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SOURCES OF MARINE POLLUTION AROUND NEW ZEALAND

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Publications in this series generally result from specific enquiries for information. They record and comment on relevant available data.

This summary was prepared in order to gather together published and unpublished accounts of marine pollution around New Zealand

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ABSTRACT

The level of marine pollution around New Zealand is low relative to that encountered around other countries, particularly the industrialised nations of the Northern Hemisphere. Nevertheless, there is evidence of pollution in some semi-enclosed coastal waters (e.g., sounds, estuaries, harbours), particularly those close to urban centres where point discharges of municipal sewage and industrial effluent occur.

Agricultural runoff is also an important pollutant but oil spillages and radioactive waste disposal constitute only a minor problem at present. It is important that pollution of coastal waters resulting from future developments be minimised for aesthetic, recreational, and health reasons, as well as for economic reasons such as the extension of marine farming.

INTRODUCTION

Marine pollution has been defined by the Intergovernmental Oceanographic Commission (IOC) as "the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources; hazards to human health; hindrance to marine activities including fishing; impairing the quality for use of seawater and reduction of amenities" (UNESCO, 1982). In spite of much progress, there remain serious deficiencies in our understanding of the input, extent, and distribution of pollutants into the oceans (Holdgate *et al.* 1982). Nevertheless, because the oceans represent the lowest topographic domain in the hydrological cycle, pollutants, once introduced into the oceans, must reside there (Park and O'Connor 1981).

Marine pollution has received less attention in New Zealand than has land or freshwater pollution, mainly because New Zealand is predominantly an agricultural economy in which grass is converted to animal protein with the aid of substantial amounts of fertiliser. Hurley (1970) noted that the principal pollution problems in this country are due to animal wastes, human sewage, chemical and trade-waste pollution of streams and harbours in the large cities, and occasional minor oil spills in harbours. Although New Zealand has a human population of only 3.2 million in an area roughly equivalent to that of Great Britain, it has an animal population of some 72 million, which is one of the highest ratios of farm animals to people in the world (New Zealand Official Yearbook 1981 (Anon. 1981)). Hurley stated that New Zealand's farm animal population was equivalent (in terms of sewage) to a human population of 36 million. This figure was based on the calculations of T. Brown (1969) who referred to the protein nitrogen equivalent of waste for dairy cattle, plus pigs and chickens (i.e., excluding sheep), and was widely used throughout the 1970s. It was never quantified in terms of the components of the waste or the nature of animals' habitats (i.e., free-ranging or housed) so that this figure is rather misleading (I.W. Gunn, pers. comm.). Gunn (1982) later calculated that New Zealand farm animals contribute a waste-load equivalent of around 800 million persons dung equivalent (i.e., solid by weight) or 180 million persons polluting equivalent (i.e., organic matter measured as BOD (Biological Oxygen Demand)). This situation is mitigated by the fact that dairy cattle, for example, drop around 95% of their waste in the fields, where it is naturally degraded, and 5% at the milk shed, where it can be washed off into waterways (I.W. Gunn, pers. comm.). Comparative figures for animal waste production in the United States are given by the American Chemical Society (1969).

Other environmental hazards result from New Zealand's agricultural economy. Soil erosion, caused by the very rapid development of agriculture over the last 100 years, has led to the introduction of considerable amounts of sediment and other matter into the coastal environment as well as into freshwater catchments. In addition, New Zealand uses 2.6 million tonnes of phosphate fertiliser annually (about 5% of which may be lost in surface run-off) as well as one million tonnes of lime and 20,000 tonnes of nitrogen fertilisers

(Fish 1969; Sharpley and Syers 1976; Cooke 1981; Hoare 1982; UNESCO 1982; McColl 1983). According to the New Zealand Fertiliser Manufacturers' Research Association, however, New Zealand imports 1.2 million tonnes of rock phosphate per year. They also state that New Zealand fertiliser statistics are not in good order.

Industrial developments, such as the Wairakei geothermal field and pulp and paper mills, have led to discharges of heavy metals into the environment (although Kinleith wastes, for example, are first trapped in ponds and not discharged directly).

Much of the marine disposal of wastes in New Zealand, as elsewhere, is based on the rationale that the volume of seawater is so large that any pollutants are diluted to such an extent that they are rendered harmless. Only in coastal inlets such as harbours, estuaries, or sounds, particularly those adjacent to urban areas, do the problems of marine pollution approach those encountered in freshwater systems (cf. Tihansky 1973). Nevertheless, no part of the oceans is entirely free from pollution (Dybern 1974; Butler *et al.* 1979). This is a consequence of the fact that, each year, world society uses about 3 billion tonnes of food, manufactured, and forest products as well as 20 billion tonnes of carbon dioxide from the combustion of fossil fuels, a proportion of which finds its way to the oceans in a wide variety of forms (Goldberg 1981). (A survey of New Zealand's wastes was recently undertaken by the Board of Health (1983).)

An index of national pollution has been devised by Goldberg and Bertine (1971) as a country's Gross National Product (GNP)/area. This is based on the idea that a country's GNP is related to the flow of materials through its society as a result of its industrial, agricultural, and domestic activities; the leaks of such substances to the environment, whether unintentional or deliberate, constitute pollution. Since the countries with the larger GNPs are all found in the Northern Hemisphere, marine pollution is most significant there (Goldberg 1976a). By comparison, New Zealand differs from most of the countries listed by Goldberg and Bertine (1971) in that its population and industry are limited. This, plus the fact that it consists of three main islands with a long coastline situated in a remote part of the open ocean, means that, although New Zealand has a relatively high per-capita GNP, it is characterised by a relatively low level of marine pollution (cf. Hurley 1970; Tihansky 1973; Dybern 1974).

Nevertheless, as was shown by a survey of estuarine conditions (McLay 1976), pollution does occur off the coast of New Zealand and it is necessary to identify its sources and effects, not least because of of the multiple-use concept of resources. Accidents and actions taken as a result of emergencies can be a source of local pollution, examples being a spill of ammonia into the Kapuni River from an ammonia-urea plant in Taranaki, in October 1982, which resulted in serious pollution of a 3-km stretch of the river (Morrison 1982); the deliberate dumping of liquid waste from the same plant directly into the sea in December of the same year (Gooding 1983); failures in sewers, as at Eastbourne in February 1982 (Anon. 1982a); and oil spills. Hazardous wastes are also becoming an increasing problem in New Zealand (Anon. 1983a; Gunn 1983). However, some forms of marine pollution appear to result from entirely natural causes, an example of this being the marine "slime" which has been recorded on several occasions during the past 120 years at various places around New Zealand (Hurley 1982; Chang 1983; Woodley 1983).

In New Zealand, regulations regarding marine pollution are set out in the Marine Pollution Act 1974 (Government of New Zealand 1974). Useful texts on pollution in New Zealand include Marine Department, New Zealand (1952), Anon. (1973a), Hicks (1974), Knox (1979), Shanks (1982), UNESCO (1982), Hileman (1983), and Williams (in press).

For comparison with the situation in the New Zealand region, the following texts dealing with marine pollution in general are worth consulting : Carson (1962), Ashby (1971), The David Davies Memorial Institute of International Studies (1971), Ruivo (1972), Smith (1974), Goldberg (1976a, 1981), Johnston (1976), Waldichuck (1977, 1979), Ketchum (1980), Ross (1980), Bright (1981), Cole (1981), Gerlach (1981), Geyer (1981), Ketchum *et al.* (1981), Bascom (1982), Feliciano (1982), Gray (1982), Holdgate *et al.* (1982), UNESCO (1982), Farrington *et al.* (1983), Harrison (1983), and Keckes (1983). Pollution problems in Britain have been discussed by Ashby (1971) and Cole (1979a, b). The latter writer contests the idea that pollution has done serious biological damage around Britain (cf. Lee 1978; Murray and Portmann 1982; Cole 1983). Similarly, Holdgate (1983) takes a cautiously optimistic view on the development of marine pollution over the last 10 years. The importance of marine pollution has been recognised by IOC in the establishment of a programme called Global Investigation of Pollutants in the Marine Environment (IOC-GIPME). New Zealand is involved with this programme through the Taranaki Catchment Commission.

Whilst agricultural development has been a major factor in pollution in New Zealand to date, Ketchum (1980) and Förstner and Wittmann (1981) make the point that pollution has increased markedly since the Industrial Revolution. This is also true in New Zealand, since it was the arrival of the European with his tendency to urbanise, industrialise, and to practice intensive agriculture, together with the increase in population from that time, that dates the increase in pollution in New Zealand. Some of these impacts have been documented by Whittlestone (1973), Salmon (1975), and Cumberland (1981). Useful reviews of New Zealand's environment have been presented by the OECD (1980, 1981), and Nature Conservation Council (1981), and an indication of the range of New Zealand work in

marine pollution can be seen by an inspection of the New Zealand Marine Sciences Newsletter (Gordon and Thompson 1983) and previous issues.

The following categories of pollutants are considered in this review : sewage, chemicals (including heavy metals), heat, oil, litter, and radioactive wastes.

MUNICIPAL SEWAGE

The discharge of raw or untreated sewage into the sea is a relatively cheap method of disposal and it is doubtless for this reason that it is a common practice in maritime countries. This method is usually justified on the grounds that the assimilative capacity of the sea, on a global scale, is very large. At any particular location, however, the ability of the sea to disperse and dilute effluent depends upon the method of discharge and on local currents. In adverse conditions, high concentrations of effluent can occur near the point of discharge. Nevertheless, it has been claimed that the discharge of sewage through long submarine outfalls, when properly sited, is an efficient method for the disposal of untreated sewage (State Water Pollution Control Board 1956; Bascom 1974; Calvert 1975; Thorstensen 1980; Pearce 1982), although this view has been challenged (Baalsrud 1975; Howell 1977; Tortell 1980).

In New Zealand, most sewage effluent is discharged into the sea, directly or indirectly, with land disposal accounting for only a small fraction of the total (Stevenson *et al.* 1978). This reflects the fact that the majority of New Zealand's population lives by the sea. In a recent account of sewage disposal systems operating in New Zealand, Gunn (1982) states that 33% of community sewage (98% treated) is discharged into harbours and estuaries, 25% (50% treated or passed through modern ocean outfalls) enters the ocean directly, 18% enters streams (80% treated), and 2% enters lakes (98% treated). The remainder is disposed of mainly in septic tanks. A listing of the main sewage discharges is given in Table 1 and their locations are shown in Fig. 1. A useful review of sewage treatment and disposal practices in New Zealand is given by Steven and Fitzmaurice (1976).

Municipal sewage often contains a proportion of industrial waste, much of which reacts to the oxidation processes used in municipal sewage treatment. This applies particularly to waste from meatworks, dairy factories, and vegetable freezing and canning plants (Health Department 1975). The pollution load of these effluents is often expressed as being equivalent to the domestic sewage produced by a particular population, based upon the relative biological oxygen demand (BOD). For example, in reviewing the pollution problems of the New Zealand meat industry, Cooper *et al.* (1979) state that each major slaughterhouse has a pollution load equivalent to a city of population 60-100,000 and that the meat industry produces a pollution load well in excess of that from domestic sources, some of which is discharged via municipal sewers. Thus, of the 38 export slaughterhouses operating in 1976, 11 discharged their wastes into the ocean, either directly or via municipal sewers employing primary treatment only; and 6 discharged into municipal sewers which employed secondary treatment (Cooper *et al.* 1979, p. 59, Table 5). Effluent discharges of a typical meatworks have been described by Cooke *et al.* (1980) and Devine (1981).

The extent to which receiving waters are polluted by sewage depends upon the degree of prior treatment, as well as how the sewage is diluted and dispersed. Sewage contains a high proportion of organic matter, which can contribute to an increase in nutrients and a decrease in dissolved oxygen levels. These changes may result in biological effects which are most apparent in the benthic communities surrounding submarine sewage outfalls (Topping 1976). Observations have shown that, whilst species diversity is reduced, the populations of particular organisms are increased (Filice 1959; Resig 1961; Perkins 1976; Knox and Fenwick 1978). Sewage also contains micro-organisms (e.g., viruses, bacteria, protozoa), some of which can cause human illnesses such as infectious hepatitis and gastroenteritis. These micro-organisms may be concentrated in shellfish, and the use of polluted waters for food-gathering and swimming can present a health risk (Clarke *et al.* 1964; Anon. 1973b; Craun and McCabe 1973; Cabelli 1978a, b; Patrick and Kendrick 1980a; Pearce 1981; Lewis *et al.* 1982; Simmonds *et al.* 1982), although Hewings (1968) concluded that bathing presented little danger where domestic sewage had been adequately diluted.

