some particularly noteworthy or useful aspect of the subject and this is frequently reflected in variations in the annotations from the authors' abstracts. The annotations themselves are not necessarily comprehensive and may emphasise rather minor findings to the exclusion of the more obvious conclusions because the obvious findings, while confirming or extending previous work do not necessarily introduce new ideas. Rather more references than originally planned are included because of the number of papers which have appeared after any of the available bibliographies.

Those wishing further reading on any aspect of oil pollution are referred to the bibliographies listed in this work and to the abstracting journals, *Oceanic Abstracts* and *Pollution Abstracts*. In addition to these, there is a new monthly publication, *Marine Pollution Research Titles*, from the Marine Pollution Research Centre at Plymouth and, for a more general approach, there is the *Marine Pollution Bulletin*.

A surprising amount of the literature on marine oil spills belongs to the underground scientific literature - manuscript reports (many of which, despite their relatively wide circulation to marine laboratories throughout the world, still claim to be unpublished), "one-off" pamphlets and reports, special numbers of journals not widely known or held and other restrictively circulated literature.

However, most of the items listed are available in New Zealand. While most of the books should be available from public libraries, the more scientific publications are held only in specialist libraries but can be obtained on interloan through the public library system.

Most symposia volumes are listed only under general title but where individual papers have made a significant contribution they have been separately listed with a back-reference to the main title.

References are arranged alphabetically under a number of subject headings, but there is naturally some overlap and, where appropriate, papers are cross-referenced under other topics.

D.E. Hurley

Books, Symposia and Reviews

[*See also* No. 52]

AMERICAN PETROLEUM INSTITUTE AND FEDERAL WATER POLLUTION CONTROL ADMINISTRATION [1970] [1]

"Proceedings. Joint conference on prevention and control of oil spills". *American Petroleum Institute Publication No. 4040* : x, 345 pp.

This conference was sponsored by the American Petroleum Institute and Federal Water Pollution Control Administration "to delineate the overall dimensions of the oil spills problem, explore the present state of the art of prevention and control of oil spills, and review the relevant research and development efforts of government and private industry".

Includes useful papers on U.K. methods for dealing with oil spillages (J. Wardley Smith), fluid dynamics of floating oil (Wicks), design requirements for booms (Lehr & Scherer), toxicity test procedure and evaluation, mechanical methods of oil collection ("Until something comes along that is better than straw, that is as cheap as, is practically universally available, presents no more difficult problems of dispersal or collection and has the capacity to adsorb up to five times its own weight without sinking, then we shall use straw and be grateful that we have it"), and microbial modification of crude oil in the sea. (ZoBell).

AMERICAN PETROLEUM INSTITUTE [1971] [2]

"Proceedings of joint conference on prevention and control of oil spills. June 15-17, 1971, Sheraton Park Hotel, Washington, D.C." American Petroleum Institute Washington, D.C. 544 pp.

Subdivided into sections on Laws and Enforcement; oil spill prevention, control and monitoring; treating agents; physical removal and containment; physical-biological effects and oil-spill clean-up. Includes a number of review articles and progress reports, papers on experimental work and equipment and clean-up and contingency plans (Alberta, California).

BARCLAY-SMITH, P. (Ed.) [1968] [3]

"International conference on oil pollution of the sea, 7-9 October 1968 at Rome. Report of proceedings." Sponsored by the British Advisory Committee on Oil Pollution of the Sea, the Italian National Committee on Oil Pollution of the Sea and the Nordic Union for the Prevention of Oil Pollution of the Sea. 414 pp.

Papers of varying length and importance discuss pollution especially around Italy, also other European countries and South Africa, biological aspects of spills including *Torrey Canyon*, seabirds and oil, measures to prevent tanker pollution, international and legal aspects of pollution, even the deleterious effects of detergent in the sea on coastal pine woods.

CARTHY, J.D.; ARTHUR, Don R. (Eds) 1968. [4]

"The biological effects of oil pollution on littoral communities". (Supplement to Volume 2 of *Field Studies*). Field Studies Council, London. 198 pp.

A scientific introduction to aspects of oil pollution. Deals with the technical background (chemistry of crude oils and seawater, detergents, absorption methods for cleaning up), effects on plant and animal communities including bird populations and shellfish beds, and microbiological aspects of oil pollution.

COMMISSION INTERNATIONAL POUR L'EXPLORATION SCIENTIFIQUE DE LA MER MEDITERRANEE. 1965. [5]

"Pollutions marines par les microorganismes et les produits petroliers. Paris. Symposium de Monaco (avril 1964)". Secrétariat, General de la Commission, Paris. 384 pp.

Account of a symposium at Monaco in April 1964. Contains several papers dealing with oil pollution at sea, refining wastes and effects on fish and molluscs.

COWAN, Edward. 1969. [6]

"Oil and water. The Torrey Canyon disaster". William Kimber, London. 252 pp.

A comprehensive general account from the chartering of the *Torrey Canyon* to the role of IMCO in preventing future mishaps.

COWELL, E.B. (Ed.) 1971. [7]

"The ecological effects of oil pollution on littoral communities". Institute of Petroleum, London. viii, 250 pp.

Proceedings of a symposium. The first part, "Studies on spillages and effects of remedial measures in salt marsh communities" is a series of papers by Jenifer M. Baker on the botanical effects of single and repeated spillages. "Zoological studies on shore communities" is, for the most part, a similar series of papers by Geoffrey B. Crapp on methods of monitoring, field and laboratory experiments with oil and emulsifiers and biological consequences of emulsifier cleaning.

Mechanical removal is recommended in preference to emulsification wherever possible. Second generation emulsifiers (e.g., BP 1100) are much less toxic than older products and thus allow beach cleaning without ecological disturbances; nevertheless, they cannot be recommended for unrestricted use.

DEVON TRUST FOR NATURE CONSERVATION LTD. 1967. [8]

Conservation and the *Torrey Canyon*. *Journal of the Devon Trust for Nature Conservation Ltd, Supplement, July 1967*. 72 pp.

Papers on biological effects of the *Torrey Canyon* and a longer paper (Manwell & Baker) on the wider issues of oil spillage, detergent use and politics of pollution.

DYE, Lee. 1971. [9]

"Blowout at Platform A". Doubleday and Company Ltd, New York. viii, 231 pp.

An unsympathetic account of the Santa Barbara spill in the context of American and oil industry politics. Very little on the physical effects of the spill or clean-up operations.

GILL, Crispin; BOOKER, Frank; SOPER, Tony. 1967. [10]

"The wreck of the *Torrey Canyon*". David Charles, Newton Abbot. 128 pp.

Basically a journalistic account, well-illustrated and still a good starting point.

HEPPLE, Peter (Ed.) 1971. [11]

"Water pollution by oil. Proceedings of a seminar held at Aviemore, Scotland ..." Institute of Petroleum, London. viii, 393 pp.

Papers on marine pollution deal with general aspects of marine spills, ballast and wash waters from tankers, pollution on and close to the shore, use of booms, degradation of oil at sea, *Torrey Canyon* effects in Brittany, Santa Barbara spill, *Hamilton Trader* spill, legal problems, and effects on marine plants and animals.

HOULT, David P. (Ed.) 1969. [12]

"Oil on the sea". Plenum Press, New York. 114 pp.

Subtitled "Proceedings of a symposium on the scientific and industrial aspects of oil pollution of the sea, sponsored by Massachussets Institute of Technology and Woods Hole Oceanographic Institution ...". Mostly short, generalised papers but contains a general account of the Santa Barbara spill and useful technical papers on the role of chemical dispersants in oil clean-up, the spread of oil slicks on a calm sea and a mathematical treatment of containment and collection devices for oil slicks.

MOSTERT, Noël. 1974. [13]

"Supership". Knopf, New York. 332 pp.

The rise of supertankers, their problems and dangers. During the first three months of 1974, there were 326 tanker casualties - when the *Taxanita* collided with the *Oswego Guardian* in 1972 it created an oil slick 65 miles long and 10 miles wide and when the 50,380 ton *Polycommander* ran aground off Spain and caught fire it raised a fire-storm which is considered responsible for a "black rain" several days later on the adjoining coastline. "The damage to homes, gardens and crops was extensive, and cattle died of eating oil-covered grass".

"Many instances have been reported of smaller ships trying to steer *between* the forward and after lights of a supertanker, on the natural assumption that the distance between the two indicated two different ships". The author argues that increased draught, lack of manoeuverability, and constructional and operational practices of supertanker operators make mishaps more likely than with conventional ships and these dangers will increase when supertankers reach their write-off life of ten years and are purchased by flag of convenience owners with less stringent standards. Docking facilities for damaged supertankers already raise problems and suspension of IMCO regulations to allow them to round South Africa on summer marks offers "the alarming paradox of a load-line convention suspended at the point of greatest danger".

Operational problems include boiler failure which "time after time has put oil cargoes in peril, especially in the South Atlantic and Indian Oceans" and many giant tankers have only one large high-pressure boiler unlike the 1950's when two or three were the practice. Provision of single screws only on supertankers presents another hazard. Added to this are failure of navigational equipment and the use of unqualified officers and engineers on ships under flags of convenience. Trans-shipment of oil from supertankers to more conventional ships at deepwater moorings is a potential and real source of chronic pollution capable of greater long-term damage than a large single inundation from a wrecked tanker.

[Extracts of this book appeared in *The New Yorker* for May 13, 1974 : 45-100 and May 20, 1974 : 46-99.]

NATIONAL BUREAU OF STANDARDS. 1974. [14]

"Marine pollution monitoring (petroleum). Proceedings of a symposium and workshop held at the National Bureau of Standards, Gaithersburg, Md., May 13-17, 1974. Sponsored by the Intergovernmental Oceanographic Commission (IOC-UNESCO), the World Meteorological Organisation, the U.S. Department of Commerce". *Special Publication National Bureau of Standards 409* : xvi, 316 pp.

Includes numerous short contributed papers on tar balls, sampling and monitoring of oil slicks, movement and fingerprinting of oil, and sampling and establishing levels of contamination in animals and sediments.

NELSON-SMITH, A. 1970. [15]

The problem of oil pollution of the sea. *Advances in Marine Biology 8* : 216-306.

A comprehensive and well-referenced review, which treats the subject under four heads.

Sources and control: Tanker operation, harbours and terminals, coastal industry and other sources. The largest and most dramatic spills are from tanker collisions and strandings; the major cause of oil-port spillage is human error and most terminals have an initial spate of minor incidents until the staff gain experience; most spillages at offshore terminals and moorings occur during transfer operations. Onshore, serious pollution incidents are rare. Discharges from refinery effluents, however, can appreciably affect vegetation and animal life and cause mud-flat erosion.

Properties of petroleum oils: Characteristics, behaviour when spilt, detection and identification.

Effects of oil pollution: Mode of action and toxicity, effects on individual groups (birds, mammals, fish, molluscs, other animals and plankton, and larger plants), effects on marine communities, carcinogenesis, rehabilitation of oiled birds, amenity and tourist aspects.

Removal of spilt oil: Bacterial degradation, dispersal, sinking and recovery, shore cleansing problems, action and toxicity of solvent emulsifiers.

NELSON-SMITH, A. 1972. [16]

"Oil pollution and marine ecology". Elek Science, London. ix, 260 pp.

A wide-ranging book which devotes introductory chapters to marine ecology and water pollution (including toxicity testing) and gives background information on the growing problem of oil pollution (growth of the petroleum industry, development of tanker-shipping, international control, offshore oil production, marine terminals). Other chapters deal with the properties of spilt oil, the effects of oil on marine organisms and on marine communities including bird populations and bird rehabilitation, economic and other effects of spills (fisheries, tourist industry, hazards to life and property). A final chapter deals with methods and organisation for cleaning up spills. A reasonably comprehensive general review of the subject which, to quote one reviewer, "inevitably reflects the short-comings of the literature. The investigations are of very uneven quality, reports may be preliminary notes or deal with finished, thorough pieces of work".

PETROW, Richard. 1968. [17]

"The black tide in the wake of the *Torrey Canyon*". Hodder and Stoughton, London. 256 pp.

A racy and comprehensive account commencing on the bridge of the *Torrey Canyon* before the impact. Discusses graphically both English and French aftermath and is particularly interesting on the politics of the clean-up. Valuable for its discussion of the social implications of the spill and especially the logistics involved in a clean-up operation of this magnitude drawing in everybody from troops through government departments and local bodies to underwriters, fishmongers and hoteliers.

POTTER, Jeffrey. 1973. [18]

"Disaster by oil. Oil spills : why they happen, what they can do, how we can end them". The Macmillan Company, New York. 301 pp.

What the publishers describe as "case studies" of the *Torrey Canyon, Ocean Eagle, General Colocotronis* and Santa Barbara disasters with a final chapter on the wider aspects of oil and the sea - Alaskan pipe-lines, tanker problems, politics of offshore drilling, pollution and clean-up. Narrative rather than scientific accounts.

SMITH, J.E. (Ed.) 1968. [19]

""Torrey Canyon" pollution and marine life. A report by the Plymouth Laboratory of the Marine Biological Association of the United Kingdom". Cambridge University Press, Cambridge. 196 pp.

The best scientific account of the *Torrey Canyon* and subsequent investigations. Details investigations at sea on the effects of oil and dispersants, and of subsequent treatment of rocky and sandy shores and estuaries, toxicity experiments, pattern of discharge and oil movements. Discusses effects on France and Guernsey and lessons learnt from spill. Good coloured illustrations.

STEINHART, Carol E.; STEINHART, John S. 1972. [20]

"Blowout. A case study of the Santa Barbara oil spill". Duxbury Press, North Scituate, Massachusetts and Belmont, California. 138 pp.

An in-depth attempt to provide "a balanced and comprehensive account of the Santa Barbara spill". As well as a chronological account, the authors give a background to the hazards and techniques of oil drilling, the geology and history of oil drilling in California, the ecological effects of the spill and subsequent research, and the wider geopolitics of oil, oil spills and energy conservation.

ZELDIN, Marvin. 1971. [21]

Oil pollution. Audubon Black Paper No. 1. *Audubon 73(3)* : 99-119.

A general account of marine oil pollution with interesting sections on the West Falmouth spill and on refinery spills including brief account of U.S. legal proceedings against oil companies for violations of offshore drilling rig and well regulations, "more than 1500 alleged offences", mostly relating to failure to have storm chokes "or similar subsurface safety devices" in operation.

