Note

R&D archive holds a master copy, unbound, from which copies can be taken of specific sections.

MGB - 20/6

HEALTH EFFECTS OF SEA BATHING (ET 9511 SLG)
PHASE I - PILOT STUDIES AT LANGLAND BAY 1989

DoE 2518-M

JUNE 1990

HEALTH EFFECTS OF SEA BATHING (ET 9511)
PHASE I - PILOT STUDIES AT LANGLAND BAY 1989

Report No: DoE 2518-M

June 1990

Authors: E B Pike, with appendices by R Balarajan and
by F Jones, D Kay, R Stanwell-Smith and M Wyer

Contract Manager: E B Pike

Contract No: ET 9511

Contract Duration: June 1989 to May 1991

DoE Reference No: PECD 7/7/331

NRA Reference No: 5.2.1a

This contract was jointly funded by the Department of the Environment and the National Rivers Authority

Any enquiries relating to this report should be referred to the Contract Manager at the following address:

Water Research Centre (1989) plc, Henley Road, Medmenham, PO Box 16,
Marlow, Buckinghamshire SL7 2HD. Telephone: Henley (0491) 571531

SUMMARY

I BACKGROUND

In May 1989 the Department of the Environment contracted WRc to (a) test and validate epidemiological procedures for determining the risks, if any, to the health of bathers in coastal water contaminated by sewage, and (b) establish the relationships, if any, between microbiological quality of coastal waters and the risk to health of bathers and to report by end May 1990.

II WORK PROGRAMME

The need for researching in this field was indicated by the Royal Commission on Environmental Pollution in its Tenth Report, in which it recognised that the risk of acquiring serious illnesses from bathing in UK waters was very small, but that this could not be said for milder diseases of the digestive system. Epidemiological studies in other countries have established that gastroenteritis, skin irritations and symptoms of the eyes, ears, nose and throat are commoner in bathers than non-bathers and that gastroenteritis rates can be related to microbiological quality at the time of bathing. Publication of the results of bathing water monitoring under the Council Directive 76/160/EEC and other publicity campaigns have focused public interest on the quality of coastal bathing waters and the risks to health.

A number of studies have been carried out in a variety of countries to assess such health risks. These have demonstrated the difficulty of conducting such research arising from the difficulty of isolating many of the pathogens, and because the risk to health is relatively low. Previous studies have relied on differences between reported levels of symptoms by bathers and non-bathers: such reporting may not correspond to medical diagnosis of illnesses. In this study two methods of assessing health risks have been tested as a basis for possible more extensive studies.

The prospective Beach Survey method was based on the approach adopted in previous studies of comparing reported incidences of illnesses by bathers and non-bathers. Although well precedented, the precise method requires further study to establish the characteristics of beach goers at beaches in Britain eg what proportion bathe, or are locals on day trips as opposed to visitors on holiday, and secondly to establish the most reliable method of interviewing. In this pilot study two methods of reporting were used: Interviews were conducted at the beach to establish recent history and symptoms and a sample of people were telephoned a few days later to ascertain symptoms.

The second method, the controlled Cohort Study, is novel in that the main aim is to discover the relationships between clinical diagnosis of disease and water quality. Healthy adult volunteers were recruited and divided randomly into those who bathed with full immersion, and those who remained on the beach and did not enter the water. They were interviewed before, on and after the day of exposure and were also examined by taking clinical samples (ear and throat swabs, faeces samples) before and after exposure. Because there is only one exposure and the study can be carefully supervised, this type of study can, in theory, provide a more precise indication of the risks to health and their relationships to quality of water. However, ethical considerations limit exposure to adults and to water of satisfactory quality and because exposure is on a single day, the method has to be repeated in locations of different water quality to establish the relationship between risk to health and water quality.