The dispersion of sewage discharged into the sea depends, in part, upon local water movements which, in turn, depend upon variations in winds, tides, waves, and water density. The overall pattern of coastal currents around New Zealand has been studied by a number of workers and the results have been summarised by Heath (1973, in press). In addition, a number of studies of the marine environment have been carried out in the vicinity of various sewage outfalls - some of these are now briefly discussed below.

New Zealand's largest city, Auckland, has two harbours - the Waitemata and the Manukau - situated on the east and west coasts respectively. Sewage was discharged directly into the Waitemata Harbour until the 1950s, when a secondary sewage treatment plant was built at Manukau Harbour. This latter harbour now receives sewage, via oxidation ponds, from a large population (Table 1) and has been the subject of various reports and studies (Powell 1937; Wallace *et al.* 1956; Auckland Regional Authority 1972; Beca Carter Hollings and Ferner Ltd 1975; Henriques 1976; Grange 1977, 1979; Heath *et al.* 1977), whilst the performance of oxidation ponds in New Zealand has been discussed by Ferrier and Ralston (1970).

TABLE 1

Major Sewage Outfalls in New Zealand.
(from a survey of sewage systems conducted in 1978 by the Department of Health, Wellington)

CODE No.	COMMUNITY	POPULATION ($\times 10^3$)	OUTFALL	TREAT-MENT *	REMARKS
1	Auckland Regional Authority	500	Manukau Harbour	3 + 2	
2	Christchurch Drainage Board	260	Heathcote Estuary	3 + 2	
3	North Shore Harbour Board	200	East Coast Bays, Hauraki Gulf	3 + 2	
4	Wellington	140	Moa Point, Cook Strait	1	Screened
5	Hutt Valley Drainage Board	110	Pencarrow Head, Cook Strait	1	
6	Dunedin	83	Lawyers Head, Dunedin	1	Primary Sedimentation
7	Porirua and Tawa	55	Titahi Bay, Cook Strait	1	Screened
8	Invercargill	50	New River Estuary		Primary Sedimentation
9	Napier	47	Hawke Bay	1	Screened
10	New Plymouth	38	Tasman Bay	1	Screened
11	Whangarei	35	Limeburners Creek (off Harbour)	3 + 4	Discharges into stream
12	Hastings	34	Hawke Bay	1	Screened
13	Gisborne	30	Poverty Bay	1	Screened
14	Timaru	30	Pacific Ocean	1	Screened
15	Nelson	20	Wakapuaka, Tasman Bay	1 + 2	
16	Tauranga	16	Tauranga Harbour	4	45% connected
17	Oamaru	13½	Pacific Ocean		3 outfalls
18	Whakatane	11	Bay of Plenty	2	Discharges into river
19	Mount Maunganui	10	Bay of Plenty	2	Under construction
20	Stoke, Nelson	10	Waimea Inlet	3	
21	Hawera	8½	Tasman Sea	1	Screened
22	Green Island, Dunedin	7	Pacific Ocean	1	Screened
23	Thames	7	Firth of Thames	2	
24	Waitara	6	Tasman Sea	1	Screened
25	Wairoa	5	Hawke Bay	Aerated Lagoon	
26	Hokitika	3½	Tasman Sea	2 + 1	
27	Port Chalmers	3	New River Estuary		Primary Sedimentation

* 1, Sea Outfall; 2, Oxidation pond; 3, Sedimentation and filtration; 4, Activated sludge.

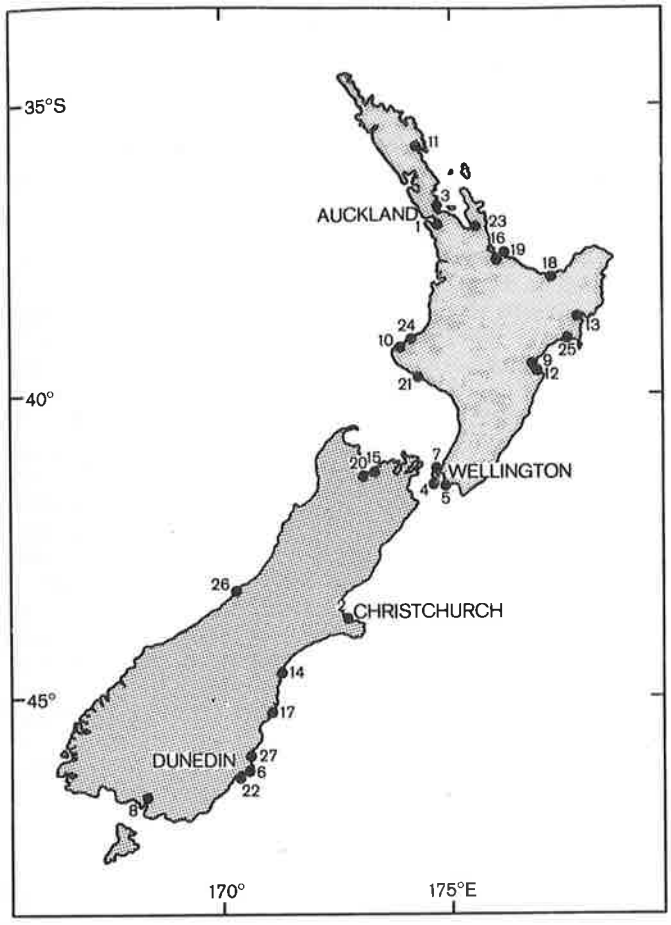

Fig. 1. Map of New Zealand showing the sewage outfalls listed in Table 1. Locations are indicated by code numbers which are given in the table.

Henriques (1976) described how the effluent discharged into Manukau Harbour has resulted in some reduction in intertidal faunal density in the vicinity of the discharge. He suggested that this reduction may be linked to one or more factors - salinity variations (caused by freshwater discharges from the oxidation ponds), smothering of the fauna by silt and clay (caused by initial dredging of the ponds and the subsequent continuous discharge of fine particles), and variations in the amounts of nutrients introduced from the ponds. He also discussed the bacterial status of the harbour and concluded that, although most of it is suitable for swimming, a lesser area is suitable for the collection of shellfish.

Larcombe (1973) studied the ecology of Waitemata Harbour and a report on water-quality standards applicable to the harbour was published by the Auckland Harbour Board and Auckland Regional Authority (1972). Although most of Auckland's sewage is discharged into Manukau Harbour, some is released into Waitemata Harbour from emergency overflows on the main drainage system and from private craft (mainly during summer months). Larcombe (1973) reported that the release of sewage, at the levels then existing, had little immediate obvious ecological impact, except at some localised areas which received regular overflows. Other studies of this region include those of Taylor (1973), Chapman and Larcombe (1974), Van Roon (1981, 1982), and Parnell (1982).

The Avon-Heathcote estuary receives effluent from much of greater Christchurch (Table 1) and has been the subject of a number of studies including those of Hogan and Wilkinson (1959), Estcourt (1967), Cameron (1970), Knox and Kilner (1973), Millhouse (1975, 1977), Millhouse and Knox (1976), and Stephenson (1980). Effects such as algal blooms and the encouragement of a few tolerant species were found in some areas of the estuary; however, subsequent improvements in treatment methods and the termination of industrial waste discharges into the estuary have led to a reduction in the nutrient load input. Consequently, algal blooms have reduced in intensity and whitebait have recently returned in numbers worth catching for consumption (Stephenson 1980, p. 24).

The Christchurch Drainage Board has proposed a sewage treatment plant to service an eventual population of 110–120 thousand residing north of Christchurch city. One proposal is to discharge the effluent into Brooklands Lagoon, which opens to the Waimakariri River and is separated from the sea by a sandspit about 200 m wide. A second proposal is to discharge the effluent via a 2-km sea outfall into Pegasus Bay, near the small settlement of Spencerville about 15 km north of Christchurch and at the southern end of Brooklands Lagoon. In connection with these proposals, studies were made of the ecology of Brooklands Lagoon (Knox and Bolton 1978) and of the benthic fauna off Spencerville (Knox *et al.* 1978). One conclusion of this second study was that organic enrichment of the bottom, resulting from sewage input, could lead to increased numbers of fish, providing the correct level of input was maintained. This is because probable increases in the population of particular benthic species, particularly polychaete worms, could enhance food supplies for bottom-feeding fish.

In Wellington city, the main sewer outfall is located at Moa Point (on the western approaches to the harbour) and there are three smaller outfalls - at Houghton Bay, at Island Bay, and by the mouth of the Karori Stream. Two other small outfalls which entered Wellington Harbour at Ngauranga and Kaiwharawhara are no longer in use, and their loads are pumped into the Moa Point sewage line.

A comprehensive study of the Wellington city sewage discharge at Moa Point, and of options for future sewage treatment and ocean disposal of the effluent, was made by Beca Carter-Caldwell Connell (1980) following an environmental impact assessment (Wellington City Corporation 1976). The study described

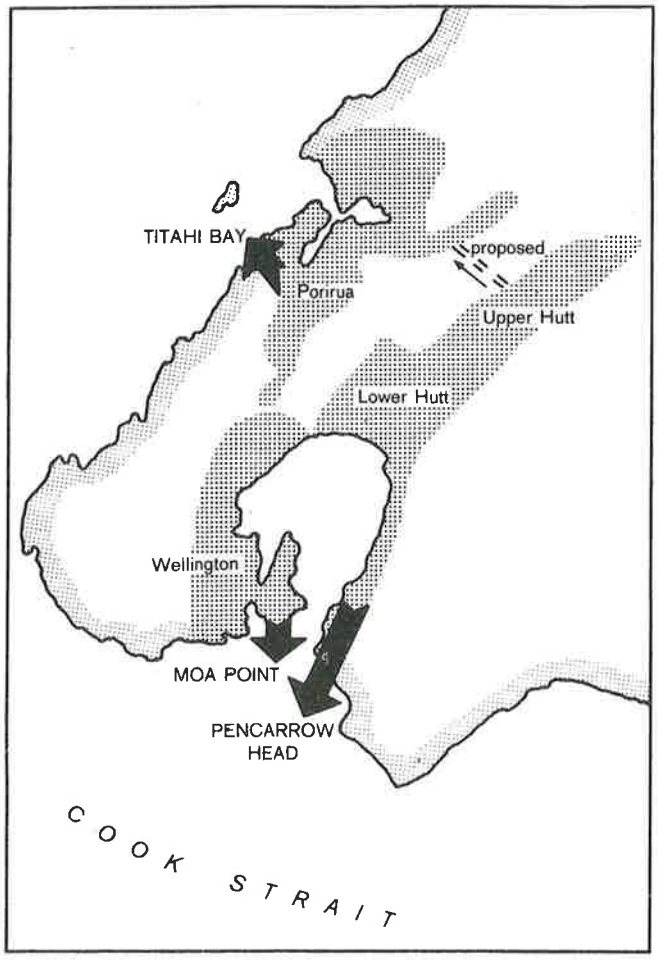

Fig. 2. Location of main sewage outfalls in the Wellington region (*after* Spooner 1977).

nine potentially feasible wastewater treatment options and presented estimates of their capital, operating, and annual costs. Their recommended treatment plant would involve fine-screening to remove floatables and particulate matter larger than 1 mm, followed by primary sedimentation at high settlement rates. The recommended sea outfall would extend 1,950 m offshore from Moa Point. The existing outfall discharges at about low water mark and the report states that its effects upon marine communities are most obvious within 250 m (but may extend to 600 m) from the outfall.

Some additional sewage can enter directly into Wellington Harbour from 77 known emergency discharge points and numerous unidentified discharge points via storm-water systems (Anon. 1982b). The consequences of such discharges have been highlighted by Davis (1982), who suggested that any significant improvement in the quality of harbour water depends upon the continued upgrading of urban drainage systems and stated that this may not be feasible, either practically or economically. Bacteriological surveys of Wellington Harbour have been reported by Johannesson (1955), Johannesson and Martin (1955, 1956), Mawson (1956), Vidal and Collins (1970), Loutit (1972), and Davis (1982), and surveys of harbour circulation by Brodie (1958), Wallace and McCabe (1974), Booth (1975), and Heath (1977). For the Wellington region as a whole, sewage disposal problems have been discussed by Spooner (1977).