Organisation and Decision-Making

[Readers are referred to early issues of the *Marine Pollution Bulletin* (old series) and its predecessor, *North-west Pollution Bulletin*, for detailed accounts of the regional organisations set up in the United Kingdom after *Torrey Canyon* to deal with future spills.]

[*See also* Nos 2, 16, 17, 41, 49, 79, 118, 170, 171]

CABINET OFFICE. 1967. [22]

"The *Torrey Canyon*. Report of the committee of scientists on the scientific and technological aspects of the *Torrey Canyon* disaster". H.M. Stationery Office, London. 48 pp.

The official report on the *Torrey Canyon* ... "to outline some of the lessons and to indicate the further enquiries which should be undertaken". Recommendations include recognition of the fact that "practically every issue on which decisions for action had to be taken during the period of crisis was at least partly of a scientific or technical nature. If another disaster on a corresponding scale occurs, we would, therefore, suggest ... that a team of scientists should be immediately appointed to co-ordinate scientific activity".

EVANS, Dale R.; RICE, Stanley D. 1974. [23]

Effects of oil on marine ecosystems : a review for administrators and policy makers. *Fishery Bulletin 73(3)* : 35-8.

Reviews a broad selection of recent oil spill literature. Most literature deals with catastrophic effects but any affected area will probably recover if oil is removed. Chronic low-level pollution is potentially more dangerous to the ecosystem as desirable species may be permanently removed and replaced by less desirable species.

[STANFORD, A.E.; JARVIS, B.N.] 1973. [24]

Clean-up plan for oil spillage. *Dock and Harbour Authority 53(630)* : 474-6.

Short resumé of U.K. thinking on best practicable methods. Recommends use of dispersants in open seas, mechanical removal in sheltered and sensitive areas. Contains basic contingency plan diagram.

ZUCKERMAN, Solly. [1968] [25]

The scientific approach to the problem of oil pollution. Pp 148-58 *in* BARCLAY-SMITH, P. (Ed.) "International conference on oil pollution of the sea. [*See* No. 3]

Includes Battelle Institute chart setting out inter-relationships of the various possible events involved in a spill and the choices open to the administrator.

Spills and their Treatment

[*See also* Nos 6, 8, 9, 10, 11, 12, 15, 16, 17, 18, 19, 20, 21, 64, 144, 150]

ALLAN HANCOCK FOUNDATION, UNIVERSITY OF SOUTHERN CALIFORNIA. 1971. [26]

Biological and oceanographical survey of the Santa Barbara Channel oil spill 1969-70. *Allan Hancock Foundation, University of Southern California, Sea Grant Publication No. 2* : 426 and 477 pp.

Volume 1 deals with biology and bacteriology and includes papers on zooplankton and benthos, sandy beaches, bacterial populations of bottom sediments, subsequent breeding and larval settlement of invertebrates, effects on birds and sea mammals, and discussion of after-effects. One explanation for a less-than-expected effect was the possibility that the biota of the area had a high tolerance to oil built up by long continued exposure to oil from natural seeps.

Volume 2 deals with physical, chemical and geological studies. Topics include the physical characteristics of the sandy beaches, foraminiferal populations, hydrocarbon content of channel sediments and nearshore sediment characteristics.

ALPINE GEOPHYSICAL ASSOCIATES, INC. 1971. [27]

Oil pollution incident Platform Charlie, Main Pass Block 41 field, Louisiana. *Environmental Protection Agency, Water Pollution Control Research Series 15080 FTU 05/71* : 134 pp.

Wells on Chevron Oil Platform Charlie were out of control for eight weeks in February and March 1970, but until the fire was put out after the first month almost all oil was burned. Spills only commenced seriously when the fire was put out. 35,000 to 65,000 barrels of extremely light gravity oil (about 36 API) were estimated spilled. Corexit and Cold Clean dispersants were used and skimmers, barges and booms; the best of these devices were "home-made" at the scene. No acute biological damage was reported. The report summarises the history of the spill and describes the movement and behaviour of the oil. The oil plume was almost always observed to leave the platform in the same direction as the wind. Old oil appeared to disappear after two days but this could have been due to its moving off to sea and not being noted or to rapid spreading aiding dispersion and hindering observation. Details of various booms used are given; the most effective was constructed on the scene from 55-gallon drums and a fabric skirt (Fasilon canvas) at 20-25 ft/hr at an estimated cost of $15 per foot.

Oceanographic and biological background is detailed.

BARBER, F.G. 1971. [28]

An oiled Arctic shore. *Arctic 24(3)* : 229.

A mixture of diesel fuel and a heavier fuel, light enough to penetrate gravel, occurred in the harbour at Resolute in August 1970. About three inches penetration was observed. The oil was contained by ice cover but clean-up options were waived to observe effects on sheltered shore at high latitude.

BLACKMAN, R.A.A.; BAKER, Jenifer M.; JELLY, J.; REYNARD, Susan. 1973. [29]

The *Dona Marika* oil spill. *Marine Pollution Bulletin 4(12)* 181-2.

A spill of 3,000 tons of petrol from the tanker *Dona Marika* which ran aground in Milford Haven, noteworthy because a spill of refined products of this magnitude is unusual in U.K. waters. The spill occurred over two periods of about 48 and 36 hours into a small area of enclosed bays during high winds and heavy seas and showed that the petrol did not behave as a non-persistent oil but formed water-in-oil emulsions before much evaporation could take place.

Thick yellow to deep rusty red slicks of emulsified residues were due solely to petrol and not to heavier oils. The initial effect on littoral mollusca was narcotic rather than lethal. Sublittoral effects observed were narcotised molluscs and large numbers of dead *Echinocardium*. Death of molluscs resulted from prolonged anaesthesia or from predation by gulls. There was no evidence of significant accumulation of lead from included additives and no obvious traces of petrol remained on rocks one week later but four weeks later there was a significant growth of *Enteromorpha* following the limpet kill.

CABIOCH, L. 1971. [30]

The fight against pollution by oil on the coasts of Brittany. Pp 245-9 (Discussion 251 - 6) *in* HEPPLE, P. (Ed.) "Water pollution by oil".

[*See* No. 11]

The affected coast included the Roscoff Biological Station "in a natural zoological and botanical park of exceptional richness" and extremely valuable oyster beds, as well as many holiday resorts and beaches. Detergents were used for tourist areas, steam cleaning in the vicinity of oyster beds. Polyurethane booms with straw jackets and jute coverings proved successful for sheltered areas. At sea, 3,000 tons of powdered stearated chalk were used to precipitate oil and 2,000 tons of oil were recovered by pumping into a specially fitted vessel.

CABIOCH, L.; LACASSAGNE, M. 1969. [31]

How Roscoff won the *Torrey Canyon* 'battle'. *Dock and Harbour Authority 50(583)* : 6-8.

Description of boom prevention measures which successfully kept Roscoff port and foreshore clear of oil. Booms were essentially made from straw, fishing netting, jute sacking or flexible pvc squares. Expanded polyurethane was used for floats and concrete-filled packing cases for mooring weights.

CERAME-VIVAS, M.J. 1969. [32]

The wreck of the *Ocean Eagle*. *Sea Frontiers 15(4)* : 224-31.

Oil from tanker landed on tourist industry beaches. Non-detergent cleansers tried included sugar-case bagasse (useless), talc (ineffective when left in sun), vermiculite (no affinity for oil) and perlite (effective).

COMMISSION INTERMINISTERIELLE. 1968. [33]

"Le sinistre du *Torrey Canyon*. Rapport rédigé par les membres de la Commission Interministerielle chargée de la lutte contre la pollution provoquée par le naufrage du *Torrey Canyon*". La Documentation Française, Paris. 48 pp.

The *Torrey Canyon* as it affected French coasts. Intended for general readers, has particularly good illustrations of the extent of pollution and of clean-up measures.

COOPER, L.H.N. 1968. [34]

Scientific consequences of the wreck of the "Torrey Canyon". *Helgoländer wissenschaftliche Meeresuntersuchungen 17(1-4)* : 340-53.

Drift of oil was directly ahead of wind at 3.3 per cent of the wind speed; where known, strong surface currents should be added vectorially to the calculated wind drift. French treatment included the use of "craie de champagne", French blackboard chalk consisting of calcium carbonate treated with 1 per cent sodium stearate. 3,000 tons were used on ten times the weight of oil present (as oil-in-water emulsion) and prevented it coming ashore. None appeared to sink to the bottom in the area but dispersal may also have been assisted by blooming of the flagellate, *Noctiluca miliaris*, which may have eaten almost all of the dispersed oil.

DEDERA, Don. 1970. [35]

Santa Barbara and beyond. *Oceans Magazine 3(3)* : 17-32.

Illustrated popular account of Santa Barbara spill, its politics and social effects. "In the end, ten thousand truckloads of common barnyard straw proved to be the best treatment".

EDMISTON, Ken. 1971. [36]

Shell fire dying peacefully. *Ocean Industry 6(3)* : 36-41.

Fighting the Bay Marchand blow-out used 650 men and cost $210,000 a day for relief well and clean-up operations. Ten wells were killed and four jack-up rigs and a submersible used to drill ten relief wells. A fireboat was required to fight secondary fires. The escaping oil, mostly in slicks 1/10,000 in. to 1/100,000 in. thick, was sprayed with chemical agent ("Oil Herder") and dispersants and various skimmers and booms were used. "Oil blotters" attached to hurricane fence were erected across Bay Champagne entrance to prevent oil entering and straw filled sacks, floated in oil until saturated, were used to soak up oil reaching the shore.

FOSTER, M.; CHARTERS, A.C.; NEUSHUL, M. 1971. [37]

The Santa Barbara oil spill. Part 1 : initial quantities and distribution of pollutant crude oil. *Environmental Pollution 2(2)* : 97-113.

Estimates from intertidal oil samples and aerial photographs indicate 4,500 metric tons of crude oil were deposited on nearly 90 km of beach 11 days after the spill began. 2.7 to 118.1 metric tons/km landed in the intertidal zone suggesting a well flow rate of around 5,000 barrels or 726 metric tons/day during early stages of the spill. Instead of the expected movement of oil relative to water of 3.3 to 3.4 per cent of the relative wind vector, it appears to have been from 10 to 20 per cent but there were two severe storms during this period. Much of the oil was held for varying periods in the surface canopies of offshore kelp beds.

HERLINVEAUX, R.H. 1972. [38]

Preliminary report on the oil spill from the grounded freighter "Vanlene". March 1972. *Pacific Marine Scientific Report 72-11* : 11 pp, illustrations.

Discusses preventative measures on small spill of 400 tons of Bunker B oil, diesel fuel and lubricating oil. In open coastal areas, booms used in attempt to corral oil were effective only as deflectors, and "slicklickers" were of little use.

GLUDE, J.B. 1968. [39]

Observations on the effect of oil from the tanker *Ocean Eagle* and oil control operations on the fisheries of San Juan, Puerto Rico. Unpublished report. Bureau of Commercial Fisheries, Seattle. 42 pp.

The *Ocean Eagle* stranded at the entrance to San Juan Harbor, March 4, 1968, spilling an estimated two million gallons of Venezuelan crude. Dispersants applied included "Wyandotte No. 20", "Murati", and "Polycomplex A-11"; perhaps 9,000 to 13,000 gallons of dispersant chemicals containing petroleum were used in all. Most stranded oil was treated with a talc, "Mistron Vapor", and scooped or raked into containers. A small amount was trapped in pits and pumped out. Test applications with "Ekoperl", a silicone-treated perlite, were "moderately effective" with no apparent ill-effects on animal life. "Ekoperl" is spread on slicks to adsorb or absorb oil. "It is reported to be easier to collect ... from the surface or from beaches than ... untreated oil". Booms proved ineffective but a small oil-skimmer showed promise.

Chemical solvent emulsifiers were used by hoteliers on resort beaches with apparent initial success but the owners subsequently regretted the use of chemicals since they had to replace treated sand which had become soft and "quick" to a depth of five inches.

Oil or, more probably, chemicals, appeared to cause some mortality to anchovies and oil was blamed for many dead sea urchins and affected fiddler crabs (*Uca*), making them lethargic and unreactive to stimuli, but there were later indications of a high rate of survival. The 400 to 500 pelicans in the harbor were expected to be adversely affected. Commercial fishing was temporarily suspended for fear that nets and gear would be fouled and the catch contaminated.

KELLER, A. 1968. [40]

Bahama beaches saved from pollution. *Dock and Harbour Authority 49(573)* : 100-2.

Account of clearance measured used in *General Colocotronis* spill involving 3,000 tons of heavy fuel oil.

[McTAGGART-COWAN, P.D.; SHEFFER, H.; MARTIN, M.A.] 1970. [41]

"Report of the Task Force-Operation Oil (Clean-up of the Arrow oil spill in Chedabucto Bay) to the Minister of Transport". 3 volumes. Information Canada, Ottawa. 41, 104, 183 pp.

This is the official 3-volume report on the *Arrow* spill off Nova Scotia in February 1970.

Volume 1 is essentially the administrative report and includes an account of the spill and subsequent action, breakdown of costs incurred in the clean-up, a listing of other known Canadian spills, and conclusions and recommendations of the task force which refer especially to legislation and practice in the shipping and containment of oil; to areas of responsibility; federal, industrial and scientific preparedness; need for a contingency plan and its essential components, and aspects of community and public relations.

Volume 2, the report of the scientific coordination team, deals with the physical environment; the distribution and behaviour of the oil; properties of Bunker C oil, its behaviour in sea-water emulsion and subsequent weathering; details the ecological effects of the oil on marine organisms, wildlife and sheep; the containment, removal, absorption, dispersal and disposal of oil; the measurement and removal of oil in the wreck, and the clean-up procedures and their effectiveness. There is a final 8-page section on conclusions and recommendations. This volume is the significant scientific section, and is of equal importance with the Plymouth report on the *Torrey Canyon*. Novel features are brief discussions on the use of peat moss as an absorbent and peat moss booms, and "the conifer boom", a vertical wire mesh covered with spruce boughs which was effective in preventing the entrance of oil into a number of unpolluted embayments with entrances as wide as 1,000 feet. An unusual hazard was oil contamination of seawater used in fish-processing plants. Oil-burning tests were carried out and a satisfactory oil-skimmer, the "oleovator" or "slick-licker" was used extensively, to remove oil, oil mixed with seawater and other debris from the surface of the water. Promising trials were also made with a fine mesh (5/8 in.) seine net to contain Bunker C oil.

Volume 3 contains the report of the Task Force Operations Officer (communications, transport, logistics), the meteorological report, reports on oil reconnaissance, cargo salvage operations, diving operations, seine net for containing slicks, seawater filtration plant for fish-processing plants, plans for a "fish-gear laundromat", and reports on absorbents, slick-lickers and steam cleaning of docks and jetties.