III CONCLUSIONS

An exhaustive study of the literature has shown that certain serious illnesses have been associated with bathing in grossly contaminated waters. These are typhoid fever, shigellosis, leptospirosis, gastroenteritis and Hepatitis A. The complaints which are most often reported by bathers in acceptable or marginal quality water, are gastroenteritis, symptoms of the eye, ear, nose and throat and of the skin. In chlorinated swimming pools, the infections most commonly reported are of the eye, ear, nose and throat. In general swimmers show higher attack rates than non-swimmers; the rate of reporting illness is related to the degree or duration of exposure to the water; the young report a greater incidence of illness than adult participants; and the rates of reporting illnesses, particularly gastroenteritis, are related to counts of faecal indicator bacteria at the time of exposure. The literature, however, shows a wide divergence in the rates of attack for various symptoms which suggest that acquired immunity or socio-economic factors affect the susceptibilities of the population to illness.

The two studies carried out at Langland Bay, Swansea yielded information both about the logistics of carrying out such surveys, and early indications of the health risks involved. The following conclusions were derived concerning the logistics of the two methods:

a) there are difficulties in obtaining sufficient numbers for the studies to yield statistically valid results; local publicity is useful in attracting volunteers for the Cohort Study, but undesirable for the Beach Survey since it can bias results;

b) only around half of the initial volunteers for the Cohort approach may be expected to complete the programme of interviews, exposure and clinical examinations;

c) telephone interviews proved a reliable way of collecting information;

d) about half of those on the beach went into the water, but only about half of those immersed themselves completely;

e) co-operation of local bodies was found to be vital.

Although the studies were not designed to produce statistically valid results, the following preliminary indications concerning health effects were found:

a) for both studies the water quality was good and counts of bacteria were well within the standards set in the EC bathing water Directive;

b) in neither study was there any apparent significant effect of water quality upon the symptom rates;

c) the rates of reporting symptoms of the eyes, ear and throat in the two studies were similar to those reported at beaches in Britanny in 1979;

d) in the Beach Survey ear and throat symptoms were the most frequently reported with around one in 13 bathers reporting symptoms compared with one in 32 non-bathers; but fever bathers reported gastroenteritis than did non-bathers - one in 31 compared with one in 26. Of those reporting symptoms fewer than one-quarter saw a doctor about them;

e) the Beach Survey found that the likelihood of reporting symptoms increased with the extent of exposure to water;

f) in the Cohort Study, bathers reported higher rates of ear, eye and throat illnesses than non-bathers, but there was no significant association between reported symptoms and clinical diagnosis.

IV RECOMMENDATIONS

If it is desired to determine the relationship between microbiological quality of water and the risk to health of bathers, greatly extended studies will be needed at beaches displaying varying quality of water. Size calculations are given, for a given level of risk to bathers. The Cohort Study approach will be needed, if it is desired to investigate the relationships between reported symptoms and the clinical diagnosis of infection.

V RESUME OF CONTENTS

The objectives of the Department's contract and the background to the study are stated. This is followed by exhaustive reviews of (a) those waterborne diseases which are associated with aquatic recreation (b) the findings of epidemiological studies of bathing water quality and health and (c) the description of how existing standards for quality of bathing waters have been developed. The third section of the report details the setting-up of the two pilot studies at Langland Bay, Swansea, the methods used and the results obtained. Finally, the significant findings are discussed and placed in context with previous findings and conclusions and recommendations for further study are presented. A copious list of acknowledgements is given.

CONTENTS

Page

APPENDIX A HEALTH RISKS ASSOCIATED WITH BATHING IN THE SEA. RESULTS OF A PILOT STUDY IN LANGLAND BAY. By R Balarajan.

APPENDIX B THE LANGLAND BAY CONTROLLED COHORT PILOT STUDY - FINAL REPORT. By F Jones, D Kay, R Stanwell-Smith and M Wyer.