There are two other outfalls in this region (Fig. 2), the one at Pencarrow Head (at the eastern approaches to Wellington Harbour), and the other at Rukutane Point near Titahi Bay (on the west coast, about 30 km north of Wellington). The Pencarrow outfall serves the cities of Upper Hutt and Lower Hutt and has been in use since 1962, but its capacity is now being approached. Reports on alternative methods of increasing the present capacity were prepared by Steven and Fitzmaurice (1970, 1971) who recommended that wastes from the Upper Hutt and Porirua regions be combined and discharged via an outfall sited at Kaumanga Point near Titahi Bay. (Sewage from the Porirua area is presently discharged at Rukutane Point, Titahi Bay (Ministry of Works 1961, 1962; Ridgway 1962a).) Some of the objections to this scheme have been reported by du Fresne (1982). Lower Hutt wastes would continue to be discharged at Pencarrow Head after primary treatment – a detailed discussion of their suggested disposal has been given by Steven and Fitzmaurice (1981).

Three local authorities – Napier, Hastings, and Wairoa – discharge sewage into Hawke Bay (Table 1), where a number of studies have been carried out (Ridgway 1960, 1962b; Stone 1961; Gibb 1962; Pantin 1966; Steven and Fitzmaurice 1967; Ridgway and Stanton 1969; Burgess 1972; Hastings City Council 1972; Knox and Fenwick 1978; Bradford *et al.* 1980). The biological study by Knox and Fenwick (1978) showed that a decline in species diversity with increased pollution was accompanied by an increased population of a few species. They also found higher yields of flatfish in the area of the Hastings outfall compared with other fishing grounds in Hawke Bay. This probably results from organic enrichment of the bottom sediments causing higher densities of benthic invertebrates.

In New Plymouth, untreated sewage is discharged into the sea via a short outfall which extends to about low-water mark and has been in operation since 1930. However, a new sewage disposal system is presently nearing completion and is expected to be fully operational during the second half of 1984. This new system will employ secondary treatment in which the sewage is subjected to forced aeration during its passage through circular ditches before discharge through an outfall located near the mouth of the Waiwakaiho River. A number of alternative disposal systems and sites were considered before the new scheme was adopted (*see* Steven and Fitzmaurice 1978).

Other sewage discharge areas which have been studied include the Hibiscus Coast in the Hauraki Gulf (Beca Carter Hollings and Ferner Ltd 1974), Tauranga Harbour (Steven and Fitzmaurice 1974), Wanganui (Worley, Downey, Muir and Associates 1967), the Manawatu River (Suckling 1982), and Tasman Bay (Heath 1971; Bolton and Knox 1977; Knox 1977; Ridgway 1977; Updegraff *et al.* 1977).

THERMAL EFFLUENT

Thermal pollution is mainly associated with the discharge of heated water from thermal-electric generating stations; other sources are much less significant. For example, in the U.S., thermal-electric power stations use 70% of all industrial cooling water (Bell 1971). An essential requirement for such power stations is a large supply of cold water, used to condense steam on the outlet side of the turbines. The electrical efficiency of thermal power plants is approximately 40%, most of the fuel's energy being returned to the atmosphere and to the cooling water in the form of heat. For this reason, thermal power stations are built alongside rivers, lakes, estuaries, or the sea into which the heated water is discharged. At thermal power stations, the temperature of the water rises (by 15°C, on average, in the U.S.) during its passage through the condensers (Bell 1971). When discharged into the receiving water, a buoyant plume of heated water is formed which takes several hours to cool to ambient temperature. Initial cooling of the discharged water occurs by the entrainment of receiving water and, when the plume stabilises as a surface layer, heat is lost to the atmosphere mainly as a result of evaporation.

Studies of the ecological effects of heated effluent have been listed by Grange and Pishief (1976) and Grange (1983) and the effects of elevated water temperatures upon various groups of animals have been reviewed by The Heated Effluent Study Technical Group (1973), which stated that, although changes occur in animal communities exposed to heated effluents, it is rare for species to be completely eliminated.

In New Zealand, most of the electric power is provided by hydro-electric stations, but four thermal power stations occur at coastal sites. The largest, at New Plymouth, is fuelled by natural gas. The site is exposed to storm waves and frequently to heavy swell from the south and west. Consequently, effective mixing and dispersal of the warm-water discharge can be expected. The station has a designed output of 600 megawatts and an average load factor of 60%. Each of the five turbines requires 2.5×10^5 litres of cooling water per minute, the water temperature rising by about 10°C when passing through the condensers. Measurements made before the commissioning of the station showed considerable natural fluctuations in sea-surface temperature (Ridgway 1973), so that, except in the immediate vicinity of the discharge, elevated sea-surface temperature cannot be correlated with the discharge of cooling water. The settlement and growth of sessile organisms in the vicinity of the cooling water intake and discharge outlet at this station were studied by Luckens (1975). Such organisms growing in the pipes and ducts cause problems in the operation of a power station and are usually controlled by dosing with chlorine. The work of Luckens was undertaken to enable the optimum amount of chlorine to be determined.

An oil-powered thermal-electric power station, Marsden 'A', now being converted to natural gas, is sited close to the entrance to Whangarei Harbour. This station has a designed output of 240 megawatts and operates intermittently either when hydro-electric power production is reduced because of low river flows or when there are peak demands during winter months. In 1982, for example, it operated for only 5% of the year. The thermal effluent plume from the discharge was measured by Bradford and Burns (1977) and was found to be largely confined to the upper 2 m of water and to be limited in area. Major plankton mortality occurred as a result of mechanical damage to the organisms during their passage through the cooling system rather than by elevated water temperatures. A second thermal power station, Marsden 'B', is sited alongside the Marsden 'A' station, but is presently not in use. (It is planned to convert the Marsden 'B' station to the use of coal but it is not expected to come into operation for at least 3–4 years.)

A gas-turbine power station at Otara, in the estuary of the Tamaki River, Auckland Harbour, also operates intermittently. Eight engines are employed, two of which are cooled by water taken from a nearby lake. The heated condenser water is discharged into a collecting pond and released into the estuary at times of high tide when there is adequate receiving water for mixing and initial cooling. The other six engines use a closed-circuit cooling system. A survey of two species of edible bivalves living in the estuary was carried out before the station went into operation and the temperature tolerance of one of the species was studied in the laboratory (R. Brown 1969).

As the above summary indicates, except at New Plymouth, the volume of thermal effluent discharged into the sea is quite small and even at New Plymouth no adverse effects resulting from the discharge of heated cooling water have been reported.

OIL POLLUTION

New Zealand is fortunate in that, to date, there have been no instances of excessive discharges of petroleum products into the sea, although there have been minor accidental discharges. Two examples of

these were the sinking of T.E.V. *Wahine* in Wellington Harbour in April 1968 (Ridgway 1972) and the grounding of M.V. *Pacific Charger* on the coast near Wellington in May 1981 (Ministry of Transport 1982a).

Local sources of relatively minor oil pollution include power boats and aircraft. Oil can accumulate particularly in boat marinas, as a result of oil spillages, oil leaks, and exhaust fumes from boats, while the sea margin alongside some airport runways in New Zealand is heavily impregnated with oil deposited from aircraft during landings and take-offs (Hicks 1974). An oil refinery at Marsden Point, Whangarei Harbour, is supplied with crude oil from overseas by large tankers. (An application has been lodged to discharge 4,000 m^3 of treated waste daily (Anon. 1983b).) Coastal tankers, in turn, carry refined petroleum products from Marsden Point to ports around the coast, so the potential for a large oil spill resulting from a tanker mishap is always present. Only a small number of minor spills, however, have so far occurred during loading, discharging or tank-cleaning operations in New Zealand but, as pointed out by Douglas (1978), numerous small oil spills can be as hazardous as one large spill.

In general, such accidents have contributed only about 5% of the oil pollution in the world's oceans (cf. Holdgate *et al.* 1982) (~0.3 million tonnes of oil per year compared with up to 2.5 million tonnes per year contributed from the land via rivers (Gerlach 1981)). When large tanker accidents do occur, however, massive amounts of oil enter the sea at one location and the environmental effects of both the spill and subsequent clean-up operations can be devastating. New Zealand lies far from the world's main tanker routes and consequently the risk of tanker spillages is proportionately less than in other areas of the world's oceans (Levy *et al.* 1981). The exploitation of the offshore Maui Gasfield however, and the continuing search for offshore oil deposits provides another potential hazard in the New Zealand region, and this has led to detailed environmental studies being carried out in the region of the Maui gas production platform (Kibblewhite *et al.* 1982).

To facilitate a rapid response in the event of a major oil spill, a contingency plan has been prepared (Ministry of Transport 1981) which describes the actions and procedures to be adopted (cf. Ministry of Transport 1982b). To assist in deciding what appropriate remedial action should be taken in any particular instance, an atlas which describes and illustrates the location of commercial, recreational, historical, and wildlife resources along New Zealand's coastline has been prepared (Tortell 1981). This atlas includes an oil sensitivity index for New Zealand shores, first developed by Gregory (1979). This index classifies categories of coastal geomorphology on a scale of 1-10, in order of their susceptibility to environmental damage from an oil spill. Studies have also been carried out (Power 1983a, b, c) on the long-term effects of oil dispersants on common intertidal New Zealand organisms. In addition, the Royal Society of New Zealand (1968) reported on oil pollution, a bibliography of the literature on oil spills was prepared by Hurley (1975), and Tortell (1981, 1982) provided useful discussions on the legislation, planning and management aspects of oil pollution. Finally, Chemistry Division, DSIR, is responsible for the chemical analysis of oil spills, with the aim of establishing their source.

HEAVY METALS AND OTHER CHEMICAL POLLUTANTS

Although heavy metals are known to be associated with offshore dumping of sewage and industrial wastes (Halcrow *et al.* 1973; Thornton 1975; Hershelman *et al.* 1981; Coker and Matthews 1983), they are not believed to be a major problem in New Zealand as they are in the North Sea for example (Anon. 1982c). The main area of concern is the localised discharge of mercury into the waters of the central North Island from the geothermal systems as well as from the Kinleith pulp and paper plant (Weissberg and Zobel 1973; Weissberg 1975; Brooks *et al.* 1976; Weissberg and Rohde 1978), although production using a mercury cell at the mill has now ceased.

In spite of the lack of direct discharge of heavy metals into New Zealand coastal waters, some effort has gone into studying the mercury content of marine fish species in order to see if they conform to the New Zealand Food and Drug Regulations 1973 (Government of New Zealand 1973), which require that fish offered for sale on the local market do not contain more than 0.5 ppm mercury. This problem is important in view of the increasing value of New Zealand's fish exports, which in 1982 were worth $NZ253 million. In 1972, for example, a shipment of schoolshark was prevented from entering Australia because the mercury content exceeded 0.5 ppm (van den Broek *et al.* 1981). New Zealanders ingest, on average, 20 g of fish per day. No problem of mercury ingestion from marine fish has emerged in New Zealand, although fish remains the dominant source of mercury in the diet (Dick *et al.* 1978). That this arbitrary level of mercury in fish of 0.5 ppm might now need revision has been well stated by Goldberg (1976b), Walker (1980), and Officer and Ryther (1981).

Several studies of heavy metals in fish (Brooks and Rumsby 1965; Brooks and Rumsey 1974; Robertson *et al.* 1975; van den Broek and Tracey 1981, 1983; van den Broek *et al.* 1981; Mitchell *et al.* 1982) and in molluscs (Nielsen 1974; Nielsen and Nathan 1975) have now been carried out in New Zealand. The most comprehensive survey was that by van den Broek *et al.* (1981) who analysed 1,357 samples from 27 species of deep-water fish. Of these, 24 species averaged less than the 0.5 ppm limit. A dependence of the mercury content of the fish with fish length and water temper-

ature was established. Studies of the methods by which metals enter into higher organisms in polluted waters have also been undertaken, by Lee *et al.* (1975), Patrick (1976), Patrick and Loutit (1976, 1977, 1978), Shirer (1979), Smillie (1980), Johnson *et al.* (1981), Pillidge (1981), and Smillie *et al.* (1981). These results are of interest because, without doubt, the seas around New Zealand are among those least polluted by heavy metals and can therefore provide useful baseline data.

Although heavy metal pollution is small, the possibility of some anthropogenic input of heavy metals into the marine environment of New Zealand cannot be overlooked. Thus an extensive survey of trace metals in sediments from a number of estuaries (including Pauatahanui, Waikanae, Waitara, and Avon-Heathcote) has recently been carried out by P.C. Kennedy (Community Health Department, Auckland University School of Medicine) as part of a Ph.D. thesis (for the Botany Department, Victoria University of Wellington). This study included trace-metal monitoring using bivalves and gastropods, as well as pollution studies in Wellington Harbour and the Hutt River. Studies of Cu and Ni contents of seawater in Otago Harbour and Cook Strait showed no evidence of pollution being a major influence (Dickson and Hunter 1981; Hunter 1983). Chemistry Division, DSIR, is studying the levels and forms of lead in tanker deballast water, as well as monitoring the distribution of lead in Port Taranaki seawater in relation to the deballast water-treatment facilities.