NEWELL, B.S.; TRANTER, D.J. [1970] [42]

"Oil pollution from the tanker 'Oceanic Grandeur'". Unpublished report. CSIRO, Division of Fisheries and Oceanography, Cronulla, N.S.W. 19 pp.

Illustrated mimeographed report of stranding of *Oceanic Grandeur* near Thursday Island, March 3, 1970. Good weather and skilful ship handling prevented a major disaster. Oil spills were relatively small and effects minimal although some grass and beach vegetation were "burnt" by stranded oil. Use of "Corexit" was discontinued because of claims it had no visible effect on oil patches and "Sea-clean" and "Gamosol" used. Authors argue that with prevailing good weather it would have been better to have attempted containment of escaping oil around ship and salvage rather than spraying, particularly in view of cost of detergents and spraying operations. Plankton samples from under oil slicks and in wake of detergent spraying showed no adverse effects although later microscopic examination revealed appendages of some organisms fouled with oil droplets.

O'SULLIVAN, A.J. 1971. [43]

Some aspects of the *Hamilton Trader* oil spill. Pp 307-16 *in* HEPPLE, P. (Ed.) "Water pollution by oil".

[*See* No. 11]

Following a collision with the *Hannes Knuppel*, the tanker *Hamilton Trader* lost 500 to 600 tons of fuel oil in Liverpool Bay. A 3-mile long, 1-mile wide slick on the first day had broken by the third day into patches about 10 feet across; and after 7 or 8 days was in lumps rather than patches, stiffer and waxy in consistency. Some "Corexit 7664" was used. "It was later stated by Esso that Corexit 7664 would not destroy patches or lumps of oil but would merely break them up into smaller pieces".

OWENS, E.H. [1972] [44]

The cleaning of gravel beaches polluted by oil. *Proceedings of the Thirteenth Coastal Engineering Conference, July 10-14, 1972, Vancouver, B.C., Canada. Vol. 3* : 2549-56.

Following the *Arrow* spill in Chedabucto Bay, beaches were cleaned without dispersants. Sandy beaches were cleaned manually with peat moss, rakes and shovels, and oil was removed with relative ease, care being taken to minimise damage to backshore vegetation by vehicles reaching the beach. Attempts to clean gravel beaches mechanically involved excavating deeper than one metre and here 3 to 6 cubic metres were removed from each linear metre of beach, mostly near or above high water level. Removal from this zone is undesirable because natural replacement of material is slow and may endanger beach stability. In one cove, removal of sediment enabled waves to wash over the crest of the beach resulting in its retreat by 20 metres in 12 months.

PILPEL, Neiton. 1967. [45]

Oil pollution of the sea. *Science Journal 3(6)* : 73-80.

An illustrated account and evaluation of *Torrey Canyon* preventative and clean-up measures. Useful introduction to chemistry of oil on seawater.

ROBERTSON, D.R. 1970. [46]

The 'Oceanic Grandeur' incident. *Newsletter of the Queensland Littoral Society No. 37, March-April 1970* : 17-25.

On March 3, 1970, the tanker *Oceanic Grandeur* struck an uncharted rock in Torres Strait releasing 1,000 to 3,000 tons of oil in the initial collision and smaller quantities in later spills. These were treated with surfactant ("Gamlen" and "Corexit 7664"). Strong tidal currents carried slicks past rather than onto nearby islands and virtually no damage to marine life was observed.

SIMPSON, A.C. 1968. [47]

The *Torrey Canyon* disaster and fisheries. *Laboratory Leaflet, Ministry of Agriculture, Fisheries and Food (new series) 18* : 43 pp.

Details quantities and types of detergents used. Adverse effects on fisheries were small but some tainting of fish and lobsters occurred probably due to detergent rather than oil. Sufficient crab tainting occurred to stop the fishery for 2 to 3 weeks in one area. Damage to shore life and tainting would have been 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 the instructions".

STANDER, G.H. 1968. [48]

Oil pollution off the S.A. coast : the "World Glory" disaster. *South African Shipping News and Fishing Industry Review, 23(11)* : 47, 49, 51.

World Glory broke up off Durban, 13 June 1968, carrying 45,572 tons of crude oil. Estimated that up to 15,000 tons were released initially but the bulk probably reached the surface eventually. Initial aerial spraying with non-toxic detergent was moderately successful, but later up to 12 ships were expending 20,000 gallons of non-ionic detergents per day, from

18 June to 2 July. There was no significant evidence of mortality to animals : zooplankton from 2 metres below the surface, in areas of heavy detergent dosing, was generally alive. No oil reached beaches.

STANDER, G.H.; VENTER, J.A.V. [1968] [49]

Oil pollution in South Africa. Pp 251-59 *in* BARCLAY-SMITH, P. (Ed.) "International conference on oil pollution of the sea ..."

[*See* No. 3]

Resumé of South African spills and subsequent action - cleaning-up, detergents, legislation and thinking. Spills include the *Sivella*, grounded off Cape Town, February 1968; the *Esso Essen*, tanks ruptured off Cape Peninsula, April 1968; the *Andron*, which sank off South-West Africa, May 1968; and the *World Glory*, 65 miles north-east of Durban, which broke in two releasing at least 20,000 tons of oil, the bow section sinking 40 miles south of the stern. "The heavy pollution [from the *Andron*] created problems to firms collecting this material for the production of alginates".

Crop-spraying aircraft and ships have been used and experience is that suitably-equipped ships are the most effective, "if not least expensive". With larger ships, 45-gallon drums have been replaced by 500-gallon "farm tanks" tack-welded to decks or lashed in position and refilled from bulk-carriers. Guidance of spraying ships by aircraft to by-passed slicks has been found most effective. Grossly contaminated beaches have been left untreated where amenity value did not justify cleaning.

Oil and Seawater

[*See also* Nos 4, 15, 16, 29, 41, 43, 45, 61, 129]

PILPEL, Neiton. 1968. [50]

The natural fate of oil on the sea. *Endeavour 27(1)* : 11-13.

Natural processes removing oil from the sea include evaporation, formation of emulsions, sinking, auto-oxidation and oxidation by micro-organisms, the last being the most effective, destroying some hundreds of grams per cubic metre of contaminated ocean per year. Oxidation can be increased by adding nitrogen and phosphorous nutrients.

WILSON, R.D.; MONAGHAN, P.H.; OSANIK, A.; PRICE, L.C.; ROGERS, M.C. 1974. [51]

Natural marine oil seepage. *Science 184(4139)* : 857-65.

Petroleum seepage into the marine environment from natural sources is estimated to be of the order of 0.6 x 10^6 metric tons per year, mostly along continental margins where a certain minimum thickness of sediment is exceeded. Seepage rates have a log-normal distribution and seepage is primarily dependent on area of rock available for fracture and faulting, not of oil or sediment volume.

ZoBELL, C.E. 1964. [52]

The occurrence, effects and fate of oil polluting the sea. *In* PEARSON, E.A. (Ed.) *Advances in Water Pollution Research. Proceedings of the International Conference held in London, September 1963, Vol. 3.* : 85-109, (Discussion : 110-18).

[Also in *Contributions from the Scripps Institution of Oceanography 34* : 1257-92.]

A very good general review. "In the marine environment, oil persists only when protected from bacterial oxidation ... oil might be oxidised in the sea at rates as high as 100-960 mg/m^3 day or 36-350 g/m^3 per year.

Detection of Oil in Seawater and in Organisms

[*See also* No. 15]

AXELSSON, S.; OHLSSON, E. 1973. [53]

Remote sensing of oil slicks. *Ambio 2(3)* : 70-6.

Review of air-borne remote sensing techniques for detecting and measuring slicks. Best results for measuring extent of slicks are ultraviolet in sunshine, near infra-red in cloudy weather, green band for thickness. Low light television or thermal infra-red equipment permits operation at night.

ESTES, J.E.; COLOMB, B. 1970. [54]

Oil spills : method for measuring their extent on the sea surface. *Science 169(3946)* : 676-8.

Infra-red images are processed through a Datacolor system which allows selected density values to be enhanced and others to be suppressed giving a display in any desired combination of three colours. Colour enhancement allows "identification of any oil patches, slicks and films that show even minor differences in density from the background water". Coupled with a digital planimeter any one or any combination of the ten basic colours can be quickly measured as a percentage of the total area. The system uses stock commercial components.

HOLLINGER, J.P.; MENNELLA, R.A. 1973. [55]

Oil spills : measurements of their distributions and volumes by multi-frequency microwave radiometry. *Science 181(4094)* : 54-5.

Using this aircraft-borne technique, it was possible to estimate the amount of oil in pre-measured spills to within about 25 per cent of volume spilled.

MILLARD, J.P.; ARVESEN, J.C. 1973. [56]

Polarization : a key to an airborne optical system for the detection of oil on water. *Science 180(4091)* : 1170-1.

Airborne infra-red photographs of spills can be enhanced by using cameras equipped with polarising elements which help to distinguish thin slicks.

NOBLE, V.E. 1972. [57]

Multi-spectral remote sensing for monitoring of marine pollution. Pp 500-5 *in* RUIVO, M. (Ed.) "Marine pollution and sea life". Fishing News (Books) Ltd, West Byfleet and London. 624 pp.

Experience from the Santa Barbara spill and other experiments demonstrate the feasibility of using airborne equipment to detect oil slicks. A multi-lens camera, thermal (8μ to 13μ) radiometer and ultra-violet radiometer (0.32μ to 0.38μ) will provide flexible capability for measuring water colour and detecting oil slicks. (Thermal infra-red detects the thick portion of slicks, ultra-violet detects thin oil films and oil-dispersant mixtures.) An alternative to multi-lens camera is a 70 mm strip camera to record flight tracks and a 5 in. film serial camera using either standard aerial colour film or false-colour infra-red film.

SWABY, L.G.; FORZIATI, A.F. [1970] [58]

Remote sensing of oil slicks. Pp 297-307 *in* American Petroleum Institute and Federal Water Pollution Control Administration, "Proceedings. Joint conference on prevention and control of oil spills".

[*See* No. 1]

Review of methods of remote sensing. Illustrated with data from the Santa Barbara spill.

ZITKO, V. 1970. [59]

Determination of residual fuel oil contamination of aquatic animals. *Bulletin of Environmental Contamination and Toxicology* 5 : 559-64.

A simple spectrofluorometric method for the quantitative determination of uptake, excretion and metabolism of heavy residual fuel oil (Bunker C) in aquatic animals.

Movement of Oil and Oil Slicks

[*See also* Nos 12, 27, 34, 37, 41, 46, 118, 170]

AGES, A.B. 1972. [60]

The "Vanlene" accident, March 1972. *Pacific Marine Science Report 72-4* : 12 pp, illustrations.

Discusses physical spread of 400 tons of Bunker B oil in Barkley Sound off Vancouver Island. Includes formula for effectiveness of booms based on current velocity and depth of water.

FORRESTER, W.D. 1971. [61]

Distribution of suspended oil particles following the grounding of the tanker *Arrow*. *Journal of Marine Research 29(2)* : 151-70.

Small particles (5μ to 1 or 2 mm) suspended in the water column are believed formed mainly by wave and surf action, possibly influenced by the spraying of 10 tons of dispersant to at least 80 m depth in places, and provided an excellent tracer for near-surface current and drift. Drift at an average rate of 8 km/day corresponded with known drift rates from drift bottle studies.

McINTYRE, William G. *et al*. 1974. [62]

Investigation of surface films - Chesapeake Bay entrance. *Environmental Protection Technology Series EPA-670/2-73-099* : 168 pp.

A nine-author work included here because of Appendix A : "Program description for oil slick motion", an IBM 1130 computer programme which computes current paths from wind and tidal data and predicts the movement of surface water masses or oil slicks where the movement is due to wind and surface tidal currents. Other sections deal with initial aging of oil films on sea water, remote sensing of oil slicks, phytoplankton in surface slicks and in adjacent subsurface and non-slick water and the biological effects of a No. 6 fuel oil spill on a salt marsh near the Amoco Refinery at Yorktown, Virginia, where *Spartina alterniflora* leafblades were killed, apparently by respiratory failure, but rhizomes survived and produced new shoots within the month.

MURRAY, Stephen P. 1972. [63]

Turbulent diffusion of oil in the ocean. *Limnology and Oceanography 17(5)* : 651-60.

Observations from the Chevron spill have allowed evaluation of large scale turbulence (in the form of a horizontal eddy diffusivity) and surface tension effects in the spreading of oil from a continuously emitting source into a steady current. The initial outline of the slick follows the laws of expansion as predicted by Taylor's turbulent diffusion theory; the gross size and overall shape of the slick can be successfully predicted with a simple Fickian diffusion model. The slick geometry is a function of current speed, horizontal eddy diffusivity, oil discharge rate, and an empirically determined constant (the boundary concentration). Surface tension effects are confined to the first few hundred metres downslick and can probably be neglected for practical purposes under moderate oil discharge rates and current speeds as low as even 5 cm/sec.

MURRAY, S.P.; SMITH, W.G.; SONU, C.J. 1970. [64]

Oceanographic observations and theoretical analysis of oil slicks during the Chevron Spill, March 1970. *Technical Report Coastal Studies Institute, Louisiana State University 87* : 106 pp.

Chevron production platform off Mississippi Delta caught fire on February 10, 1970. Although extinguished March 10, oil spills continued for about a month until all wells were capped. Escaping oil during the fire was estimated at 1,000 barrels per day, most of which was burned, but light slicks were caused by hosing the platform during this period.

Oceanographic monitoring included current observations, at surface and depth, temperature, salinity, wind, tides, wave height and wave period and slick observations. Strong winds reduced the amount of oil reaching the shore, and at least once a week generated waves of 2 to 4 feet. Stirring and mixing caused by such waves were significant in breaking up and diffusing oil slicks. Interfaces between river-derived and marine water masses acted as barriers to oil movement and large river discharges deterred movement of oil into the marshes.

Tidal currents produced L-shaped oil slick geometry because of current rotation, and slick movement was generally associated with wind direction. Most oil reached shore during strong winds from well to land, the oil spilling directly on to a thin freshwater layer on the surface which allowed it to reach shore without difficulty.

Slick shapes and orientations were often controlled by convergent rip lines or zones separating waters of brackish and normal salinity; these often formed natural barriers preventing oil moving ashore. Slicks separate into independent patches when they meet transverse shear because of wind blowing across it.