SECTION 1 - INTRODUCTION

1.1 THE BACKGROUND TO THE STUDY

On 17 May 1989, Michael Howard, Minister for Water announced, in response to a Parliamentary Question from Mr Barry Field (Isle of Wight), that the Water Research Centre had been contracted to carry out a study to assess the risk of contracting illnesses from sea bathing (DoE 1989):

> "I can today announce that my Department has let a contract to establish the risks to health of bathing in the seas off the United Kingdom. This is on the recommendation of a Working Group of experts which was set up last year to advise me on the best way to assess the risk of contracting illnesses from sea bathing. The Working Group has recommended that two types of study should be made at bathing waters that meet the standards set in the EEC Bathing Water Directive."
>
> "The first study involves bathers who are on the beach of their own volition. Information of any perceived symptoms will be obtained by means of a questionnaire at the time and subsequent telephone follow-ups."
>
> "The second study will involve the use of healthy volunteers who will be asked to swim in waters meeting EEC standards. The volunteers will be examined medically both before and after swimming. The Committee on Ethical Issues in Medicine of the Royal College of Physicians has given clearance for this study."
>
> "A contract has now been let to the Water Research Centre to carry out the first stage of the study this year. Further studies are likely to be required in 1990 and later years. The bathing waters at which the studies are to take place have yet to be selected."

> "Reports of the studies, will be placed in the Library in due course. The studies will not be extended to study the effect of sewage disposal at sea or marine wildlife and the food chain. This area of research is a matter for my Rt Hon Friend, the Minister for Agriculture, Fisheries and Food."

The Working Group of experts were drawn from the Department of Health, the Public Health Laboratory Service, Health Authorities, Water Authorities, the Water Research Centre, Universities, the Scottish Development Department, the Welsh Office, DoE Northern Ireland and the Department of the Environment. It was noted that:

> "Studies of this type are very complex, and these will be breaking new ground in the UK. The studies carried out in the first year will test the methods proposed, and the Working Group will then advise on how the work should be carried forward in later years."

The Working Group continued to meet and advise the Department of the Environment during the Phase I pilot study to be described in this report. With privatisation of the UK Water Industry in 1989, the composition was amended from September 1989 to include representation from the Water Supply Companies and the National Rivers Authority.

Any consideration of the health effects of sea bathing must include a discussion of marine treatment schemes for disposing of the community's waste water. Waste water must be returned to the environment for recycling and the aim of efficient treatment, whether inland or in the sea is to avoid health and environmental hazards. Thus, a World Health Organization Working Group (WHO 1975) has stated that coastal waters used for recreation, should be sufficiently free from faecal contamination and pathogens to ensure that the risk to health is negligible. It is natural to consider setting microbiological standards for the quality of bathing waters with the aims of protecting health, amenity and the environment and this report will consider, in depth, the attempts which have already been made.

Within the European Economic Community, the quality required of bathing waters is specified in the Directive 76/160/EEC (Community Directive 1976). One of the subsidiary aims of this Directive is to provide the public with objective information on the quality of bathing water, because public interest in the environment and in the improvement of its quality is increasing. Against this climate of awareness, there is the opinion that standards for bathing water quality should be related to risk (Shuval 1974, Cabelli et al 1983). The setting of standards has been opposed on rational grounds (eg Moore 1974), because of the lack of evidence for serious bacterial disease, the lack of suitable methods for identifying and implicating the pathogens involved at the time and the inconstancy of risk. The difficulty can be resolved if it is realised that standards are an attempt to improve water quality by pragmatic means. They offer a fixed yardstick or objective for the design of marine treatment schemes (WRc 1990). Improvement in water quality will reduce risk.

There is a natural desire to enquire what the risk is. Whether or not the prevailing risk is acceptable is a public decision not necessarily amenable to scientific enquiry. However, epidemiology has been used to relate microbial quality of bathing waters to the risk of acquiring gastroenteritis (Cabelli 1983, Dufour 1984), thereby enabling the risks associated with bathing in marine and fresh waters meeting current standards to be defined (US EPA 1986).

The need for UK research was pointed out by the Royal Commission on Environmental Pollution (1984) in its Tenth Report (paragraph 4.56):

> "While, therefore, the risk of contracting serious illness from bathing in the sea of the United Kingdom appears to be very small, we are less confident that the same can be said of milder diseases of the digestive system, such as those known as 'traveller's diarrhoea'."