A potential source of seawater contamination is the synthetic petrol plant under construction at Motunui, north Taranaki (Commission for the Environment 1981; Environment Group 1981; Hutchings 1981; Noonan 1981, para. 4.6.3). Apart from the possibility of spills of methanol and synthetic petroleum as part of this general expansion of the petrochemicals industry (Douglas 1978), it was originally proposed to discharge about five tonnes of zinc per year, in addition to several other components (the zinc acting as a cooling-tower corrosion inhibitor) through an outfall at Motunui. Various limited trace-element studies were made in respect of this discharge, including baseline surveys of Zn and Cd in seawater as well as in paua and mussels by Chemistry Division, DSIR (cf. Taranaki Catchment Commission and Regional Water Board 1980; Matthews 1982; Taranaki Catchment Commission, unpubl. data). In 1982, it was decided instead to use Alfloc 8339 as the cooling-tower corrosion inhibitor and Alfloc 324 as a biocide, both of which have a very low order of toxicity. Toxicological studies of the various reagents involved have been carried out (Power 1982a, b, c, 1983d; Taranaki Catchment Commission and Regional Water Board 1983). In 1981, the NDA (National Development Act) Planning Tribunal recommended extension of the offshore pipeline at Motunui to 1,800 m. These proposed discharge plans were, however, changed in 1983 after consideration by the Waitangi Tribunal (1983) who asserted that the Treaty of Waitangi obliges the Crown to ensure that priority is given to Maori interest in fishing grounds, and recommended that the proposal for the ocean outfall at Motunui be discontinued and interim arrangements made to discharge the effluent through the Waitara Borough Council's existing outfall.

Other studies of chemical pollutants in New Zealand's marine environment, and baseline studies of the environment prior to anticipated pollution, include pesticides in farmed oysters (Winchester and Keating 1980), other marine fauna (Solly and Harrison 1972), and seabirds (Turner *et al.* 1978); natural fluoride levels at Bluff prior to the operation of a proposed aluminium smelter (Manley *et al.* 1975); nitrogen fixation in Waimea Inlet (Bohlool 1978) which receives effluent from an apple cannery and which can be compared with a nearby unpolluted area (Stanton *et al.* 1977; Mountfort *et al.* 1980); and the discharge of chemicals into the Avon-Heathcote Estuary (Stephenson 1980). In addition, K. Hunter (University of Otago) proposes to study chromium in Otago Harbour (from tannery effluent) (cf. Smillie *et al.* 1981); Chemistry Division, DSIR, is engaged in a baseline study of toxic metals, particularly in the streams of the Coromandel Peninsula, to monitor the effects of possible mining there; and New Zealand is involved in the international mussel watch programme through Fisheries Research Division, Ministry of Agriculture and Fisheries, Wellington (cf. Goldberg *et al.* 1978; Dinamani 1981). From a map prepared by Goldberg (1976a), it would appear that DDT pollution is not a problem in New Zealand.

The dumping of any material at sea requires a permit from the Ministry of Transport, issued in accordance with the Marine Pollution Act 1974 (Government of New Zealand 1974). Virtually all the permits issued are for dredge spoil and the problem of dumping of chemicals at sea is virtually non-existent in New Zealand (except, of course, for those chemicals introduced via sewage outfalls). Explosives may also be dumped at sea in approved explosives dumping areas, the positions of which are shown on hydrographic charts. These dumping grounds are located, in the main, near Auckland, Wellington, and Lyttelton.

LITTER

Litter is an increasingly important component of marine pollution in other parts of the world (cf. Wong *et al.* 1974; Dixon and Dixon 1983), and is becoming so in New Zealand. For example, > 1,000 tonnes of plastic pellets, originally worth more than $1 million, were estimated to occur on New Zealand beaches, principally near the metropolitan centres (Gregory 1977, 1978). These pellets are the feedstock of the local plastics industry. Other types of litter, such as glass and plastic bottles, plastic containers and sheeting,

cellophane, and empty food and beer cans, are also present on New Zealand beaches. Most of this litter originates at sea when people travelling on boats and ships discard their rubbish into the sea. The annual quantity of garbage thrown into the world's oceans from various classes of shipping have been estimated as : fishing vessels, 340,000 tonnes; merchant ships, 110,000 tonnes; pleasure craft, 103,000 tonnes; navy vessels, 74,000 tonnes, and passenger ships, 28,000 tonnes (Gerlach 1981). From these estimates, it is likely that most ship-derived garbage in New Zealand would originate from fishing vessels and pleasure craft, since the number of merchant, passenger, and naval vessels operating in New Zealand waters is very small. An additional source of waste is the inter-island passenger ferries which cross Cook Strait up to eight times per day between Wellington and Picton.

Although the amount of litter on New Zealand's beaches is probably small by world standards, some form of litter is nearly always evident, particularly on beaches close to urban centres.

RADIOACTIVITY

In the Northern Hemisphere, the introduction of artificial radioisotopes into the sea from nuclear weapons and civilian reactor programmes continues to be a problem. New Zealand has also dumped low-level radioactive wastes, in the Hikurangi Trough east of North Island. Since the passing of the Marine Pollution Act 1974 (Government of New Zealand 1974), seven drums of waste, with an activity of 13 curies, have been dumped. This is a trivial amount and is likely to be so until New Zealand develops an indigenous nuclear industry. A useful review of the London Convention for the dumping of radioactive waste at sea has been given by Sutton (1982).

DISCUSSION

The preceding sections indicate that, by many criteria, New Zealand coastal waters are relatively unpolluted, certainly in comparison with the North Atlantic, for example. The main areas of concern are semi-enclosed waterways, such as estuaries, harbours, and sounds in the vicinity of metropolitan centres where sewage seems to be the principal source of pollution. Estuaries are very important areas in the overall productivity of the oceans (Deuser 1979; Knox 1980) and it is clear that they must be accorded priority in terms of marine pollution control, particularly in view of the fact that estuaries can act as traps for metals (Turekian 1974; Goldberg 1976b). This is exemplified by the Avon-Heathcote Estuary which has been significantly degraded as a result of metropolitan development. It is therefore encouraging to see that new development areas, such as Pauatahanui Inlet, are receiving adequate scientific study (including determinations of heavy metals, pesticides, and nutrients) *before* development (Healy 1980; Kennedy 1980) and that detailed environmental surveys of Wellington Harbour are being undertaken. The publication of the New Zealand Atlas of Coastal Resources (Tortell 1981) is very useful in this respect.

For the future, close attention should be paid to the coastal system. In particular, it is important that industrial developments are undertaken with minimal environmental degradation and baseline studies are essential in order that the effects of such developments can be monitored and assessed (cf. Heath and Grange, in press). As an example, the environmental impact of onshore mining has been discussed by Blaiklock (1981). Such mining, particularly in the Coromandel area, could affect the biota of the Firth of Thames (Duncan 1981; Morton 1981; van den Broek 1982); offshore mining, such as the possible exploitation of Chatham Rise phosphorites (Dawson, in press) would require strict environmental controls (Ward 1977).

Marine farming (e.g., mussel farming in the Marlborough Sounds) is becoming established in New Zealand and a clean marine environment is essential to its success. Problems which can arise in the event of contamination have been discussed by Boustead (1980), Patrick and Kendrick (1980b), and Till (1980) and the need for controlled purification of the shellfish before sale has been discussed by Hayden (1981a, b) and Buisson *et al.* (1981, 1982). Even forestry can be detrimental to the local marine environment (Johnston *et al.* 1981) and have a deleterious effect on mussel farming (cf. MacPherson 1981; Jackman 1981). According to Hickman (1982), there is a need for a national policy on marine farming to avoid conflict in the use of coastal water.

To some extent, the amount of environmental hazards due to pollution within an individual country reflects that country's desire to limit such hazards by legislation; the improvement of air and water pollution in Britain over the last 30 years (but not its beach pollution (Pearce 1981, 1982)) is an example of this. Sound environmental policies are therefore of the utmost importance. Of interest here is the assertion that the margin of cost of meeting acceptable standards of pollution control is of the order of 1-2% of the GNP of those developed countries that have made estimates (Holdgate *et al.* 1982). Nevertheless, we concur with Amann's (1982) view that responsible environmental policies should be formulated and implemented on the basis of scientific, technical, and social evidence and not simply on political considerations.

In summary, although New Zealand's coastal waters are, for the most part, substantially free from pollution, significant pollution can nevertheless occur as a result of designed or accidental discharges of effluent into the sea. New Zealand's relative freedom from marine pollution is mainly because it has a relatively long coastline, a small population, few heavy industries, and is remote, and not as a result of enlightened planning and legislation. If marine pollution is not to increase in the face of future industrial growth and developments it may be well to bear in mind the following words of Berg (1975, p. 23) :

> "Man's existence on earth was measured in millennia but his capability for seriously disrupting the earth's ecosystems and seriously affecting his own existence went back barely a few score years. Even if he decided he had to live with some of his pollution, he could not live with all of it. In the next decade or two, man had little alternative but to alter his ways, or pay the piper a measure and beyond."

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REFERENCES

AMANN, H. 1982: Technological trends in ocean mining. *Phil. Trans. R. Soc. Lond. A307* : 377-403.

AMERICAN CHEMICAL SOCIETY, 1969: "Cleaning our Environment : the chemical basis for action". American Chemical Society, Washington, D.C. 249 p.

ANON., 1973a: "Proceedings of the Pollution Research Conference, Wairakei, New Zealand, 20-21 June 1973". *N.Z. DSIR Inf. Ser. 97* : 568 p.

ANON., 1973b: Sewage in the sea. *Mar. Pollut. Bull. 4(10)* : 145-46.

ANON., 1981: "New Zealand Official Yearbook 1981 - 86th Annual Edition". Department of Statistics, Wellington. viii + 1040 p. + [8] pls.

ANON., 1982a: Eastbourne beaches polluted. *Wellington Evening Post, February 12* : 4.

ANON., 1982b: Harbour safe for swim but don't eat shellfish. *Wellington Evening Post, June 2* : 21.

ANON., 1982c: Report on N. Sea metal pollution. *Mar. Pollut. Bull. 13(9)* : 297.

ANON., 1983a: National policy on hazardous wastes required, declares Shearer. *Chemy Ind. 17(5)* : 1.

ANON., 1983b: Challenge to tribunal on oil discharge. *Wellington Evening Post, February 23* : 16.

ASHBY, E. (Chairman) 1971: "Royal Commission on Environmental Pollution", Her Majesty's Stationery Office, London. 48 p.

AUCKLAND HARBOUR BOARD and AUCKLAND REGIONAL AUTHORITY, 1972: "Water quality standards applicable to Waitemata Harbour". Report. Auckland Harbour Board, Auckland Regional Authority, Auckland. 33 p. + apps.

AUCKLAND REGIONAL AUTHORITY, 1972: "Investigation of dispersion of effluent from Manukau treatment works". Report. Auckland Regional Authority, Auckland.

BAALSRUD, K. 1975: The case for treatment. Pp. 165-72 *in* Gameson, A.L.H. (ed.) "Discharge of Sewage from Sea Outfalls". Pergamon Press, Oxford. xiv + 455 p.

BASCOM, W. 1974: The disposal of waste in the ocean. *Scient. Am. 231(2)* : 16-25.

BASCOM, W. 1982: The effects of waste disposal in the coastal waters of Southern California. *Envir. Sci. Technol. 16* : 2264-364.

BECA CARTER - CALDWELL CONNELL, 1980: "Moa Point wastewater treatment plant and outfall study. Study of wastewater treatment and disposal into Cook Strait for Wellington City Corporation". Report. Beca Carter Hollings & Ferner Ltd, Caldwell Connell Engineers Pty Ltd, Wellington. x + 177 p.

BECA CARTER HOLLINGS AND FERNER LTD, 1974: "Wastewater disposal for the Hibiscus Coast. An Environmental Impact Report prepared for the Waitemata County Council". Beca Carter Hollings & Ferner Ltd, Auckland. 85 p. + 9 apps.

BECA CARTER HOLLINGS AND FERNER LTD, 1975: "Environmental Impact Report on Pikes Point East Reclamation". Report to the Auckland Regional Authority and New Zealand Railways. Beca Carter Hollings and Ferner Ltd, Auckland. vii + 45 p. + 5 apps.

BELL, H.W. 1971: Thermal effluents from electrical power generation. *Tech. Rep. Fish. Res. Bd Can. 262* : 54 p.