Theoretical analysis showed that for a given spill, current speed largely determines the size a slick will reach, the ratio of diffusion coefficient to the rate of oil discharge controls the shape of the slick, high discharges produce elongate slicks. Consistently high current speeds during the Chevron spill kept the slick size minimal and greatly enhanced an oil diffusion rate.

MURTY, T.S.; KHANDEKAR, M.L.; RAO, G.V. 1974. [65]

The movement of oil slicks. *Rapports et Proces-Verbaux des Reunions 167* : 66-74.

The movement of oil slicks is studied using a mainly numerical approach. Oil slicks show strong resemblances to wind streaks but may also appear in more or less circular forms resembling some iceberg patterns. Slicks could be visualised as a set of rectilinear vortices and this possibility is given mathematical treatment. There is also strong evidence that the presence and movement of oil slicks over water is somewhat similar to frontal motion and the point is made that slight differences in the density difference between oil and water and the frontal slope could cause drastically different patterns of vertical motion.

NEU, H.A. 1970. [66]

The hydrodynamics of Chedabucto Bay and its influence on the "Arrow" oil disaster. *Atlantic Oceanographic Laboratory, Bedford Institute. Report. AOL 1970-6.* viii, 68 pp.

Influence of wind, waves, tides, density differences and seiche movements are discussed in relation to oil movement. Prediction of oil movement from these factors immediately following the spill was verified by its subsequent course.

RIDGWAY, N.M. 1972. [67]

Direction of drift of surface oil with wind and tide. *New Zealand Journal of Marine and Freshwater Research 6(1 & 2)* : 178-84.

Movements of oil slick from the wreck of the *Wahine* agreed with those predicted from vectorial addition of wind-induced surface currents and tidal currents. The method can be used to predict the movements of surface oil on seawater.

TAYFUN, Mehmet A.; WANG, Hsiang. 1973. [68]

Monte Carlo simulation of oil slick movements. *Journal of the Waterways, Harbors and Coastal Engineering Division, ASCE 99(3)* : 309-24.

Methods for forecasting the movement of oil slicks "under the action of deterministic water currents and random wind effects", using random walk and time series models.

Oil Dispersants and their Toxicity

[*See also* Nos 2, 7, 12, 15, 19, 27, 39, 42, 46, 47, 48, 78, 114, 138, 140, 141]

AVOLIZI, R.J.; NUWAYHID, M. 1974. [69]

Effects of crude oil and dispersants on bivalves. *Marine Pollution Bulletin 5(10)* : 149-53.

Corexit 7664, which is considered one of the low-toxicity dispersants, was found to be lethally toxic to the mussel, *Brachidontes variabilis*, and also interfered with the mussel's ability to produce normal byssus thread. This would make mussels on wave-swept beaches vulnerable to being swept away.

BLACKMAN, R.A.A. 1974. [70]

Toxicity of oil-sinking agents. *Marine Pollution Bulletin 5(8)* : 116-18.

Wetting agents and solvents used to make sand slurry oleophilic in order to sink oil are unlikely to have toxic effects and the risk of harmful effects can be reduced by careful selection of the agent used. Of those tested, "Armac T" in ethylene glycol was the least toxic combination.

JEFFERY, P.G.; NICHOLS, J.A. 1974. [71]

Dispersants for oil spill clean-up operations at sea, on coastal waters and beaches. [*Report*] *Warren Spring Laboratory LR 193(OP)* : 14 pp.

Specifications for low-toxicity, high flash-point dispersants for use in oil spill clean-up operations at sea and other tidal waters and beaches but not for land spills or freshwater use. Includes list of U.K. dispersants meeting specifications (January 1974) and their manufacturers.

PERKINS, E.J.; GRIBBON, E.; LOGAN, J.W.M. 1973. [72]

Oil dispersant toxicity. *Marine Pollution Bulletin 4(6)* : 90-3.

Toxicity tests of BP 1100X and Shell Dispersant LT show these are of low toxicity to a wide variety of marine animals and some three orders of magnitude less toxic than the dispersants used at the time of *Torrey Canyon*. Unlike earlier dispersants, the low toxicity emulsifiers are not believed to induce long term effects upon growth and mortality of treated animals.

Clean-up Procedures

[*See also* Nos 1, 2, 4, 7, 12, 15, 18, 19, 24, 27, 30, 31, 32, 33, 34, 35, 36, 39, 40, 41, 44, 45, 47, 48, 49, 71, 117, 120, 172]

BEYNON, L.R. 1967. [73]

"The *Torrey Canyon* incident. A review of events". British Petroleum Company Limited, London. 20 pp, illustrated.

Review of spillage, measures to combat it and their effectiveness and effect on shores and birds. Striking coloured pictures.

BEYNON, L.R. 1967. [74]

Lessons of the *Torrey Canyon*. *B.P. Shield No. 10, October 1967* : 24-9.

Brief well-illustrated account; discusses briefly burning of oil on water and on shore.

BEYNON, L.R. 1968. [75]

Cleaning up. *Hydrospace 1(2)* : 17-27.

Illustrated review of cleaning-up methods in the light of the *Torrey Canyon*. If salvage is not possible, treatment at sea with detergent is desirable. Absorbent materials can be used effectively in sheltered waters and straw has the advantage of being easily disposed of by burning. In principle it is best to remove oil from a beach rather than attempt to clean it. Detergent cleaning to any depth leaves a beach "soft and soggy and extremely difficult to work on" and the beach "feels and smells objectionable". Detergent must never be applied without turning over the oil/sand mixture and following with a water wash within one hour. Not following with water usually causes the oil to penetrate more deeply. For rocks and walls, burning is not very satisfactory, and it is better to use high pressure steam, if available, or detergent-spraying followed within a few minutes by high-pressure water-spraying.

CROSS, Ralph; ROBERTS, Archie; CUNNINGHAM, John; KATZ, Bernard. 1973. [76]

Oil spills control manual for fire departments. [*Report*] *Environmental Protection Agency EPA -R2-73-117* : 98 pp.

Methods for containing and recovering floating oil, and using fire hoses to control spills. Essentially a compilation of items 80, 81, 93 and 99 with some additional information.

DUDLEY, G. 1968. [77]

The problem of oil pollution in a major port. Pp 21-9 *in* CARTHY, J.D.; ARTHUR, D.R. (Eds) "The biological effects of oil pollution on littoral communities".
[*See* No. 4]

Discusses oil pollution measures in the large oil port of Milford Haven. Pollution should be dealt with before it reaches the shore; the most successful method is spraying with emulsifier and leaving for a minute or so before agitating vigorously with a water jet. Applying detergent in aqueous solution as foam is introduced into a fire-fighting branch pipe is much less efficient and extremely wasteful of detergent.

GAINES, T.H. [1970] [78]

Pollution control at a major oil spill. Pp 271-80 *in* American Petroleum Institute and Federal Water Pollution Control Administration "Proceedings. Joint conference on prevention and control of oil spills".

[*See* No. 1]

Clean-up procedures used in Santa Barbara spill. Performance of Corexit, Polycomplex and Arachem Goldcrew dispersants evaluated. Appendix includes inventory of equipment used. Cost of clean-up estimated at more than $4,500,000.

GILMORE, George A.; SMITH, David D.; RICE, Alan H.; SHENTON, E.H.; MOSER, William H. 1970. [79]

"Systems study of oil spill cleanup procedures". Dillingham Environmental Company, Washington. 89 and 110 pp, appendices.

Volume 1. "Analysis of oil spills and control materials" discusses past spills, physical factors affecting spills and effect of oil on organisms and environment. Includes discussion of mechanical containment devices, recovery devices, sinking materials, chemical treatment and makes some evaluation. Useful appendices include data sheets on previous spills, control action taken and commercial sources for materials discussed.

Volume 2. "Industry response plan" is a model operations plan - organisation, logistics, methods of cleanup and shore protection and estimates of cost.

KATZ, Bernard; CROSS, Ralph. 1973. [80]

Use of fire streams to control floating oil. [*Report*] *Environmental Protection Agency EPA-R2-73-113* : 36 pp.

How to use high pressure fire hoses to control floating oil.

KATZ, Bernard. 1973. [81]

Removal of oil from under piers. [*Report*] *Environmental Protection Agency EPA-R2-73-116* : 29 pp.

How to flush oil from under piers using artificial currents generated by fire hose streams and prop wash for subsequent pickup.

KLUSS, W.M. [1968] [82]

Avoiding accidental sea pollution from tankers. Pp 167-83 *in* BARCLAY-SMITH, P. (Ed.) "International conference on oil pollution of the sea ..."

[*See* No. 3]

What to do from the master's point of view in the event of a tanker spill and techniques for removal of the oil from the stranded vessel.

MILZ. E.A. 1970. [83]

Evaluating oil spill control equipment and techniques. *Ocean Industry 5(7)* : 40-4.

Discusses skimmers, booms, air barriers and sorbents. Has tables giving properties of test oils and evaluates a number of artificial sorbents (adsorbents) as well as hay. Pound for pound, polyurethane and urea formaldehyde foams removed about ten times more oil than other materials tested. Straw and bagasse performed similarly to hay.

PORDES, O.; JONGBLOED, L.J.Schmit. [1971] [84]

Laboratory investigation into the sinking of oil spills with particulate solids. Pp 235-44 *in* American Petroleum Institute, "Proceedings of joint conference on prevention and control of oil spills. June 15-17, 1971, Sheraton Park Hotel, Washington, D.C."

[*See* No. 2]

Aqueous sand slurries treated with an amine acetate salt have satisfactory sinking and retention properties but a slow rate of application is required to prevent the sand being washed off or shed from the emulsion. Synthetic fishing net twines are more liable to fouling than manilla. Fouling of the bottom by the formation of a "carpet" may be prevented by spraying an oil-soluble surfactant on to the oil before applying the sinker.

SCHATZBERG, P.; NAGY, K.V. [1971] [85]

Sorbents for oil spill removal. Pp 221-33 *in* American Petroleum Institute, "Proceedings of joint conference on prevention and control of oil spills. June 15-17, 1971, Sheraton Park Hotel, Washington, D.C."

[*See* No. 2]

Evaluates inorganic sorbents, natural organic products and synthetic organic sorbents. Polymeric foams have greatest sorption capacity for oil but also absorb water which reduces their capacity for oil; even so they may still have higher oil capacity than inorganic and natural organic materials. Polyethylene fibre products have a good sorption capacity. Materials investigated include perlite, glass wool, vermiculite, volcanic ash, corn-cob, redwood fibre, peanut hulls, wheat straw, wood cellulose fibre, polyurethane foams, urea formaldehyde foam, polyethylene fibres and other plastic products.

SMITH, J. Wardley. 1968. [86]

Recommended methods for dealing with oil pollution. [*Report*] *Warren Spring Laboratory LR 79(EIS)* : 20 pp.

The standard manual for U.K. use, brief and to the point.

SMITH, J. Wardley. [1970] [87]

United Kingdom Ministry of Technology work in oil pollution. Pp 27-40 *in* American Petroleum Institute and Federal Water Pollution Control Administration, "Proceedings. Joint conference on prevention and control of oil spills".

[*See* No. 1]

Good general review of methods of dealing with oil on beaches (burning, dusting, mechanically removing or emulsifying), on the sea (mechanical removal, absorbent materials, sinking, dispersion), burning *in situ* on shipboard, and other means of preventing oil spreading. Detailed table of sinking agents and their effectiveness.

SMITH, J. Wardley. 1971. [88]

Methods of dealing with oil pollution on and close to the shore. Pp 205-15 *in* HEPPLE, P. (Ed.) "Water pollution by oil.

[*See* No. 11]

Resumé of methods which "reveal little change ... from those proposed ... in 1961. It is believed, however, that they represent the best current practice". Discussion includes comments on effectiveness of peat (Griffith, p.219) and stearated limestone (Greenwood, p.221).

[SMITH, J. Wardley] 1972. [89]

"Oil pollution of the sea and shore". Warren Spring Laboratory, Department of Trade and Industry. H.M. Stationery Office, London. 33 pp.

A useful illustrated general handbook, succinct and reasonably comprehensive. Good, if brief, section on beach-cleaning techniques and problems.

STRUZESKI, E.J.; DEWLING, R.T. [1970] [90]

Chemical treatment of oil spills. Pp 217-22 *in* American Petroleum Institute and Federal Water Pollution Control Administration, "Proceedings. Joint conference on prevention and control of oil spills".

[*See* No. 1]

Gives special attention to sorbent materials and sinking agents, gelling and burning.

VANCE, George P. 1971. [91]

Control of Arctic oil spills. *Ocean Industry 6(1)* : 14-15.

Controlled spills in Arctic conditions showed that ice acted as a natural containment barrier; oil could be burned in place, absorption by straw was very effective and spills under ice worked their way up into pockets in the undersurface of the ice. Peat moss contained spread but was not as effective as straw, which absorbed up to 90 per cent of oil in water and 40 to 50 per cent of oil on ice.

WALKUP, P.C.; POLENTZ, L.M.; SMITH, J.D.; PETERSON, P.L. [1970] [92]

Study of equipment and methods for removing oil from harbor waters. Pp 237-48 *in* American Petroleum Institute and Federal Water Pollution Control Administration, "Proceedings. Joint conference on prevention and control of oil spills".

[*See* No. 1]

Cost effectiveness study of removal methods.

Equipment

[*See also* Nos 1, 11, 12, 27, 30, 31, 39, 41, 49, 79, 83, 92]

CROSS, Ralph H. 1973. [93]

A small vacuum oil skimming system. [*Report*] *Environmental Protection Agency EPA-R2-73-115* : 19 pp.

Describes a readily assembled oil-skimming system for use on harbour craft suitable for picking up small quantities of No. 4 fuel oil and lighter oil. No. 6 fuel oil tends to clog the system.

CROSS, Ralph H.; HOULT, David P. 1972. [94]

Oil booms in tidal currents. *Journal of the Waterways, Harbors and Coastal Engineering Division, ASCE 98(1)* : 25-34.

Formulae for the design and operation of floating barriers intended to capture oil spills in rivers and tidal currents at modest velocities. Concentration of oil in a pool greatly simplified its collection and removal.

KETCHEL, R.J.; SMITH, H.D. [1971] [95]

Development of an air deliverable antipollution transfer system including the development of an optimum oil storage container. Pp 165-77 *in* American Petroleum Institute, "Proceedings of joint conference on prevention and control of oil spills. June 15-17, 1971, Sheraton Park Hotel, Washington, D.C."