The Royal Commission recognised that there were major problems with such research, because of the difficulty of isolating many of the pathogens and of obtaining reliable epidemiological data. It will be seen in this report that, to reveal statistically significant relationships between water quality and health effects such studies have to be extremely large, because the risks are low. There are also considerable problems in obtaining health information of sufficient reliability. Because of these factors, most epidemiological studies have been preceded by a pilot investigation to determine the best way of carrying out the major study. This report is concerned with such a pilot study and assesses two methods of epidemiology:

(a) a prospective survey of holidaymakers on the beach of their own volition and of their health symptoms, perceived at the time of interview on the beach and subsequently by means of a telephone interview (the 'Beach Survey');

(b) a controlled exposure study, in which healthy adult volunteers, either swam in the sea or remained on the beach and did not enter the water; both groups being examined clinically and by questionnaire for perceived symptoms before and after exposure (the 'Cohort Study').

The two convenient terms, 'Beach Survey' and 'Cohort Study' are used in this report to identify the two methods, despite their statistical imprecision.

1.2 THE OBJECTIVES OF THE PHASE I PILOT STUDY

These were as follows:

to test and validate epidemiological procedures for determining the risks, if any, to the health of bathers in coastal water contaminated by sewage;

to establish the relationships, if any, between microbiological quality of coastal waters and the risk to health of bathers.

It is pointed out that the main purpose of the Phase I pilot study was testing and validating methods. It was realised at the outset that the scale of the work to be undertaken would not be sufficient to enable a predictive risk assessment model to be constructed, relating microbiological quality to be related to health effects. However, if successful, the study would enable the risk of bathing in water of the quality prevailing at the one site to be assessed, thereby providing one point on a graph of risk against water quality. Secondly, a drawback of most previous epidemiological studies has been that health risks were assessed by questioning participants about illness and not by clinically diagnosis, so that risk was of perceived illness rather than confirmed illness. The UK pilot study has been the first in the field to address this difficulty.

1.3 SCOPE OF THIS REPORT

It is realised that this report will be read equally by interested lay people and by scientists and physicians. The latter will appreciate a depth of consideration and argument that will perhaps be tedious to the former.

For this reason, the detailed reports upon the two studies provided by their sub-contractors are presented in entirety as two appendices to this report. These are as follows:

A. Health risks associated with bathing in the sea. Results of a pilot study in Langland Bay. March 1990. By Professor A Balarajan, Epidemiology and Public Health Research Unit, University of Surrey, Guildford.

B. The Langland Bay controlled cohort pilot study. Final Report. December 1989. By F Jones (Altwell Ltd, Runcorn), Dr D Kay (St David's University College, Lampeter), Dr Rosalind Stanwell-Smith (Communicable Disease Surveillance Centre, Colindale, London NW9) and M Wyer (St David's University College, Lampeter).

Section 2 of this report is an exhaustive review of the approaches which have been made so far to determine those illnesses which result from bathing in polluted marine and freshwaters, the extent of the risks and the derivation of health-related standards for recreation. An attempt is made to compare their often disparate findings and to set the scene for the present pilot study.

The design of the Phase I pilot study and its results are broadly presented and then critically discussed in Section 3. The general reader will prefer to read this before referring to the two Appendices for detail. Finally, recommendations are made for future studies in Section 4.

SECTION 2 - WATER-BORNE AND WATER-ASSOCIATED ILLNESSES AND THE SETTING OF HEALTH-RELATED STANDARDS FOR WATER QUALITY

2.1 PATHOGENS IN POLLUTED WATERS

Infectious diseases are acquired after contact with pathogenic organisms, which will include certain bacteria, viruses, fungi and parasites. Pathogens occur sporadically or even universally in polluted water, being excreted by patients and carriers. Their concentration in sewage and in receiving waters and indeed their presence, depend upon the state of health of the community. Whether or not they pose a risk to health of water users, depends upon a variety of circumstances. An important one is whether or not water is a mode of infection and transmission of the disease. The biology of the pathogen and its mode of infection may militate against water-borne transmission. Thus tuberculosis is not waterborne even though the causative organism may occur in sewage. Legionnaires' disease is acquired through inhalation of aerosols and not through participation in water sports, even though the Legionella bacteria are widely present in natural waters. The countering effects of natural immunity, either innate, or acquired and of invasiveness and pathogenicity are major factors influencing the outcome of contact with or ingestion of a pathogen in water.