BERG, G. 1975: Regional problems with sea outfall disposal of sewage on the coasts of the United States. Pp. 17-24 *in* Gameson, A.L.H. (ed.) "Discharge of Sewage from Sea Outfalls". Pergamon Press, Oxford. xiv + 455 p.

BLAIKLOCK, K. 1981: The environmental impact of mining. *N.Z. Envir. 29* : 6-16.

BOARD OF HEALTH (N.Z.), 1983: 1982 refuse survey and grading of landfills. *Bd Hlth (N.Z.) Rep. Ser. 32* : 84 p.

BOHLOOL, B.B. 1978: Nitrogen fixation in polluted intertidal sediments of Waimea Inlet, Nelson. *N.Z. Jl mar. Freshwat. Res. 12(3)* : 271-75.

BOLTON, L.A.; KNOX, G.A. 1977: The ecology of selected sites near Mapua, Waimea Inlet. *Estuar. Res. Unit Rep. (Dep. Zool., Univ. Canterbury) 10* : 30 p.

BOOTH, J.D. 1975: Seasonal and tidal variations in the hydrology of Wellington Harbour. *N.Z. Jl mar. Freshwat. Res. 9(3)* : 333-54.

BOUSTEAD, N.C. 1980: Disease control in cultivated fish. Pp. 77-80 *in* Dinamani, P.; Hickman, R.W. (comps) "Proceedings of the Aquaculture Conference". *Occ. Publ. Fish. Res. Div. 27* : 104 p.

BRADFORD, J.M.; BURNS, D.A. 1977: The effects of the Marsden 'A' thermal power station on the marine plankton. *NZOI Rec. 3(9)* : 69-86.

BRADFORD, J.M.; RIDGWAY, N.M.; ROBERTSON, D.A.; STANTON, B.R. 1980: Hydrology, plankton and nutrients in Hawke Bay, September 1976. *NZOI oceanogr. Fld Rep. 15* : 38 p.

BRIGHT, D.B. 1981: International pollution control strategies. *Bull. mar. Sci. 31(3)* : 479-94.

BRODIE, J.W. 1958: A note on tidal circulation in Port Nicholson, New Zealand. *N.Z. Jl Geol. Geophys. 1(4)* : 684-702.

BROOKS, R.R.; LEWIS, J.R.; REEVES, R.D. 1976: Mercury and other heavy metals in trout of central New Zealand. *N.Z. Jl mar. Freshwat. Res. 10(2)* : 233-44.

BROOKS, R.R.; RUMSBY, M.G. 1965: The biogeochemistry of trace element uptake by some New Zealand bivalves. *Limnol. Oceanogr. 10(4)* : 521-27.

BROOKS, R.R.; RUMSEY, D. 1974: Heavy metals in some New Zealand commercial sea fishes. *N.Z. Jl mar. Freshwat. Res. 8(1)* : 155-66.

BROWN, R.M. 1969: Molluscan survey of the Tamaki River, Waitemata Harbour, Auckland, August 1968, at the site of the Otara gas-turbine power station. *Fish. tech. Rep. N.Z. mar. Dep. 37* : 24 p.

BROWN, T.J. 1969: The significance of agricultural pollution in New Zealand. *Publ. Hlth (N.Z.) 84(4)* : 21-27.

BUISSON, D.H.; FLETCHER, G.C.; BEGG, C.W. 1981: Bacterial depuration of the Pacific oyster (*Crassostrea gigas*) in New Zealand. *N.Z. Jl Sci. 24(3-4)*: 253-62.

BUISSON, D.; FLETCHER, G.; BEGG, C. 1982: Depuration control for Pacific oysters. *Catch 9(1)*: 13, 15-17.

BURGESS, J. 1972: "Effluent disposal in Hawke Bay". Report to the Engineer, Hastings City Council, Department of Geography, University of Canterbury, Christchurch.

BUTLER, P.A.; HUGGETT, R.; MACEK, K.; REINERT, R.; RISEBROUGH, R. 1979: Synthetic organics. Pp. 13-22 *in* Goldberg, E.D. (ed.) "Proceedings of a Workshop on Scientific Problems Relating to Ocean Pollution, Estes Park, Colorado, July 10-14, 1978". U.S. Department of Commerce, Washington, D.C. 225 p.

CABELLI, V.J. 1978a: New standards for enteric bacteria. Pp. 233-72 *in* Mitchell, R. (ed.) "Water Pollution Microbiology". Wiley Interscience, New York. Vol. 2, xii + 442 p.

CABELLI, V.J. 1978b: Swimming associated disease outbreaks. *J. Wat. Pollut. Control Fed. 50(6)* : 1374-77.

CALVERT, J.T. 1975: The case against treatment. Pp. 173-76 *in* Gameson, A.L.H. (ed.) "Discharge of Sewage from Sea Outfalls". Pergamon Press, Oxford. xiv + 455 p.

CAMERON, J. 1970: Biological aspects of pollution in the Heathcote River, Christchurch, New Zealand. *N.Z. Jl mar. Freshwat. Res. 4(4)* : 431-44.

CARSON, R. 1962: "Silent Spring". Hamish Hamilton, London. xxii + 304 p.

CHANG, F.H. 1983: The mucilage-producing *Phaeocystis pouchetii* (Prymnesiophyceae), cultured from the 1981 "Tasman Bay slime". *N.Z. Jl mar. Freshwat. Res. 17(2)* : 165-68.

CHAPMAN, V.J.; LARCOMBE, M.F. 1974: "Ecological report on the Hobson Bay region. (An addendum to the ecology report on the Waitemata Harbour - July 1973)". Report. Auckland Harbour Board, Auckland Regional Authority, Auckland. ii + 38 p.

CLARKE, N.A.; BERG, G.; KABLER, P.W.; CHANG, S.L. 1964: Human enteric viruses in water : Source, survival and removability. Pp. 523-41 *in* Eckenfelder, W.W. (ed.) "Advances in Water Pollution Research". Pergamon Press, New York. Vol. 2, vi + 578 p.

COKER, E.G.; MATTHEWS, P.J. 1983: Metals in sewage sludge and their potential effects in agriculture. *Wat. Sci. Tech. 15* : 209-25.

COLE, H.A. 1979a: Marine pollution - facts and fiction, the situation in Britain. *Ocean. Mgmt 5(3)* : 263-78.

COLE, H.A. 1979b: Pollution of the sea and its effects. *Proc. R. Soc. Lond. B205* : 17-30.

COLE, H.A. 1981: Grim outlook for the twenty-first century. *Mar. Pollut. Bull. 12(3)* : 69-71.

COLE, H.A. 1983: Effects of pollution on fish stocks. *Mar. Pollut. Bull. 14(2)* : 37-38.

COMMISSION FOR THE ENVIRONMENT, 1981: "Environmental Impact Audit by the Commission for the Environment on the proposal by the New Zealand Synthetic Fuels Corporation for a synthetic petrol plant at Motunui, Taranaki". Commission for the Environment, Wellington. Vol. 1. viii + 129 p. + 16 apps; Vol. 2, iv + 516 p.

COOKE, J.G. 1981: Pollution from our pastures. *Soil & Water 17(5-6)* : 13-15.

COOKE, J.G.; TILLMAN, R.W.; SYERS, J.K. 1980: Characterisation of municipal sewage and meat works effluent discharges into the Manawatu River. *N.Z. Jl Sci. 23(4)* : 387-97.

COOPER, R.N.; HEDDLE, F.J.; RUSSELL, J.M. 1979: Characteristics and treatment of slaughterhouse effluents in New Zealand. *Prog. Wat. Technol. 11(6)* : 56-68.

CRAUN, G.F.; McCABE, L.J. 1973: Review of the causes of waterborne disease outbreaks. *J. Am. Wat. Wks Ass. 65* : 74-84.

CUMBERLAND, K.B. 1981: "Landmarks". Reader's Digest Services, Canberra. 304 p.

DAVIS, K.R. 1982: "Wellington Harbour : A brief history of its development and its present condition in respect of water quality from a bacteriological point of view". Report. Wellington Regional Council, 82.210 : 1 + 104 p. + 3 apps.

DAWSON, E.W. (in press): The benthic fauna of the Chatham Rise : an assessment of possible effects of phosphorite mining. *Geol. Jb. D52.*

DEUSER, W.G. 1979: Marine biota, nearshore sediments, and global carbon balance. *Org. Geochem. 1* : 243-47.

DEVINE, C.E. 1981: Chemistry in the meat industry. Pp. 117-31 *in* Williams, P.P. (ed.) "Chemistry in a Young Country". N.Z. Institute of Chemistry, Christchurch. 243 p.

DICK, G.L.; HUGHES, J.T.; MITCHELL, J.W.; DAVIDSON, F. 1978: Survey of trace elements and pesticide residues in the New Zealand diet. 1. Trace element content. *N.Z. Jl Sci. 21(1)* : 57-69.

DICKSON, R.J.; HUNTER, K.A. 1981: Copper and nickel in surface waters of Otago Harbour. *N.Z. Jl mar. Freshwat. Res. 15(4)* : 475-80.

DINAMANI, M. [P.] 1981: WESTPAC pollution monitoring. *Catch 8(2)* : 13.

DIXON, T.J.; DIXON, T.R. 1983: Marine litter distribution and composition in the North Sea. *Mar. Pollut. Bull. 14* : 145-48.

DOUGLAS, J.V. 1978: Hazardous spill contingency plans advocated. *Soil & Water 14(4)* : 7-10.

du FRESNE, K. 1982: A matter not easily disposed of. *N.Z. Listener, October 23* : 38-40.

DUNCAN, A. 1981: A position paper on policy issues relating to land and sea-bed mining and their possible impact on the fishing industry with particular reference to the Coromandel area. N.Z. Fishing Industry Board Economics and Marketing Division Report No. 33 : [v] + 40 + [6] p.

DYBERN, B.I. 1974: Water pollution : a problem with global dimensions. *Ambio 3* : 139-45.

ENVIRONMENT GROUP, 1981: "Energy Development in Taranaki. Are we on the right track?". Report. Environment Group, University of Auckland, Auckland. 21 p.

ESTCOURT, I.N. 1967: Ecology of benthic polychaetes in the Heathcote Estuary, New Zealand. *N.Z. Jl mar. Freshwat. Res. 1(3)* : 371-94.

FARRINGTON, J.W.; CAPUZZO, J.M.; LESCHINE, T.M.; CHAMP, M.A. 1983: Ocean dumping. *Oceanus 25(4)* : 39-50.

FELICIANO, D.V. 1982: Sludge on land where we are, but where are we going? *J. Wat. Pollut. Control Fed. 54* : 1259-66.

FERRIER, D.A.; RALSTON, J. 1970: Biological sewage treatment with particular reference to oxidation ponds. *N.Z. Engng 25(10)* : 263-70.

FILICE, F.P. 1959: The effect of wastes on the distribution of bottom invertebrates in the San Francisco Bay estuary. *Wasmann J. Biol. 17* : 1-17.

FISH, G.R. 1969: Lakes : The value of recent research to measure eutrophication and to indicate possible causes. *J. Hydrol. (N.Z.) 8(2)* : 77-85.

FÖRSTNER, U.; WITTMANN, G.T.W. 1981: "Metal Pollution in the Aquatic Environment". Springer-Verlag, Berlin. 2nd edn. 486 p.

GERLACH, S.A. 1981: "Marine Pollution : Diagnosis and Therapy". Springer-Verlag, Berlin. vii + 218 p.

GEYER, R.A. (Ed.) 1981: "Marine Environmental Pollution. 2. Dumping and mining". Elsevier, Amsterdam. xxii + 574 p.

GIBB, J.G. 1962: Wave refraction patterns in Hawke Bay. *N.Z. Jl Geol. Geophys. 5(3)* : 435-44.

GOLDBERG, E.D. 1976a: "The Health of the Oceans". UNESCO, Paris. 172 p.

GOLDBERG, E.D. 1976b: Pollution history of estuarine sediments. *Oceanus 19(5)* : 18-26.

GOLDBERG, E.D. 1981: The oceans as waste space : the argument. *Oceanus 24(1)* : 2-9.

GOLDBERG, E.D.; BERTINE, K.K. 1971: GNP/area ratio as a measure of national pollution. *Mar. Pollut. Bull. 2(6)* : 94-95.

GOLDBERG, E.D.; BOWEN, V.T.; FARRINGTON, J.W.; HARVEY, G.; MARTIN, J.H.; PARKER, P.L.; RISEBROUGH, R.W.; ROBERTSON, W.; SCHNEIDER, E.; GAMBLE, E. 1978: The mussel watch. *Envir. Conserv. 5* : 101-25.