[*See* No. 2]

Development and details of the ADAPTS system.

LEHR, W.E. 1971. [96]

Progress in high seas oil pollution prevention. *Marine Technology Society Journal 5(1)* : 7-14.

Describes U.S. Coastguard ADAPTS system (air delivered antipollution transfer system), claimed to unload 20,000 tons of cargo within 24 hours of accident report. The package includes transfer pumps and 500 ton capacity collapsible container (dracone) of rubberised nylon with pancryl lining weighing 13,000 lbs when palletised. The pump, module and accessories fit on one pallet with parachute, the container on another and both are dropped from 600 feet with water impact velocity of 25 fps. Delivery is by C-130 and has been tested. Additional containers are delivered as the initial package is brought into operation. Barrier or boom development is less well advanced.

LEHR, W.E.; SCHERER, J.O. [1970] [97]

Design requirements for booms. Pp 107-28 *in* American Petroleum Institute and Federal Water Pollution Control Administration, "Proceedings. Joint conference on prevention and control of oil spills".

[*See* No. 1]

Requirements and performance data for high seas booms; results of theoretical studies and tank model tests.

NEWMAN, D.E.; MACBETH, N.I. 1971. [98]

The use of booms as barriers to oil pollution in tidal estuaries and sheltered waters. Pp 225-35 *in* HEPPLE, P. (Ed.) "Water pollution by oil".

[*See* No. 11]

Tests in a tidal estuary. Perfect seals between boom and bed in estuaries drying out at low water are difficult to obtain; seals at the inshore mooring also present difficulties. Booms are practicable in tidal estuaries up to current velocities of 4 ft/sec. Most useful are booms with a smooth uncluttered profile, and it is essential they be held oblique to the flow in a smooth curve with a mean angle to the flow of about 25° for the higher currents of 2 to 4 ft/sec and up to 40° to the flow for lower velocities.

ROBERTS, Archie. 1973. [99]

Shore termination for oil spill booms. [*Report*] *Environmental Protection Agency EPA-R2-73-114* : 21 pp.

A small outboard is used to prevent oil leakage between end of boom and adjacent shoreline.

SARTOR, J.D.; FOGET, C.R. [1971] [100]

Evaluation of selected earthmoving equipment for the restoration of oil-contaminated beaches. Pp 505-22 *in* American Petroleum Institute, "Proceedings of joint conference on prevention and control of oil spills. June 15-17, 1971. Sheraton Park Hotel, Washington, D.C."

[*See* No. 2]

Studies to determine modifications and cost required to improve the capacity of selected earthmoving equipment, to develop optimum operating procedures and determine through field testing the operating costs of each method. More than 98 per cent effective removal was achieved, the best results with a motorised grader and motorised elevating scraper in combination, the least effective with tracked front end loaders. On low shear strength beaches, flotation tyres or steel-belted half-tracks on the motorised grader and a non-self-propelled elevating scraper pulled by caterpillar tractor should be used. Conveyor-screening systems are effective for loading oil-contaminated material into trucks, to separate oil-sand pellets from clean sand and partially separate oil-contaminated debris such as straw and kelp from oil-contaminated sand. The methods evaluated were successfully used in cleaning beaches after the *Oregon Standard - Arizona Standard* collision in San Francisco Bay.

SHUTTLEWORTH, F. 1971. [101]

Design of an inshore and beach spraying unit. [*Report*] *Warren Spring Laboratory LR 149(ES)* : 6 pp, 17 figs.

Plans for booms and mixing boards for small boats to spray dispersant on to oil at 4 to 5 knots and agitate mixture to produce a stable emulsion. Suitable for any boat 5 ft to 11 ft across the stern with an engine of at least 15 HP.

SMITH, J. Wardley; SHUTTLEWORTH, F. 1971. [102]

Development of the W.S.L. dispersant spraying equipment. [*Report*] *Warren Spring Laboratory LR 151(ES)* : 1-9; A1-A7; B1-B5, figs 1-11 : A1-A26; B1-B17.

Detailed plans of spraying units for beach-spraying and for use on small boats for inshore work and ocean-going tugs for open-sea. Also specifications for mixing boards to be towed behind spraying vessels.

WARREN SPRING LABORATORY. 1970. [103]

"Instructions for using the W.S.L. dispersant spraying equipment". Warren Spring Laboratory, Stevenage. 13 pp.

Instructions for fitting and using the recommended spraying equipment to small boats. "Surface-breakers", essentially 7-barred gates, are recommended to produce optimum mixing.

WICKS, Moye. [1970] [104]

Fluid dynamics of floating oil containment by mechanical barriers in the presence of water currents. Pp 55-106 *in* American Petroleum Institute and Federal Water Pollution Control Administration, "Proceedings. Joint conference on prevention and control of oil spills".

[*See* No. 1]

Mathematical design studies on the feasibility and effectiveness of booms.

General Effects of Oil Pollution

[*See also* Nos 15, 19]

BAKER, J.M. 1973. [105]

Recovery of salt marsh vegetation from successive oil spillages. *Environmental Pollution 4(3)* : 223-30.

Experiments with oiled plots in salt marsh vegetation indicate that recovery of shore communities from single oil spillages is usually good but progressive deterioration sets in with repeated spillages such as occur near oil refineries or terminals. Recovery from up to four oilings is generally good but considerable changes result from 8 and 12 oilings. *Juncus maritimus* is much reduced by two oilings, *Festuca rubra* survived four and *Agrostis stolonifera* recovers quickly and increases its coverage even after 12 to become dominant, possibly due to its fast growth rate.

BELLAMY, D.J.; CLARKE, P.H.; JOHN, D.M.; JONES, D.; WHITTICK, A.; DARKE, T. 1967. [106]

Effects of pollution from the *Torrey Canyon* on littoral and sublittoral ecosystems. *Nature, London 216(5121)* : 1170-3.

Oil and detergent pollution altered the balance of littoral and sublittoral ecosystems. The effect was most marked at the littoral zone, less so below low water, and was caused by detergent or detergent-oil emulsion, not by oil alone. Especially drastic where detergent applied to littoral directly at low water.

COWELL, E.B. 1969. [107]

The effects of oil pollution on salt-marsh communities in Pembrokeshire and Cornwall. *Journal of Applied Ecology 6(2)* : 133-42.

Compares effects on salt-marsh of spills from *Torrey Canyon* in Cornwall and *Chryssi P. Goulandris* in Milford Haven. Salt-marsh associations, especially those dominated by *Spartina townsendi* and *Pucinellia maritima*, are most severely damaged by oil pollution when oil reaches shore immediately, less so when it has been at sea some time. Surfactants also affect some salt-marsh plants severely, doubling the effect on *Spartina* by oil alone.

COWELL, E.B.; BAKER, J.M.; CRAPP, G.B. 1972. [108]

The biological effects of oil and oil-cleaning materials on littoral communities including salt marshes. Pp 359-64 *in* RUIVO, M. (Ed.) "Marine pollution and sea life". Fishing News (Books) Ltd, West Byfleet and London. 624 pp.

Studies in Milford Haven and elsewhere indicate that oil in marshes adheres firmly to plants which eventually die; recovery occurs from new shoots with annuals, and seedlings seldom recover. Species which die down during winter may not be affected by winter spills. Seedlings and annuals are vulnerable in spring and summer and oiling then may also reduce flowering and seed production. Plants may be grouped according to their susceptibility. *Very susceptible* are shallow rooting plants with little or no food resources which are quickly killed and cannot recover. Shrubby perennials with exposed branch ends which are badly damaged by oil are *susceptible*, also filamentous green algae (but unharmed spores or fragments of these quickly regenerate). *Intermediate* are perennials which quickly recover from one spillage but decline rapidly in chronic pollution. Those with large food reserves (which are usually rosette-shaped, mostly die back in winter) are *resistant* and may survive repeated oilings and those with a resistance to oils at the cellular level (e.g., Umbelliferae) are considered *very resistant*.

Isolated pollution does not cause long-term damage; continuous pollution can kill all vegetation and cause subsequent erosion. Resistance to repeated discontinuous pollution has not been established but this type of pollution is likely to cause a decline. Cutting and burning vegetation is less damaging than use of detergents.

Holiday beaches cleaned with detergents are now difficult to travel across because of fucoid algal growth and recovery will be protracted.

GEORGE, M. 1961. [109]

Oil pollution of marine organisms. *Nature, London 192(4808)* : 1209.

Intertidal organisms in Milford Haven were unharmed by oil and limpets were apparently removing oil by grazing without suffering toxic effects. Industrial emulsifiers, however, commonly destroy all limpets and 80 to 95 per cent of acorn barnacles.

NELSON-SMITH, A. 1968. [110]

The effects of oil pollution and emulsifier cleaning on shore life in south-west Britain. *Journal of Applied Ecology 5(1)* : 97-107.

Based on oil spills in Milford Haven of *Esso Portsmouth, Benjamin Coates,* and *Chryssi P. Goulandris* and off Land's End of *Torrey Canyon*, the common shore plants and animals are placed in a rough order of sensitivity of oil and emulsifiers.

Larger brown algae survive better than delicate reds or filamentous or sheet-like forms. Molluscs are most sensitive : the topshell *Monodonta* and species of winkle (*Littorina*) are most sensitive on rocky or stony shores, cockles on sandy or muddy shores and oysters in shallow sublittoral. Emulsifiers place at hazard animals which would be mostly unharmed by oil alone. Few limpets survive emulsifier spraying. Where animals lacking planktonic larval stages are eliminated, replacement may be a lengthy process.

NELSON-SMITH, A. 1968. [111]

Biological consequences of oil pollution and shore cleansing. Pp 73-80 *in* CARTHY, J.D.; ARTHUR, D.R. (Eds) "The biological effects of oil pollution on littoral communities".

[*See* No. 4]

Summary and comparison of several spills - *Tampico Maru*, Milford Haven (*Esso Portsmouth, Benjamin Coates, Chryssi P. Goulandris*), *Torrey Canyon* - detailing effects on littoral fauna and flora. *Tampico Maru* showed oil alone can have serious effects, barnacles, bivalves, crabs, echinoderms and shore algae being seriously affected. Sea-egg and abalone kills allowed heavy growth of giant kelp, persisting for at least three years.

NELSON-SMITH, A. 1971. [112]

Effects of oil on marine plants and animals. Pp 273-80 *in* HEPPLE, P. (Ed.) "Water pollution by oil".

[*See* No. 11]

Oil affects water-proofing and heat insulation of birds, causes littoral plants and animals to be torn away by wave-action due to the weight of oil, interferes with light penetration and thus photosynthesis, whether of individual plants or rock pools. Lower hydrocarbons may cause reversible narcotic effect, cause cells to swell or burst, may disrupt chloroplasts, may inhibit flowering, and may upset ecological balance.

SHELTON, R.G.J. 1971. [113]

Effects of oil and oil dispersants on the marine environment. *Proceedings of the Royal Society of London, series B, 177* : 411-22.

General review. Sinking of oil by oleophilic solids may smother benthic animals and foul nets leading possibly to tainting of catches.

TARZWELL, C.M. 1971. [114]

Toxicity of oil and oil dispersant mixtures to aquatic life. Pp 262-72 *in* HEPPLE, P. (Ed.) "Water pollution by oil".

[*See* No. 11]

Discusses effects of oil on marine organisms including tainting, anoxia caused by oil films over gill filaments, interference with feeding, production of carcinomas and papillomas, and toxic effects.

Biological Effects of Spills - Some Case Histories

[*See also* Nos 2, 3, 4, 5, 7, 11, 15, 16, 19, 26, 29, 30, 39, 41, 42, 47, 48, 49, 62, 69, 150]

CONOVER, R.J. 1971. [115]

Some relations between zooplankton and Bunker C oil in Chedabucto Bay following the wreck of the tanker *Arrow*. *Journal of the Fisheries Research Board of Canada 28(9)* : 1327-30.

Zooplankton ingested small particles of oil dispersed through the water column. As much as 10 per cent of oil in water column was associated with zooplankton but oil had apparently little effect on the organisms. As well as particulate oil exported from the bay by dynamic process, perhaps 20 per cent more was sedimented to the bottom as zooplankton faeces. "Zooplankton may be the single most important natural agent leading to the eventual dispersal of oil spills, at least in the open sea".

COWELL, E.B.; BAKER, J.M. 1969. [116]

Recovery of a salt marsh in Pembrokeshire, South-west Wales, from pollution by crude oil. *Biological Conservation 1(4)* : 291-6.

About 250,000 kg of Kuwait crude oil from the *Chryssi P. Goulandris* was carried ashore in Milford Haven on January 13, 1967, by a spring tide. Subsequent spring tides took it 7.2 m above Chart Datum.

Five months later, oil had apparently inhibited germination of the annuals *Suaeda maritima* and *Salicornia* spp., probably by preventing water and oxygen reaching the seeds. After 12 months, all visible signs of oil had disappeared and *Suaeda* and *Salicornia* had recovered but not to pre-spill levels. Filamentous green algae were affected, most obviously with *Halimione portulacoides* which was eliminated from the upper end of its range, and there was evidence that oil damage affects interspecific competition, species with a faster recovery rate spreading into the former areas of damaged, slow-recovery species.

DAY, J.H.; COOK. P.; ZOUTENDYK, P.; SIMONS, R. 1971. [117]

The effect of oil pollution from the tanker "Wafra" on the marine fauna of the Cape Agulhas area. *Zoologica Africana 6(2)* : 209-19.

Crude oil estimated at up to 26,000 tons was lost from the *Wafra* near Cape Agulhas when she stranded on a reef on February 27, 1971, and later while undertow before being sunk by missiles from aircraft. Some oil was mopped up by straw and over 670,000 litres of surfactants were used around the tanker between March 1 and 8 including "Corexit", "Chem. Serv." and "BP 1002". None was used on shore but thousands of bales of hay were scattered on polluted shores or dropped on oil slicks. Visible oil was limited to rocky shores. On sandy shores there was little sign of oil but digging showed its presence below the surface where it was expected to remain for many months.

The most severe pollution was in coves and isolated pools with reduced wave action. Fauna and flora on the upper part of the shore appeared "tougher" and more resistant to oil pollution than that at lower levels. Species of shelled molluscs varied in sensitivity even within a single genus. The rock lobster, *Jasus lalandii*, and the abalone, *Haliotis midae*, appeared unusually sensitive.

ENVIRONMENTAL PROTECTION AGENCY. 1973. [118]

Oil spill, Long Island Sound, March 21, 1972. Environmental effects. *Final Report. Water Pollution Prevention and Control, Oil and Hazardous Materials Program Series, OHM 73-06-001* : 136 pp.