GOODING, B. 1983: Poison from the plant. *N.Z. Listener, March 5* : 17-19.

GORDON, D.P.; THOMPSON, R.M.C. (Eds) 1983: "New Zealand Marine Sciences Newsletter No. 26". N.Z. Marine Sciences Society, Wellington. 130 p.

GOVERNMENT OF NEW ZEALAND, 1973: "The Food and Drug Regulations 1973". Government Printer, Wellington. 92 p.

GOVERNMENT OF NEW ZEALAND, 1974: "An Act to make better provision for preventing and dealing with pollution of the sea, and to enable effect to be given to certain international conventions relating thereto (6 April 1974)". Government Printer, Wellington. Public Document No. 14. 73 p.

GRANGE, K.R. 1977: Littoral benthos-sediment relationships in Manukau Harbour, New Zealand. *N.Z. Jl mar. Freshwat. Res. 11(1)* : 111-23.

GRANGE, K.R. 1979: Soft-bottom macrobenthic communities of Manukau Harbour, New Zealand. *N.Z. Jl mar. Freshwat. Res. 13(3)* : 315-29.

GRANGE, K.R. 1983: Environmental effects of cooling-water discharge into the ocean. *N.Z. Energy Res. Dev. Comm. Rep. 96* : 12 p.

GRANGE, K.R.; PISHIEF, P.J. 1976: Heated effluent discharge and its effect on marine organisms : a selected bibliography, with summaries of relevant papers. *Misc. Publs N.Z. oceanogr. Inst. 76* : 28 p.

GRAY, J.S. 1982: Effects of pollutants in marine ecosystems. *Neth. J. Sea. Res. 16* : 424-43.

GREGORY, M.R. 1977: Plastic pellets on New Zealand beaches. *Mar. Pollut. Bull. 8(4)* : 82-84.

GREGORY, M.R. 1978: Accumulation and distribution of virgin plastic granules on New Zealand beaches. *N.Z. Jl mar. Freshwat. Res. 12(4)* : 399-414.

GREGORY, M.R. 1979: The New Zealand shoreline and application of an oil spill vulnerability index. Pp. 42-72 *in* Hodder, P. (comp.) "A minor oil-spills workbook for two programmes developed by Centre for Continuing Education, University of Waikato and Commission for the Environment". Centre for Continuing Education, University of Waikato, Hamilton. vi + 95 p.

GUNN, A. 1983: Hazardous wastes - disposal or dispersal. *Soil & Water 19(2)* : 4-9.

GUNN, I. 1982: Where to next, wastewater? *Soil & Water 18(3)* : 25-31.

HALCROW, W.; MACKAY, D.W.; THORNTON, I. 1973: The distribution of trace metals and fauna in the Firth of Clyde in relation to the disposal of sewage sludge. *J. mar. biol. Ass. U.K. 53(3)* : 721-39.

HARRISON, R.M. (Ed.) 1983: "Pollution : Causes, Effects and Control". Royal Society of Chemistry, London. 330 p.

HASTINGS CITY COUNCIL, 1972: "Effluent treatment and disposal for Hastings and environs". Report prepared under the direction of A.H. Selles, City Engineer, Hastings City Council, Hastings, N.Z. 93 p.

HAYDEN, B. 1981a: Depuration studies on Pacific oysters. *Catch 8(2)* : 9-10.

HAYDEN, B. 1981b: Shellfish : Controlled purification. *Catch 8(11)* : 13-14.

HEALTH DEPARTMENT (N.Z.), 1975: "Sewerage and sewage disposal for health inspectors". Report. Public Health Division, Health Department, Wellington. 112 p.

HEALY, W.B. (Co-ord.) 1980: "Pauatahanui Inlet - an Environmental Study". *N.Z. DSIR Inf. Ser. 141* : 198 p.

HEATH, R.A. 1971: Hydrology and circulation in central and southern Cook Strait, New Zealand. *N.Z. Jl mar. Freshwat. Res. 5(1)* : 178-99.

HEATH, R.A. 1973: Present knowledge of the oceanic circulation and hydrology around New Zealand - 1971. *Tuatara 20(3)* : 125-40.

HEATH, R.A. 1977: Circulation and hydrology of Wellington Harbour. *NZOI oceanogr. Summ. 12* : 8 p.

HEATH, R.A. (in press): Present knowledge of the physical oceanography of the ocean around New Zealand to 1982. *N.Z. Jl mar. Freshwat. Res.*

HEATH, R.A.; GREIG, M.J.N.; SHAKESPEARE, B.S. 1977: Circulation and hydrology of Manukau Harbour. *N.Z. Jl mar. Freshwat. Res. 11(3)* : 589-607.

HEATH, R.A.; GRANGE, K.R. (in press): Use of physical parameters in biological assessments of New Zealand coastal inlets. *N.Z. Jl mar. Freshwat. Res.*

HENRIQUES, P.R. 1976: "Manukau Harbour ecology : Preliminary investigations". Reports to the Works Division, Auckland Regional Authority, Auckland. v + 112 p.

HERSHELMAN, G.P.; SHAFER, H.A.; JAN, T.-K.; YOUNG, D.R. 1981: Metals in marine sediments near a large California municipal outfall. *Mar. Pollut. Bull. 12(4)* : 131-34.

HEWINGS, J.M. [1968]: "Water quality and the hazard to health : Placarding public beaches". Natural Hazard Research, Working Paper No. 3 : iv + 68 p. [obtainable from Ian Burton, Department of Geography, University of Toronto]

HICKMAN, R.W. 1982: Marine farming and coastal water conflicts. Pp. 159-61 *in* "Geography and Development Policy. Proceedings of the Eleventh New Zealand Geography Conference". N.Z. Geographical Society, Wellington. 221 p.

HICKS, R. 1974: Sources of coastal pollution. Pp. 121-25 *in* "Regional Management of Sea Coasts and Lake Shores. Proceedings of a symposium held in conjunction with the Annual Conference of the N.Z.E.I., Wellington, 19 February 1974". The N.Z. Institution of Engineers Technical Group on Water, Wellington. 185 p.

HILEMAN, B. 1983: New Zealand at a crossroads. *Envir. Sci. Technol. 17(11)* : 522A-28A.

HOARE, R.A. 1982: Lake nutrient load calculations : a management tool. *Soil & Water 18(3)* : 14-17.

HOGAN, D.J.; WILKINSON, L. 1959: A survey of pollution in the Avon and Heathcote rivers, Christchurch, New Zealand. *N.Z. Jl Sci. 2(4)* : 506-30.

HOLDGATE, M. 1983: Changes in world environment. *Chemy Brit. 19(1)* : 31-32, 34, 38.

HOLDGATE, M.W.; KASSAS, M.; WHITE, G.F. (Eds) 1982: "The World Environment 1972-1982. A report by the United Nations Environment Programme". Tycooly International Publishing Co., Dublin. 637 p.

HOWELL, J.A. 1977: Treatment of effluents. *Oceanus 10(3)* : 63-67.

HUNTER, K.A. 1983: Copper and nickel in shelf waters of the South Taranaki Bight and greater Cook Strait, New Zealand. *Mar. Pollut. Bull. 14(11)* : 428-31.

HURLEY, D.E. 1970: Pollution problems in New Zealand. *Mar. Pollut. Bull. 1(9)* : 133-34.

HURLEY, D.E. 1975: Marine oil spills. A selected bibliography. *Misc. Publs N.Z. oceanogr. Inst. 69* : 68 p.

HURLEY, D.E. 1982: The 'Nelson Slime', observations on past occurrences. *NZOI oceanogr. Summ. 20* : 11 p.

HUTCHINGS, J. 1981: Planning for petrochemical plants. *Soil & Water 17(3)* : 6-7.

JACKMAN, G. 1982: What use water rights? *N.Z. Envir. 35* : 3-6.

JOHANNESSON, J.K. 1955: The bacteriological survey of Wellington Harbour I - The distribution of sewage in the inner harbour and its effect upon Oriental Bay. *N.Z. Jl Sci. Technol. 37B(1)* : 59-77.

JOHANNESSON, J.K.; MARTIN, R.E. 1955: The bacteriological survey of Wellington Harbour II - Extent of pollution from Kaiwharawhara and Ngauranga outfalls. *N.Z. Jl Sci. Technol. 37B(2)* : 224-42.

JOHANNESSON, J.K.; MARTIN, R.E. 1956: The bacteriological survey of Wellington Harbour III - Extent of pollution spread northwards from the Ngauranga outfall. *N.Z. Jl Sci. Technol. 37B(4)* : 445-54.

JOHNSON, I.; FLOWER, N.; LOUTIT, M.W. 1981: Contribution of periphytic bacteria to the concentration of chromium in the crab *Helice crassa*. *Microbial Ecol. 7* : 245-52.

JOHNSTON, A.; MACE, J.; LAFFAN, M. 1981: The saw, the soil and the sounds. *Soil & Water 17(3-4)*: 4-8.

JOHNSTON, R. (Ed.) 1976: "Marine Pollution". Academic Press, London. xiv + 729 p.

KECKES, S. 1983: Protecting the marine environment. *Ambio 12(2)* : 112-14.

KENNEDY, P. 1980: Pauatahanui Inlet : a closer look. *Soil & Water 16(5)* : 7-10.

KETCHUM, B.H. 1980: Marine industrial pollution. Pp. 397-413 *in* Sears, M.; Merriman, D. (eds) "Oceanography : the Past". Springer-Verlag, New York. xx + 812 p.

KETCHUM, B.H.; KESTER, D.R.; PARK, P.K. (Eds) 1981: "Ocean Dumping of Industrial Wastes". *Mar. Sci. 12* : 529 p.

KIBBLEWHITE, A.C.; BERGQUIST, P.R.; FOSTER, B.A.; GREGORY, M.R.; MILLER, M.C. (Eds) 1982: "Maui Development Environmental Study Report on Phase Two 1977-1981". Shell BP and Todd Oil Services Ltd, Auckland. 174 p.

KNOX, G.A. 1979: Sewage disposal in the coastal zone. Pp. 29-43 *in* Knox, G.A. (ed.) "Environment 77 Proceedings. 7. Coastal Zone Workshop". Environment Center (Canterbury) Incorporated, Christchurch. 142 p.

KNOX, G.A. 1980: The estuarine zone : an overview. *Soil & Water 16(2)* : 13-17.

KNOX, G.A.; BOLTON, L.A. 1978: The ecology of the benthic macro flora and fauna of Brooklands Lagoon, Waimakariri River estuary. *Estuar. Res. Unit Rep. (Dep. Zool., Univ. Canterbury) 16* : 125 p.

KNOX, G.A.; BOLTON, L.A.; HACKWELL, K. 1977: Report on the ecology of the Parapara Inlet, Golden Bay. *Estuar. Res. Unit Rep. (Dep. Zool., Univ. Canterbury) 11* : 70 p.

KNOX, G.A.; FENWICK, G.D. 1978: A quantitative study of the benthic fauna off Clive, Hawke Bay. *Estuar. Res. Unit Rep. (Dep. Zool., Univ. Canterbury) 14* : 91 p.

KNOX, G.A.; FENWICK, G.; BOLTON, L.A. 1978: A preliminary quantitative study of the benthic fauna off Spencerville, Pegasus Bay. *Estuar. Res. Unit Rep. (Dep. Zool., Univ. Canterbury) 17* : 42 p.

KNOX, G.A.; KILNER, A.R. 1973: The ecology of the Avon-Heathcote estuary. *Estuar. Res. Unit Rep. (Dep. Zool., Univ. Canterbury) 1* : 358 p.

LARCOMBE, M.F. 1973: "Ecological report on the Waitemata Harbour". Report. Auckland Harbour Board, Auckland Regional Authority, Auckland. i + 375 p.

LEE, A. 1978: Effects of man on the fish resources of the North Sea. *Rapp. P.-v. Réun. Cons. int. Explor. Mer 173* : 231-41.

LEE, Y.; PATRICK, F.M.; LOUTIT, M. 1975: Concentration of metals by a marine bacterium, *Leucothrix* and a periwinkle *Melarapha*. *Proc. Univ. Otago med. Sch. 53* : 17-18.

LEVY, E.M.; EHRHARDT, M.; KOHNKE, D.; SOBTCHENKO, E.; SUZUOKI, T.; TOKUHIRO, A. 1981: "Global Oil Pollution : Results of MAPMOPP, the IGOSS pilot project on marine pollution (petroleum) monitoring". Intergovernmental Oceanographic Commission, UNESCO, Paris. i + 35 p.

LEWIS, G.D.; AUSTIN, F.J.; LOUTIT, M.W. 1982: A method for the detection and identification of human enteroviruses in the green-lipped mussel *Perna canaliculus*. *N.Z. Jl Sci. 25(4)* : 367-70.

LOUTIT, M. 1972: Standards for faecal coliform bacterial pollution (Comment). *N.Z. Jl mar. Freshwat. Res. 6(1-2)* : 214-15.

LUCKENS, P.A. 1975: Settlement seasons of actual and potential fouling organisms at the New Plymouth power station. *NZOI oceanogr. Summ. 7* : 7 p.

McCOLL, R. 1983: Farm runoff : the mechanisms and moderating factors. *Soil & Water 19(3)* : 31-35.

McLAY, C.L. 1976: An inventory of the status and origin of New Zealand estuarine systems. *Proc. N.Z. ecol. Soc. 23* : 8-26.

MACPHERSON, J.M. 1981: Hydrology of Okarito Lagoon and the inferred effects of selective logging in Okarito Forest. *N.Z. Jl mar. Freshwat. Res. 15(1)* : 25-39.

MATTHEWS, R.S. 1982: "Physical and chemical characteristics of the Waitara Estuary and coastal embayment with particular reference to effluent disposal". Unpublished M.Sc. thesis, University of Waikato. 209 p.

MAWSON, K.J. 1956: The sewerage of Wellington with particular reference to harbour pollution. *N.Z. Engng 11(1)* : 16-23.

MANLEY, T.R.; STEWART, D.J.; WHITE, D.A.; HARRISON, D.L. 1975: Natural fluorine levels in the Bluff area, New Zealand 2. Concentrations in pasture, soil, water, and urine of sheep and cattle. *N.Z. Jl Sci. 18(3)* : 433-40.

MARINE DEPARTMENT, NEW ZEALAND 1952: "Report of the Inter-Departmental Committee on the Pollution of Waters in New Zealand". Government Printer, Wellington. 38 p.

MILLHOUSE, D. 1975: The trace metal content of animals from McCormacks Bay, Avon-Heathcote Estuary, Christchurch. *Estuar. Res. Unit Rep. (Dep. Zool., Univ. Canterbury) 4* : 10 p.

MILLHOUSE, D. 1977: Trace metals in the Avon-Heathcote Estuary, Christchurch, New Zealand. *Estuar. Res. Unit Rep. (Dep. Zool., Univ. Canterbury) 8* : 12 p.

MILLHOUSE, D.; KNOX, G.A. 1976: Report on seasonal micro-nutrient variation in the Avon-Heathcote Estuary and the use of computer modelling as a predictive tool. *Estuar. Res. Unit Rep. (Dep. Zool., Univ. Canterbury) 6* : 29 p.

MINISTRY OF TRANSPORT, 1981: "New Zealand oil pollution contingency plan". Public Affairs Branch, Ministry of Transport, Wellington. 32 p.

MINISTRY OF TRANSPORT, 1982a: "M.V. Pacific Charger, shipping casualty, 21 May 1981 : Formal investigation held in Wellington, New Zealand, 7 July - 9 October 1981 : Report of court and annex thereto". Report. Marine Division, Ministry of Transport. Wellington. 184 p.

MINISTRY OF TRANSPORT, 1982b: "Oil pollution of the sea". Public Affairs Branch, Ministry of Transport, Wellington. 16 p.

MINISTRY OF WORKS, 1961: "Report on the Titahi Bay sewer outfall". Report. Ministry of Works, Wellington. 39 p. + 56 figs.

MINISTRY OF WORKS, 1962: "Titahi Bay sewer outfall investigation". Report. Ministry of Works, Wellington.

MITCHELL, J.W.; KJELLSTROM, T.E.; REEVES, R.L. 1982: Mercury in takeaway fish in New Zealand. *N.Z. Med. J. 95(702)* : 112-14.

MORRISON, A. 1982: Planning failure and spill. *N.Z. Times, October 24* : 1.

MORTON, J. 1981: Firth of Thames : Mining and fishing? *N.Z. Envir. 29* : 34-35.

MOUNTFORT, D.O.; ASHER, R.A.; MAYS, E.L.; TIEDJE, J.M. 1980: Carbon and electron flow in mud and sandflat intertidal sediments at Delaware Inlet, Nelson, New Zealand. *Appl. envir. Microbiol. 39* : 686-94.

MURRAY, A.J.; PORTMANN, J.E. 1982: Management of conservative pollutants in the marine environment : some advantages and a few problems of using fish and shellfish. *Mar. Pollut. Bull. 13(9)* : 300-04.

NATURE CONSERVATION COUNCIL, 1981: "Integrating Conservation and Development : a proposal for a New Zealand conservation strategy". Nature Conservation Council, Wellington. [64] p.

NIELSEN, S.A. 1974: Vertical concentration gradients of heavy metals in cultured mussels. *N.Z. Jl mar. Freshwat. Res. 8(4)* : 631-36.

NIELSEN, S.A.; NATHAN, A. 1975: Heavy metal levels in New Zealand molluscs. *N.Z. Jl mar. Freshwat. Res. 9(4)* : 467-81.

NOONAN, M.E. 1981: Evidence-in-Chief : NDA Joint Tribunal Hearing, 1981 : Wastewater treatment systems. [Unpubl. document]

OECD, 1980: "Environmental Policy and Management in New Zealand : A working document for the OECD Country Review". OECD, Paris. [v] + 77 + [1] p.

OECD, 1981: "Environmental Policies in New Zealand: A review by the OECD and its Environment Committee undertaken in 1980 at the request of the Government of New Zealand". OECD, Paris. 78 p.

OFFICER, C.B.; RYTHER, J.H. 1981: Swordfish and mercury : a case history. *Oceanus 24(1)* : 34-41.

PANTIN, H.M. 1966: Sedimentation in Hawke Bay. *Mem. N.Z. oceanogr. Inst. 28. [Bull. N.Z. Dep. scient. ind. Res. 171]* : 70 p.

PARK, P.K.; O'CONNOR, T.P. 1981: Ocean dumping research : Historical and international development. Pp. 3-23 *in* Ketchum, B.H.; Kester, D .R.; Park, P.K. (eds) "Ocean Dumping of Industrial Wastes". Plenum Press, New York. 525 p.

PARNELL, K. 1982: Guidelines for contaminant release in the Upper Waitemata Harbour. Upper Waitemata Catchment Study Working Report 37 : 49 p.

PATRICK, F.M. 1976: The passage of heavy metals through food chains. Unpublished Ph.D. thesis, University of Otago.

PATRICK, F.M.; KENDRICK, T.H. 1980a: Bacterial quality of paua (*Haliotis iris*) collected from waters of various degrees of sewage contamination : Preliminary findings. *N.Z. Jl Sci. 23(2)* : 107-09.

PATRICK, F.M.; KENDRICK, T.H.; 1980b: Changes in bacterial quality of Pacific oysters from Dyers Creek, Mahurangi Harbour in response to rainfall. Pp. 86-91 *in* Dinamani, P.; Hickman, R.W. (comps) "Proceedings of the Aquaculture Conference". *Occ. Publ. Fish. Res. Div. 27* : 104 p.

PATRICK, F.M.; LOUTIT, M.W. 1976: Passage of metals in effluents, through bacteria to higher organisms. *Wat. Res. 10* : 333-35.

PATRICK, F.M.; LOUTIT, M.W. 1977: The uptake of heavy metals by epiphytic bacteria on *Alisma plantago-aquatica*. *Wat. Res. 11* : 699-703.

PATRICK, F.M.; LOUTIT, M.W. 1978: Passage of metals to freshwater fish from their food. *Wat. Res. 12* : 395-98.

PEARCE, F. 1981: The unspeakable beaches of Britain. *New Scient. 91(1262)* : 139-43.

PEARCE, F. 1982: The sea as a sewer. *New Scient. 95(1316)* : 294-95.

PERKINS, E.J. 1976: The evaluation of biological response by toxicity and water quality assessments. Pp.505-85 *in* Johnston, R. (ed.) "Marine Pollution". Academic Press, London. 729 p.

PILLIDGE, C.J. 1981: Bacterial and metal solubilization in a coastal marine environment. Unpublished B.Sc. (Hons) thesis, University of Otago.

POWELL, A.W.B. 1937: Animal communities of the sea-bottom in Auckland and Manukau harbours. *Trans. Proc. R. Soc. N.Z. 66(4)* : 354-401, pls 30, 31.

POWER, F.M. 1982a: Implications of toxicological studies for the marine discharge of liquid waste from a major energy development. Taranaki Catchment Commission and Regional Water Board Technical Report 82-1 : [22]p.

POWER, F.M. 1982b: Preliminary assessment of the toxicity of the corrosion inhibitor Alfloc 8339 to three intertidal benthic marine invertebrates. Taranaki Catchment Commission and Regional Water Board Technical Report 82-2 : 42 p.

POWER, F.M. 1982c: Toxicological aspects of regulation of liquid discharges from alcohol fuels plants. Pp. 199-206 *in* "Proceedings Fifth International Alcohol Fuel Technology Symposium". John McIndoe, Dunedin. Vol. 3, 435 p.

POWER, F.M. 1983a: Long-term effects of oil dispersants on intertidal benthic invertebrates I. Survival of barnacles and bivalves. *Oil Petrochem. Pollut. 1* : 97-108.

POWER, F.M. 1983b: Long-term effects of oil dispersants on intertidal benthic invertebrates II. Growth of barnacle *Epopella plicata* (Gray) following dispersant application to a shore. *Oil Petrochem. Pollut. 1* : 109-12.

POWER, F.M. 1983c: Long-term effects of oil dispersants on intertidal benthic invertebrates III. Toxicity to barnacles and bivalves of untreated and dispersant-treated fresh and weathered condensate. *Oil Petrochem. Pollut. 1* : 171-81.

POWER, F.M. 1983d: An examination of the toxicity of a petroleum pipeline mothballing programme (Alfloc 19 and Alfloc 216) to embryos and larvae of marine seafoods. Taranaki Catchment Commission and Regional Water Board Technical Report 83-8 : v + 25 p., 2 apps.

RESIG, J.M. 1961: Foraminiferal ecology around ocean outfalls off southern California. *In* Pearson, E.A. (ed.) "Proceedings 1st International Conference on Waste Disposal in the Marine Environment". Pergamon Press, London. 104 p.

RIDGWAY, N.M. 1960: Surface water movements in Hawke Bay, New Zealand. *N.Z. Jl Geol. Geophys. 3(2)* : 253-61.

RIDGWAY, N.M. 1962a: Tidal current patterns between Mana Island and Titahi Bay, west coast, North Island. *N.Z. Jl Geol. Geophys. 5(2)* : 243-55.

RIDGWAY, N.M. 1962b: Nearshore surface currents in southern Hawke Bay, New Zealand. *N.Z. Jl Geol. Geophys. 5(4)* : 545-66.

RIDGWAY, N.M. 1972: Direction of drift of surface oil with wind and tide. *N.Z. Jl mar. Freshwat. Res. 6(1-2)* : 178-84.

RIDGWAY, N.M. 1973: Some oceanographic observations in the vicinity of proposed thermal power stations II. New Plymouth. Pp. 505-18 *in* "Proceedings of the Pollution Research Conference, Wairakei, New Zealand, 20-21 June 1973". *N.Z. DSIR Inf. Ser. 97* : 568 p.

RIDGWAY, N.M. 1977: Currents and hydrology in Tasman and Golden Bays, South Island, New Zealand. *N.Z. Jl mar. Freshwat. Res. 11(1)* : 95-109.

RIDGWAY, N.M.; STANTON, B.R. 1969: Some hydrological features of Hawke Bay and nearby shelf waters. *N.Z. Jl mar. Freshwat. Res. 3(4)* : 545-59.

ROBERTSON, T.; WAUGH, G.D.: MOL, J.C.M. 1975: Mercury levels in New Zealand snapper *Chrysophrys auratus*. *N.Z. Jl mar. Freshwat. Res. 9(3)* : 265-72.

ROSS, D.A. 1980: "Opportunities and Uses of the Ocean". Springer-Verlag, New York. 320 p.

ROYAL SOCIETY OF NEW ZEALAND, 1968: "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 p.

RUIVO, M. (Ed.) 1972: "Marine Pollution and Sea Life". Fishing News (Books) Ltd, Surrey, for FAO. xxiv + 624 p.

SALMON, J.T. 1975: Towards the year 2000. Pp. 181-96 *in* Robson, J.L.; Shallcrass, J. (eds) "Spirit of an Age, New Zealand in the Seventies". A.H. & A.W. Reed, Wellington. 259 p.