A spill of No. 2 fuel oil from the tanker *F.L. Hayes* on Bartlett Reef, Long Island Sound (Niantic Bay) released an estimated 80,000 gallons. Most of the oil was dispersed three days later by a storm, the only visible evidence after the storm being off marshy areas or areas of seaweed, indicating a leaching effect. Booms and absorbents were used. Small areas of heavy oil concentration within the first three days caused deaths of polychaetes, amphipods, snails, small fish and shrimp. Oil was dispersed by strong currents and short flushing times characteristic of the bay. Examination of benthic fauna showed an absence at one station of the expected amphipod component, amphipods being highly sensitive to petroleum pollutants. Accumulation of oil here was apparently due to sediment transport, caused by the currents scouring the inshore sand and cobbles and depositing fine silt in mid-bay. Hermit crabs also apparently concentrated fuel oil in their tissues and may be a good indicator of low pollutant levels.

FOSTER, M.; NEUSHUL, M.; ZINGMARK, R. 1971. [119]

The Santa Barbara oil spill. Part 2 : Initial effects on intertidal and kelp bed organisms. *Environmental Pollution 2(2)* : 115-34.

Plants damaged were generally in the high intertidal where oil could remain on thalli and dry during a tidal cycle. Red algae, unlike brown and green, held crude oil over long periods of time and *Porphyra* retained oil and became brittle. Before and after comparisons indicate the loss of 16 plant species but this may be related to record winter storms before and during the spill. Contrary to some reports, highly significant damage occurred to the surfgrass *Phyllospadix torreyi* and the barnacle *Chthalamus fissus*. Despite heavy exposure to oil, offshore kelp beds showed no abnormal decay or damage - most of the oil was eventually released by wind and water movement and did not stick to healthy fronds, perhaps because of the natural mucous covering of the kelp.

GEORGE, J.David. 1971. [120]

The effects of pollution by oil and oil-dispersants on the common intertidal polychaetes, *Cirriformia tentaculata* and *Cirratulus cirratus*. *Journal of Applied Ecology 8(2)* : 410-20.

200,000 kg of fuel oil spilled at the terminal at Fawley blanketed the mud at low tide, floating off with rising water to be eventually deposited on shingle-sand beaches. Dispersants (Essolvene) were used by boat owners and on beaches. Oil did not affect either species but dispersant killed both species. Tests showed Essolvene and BP 1002 killed both species in relatively low concentrations. Emulsifiers may have caused death indirectly by dispersing oil into small droplets which were readily ingested by polychaetes causing digestive disruption or toxic effects.

GOODING, Reginald M. 1971. [121]

Oil pollution on Wake Island from the tanker *R.C. Stoner*. *Special Scientific Report. National Marine Fisheries Service, U.S. Department of Commerce 636* : 12 pp.

This spill, on September 6, 1967, involved six million gallons of high octane aviation gasoline, aviation jet fuel, aviation turbine fuel, diesel oil and Bunker C black oil. 2,500 kg of inshore reef fishes were believed killed as well as other invertebrates, mostly on shallow reef flats. Turbine shells, *Turbo* sp., were badly affected; birds appeared unharmed. Aviation gasoline or black oil were believed responsible for the fish kill.

GREEN, D.R.; BAWDEN, C.; CRETNEY, W.J.; WONG, C.S. 1974. [122]

The Alert Bay oil spill : a one-year study of the recovery of a contaminated bay. *Pacific Marine Science Report 74-9* : 42 pp.

A 200 ton heavy fuel oil spill from the *Irish Stardust* in Canadian waters on a semi-exposed shoreline. One year later, no species had been completely eliminated, recolonisation was occurring and, although the beach was still polluted in an untreated bay, 90 to 95 per cent of the volume of the oil had been removed by various natural processes, mainly bacteriological.

GUNKEL, W. 1968. [123]

Bacteriological investigations of oil-polluted sediments from the Cornish coast following the *Torrey Canyon* disaster. Pp 151-8 *in* CARTHY, J.D.; ARTHUR, D.R. (Eds) "The biological effects of oil pollution on littoral communities".

[*See* No.4]

Oil-decomposing bacteria were extremely numerous in all sediment samples containing oil, reaching values close to the maximum numbers expected from artificial media and pure cultures in the laboratory despite the use of emulsifiers, known to be toxic to bacteria. Toxicity is due to volatile solvents and the bacterial population can adapt itself to the emulsifier. Both oil and emulsifier are degraded by the bacteria.

HAMPSON, G.R.; SANDERS, H.L. 1969. [124]

Local oil spill. *Oceanus 15(2)* : 8-10.

The barge *Florida* spilled 60,000 to 70,000 gallons of No. 2 fuel oil along the shores of West and North Falmouth, Mass. Bottom-living fish and lobsters were washed ashore. Trawling in 3 metres showed approximately 95 per cent of catch dead and decaying, and live specimens were moribund. Oil appeared to have consistently penetrated sediments at depths of 7 to 10 metres in heavily polluted zones.

JONES, Laurence G.; MITCHELL, Charles T.; ANDERSON, Einar K.; NORTH, Wheeler J. 1969. [125]

Just how serious was the Santa Barbara oil spill? *Ocean Industry 5(7)* : 53-5.

Santa Barbara spill of January 28, 1969, was estimated at 500 barrels per day, 236,000 gallons over the ten-day period. Authors looked for abnormal behaviour of animals, unusual concentrations of dead organisms, unnatural appearances of living or dead organisms and total absence or low concentration of species where they would normally be expected. They concluded that nearly all communities inspected were healthy and showed no adverse effects except for birdlife; "... the channel biota is still in a healthy, vigorous and reasonably normal state".

KALUGINA, A.A.; MILOVIDA, N.Y.; SVIRIDOVA, T.V.; URALSKAYA, I.V. 1967. [126]

Effect of pollution on marine organisms of Novorossiysk Bay of the Black Sea. *Gidrobiologicheskii Zhurnal 3(1)* : 47-53. [English abstract]

Petroleum products and sewage have apparently caused changes in distribution of algae and grasses as well as benthic organisms and zooplankton.

LEPPAKOSKI, E. 1973. [127]

Effects of an oil spill in the Northern Baltic. *Marine Pollution Bulletin 4(6)* : 93-4.

Describes oil spill in icy water where 25 to 30 per cent of nesting eider population died. Burning and emulsifying of oil caused damage to fauna of upper littoral. Ice inhibits oil spreading but makes measures to prevent damage less successful, if not impossible.

LOYA, Y. 1975. [128]

Possible effects of water pollution on the community structure of Red Sea Corals. *Marine Biology 29(2)* : 177-85.

Chronic oil pollution from two terminals in the Gulf of Eilat has drastically changed the community structure of hermatypic corals in a nature reserve at Eilat.

In 1969, the reserve reef flat and a control reef had similar coral communities. After a catastrophic low tide in September, 1970, the control reef had greatly recovered by 1973 and was "blooming" with a highly diverse coral community, whereas the reserve reef was "very grey and unattractive, and ... dominated by algae" with almost no signs of recolonisation by coral. *Stylophora pistillata*, previously the most common coral, had almost disappeared and the lack of young colonies suggests interference with settlement. Phosphate eutrophication may be a contributing cause, but the most pronounced disturbances at the reserve are chronic oil spills; synergistic effects of algae and some soluble oil fractions are suggested as the major factors. Spills are suspected of preventing normal settlement and/or development of coral larvae. Damage to the coral reproductive system, decreased viability of coral larvae, and chemical changes in some physical properties of the reef flat are all suggested as possible effects of chronic oil pollution which could interfere with normal settlement.

NICHOLSON, Nancy L. 1972. [129]

The Santa Barbara oil spills in perspective. *Reports. California Cooperative Oceanic Fisheries Investigations 16* : 130-49.

Two oil spills from Santa Barbara offshore wells in 1969 were mediated by coming ashore in winter months when large amounts of freshwater and mechanical disturbance from wave action leave relatively fewer organisms to be affected. Crude oil from the first spill quickly formed a shiny skin; that from the second remained frothy and fluid during its month stay in the intertidal, then rapidly disappeared.

Barnacles in the upper intertidal tall enough to project beyond the oil crust (*Balanus*) survived; shorter ones (*Chthalamus*) were smothered. Juvenile barnacles established on weathered oil but were lost when the asphalt layer finally crumbled.

Other factors affecting intertidal life are public use of the beaches, clam collecting operations (which slackened only slightly during the oil-covered period), and winter surf rolling of large cobbles which act like a ball mill. Populations may also be reduced by a heavy persistent cover of sand. The effects of oil spillage are superimposed on already chronic conditions imposed by human changes in inshore environment including large amounts of industrial effluents.

Intertidal flora has declined by 63 per cent between 1959 and 1969; the oil spills were responsible for bird kills and loss of marine organisms in the upper intertidal but other changes, including deeper water animals, may be part of a general decline. In the upper intertidal, the tendency is now for slower growing cover like *Endocladia* and the perennial rockweeds *Pelvetia* and *Hesperophycus* to be replaced by aggresive annual colonisers such as *Ulva, Enteromorpha*, diatom films and green algal films. Substantial losses in kelp forests, not necessarily due to oil spills, may have far-reaching effects - fewer good fishing grounds, reduction in available food and interferences with migratory patterns of birds and mammals dependent on nearshore foraging.

NORTH, Wheeler J. 1967. [130]

Tampico - a study of destruction and restoration. *Sea Frontiers 13(4)* : 212-17.

General illustrated account of *Tampico* marine spill.

NORTH, Wheeler J.; NEUSHUL, Michael; CLENDINNING, Kenneth A. 1965. [131]

Successive biological changes observed in a marine cove exposed to a large spillage of mineral oil. Pp 335-54 *in* "Pollutions marines par les micro-organismes et les produits petroliers. Paris. Symposium de Monaco (avril 1964)". [*See* No. 5]

Details short and long-term effects on the littoral and benthic communities of the *Tampico Maru* spill on the Pacific coast of Baja California, Mexico. Seven years later, the cove had still not returned to its pre-spill status but all of the changes were not necessarily due to the spill.

O'SULLIVAN, A.J.; RICHARDSON, Alison J. 1967. [132]

The *Torrey Canyon* disaster and intertidal marine life. *Nature, London 214(5087)*: 541-2.

An immediate post-disaster report on effects on intertidal life detailing effects of detergents. "Thus, where the littoral marine life in concerned, the use of detergents constitutes a "cure" worse than the "disease" itself".

RANWELL, D.S. 1968. [133]

Lichen mortality due to *Torrey Canyon* oil and decontamination measures. *Lichenologist 4* : 55-6.

About 50 species of lichens occur in the upper intertidal and regular splash zones of the Cornish coast. The midlittoral zone was completely smothered with oil up to 2 cm thick on the Cornish and Brittany coasts causing mortality by exclusion of light and air, *Arthopyrenia halodytes* and *Lichina pygmaea* being the most severely affected species. Supra-littoral lichens were damaged by emulsifier and by trampling and dragging of hoses over the rocks. In Brittany, additional damage was caused by steam cleaning. Representatives of 19 species are known to have been killed.

Because shore lichens are slow-growing, recovery will take years.

RANWELL, D.S. 1968. [134]

Extent of damage to coastal habitats due to the *Torrey Canyon* incident. Pp 39-47 *in* CARTHY, J.D.; ARTHUR, D.R. (Eds) "The biological effects of oil pollution on littoral communities".

[*See* No. 4]

Greatest damage was to rocky shores where most oil was stranded. Few extensive areas of salt marsh were affected, those in Brittany more severely than in Cornwall. *Puccinellia maritima*, one of the chief components of European salt marshes, was killed by oil that had weathered at sea for at least seven days. Much oil was recycled by beach cleaning as the more toxic oil-emulsifier mixture. Damage was caused to sand dune and cliff top communities largely by trampling and emulsifier spill from cleaning activities. At least 100 species of algae, lichens, flowering plants and ferns were killed, some being rare or only locally distributed species.

RÜTZLER, K.; STERRER, W. 1970. [135]

Oil pollution : damage observed in tropical communities along the Atlantic seaboard of Panama. *Bioscience 20(4)* : 222-4.

Close to 20,000 barrels of diesel and Bunker C oil were spilled from the wreck of the tanker *Witwater* near Galeta Island in the Canal Zone. Detergents were not used but high winds caused a spray of mixed seawater and oil to cover and kill shrubs and trees up to 2 m above mean tide; supralittoral spray pools and upper mesolittoral tide pools were covered with oil and devoid of life two months later. Damage was less below these levels. Subtidal coral reefs were not affected but apparently clean, sandy beaches were oil-permeated below the top 2-5 mm and oil inflow into the interstitial water resulted in a dramatic reduction of meiofauna. Intertidal mudflats and mangroves were thickly coated, eliminating intertidal algal communities and sedentary animals such as oysters, mussels and barnacles. Young sea-turtles were affected. It was too soon to observe effects on mangroves themselves but *Avicennia*, in particular, was expected to suffer through oil covering the pneumatophores.

SANDERS, H.L. 1974. [136]

The West Falmouth Saga. How an oil expert twisted the facts about a landmark oil spill study. *New Engineer, May 1974* : 7 pages.

Reply to a critique of Woods Hole studies on the West Falmouth spill. The author refutes the suggestion that the initial mass mortality was due to meteorological conditions and resulting waves, not oil; and disputes the suggestion that massive blooming of the polychaete, *Capitella capitata*, was a normal response to lower fall and winter temperatures instead of a response to the killing of most of the original fauna by the oil. Arguments that there were no significant kill of ampeliscid amphipods, claimed by Woods Hole investigators to be highly sensitive to small concentrations of oil, are countered with further analysis of the ampeliscid populations and environment.

SANDERS, H.L.; GRASSLE, J.F.; HAMPSON, G.R. 1972. [137]

The West Falmouth oil spill. I. Biology. *Technical Report, Woods Hole Oceanographic Institution, WHOI-72-20* : 22 and [25] pp.

Discusses the effects of the West Falmouth spill on polychaete worms, molluscs and ampeliscid amphipods. Within three months of the spill, there was an explosive population increase of *Capitella capitata*, a polychaete pollution indicator. At one station, densities of 1399 polychaetes per 1/128 m^2 were reached, all but three specimens being *C. capitata*, compared with an unpolluted control station where *C. capitata* was absent, numbers were lower but species more diverse. As recovery continued at the polluted stations, polychaete numbers decreased, diversity of species increased and *C. capitata* began declining in importance from a unispecies situation.

Following the spill in September, 1969, bivalve molluscs were essentially missing through fall, winter and spring of 1969-70, the first evidence of recolonisation at polluted stations being newly settled juveniles in July, 1970. In general, bivalves were more adversely affected than polychaetes from September 1969 to the summer of 1970, particularly at the more off-shore stations.

Ampeliscid amphipods were more sensitive to the presence of oil than polychaetes or bivalves and proved excellent pollution indicators. The eye-lenses are persistent and easily identified, allowing good counts of dead and decomposing, as well as live, animals. Following the spill, there was a rapid adverse effect with slow recovery, the first signs of recovery at one station not occurring until 12 months later. Some of the stations originally chosen as control stations showed a subsequent deterioration in environmental quality with significant ampeliscid mortality.

SCARRATT, D.J.; SPRAGUE, J.B.; WILDER, D.G.; ZITKO, V.; ANDERSON, J.M. 1970. [138]

Some biological and chemical investigations of a major winter oil spill on the Canadian east coast. [*Report*] *Fisheries Improvement Committee, International Council for the Exploration of the Sea, C.M.1970/E* : 7 pp, map.

A manuscript report on the *Arrow* spill in Chedabucto Bay where the most important fishery is for lobsters. There were no major oil deposits below low water mark, although there were small amounts through the water column and in sediments. There was no sign of benthic mortality below LWM and there were no complaints of tainted lobsters although chemical analyses showed many species ingesting Bunker C oil and possibly metabolising it. Lobsters experimentally tainted with Bunker C oil effectively self-cleaned in running seawater but surface cleaning was facilitated by carefully wiping with full strength Corexit 8666 which did not cause tainting. Tainting persisted three weeks in meat, four weeks in digestive gland.

SPOONER, Molly. 1970. [139]

Oil spill in Tarut Bay, Saudi Arabia. *Marine Pollution Bulletin 1(11)* : 166-7.

Describes effects in a shallow, tidally-flushed bay. Appearance three months later was "a good deal better than expected" despite toxic effects on fauna from oil especially on mud flats.

STANDER, G.H. 1968. [140]

The "Esso Essen' incident. *South African Shipping News and Fishing Industry Review 23(8)* : 4 pp.

Esso Essen lost 15,000 tons of Arabian heavy oil on April 29, 1968 when she hit a submerged object south of Cape Town. An estimated 3,000 to 4,000 tons of this was spilt off the Peninsula coast. Sea birds and sand hoppers were the main observed casualties. Corexit, sprayed from the air, appeared to have no ill effects. Toxicity tests with Corexit are briefly described.

STEBBINGS, R.E. 1970. [141]

Recovery of salt marsh in Brittany sixteen months after heavy pollution by oil. *Environmental Pollution 1(2)* : 163-7.

Salt marshes in Brittany were visited 14 days and 16 months after *Torrey Canyon* spillages. The original oil had been at sea at least 12 days "and must have lost much of its toxic fractions". The later visit still revealed many pools of oil of 2 m diameter and 3 cm deep of greatly thickened although still soft oil beneath which the oil had penetrated 3 cm into litter and soil. There were severe reducing conditions below this again. Pure stands of *Salicornia perennis* and *Beta maritima* had died but *Halimione portulacoides* had survived. Stands of *Agropyron pungens, Juncus maritimus, Scirpus maritimus* and *Festuca rubra* were extremely vigorous and thought to be deriving some nutritional benefit, perhaps from oil breakdown products. *Juncus gerardii, Triglochin maritima, Halimione portulacoides* and *Puccinellia maritima* were particularly successful in withstanding the heaviest pollution.

STRAUGHAN, D. 1972. [142]

Biological effects of oil pollution in the Santa Barbara channel. Pp 355-9 *in* RUIVO, M. (Ed.) "Marine pollution and sea life". Fishing News (Books) Ltd, West Byfleet and London. 624 pp.

Isolation of oil pollution effects is difficult because at the time of the spill there was increased freshwater run-off, possibly contaminated with orchard pesticides, and increased sedimentation. Planktonic, benthic and intertidal investigations produced no significant evidence of impairment. Fish appeared healthy; bird mortality from all causes including oiling was 3,500 to 4,000 birds in the immediately following months. Marine mammals showed no increase in mortality. It is considered that "there was very little mortality in the Santa Barbara channel due to the direct toxic effects of spilled oil" and possible reasons for this are discussed.

STRAUGHAN, D.; ABBOTT, B.C. 1971. [143]

The Santa Barbara oil spill : ecological changes and natural oil leaks. Pp 257-62 *in* HEPPLE, P. (Ed.) "Water pollution by oil".

[*See* No. 11]

Oil did not cause as much damage as originally predicted and it is difficult to establish which factors were involved in mortality and other changes because of the composition of the oil, the time lag between its release and arrival onshore, the presence of natural seeps in the area over a long period and accompanying unusually heavy rain and flooding and possible increase in insecticide levels.

THOMAS, M.L.H. 1973. [144]

Effects of Bunker C oil on intertidal and lagoonal biota in Chedabucto Bay, Nova Scotia. *Journal of the Fisheries Research Board of Canada 30(1)* : 83-90.

More than half the 2,800,000 gallons of Bunker C oil aboard the tanker *Arrow* were spilled, mostly within the first two weeks, heavily oiling the shore which is mainly rocky with small sand and gravel areas and extensive areas of shallow muddy lagoon. Spillage occurred in February 1970 and by August 1971 only small quantities remained in exposed areas but heavy contamination remained in sheltered areas, particularly the lagoons. Initial effects included minor smothering of fauna and algae torn loose. Longer term effects were extensive mortality of *Fucus spiralis* on rocky shores, *Mya arenaria* and *Spartina alterniflora* in lagoons, mortality occurring either continuously or only in the second year of pollution. Freezing water, minimum detergent use and repeated re-oilings were unique features of this spill. Recommendations include mechanical removal of oil wherever possible and removal of oiled plant remains from the shore.

ZOUTENDYK, P. 1972. [145]

Oil pollution of the Cape Infanta coastline. *Zoologica Africana 7(2)* : 533-6.

Observations over 24 years along the Cape Infanta coastline where no shipping disasters have occurred shows an accumulation of oil, corresponding in vertical distribution to that at Cape Agulhas after the *Wafra* grounding. Intertidal life appears largely unaffected although the winkle *Oxystele variegata* is absent from exposed rocks where oil cover is dense. However, the octopus, *Octopus granulatus* is completely absent from low water pools where it is normally common.

Persistence of Stranded Oil

[*See also* Nos 117, 118, 122, 123, 129, 135]

BLUMER, M.; EHRHARDT, M.; JONES, J.H. 1973. [146]

The environmental fate of stranded crude oil. *Deep-Sea Research 20(3)* : 239-59.

At both Martha's Vineyard, Mass., and beaches in Bermuda, considerable and environmentally important oil fractions persisted throughout 13½ and 16 month study periods. The residues "are far from being inert asphalts; they remain crude oils, modified by evaporation of the lower boiling points and by partial microbial degradation ... The half-life of oil in the environment must be measured in terms of years".

Oil exposed to the atmosphere loses its lower boiling components within a few months of spillage; oil incorporated into bottom sediments and organisms soon after a spill shows little loss by evaporation. Microbial disintegration depends on the substrate and is more rapid in the presence of decaying seaweed.

BLUMER, M.; SASS, J. 1972. [147]

Oil pollution : persistence and degradation of spilled fuel oil. *Science 176(4039)* : 1120-2.

600 metric tons of No. 2 fuel oil spilled in Buzzard's Bay, Mass., produced a heavy kill of organisms within the first few hours or days, followed by a slow spread of oil to outlying areas with an accompanying though sometimes delayed kill. Recolonisation did not take place until degradation of the oil with reduction in toxicity, first by the most resistant faunal opportunists and later by a more normal and varied fauna. Two years later fuel oil was still present to a depth of 7.5 cm below the sediment surface and as fresh as oil at the surface after 10 months. Penetration in marsh areas reached 60 cm. Pristane-phytane ratios remain constant, possibly providing an extended identification time. It is suggested that oil products and crude oils have a considerable environmental persistence.

DRAPEAU, G. [1972] [148]

Natural cleaning of oil polluted sea shores. *Proceedings of the Thirteenth Coastal Engineering Conference, July 10-14, 1972, Vancouver, B.C., Canada. Vol. 3* : 2557-75.

Bunker C oil from the *Arrow* formed a very stable emulsion containing 40 per cent sea water, 40 times as viscous as pure Bunker C. After 18 months, accumulations still appeared as fresh as when new but its viscosity prevented deep penetration into sand. Oil slicks half an inch thick on moderately exposed beaches cleaned within one or two months, but where the oil was too thick the beach was "frozen" under the slick and waves ran off without cleaning.

Oil abraded most rapidly on sand. Sandy beaches cleaned within six months, cobble and boulder beaches took 12 months, and bedrock outcrops were still covered with a veneer of "dried oil" after 20 months. Wave action is the dominant energy source and cleaning is directly related to the amount of wave energy reaching the shore. Also involved is the weather at the time of stranding; high waves and tides will push oil high up on the beach beyond reach of normal wave action. The spread of oil will be much less in calm weather.

Oil should be prevented from entering inlets, even if they are less important for recreation than exposed beaches because inlets remain polluted much longer and become a continuous source of pollution for clean beaches whereas exposed sandy beaches clean quickly but can become recontaminated many times during a season. Salvage operations should be restricted to calm periods and neap tides so that if spills occur during salvage, oil will strand lower on the beach where natural cleaning is most effective.

JOHNSTON, R. 1970. [149]

The decomposition of crude oil residues in sand columns. *Journal of the Marine Biological Association of the United Kingdom 50(4)* : 925-37.

Experimental results indicate that oil is removed from sand columns by microorganisms at a rate of 0.09 g oil m^{-2} day^{-1} for heavily oiled sand (e.g., 1.1 kg crude oil m^{-2}) to 0.04 g oil m^{-2} day^{-1} for sand with a uniform light coating (12 g oil m^{-2}) when the oil is situated approximately 4 cm deep. The amount of oil on a beach affects the oxidation rates below the surface and hence the decomposition rates, and more than 100 g m^{-2} would probably affect oxidation rates for some months.

Burial of oil residues also slows down destruction. About one-sixth of the oil destroyed is related to natural sea-water nutrients, nitrate being the most important, but in aerobic conditions ammonium-nitrogen may assist the removal of oil by contributing nitrogen to a food supply dominated by hydrocarbons.

Results suggest there is little advantage in ploughing superficial oil into sand for other than amenity reasons since burial prolongs the life of the oil. Chance burial of deep oil slugs may form much worse spots than average.

MAYO, D.W.; DONOVAN, D.J.; JIANG, L. 1974. [150]

Long term weathering characteristics of Iranian crude oil : the wreck of the "Northern Gulf". Pp 201-8 *in* "Marine pollution monitoring (petroleum)".

[*See* No. 14]

The tanker *Northern Gulf* ran aground on West Cod Ledge, Casco Bay, Maine on November 25, 1963, losing approximately 5,000 metric tons of Iranian crude, most of which was driven ashore five days later along more than 64 km of coast, contaminating all commercial shellfish sites, principally soft clam (*Mya arenaria*). One area could not be harvested for two years; production from contaminated areas dropped 20 per cent compared with an increased production elsewhere of 249 per cent, much of the loss being due to unpalatable oily flavour apparently imparted by repeated or continuous recontamination by oil entrapped in bottom sediments. Immediate losses of 28,800 lobsters (*Homarus americanus*) were also reported by impoundment operators.

Weathered oil is dominated by pristane fractions which appear to be degraded more slowly than the other six isoprenoids; alternatively, pristane is being incorporated into the residues from the natural environment, a theory for which there is some evidence. Impounded lobsters possess pristane as the single dominant hydrocarbon and this is even so with clams in one impoundment. In another, the clams have a hydrocarbon distribution essentially identical to the sediments in which they are found, and their stunted growth indicates eight or more growing seasons to reach marketable size, normally achieved in five seasons and sometimes three. Experiments with clams transplanted into the contaminated areas produced mortality rates of 87 and 99 per cent, the latter within a 29-day period in 1973, ten years after the spill. The relative abundance of the isoprenoids indicates that the residues are traceable to the *Northern Gulf* spill.

RASHID, M.A. 1974. [151]

Degradation of Bunker C oil under different coastal environments of Chedabucto Bay, Nova Scotia. *Estuarine and Coastal Marine Science 2(2)* : 137-44.

Degradation of spilled oil depends largely on the environmental conditions, taking place faster in high energy environments than in protected areas, probably because of bacterial and oxidative processes. Residues become more viscous with weathering and mobility is reduced. Residual oils on contaminated low and moderate energy beaches are likely to persist for several years but will be more mobile than the highly viscous residues which remain adhering to sand and pebble substrates in higher energy environments.

SCARRATT, D.J.; ZITKO, V. 1972. [152]

Bunker C oil in sediments and benthic animals from shallow depths in Chedabucto Bay, N.S. *Journal of the Fisheries Research Board of Canada 29(9)* : 1347-50.

Oil was still detectable in sediments and many animals 26 months after the *Arrow* spill of 1970. The waters had cleared but in April, 1972, there was still a large amount of oil on the beaches bound up as matrix with beach material. Oil did not seem to be being concentrated in higher elements of the food chain.

WERTENBAKER, William. 1974. [153]

Anatomy of an oil spill. *Marine Technology Society Journal 8(3)* : 16-28.

Illustrated account, originally published in *The New Yorker* in 1973, of 1969 spill in Buzzards Bay, near Woods Hole Oceanographic Institution. Effects were monitored by local scientists and are still showing four years afterwards. Area has been repopulated but some areas are still closed to shell-fishing and large amounts of oil remain absorbed in the mud to be released by bad weather in toxic quantities. It is claimed that the spill shows, contrary to published statements, that toxic aromatics do dissolve in water and petroleum will as readily sink as evaporate.

Oiled Seabirds

[*See also* Nos 3, 4, 15, 16, 26, 127, 142, 144, 178, 178a *and especially* 180]

ADVISORY COMMITTEE ON OIL POLLUTION OF THE SEA, RESEARCH UNIT ON THE REHABILITATION OF OILED SEABIRDS. 1972. [154]

"Recommended treatment of oiled seabirds". Department of Zoology, University of Newcastle upon Tyne. 10 pp.

First priority is not washing but keeping birds warm, quiet and well-fed. Named washing-up detergents are best. Physical condition of the birds is more important to survival than the degree of oiling.