SHANKS, A.D. 1982: Industrial wastewater treatment. A New Zealand perspective. *Univ. Auckland Dep. civ. Engng Rep. 296* : 90 p.

SHARPLEY, A.N.; SYERS, J.K. 1976: Phosphorus transport in surface run-off as influenced by fertiliser and grazing cattle. *N.Z. Jl Sci. 19(3)* : 277-82.

SHIRER, M.T. 1979: Epiphytic bacteria and metal accumulation. Unpublished Dipl. Sci., University of Otago.

SIMMONDS, R.S.; LEWIS, G.D.; LOUTIT, M.W.; AUSTIN, F.J. 1982: A method for detecting and identifying enteroviruses in effluents. *N.Z. Jl Sci. 25(1)* : 57-60.

SMILLIE, R.H. 1980: Metals in waste water. Unpublished Ph.D. thesis, University of Otago.

SMILLIE, R.H.; HUNTER, K.; LOUTIT, M. 1981: Reduction of chromium (VI) by bacterially produced hydrogen sulphide in a marine environment. *Wat. Res. 15* : 1351-54.

SMITH, L.J. 1974: Economics of marine pollution. *Oceanus 18(1)* : 55-60.

SOLLY, S.R.B.; HARRISON, D.L. 1972: DDT in some New Zealand marine and freshwater fauna. *N.Z. Jl mar. Freshwat. Res. 6(4)* : 456-62.

SPOONER, B. 1977: Wellington regional sewerage problems need combined action. *Soil & Water 13(5)* : 10, 11, 23.

STANTON, D.J.; BOHLOOL, B.B.; BEASLEY, C. 1977: Intertidal zone of Delaware Inlet, Nelson, New Zealand. *N.Z. Jl mar. Freshwat. Res. 11(3)* : 577-87.

STATE WATER POLLUTION CONTROL BOARD, 1956: An investigation of the efficacy of submarine outfall disposal of sewage and sludge. *Publ. State Wat. Pollut. Control Bd Sacramento 14* : 154 p.

STEPHENSON, R. 1980: Avon-Heathcote Estuary under stress. *Soil & Water 16(2)* : 22-25.

STEVEN AND FITZMAURICE, 1967: "Napier City Council pre-design report on disposal of sewage for City of Napier prepared for Napier City Council". Steven & Fitzmaurice, Christchurch. 40 p.

STEVEN AND FITZMAURICE, 1970: "Sewerage proposals for the Porirua region and Upper Hutt Valley". A report for the Wellington Regional Planning Authority. Steven & Fitzmaurice, Christchurch. viii + 83 p., + fold.

STEVEN AND FITZMAURICE, 1971: "Disposal of Hutt Valley wastes : a report prepared for the Hutt Valley Drainage Board". Steven & Fitzmaurice, Christchurch. vi + 91 p.

STEVEN AND FITZMAURICE, 1974: "Tauranga Harbour water quality survey : a report prepared for the Bay of Plenty Catchment Commission and Regional Water Board". Steven & Fitzmaurice, Auckland.

STEVEN AND FITZMAURICE, 1976: "A review of wastewater treatment and disposal in New Zealand : a report prepared for the Hutt Valley Drainage Board". Steven & Fitzmaurice, Christchurch, Auckland. 106 p.

STEVEN AND FITZMAURICE, 1978: "New Plymouth sewage disposal : Waiwakaiho ocean outfall". Steven, Fitzmaurice and Partners, Auckland. [iv] + 36 p. + 3 apps.

STEVEN AND FITZMAURICE, 1981: "Disposal of Hutt Valley wastewaters : a report prepared for the Hutt Valley Drainage Board". Steven, Fitzmaurice and Partners, Christchurch. 162 p.

STEVENSON, C.D.; WILCOCK, R.J.; ANDERSON, R.N. FOX, E.G.; CAMERON, D.R. 1978: Trial studies of land application of treated sewage effluent from Carterton Borough, New Zealand. *N.Z. Jl Sci. 21(4)* : 573-79.

STONE, H.M. 1961: A bacteriological survey of pollution of the foreshore and rivers in the Hastings district, New Zealand. *N.Z. Jl Sci. 4(4)* : 811-21.

SUCKLING, D.M. 1982: Organic wastewater effects on benthic invertebrates in the Manawatu River. *N.Z. Jl mar. Freshwat. Res. 16(3-4)* : 263-70.

SUTTON, H.C. 1982: Requirements of the London Convention for Dumping Radioactive Waste at Sea. *Inst. nucl. Sci. (N.Z.) Rep. INS-R-312* : 41 p.

TARANAKI CATCHMENT COMMISSION AND REGIONAL WATER BOARD, 1980: Chemistry water resources investigations. Petrochemical developments - Tikorangi. Report. Taranaki Catchment Commission and Regional Water Board, Stratford, N.Z. [104] p.

TARANAKI CATCHMENT COMMISSION AND REGIONAL WATER BOARD, 1983: Assessment of the toxicity of selected catoleum cooling tower water treatment chemicals to five intertidal benthic marine invertebrates. Taranaki Catchment Commission and Regional Water Board Technical Report 83-2 : vii + 111 p.

TAYLOR, R.J. 1973: Phytoplankton and nutrients in the Hauraki Gulf Approaches. Pp. 485-92 *in* Fraser, R. (comp.) "Oceanography of the South Pacific". N.Z. National Commission for UNESCO, Wellington. 524 p.

THE DAVID DAVIES MEMORIAL INSTITUTE OF INTERNATIONAL STUDIES, 1971: "Water Pollution as a World Problem : the legal scientific and political aspects". Europa Publications, London. ix + 240 p.

THE HEATED EFFLUENT STUDY TECHNICAL GROUP, 1973: "The heated effluent study for Victorian coastal water". Report. The Heated Effluent Study Technical Group, Melbourne. 55 p.

THORNTON, I. 1975: Geochemical parameters in the assessment of estuarine pollution. Pp. 157-69 *in* Chadwick, M.J.; Goodman, G.T. (eds) "The Ecology of Resource Degradation and Renewal". Blackwell Scientific Publications, Oxford. xiii + 480 p.

THORSTENSEN, A.L. 1980: Marine sewage disposal : Myths and truths. *Health (N.Z.) 32(1)* : 15.

TIHANSKY, D.P. 1973: International scope of marine pollution damage. *Mar. Pollut. Bull. 4(10)* : 149-53.

TILL, D.G. 1980: Water quality and public health problems in marine farming. Pp. 81-85 *in* Dinamani, P.; Hickman, R.W. (comps) "Proceedings of the Aquaculture Conference". *Occ. Publ. Fish. Res. Div. 27* : 104 p.

TOPPING, G. 1976: Sewage and the sea. Pp. 303-51 *in* Johnston, R. (ed.) "Marine Pollution". Academic Press, London. 729 p.

TORTELL, P. 1930: Marine sewage disposal : Why not? *N.Z. Local Govt 16(9)* : 2-5.

TORTELL, P. (Ed.) 1981: "New Zealand Atlas of Coastal Resources". Government Printer, Wellington. 28 p., 16 maps + gazetteer.

TORTELL, P. 1982: Coastal resources and oil pollution in New Zealand. Pp. 171-80 *in* "Proceedings of the Fourth National Water Conference, August 24-26, 1982, Auckland, New Zealand : Water in New Zealand's Future". Institution of Professional Engineers (N.Z.) and Royal Society of New Zealand, Auckland. iv + 454 p.

TUREKIAN, K.K. 1974: Heavy metals in estuarine systems. *Oceanus 18(1)* : 32-33.

TURNER, J.C.; SOLLY, S.R.B.; MOL-KRIJNEN, J.C.M.; SHANKS, V. 1978: Organochlorine, fluorine, and heavy-metal levels in some birds from New Zealand estuaries. *N.Z. Jl Sci. 21(1)* : 99-102.

UNESCO, 1982: The review of the health of the oceans. *GESAMP Rep. Stud. 15* : 108 p.

UPDEGRAFF, D.M.; STANTON, D.J.; SPENCER, M.J. 1977: Surface waters of Waimea Inlet and Nelson Haven : a preliminary assessment of quality. *N.Z. Jl mar. Freshwat. Res. 11(3)* : 559-75.

Van den BROEK, W. 1982: Coromandel heavy metal levels. *Catch 9(1)* : 6-7.

Van den BROEK, W.L.F.; TRACEY, D.M. 1981: Concentration and distribution of mercury in flesh of orange roughy (*Hoplostethus atlanticus*). *N.Z. Jl mar. Freshwat. Res. 15(3)* : 255-60.

Van den BROEK, B.; TRACEY, D. 1983: Study on orange roughy mercury. *Catch 10(6)* : 12-13.

Van den BROEK, W.L.F.; TRACEY, D.M.; SOLLY, S.R.B.; AVRAHAMI, M. 1981: Mercury levels in some New Zealand sea fishes. *N.Z. Jl mar. Freshwat. Res. 15(2)* : 137-46.

VAN ROON, M. 1981: "Water quality standards for minimising health risks of swimming and shellfishing". Upper Waitemata Harbour Catchment Study Working Report 18 : 26 p.

VAN ROON, M. 1982: A pesticide survey in the Upper Waitemata Harbour. Upper Waitemata Harbour Catchment Study Working Report 29 : 20 p.

VIDAL, I.L.; COLLINS, A.A. 1970: Faecal coliform bacteria : Is a national standard applicable to the Wellington area? *N.Z. Jl mar. Freshwat. Res. 4(4)* : 445-55.

WAITANGI TRIBUNAL, 1983: Report findings and recommendations of the Waitangi Tribunal on an application by Aila Taylor for and on behalf of Te Atiawa Tribe in relation to fishing grounds in the Waitara District. Report WAI 6 to the Minister of Maori Affairs, Wellington. 75 p.+ apps.

WALDICHUK, M. 1977: Global marine pollution : an overview. *IOC Tech. Ser. Rep. 18* : 96 p.

WALDICHUK, M. 1979: Review of the problems. *Phil. Trans. R. Soc. Lond. B286* : 399-424.

WALKER, T.I. 1980: Management of mercury content of marketed fish : an alternative to existing statutory limits. *Ocean Mgmt 6(1)* : 35-50.

WALLACE, G.; McCABE, W.J. 1974: Preliminary Wellington Harbour sewage outfall investigation. *Inst. Nuclear Sci. (N.Z.) Rep. INS-R-143* : 16 p., 23 figs, 2 tables.

WALLACE, G.M.; NEWMAN, L.E.; JERROME, J.L. 1956: Bacteriological survey of Auckland harbours IV. Manukau Harbour. *N.Z. Jl Sci. Technol. B37 (6)* : 663-70.

WARD, M.A. 1977: Environmental implications of marine mining. *N.Z. Sci. Rev. 34(3)* : 52-61.

WEISSBERG, B.G. 1975: Mercury in some New Zealand waters. *N.Z. Jl Sci. 18(2)* : 195-203.

WEISSBERG, B.G.; ROHDE, A.G. 1978: Mercury in some New Zealand geothermal discharges. *N.Z. Jl Sci. 21(3)* : 365-69.

WEISSBERG, B.G.; ZOBEL, M.G.R. 1973: Geothermal mercury pollution in New Zealand. *Bull. envir. Contam. Toxicol. 9* : 148-55.

WELLINGTON CITY CORPORATION, 1976: "Environment Impact Assessment : Alternative wastewater treatment plant sites for Wellington City". Welling-

ton City Corporation, Wellington. [various pagination]

WHITTLESTONE, W.G. 1973: Developmental aid and environmental pressures. Pp. 121-29 *in* Stenson, M.R. (ed.) "New Zealand and the Global Ecological Crisis". Price Milburn, Wellington. 139 p.

WILLIAMS, B. (in press): Coastal outfall handbook. *Wat. Soil Misc. Publ.*

WINCHESTER, R.V.; KEATING, D.L. 1980: Trace metal and organochlorine pesticide residues in New Zealand farmed oysters : a preliminary survey. *N.Z. Jl Sci. 23(2)* : 161-69.

WONG, C.S.; GREEN, D.R.; CRETNEY, W.J. 1974: Quantitative tar and plastic waste distributions in the Pacific Ocean. *Nature, Lond. 247(5437)* : 30-32.

WOODLEY, B. 1983: Massive plankton blooms killing other marine life. *Wellington Evening Post, January 21* : 2.

WORLEY, DOWNEY, MUIR AND ASSOCIATES, 1967: "Wanganui City Council sewerage facilities : a preliminary report on investigations and data collection". Worley, Downey, Muir & Associates, Auckland. 17 p. + 2 apps.

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