BEER, J.V. 1968. [155]

Post-mortem findings in oiled auks dying during attempted rehabilitation. Pp 123-9 *in* CARTHY, J.D.; ARTHUR, D.R. (Eds) "The biological effects of oil pollution on littoral communities".

[*See* No. 4]

Animals examined suffered from severe stress, powerful irritants or poisons in the gut, coagulative necrosis or sloughing possibly due to phenolic compounds, enteritis, aspergillosis and arthritis. Renal failure was also indicated.

BOURNE, W.R.P. 1968. [156]

Oil pollution and bird populations. Pp 99-121 *in* CARTHY, J.D.; ARTHUR, D.R. (Eds) "The biological effects of oil pollution on littoral communities".

[*See* No. 4]

Extreme adaptation for an aquatic environment makes birds particularly susceptible to oil pollution by reducing their capacity for sustained flight and keeping them on the water surface where they are continually exposed to floating oil, against which they are particularly defenceless. Swimming birds do not notice oil until they swim into it. Then aerial species like gulls fly away but aquatic species like auks try to escape by diving. Oil breaks down the insulating capacity of their feathers making them raise their metabolic rates when they are already ill from ingested oil and unable to feed. When their fat stores are exhausted, they die from toxic effects, starvation and exposure.

Birds that allow themselves to be caught are usually moribund making rehabilitation difficult and success rates low. Laying birds may get oil on their eggs, thus preventing hatching by interference with respiration through the shell.

[BOURNE, W.R.P.] 1970. [157]

Special review - After the "Torrey Canyon" disaster. *Ibis 112(1)* : 120-5.

Briefly reviews knowledge of bird mortality from *Torrey Canyon* and similar incidents and points out the difficulties of rehabilitating oiled birds on a large enough scale to make a significant impact on overall survival rates. Even with complete success with all oiled birds found on British beaches, this could involve dealing with 15,000 birds in a normal year "merely in order to save some 5 to 12½ per cent of the total number of birds affected". However, limited success with breeding rehabilitated birds suggests the possibility of establishing breeding populations in captivity or protected situations where they could be used to initiate the recolonisation of extinct colonies or start new ones away from hazards "in the hope that other wild birds might join them later if they did well".

BOURNE, W.R.P.; JOHNSTON, Laughton. 1971. [158]

The threat of oil pollution to North Scottish seabird colonies. *Marine Pollution Bulletin 2(8)* : 117-19.

An estimated 2,000 to 10,000 birds, mostly guillemots, were killed in a spill near the Shetlands; the authors emphasise that the tendency of seabirds to concentrate near major breeding colonies makes them vulnerable to even small quantities of oil.

BOURNE, W.R.P.; PARRACK, J.D.; POTTS, G.R. 1967. [159]

Birds killed in the *Torrey Canyon* disaster. *Nature, London 215(5106)* : 1123-5.

It is estimated that 30,000 birds were killed, mostly guillemots and razor bills.

BOYLE, C.L. 1969. [160]

Oil pollution of the sea : is the end in sight? *Biological Conservation 1(4)* : 319-27.

Useful section on oil and seabirds. Birds most affected by oil in South Africa were the Cape Gannet, four species of cormorant and the Jackass Penguin (*Spheniscus demersus*). Over 1,700 oiled Jackass Penguins were collected from South African beaches between June and August of 1968 of a total population estimated in 1960 as being 103,000. In February, 1952, oil from two tankers off Massachussetts is said to have reduced the wintering Eider duck population from 500,000 to 150,000 in 1953 and oil is also blamed for reducing an auk population on the Grand Banks by 250,000 in two years.

CLARK, R.B. [1968] [161]

Oil pollution and the conservation of seabirds. Pp 76-112 *in* BARCLAY-SMITH, P. (Ed.) "International conference on oil pollution of the sea, 7-9 October 1968 at Rome. Report of proceedings".

[*See* No. 3]

A very comprehensive and informative review. Includes instances of precautionary measures where oil affected wintering and nesting grounds. Mortality of snow geese was avoided by using student labour to cut down oiled vegetation along the St Lawrence and burn it. Oil on tern nesting areas in the Dry Tortugas was covered with clean seabed fill before the birds arrived thus minimising mortality. Long-lived birds with low replacement and high infant mortality rate, such as auks, are extremely vulnerable to oil. As well as direct effects of oil on birds, there are also indirect effects on, for instance, hatchability of eggs. There is a detailed discussion on treatment and rehabilitation and its attendant problems and an extensive bibliography. Recommended.

CLARK, R.B.; CROXALL, J.P. 1972. [162]

Rescue operation for oiled seabirds. *Marine Pollution Bulletin 3(8)* : 123-7.

New cleaning methods using domestic washing-up liquid detergents enable release of treated birds within 2 to 3 weeks. First priority is not cleaning but keeping birds warm and restoring them to health by feeding provided they are prevented from preening and swallowing further oil. Success of up to 46 per cent was achieved.

HEINEKAMP, H.F.; RAMSAY, G.W. 1973. [163]

"Interim report on oiled sea-birds, presented to the Nelson Section, Royal Forest and Bird Protection Society, November 1973". Unpublished report. Nelson Section, Royal Forest and Bird Protection Society, Nelson. 8 pp.

Lists several methods of treatment and recommends the techniques developed by the Research Unit on the Rehabilitation of Oiled Sea-Birds, at Newcastle, which are detailed.

KAMPEN, D.M. van. 1971. [164]

Successful cleaning of oiled birds in Holland. *Marine Pollution Bulletin 2(9)* : 140-2.

Formulae are given for oil removal and restoration of water-repellency. 55 per cent of birds treated were completely recovered and released within three weeks.

NATHAN, A.J. 1972. [165]

A double marine disaster. *Sea Frontiers 18(4)* : 202-9.

After the *Wafra* spill, 1,200 Jackass Penguins were treated using Fuller's Earth. Initially, they also required force-feeding, apparently not recognising their natural food in the form of dead fish. Success in rehabilitating the birds was estimated at 65 per cent. Treated birds were ringed and ringed birds released as far back as 1968 have recently been seen in breeding colonies.

NORRIS, B.N. 1965. [166]

Caring for white flippered penguins. *Notornis 12(3)* : 185-6.

White flippered penguins were among birds affected by a 5,000 gallon spill of fuel oil in Lyttelton Harbour, July, 1965. Penguins were successfully treated with detergent, warmth and fish dipped in salt water or mixed with cod liver oil.

ROWAN, M.K. [1968] [167]

Oiling of marine birds in South Africa. Pp 121-4 *in* BARCLAY-SMITH, P. (Ed.) "International conference on oil pollution of the sea, 7-9 October 1968 at Rome. Report of proceedings".

[*See* No. 3]

Highly pelagic species are less vulnerable than birds which feed in the intermediate zones, in particular, four species of cormorant, Cape Gannets and Jackass Penguins. Soaps and detergents are effective for cleaning but prevent penguins staying in the sea for any length of time even three months after cleaning.

Best results have been obtained with Fuller's Earth, patted into all oiled parts, left two hours and removed by spraying with or swimming in fresh water, the process repeated over several days until cleaning is complete. Proper feeding with oily fish is also necessary. Some sick and dying birds have been found affected with *Salmonella typhimurium*, thought (according to a discussant) to be of human origin.

STANTON, P.B. 1972. [168]

"Operation Rescue. Cleaning and care of oiled waterfowl". American Petroleum Institute, Washington, D.C. 32 pp.

[*See* No. 162]

A well-illustrated American publication for popular use. Recommended treatments in some respects superseded by later refinements.

WESTPHAL, Althea; ROWAN, M.K. 1971. [169]

Some observations on the effects of oil pollution on the Jackass Penguin. *In* MACLEAN, G.L. (Ed.) "Proceedings of the third Pan-African Ornithological Congress &c." *Ostrich, Suppl. 8* : 521-6.

Following the *Esso Essen* spill in 1968, chief sufferers were cormorants (*Phalacrocorax* spp.), Cape Gannets (*Sula capensis*) and Jackass Penguins (*Spheniscus demersus*). At least 500 gannets perished and 1,700 oiled penguins were found on the beaches, 750 of which died before or during treatment. The remainder were returned to the sea after treatment, 400 being flipper-banded. This paper deals with 51 penguins treated in some way. "Larodan" was tried but found unsuitable for heavy oils and penguin feathers; Fuller's Earth was preferred. Best results were obtained with freshly-oiled penguins, 4 only of 17 dying. Over 50 per cent of birds handled had pathogenic infections and two died of *Salmonella typhimurium*, one being found near a sewage outfall. The major killer was a *Staphylococcus aureus*, apparently introduced by a bird with a suppurating wound and spread by cross-infection in captivity. Extrapolation of data suggests that this spill and an earlier one in 1963 may have wiped out more than one-tenth of all penguins breeding on Cape islands.

New Zealand Reports

[*See also* Nos 66, 163, 166]

CUNDELL, A.M. 1972. [170]

Oil pollution and offshore field development. *Chemistry in New Zealand 36(6)* : 184-7.

Overseas experience with offshore production and oil pollution extrapolated to the Maui situation. The author states that prevailing onshore winds and the northwest convergence of the West Wind Drift and the Eastern Australian currents would deposit any spilled oil on Taranaki and Cook Strait beaches. "Maui condensate, which is of low specific gravity with a paraffinic base and a predominance of low boiling point fractions would be more readily dispersed than high residue crude oils containing asphaltenes or paraffin waxes. However, its aromatic content (25 to 30 per cent by weight) may be toxic to marine organisms". Surface temperatures on the shelf suggest its destruction would be moderately slow but, offshore operations should not be "extra-hazardous" providing proper precautions are taken including "mandatory inspection and weekly blowout practice and the provision of a disaster contingency plan ... the installation of subsurface safety devices [in producing wells] together with their regular inspection and checks that they will close the well in".

NEW ZEALAND MARINE DEPARTMENT. 1968. [171]

Preliminary report of the New Zealand Committee on pollution of the sea by oil . Unpublished report. Marine Department, Wellington. 39 pp.

Discusses nautical, engineering and scientific aspects of tanker casualties or oil spillages. On the basis of prediction of likely spillage areas, recommendations are made regarding shipping lanes and practices, salvage possibilities discussed and recommendations given for treating spills.

[SHORLAND, F.B.; HURLEY, D.E.] 1968. [172]

"Oil pollution on the open sea, rocky beaches and sandy beaches and methods of disposal. Report of the committee on problems of oil pollution". Royal Society of New Zealand, Wellington. 10 pp.

A short resumé of the *Torrey Canyon* and other spills; includes recommendations for treatment and short annotated bibliography.

Bibliographies

CHRISTOL, C.Q. 1970. [173]

Oil pollution of the marine environment - a legal bibliography. *University of Southern California, Sea Grant Publication No. 1* : 93 pp.

[*Also United States Senate, Committee on Public Works, Serial No. 92-1*, 1971.]

The first section, "Articles" and "Books", includes many references to general papers on oil pollution and marine problems, useful background reading to a lawyer entering the field, no doubt, but hardly qualifying as legal references. The second half is more in line with the title and covers United Nations Documents; Documents of other international organisations; United States Congress Statutes, Committee hearings and reports; United States Executive Department and Administrative Agency reports and documents; multilateral and bilateral treaties dealing with the seas and pollution; statutes and official decisions of foreign states, and United States statutes and governmental acts.

HOLMES, R.W. 1972. [174]

"Oil pollution - an index-catalog to the collection of the Oil Spill Information Center." University Library, University of California. 1157 pp.

Expensive ($300) 4-volume listing of 20,000 entries. American coverage very good, European less efficient.

MOULDER, D.S.; VARLEY, A. 1971. [175]

"A bibliography on marine and estuarine oil pollution". Marine Biological Association of the United Kingdom, Plymouth. viii, 129 pp.

1073 entries covering all scientific literature on subject to July, 1971, excluding oiled seabird papers and journalistic articles. Topics covered include sources of oil pollution and their controls, properties, detection, analysis and identification of oil; reports on particular spills; biological effects; methods of containment and treatment.

NELSON-SMITH, A. 1968. [176]

A classified bibliography of oil pollution. Pp 165-96 *in* CARTHY, J.D.; ARTHUR, D.R. (Eds) "The biological effects of oil pollution on littoral communities".

[*See* No. 4]

800 references to oil pollution classified under various subject headings in three main groupings : General accounts and overall effects of oil pollution; more specific accounts of biological effects of oil pollution; and processes and methods by which spilt oil is removed.

OFFICE OF WATER RESOURCES RESEARCH. 1973. [177]

"Oil spillage. A Bibliography". 2 vols. *Water Resources Scientific Information Center Report WRSIC 73-207* : 387 and 446 pp. (*National Technical Information Service PB-221 107, PB-221 108*.)

Titles and abstracts from "Selected Water Resources Abstracts" to the end of 1972. Comprehensive descriptor and author index.

STANTON, P.B. 1972. [178]

"A selected bibliography on oiled waterfowl and their rehabilitation". Wildlife Rehabilitation Center, Upton, Massachusetts. 21 pp.

"A very useful conspectus of much relevant literature, although mistakes are regrettably frequent. To cover diseases, physiology, morphology, ecology and mortality relationships of seabirds, as well as oiling and treatment, is perhaps hardly feasible in about 500 entries, and many important papers are inevitably left out. The coverage of papers on oiling incidents and care and cleaning of birds is much better, but quite a number of useful papers are omitted".

STANTON, P.B. [Undated] [178a]

Operation Rescue. A bibliography. A selected bibliography on oiled waterfowl and their rehabilitation. American Petroleum Institute, Washington, D.C. [20 pp.]

Apparently a re-presentation of 178.

VERMEER, Rebecca; VERMEER, Kees. 1974. [179]

Oil pollution of birds : an abstracted bibliography. *Manuscript Report, Pesticide Section, Canadian Wildlife Service 29* : 68 pp.

Over 200 references are arranged (a) in chronological order to show the evolution of the problem of oil pollution of birds over a period of 50 years, and (b) in alphabetical order by author without abstracts.

WALSTAD, K.; HEARTH, F.E. 1972. [180]

"Oil pollution in the Santa Barbara Channel : a comprehensive bibliography." University Library, University of California. viii + 195 pp.

Includes many newspaper references : a comprehensive coverage of articles on the Santa Barbara spill.

Author Index

[*Numbers refer to individual references, not pages.*]

Index to Spills

Cleansing Agents and Absorbents

Only those actually mentioned in the Abstracts are listed.