2.2 PROVING A CAUSAL RELATIONSHIP BETWEEN EXPOSURE AND DISEASE

Whether or not a particular pathogen is water-borne can only be determined by clinical experience and by epidemiology. Rigid proof is required and arguments of the post hoc, ergo propter hoc type - ie the assumption that the onset of disease is related to a particular exposure or event at about the same time - are unconvincing or worthless.

Environmental exposure may produce many examples of association with the onset of disease, but the proof of causality requires a number of factors to be demonstrated. These were discussed in the Presidential Address of Sir Austin Bradford Hill (1965) to the Royal Society of Medicine and were later used by Moore (1971) in assessing epidemiological studies upon bathing water quality and health. Bradford Hill's nine points are summarised in Table 1. In general, the more criteria which apply, the stronger is the proof of a causal relationship.

These criteria are similar to Koch's Postulates, well known to medical bacteriologists, for proving that a particular micro-organism is responsible for disease. They are of relevance here because epidemiology in the field of sea bathing and health has been hampered because the identities of the pathogens were until recently unknown and are still not clear.

The available information from epidemiological studies and case histories of the relationships between illness and bathing or other recreation in freshwater will now be examined. It seems appropriate firstly to consider individual diseases and case histories showing association with water and then to examine critically those epidemiological studies which have been conducted in fresh waters.

Table 1 - Criteria to be used in assessing causality between environmental exposure and disease (Bradford Hill 1965)

Criterion	Explanation
1. Strength of association	Difference in rates of illness between exposed and non-exposed groups. Chi-square test provides a measure.
2. Consistency	Has it been repeatedly observed by different people at different places and times?
3. Specificity of association	A particular type of exposure is linked with a particular site of infection or a particular disease.
4. Temporality	A 'cart and horse' problem - does the exposure predispose to disease or do people susceptible to a particular disease choose that exposure or occupation?
5. Biological gradient	A dose-response curve can be detected. The more severe the exposure, the greater is the incidence of disease.
6. Plausibility	Does the relationship seem likely in terms of present knowledge? But present knowledge may change.
7. Coherence	The cause and effect interpretation of the data should not conflict with what is known about the biology of the disease.
8. Experiment	Because of an observed association, some action is taken. Is the frequency reduced? This is strong evidence for causation.
9. Analogy	If one agent is shown to cause disease, it would be reasonable to expect it of a related agent.

2.3 DISEASES ASSOCIATED WITH WATER RECREATION

2.3.1 Typhoid and paratyphoid fevers

These diseases are notifiable and are often classified together as Enteric Fever. The annual incidence in Britain is about 200 cases yearly of which the majority are in persons returning from overseas. These infections often set up a carrier state in otherwise healthy, recovered cases and this can often persist for many years, with excretion of the causal organisms *Salmonella typhi* and *Salmonella paratyphi* into sewage. This has led to outbreaks at seaside resorts wrongly being ascribed to sea bathing. For instance, one seaside outbreak was traced to the wife of an ice-cream vendor (Moore 1960) and another to sewage-contaminated river water being used to irrigate salad crops (Moore, Perry and Chard 1952).

In the case of sea bathing, there is evidence to suggest that the water must be grossly polluted for there to be a real risk of infection (Medical Research Council 1959, PHLS 1959). In the 50 years, 1937-1986, there have been nine recorded incidents, involving about 80 cases, of typhoid fever associated with recreational use of water and in over 61 of these (six incidents) there was a history of drinking river water. Over the same period there were two outbreaks of paratyphoid fever associated with bathing in contaminated water. Nine cases occurred after bathing in a tidal river bathing pool at Beccles, Suffolk and three after bathing in a river in Edinburgh in 1954 (Galbraith 1987). Harvey and Price (1981) report 3 cases of typhoid fever contracted by children playing in waters of the Ogmore Valley, near Bridgend, which then received sewage infected by carriers.

2.3.2 Infectious hepatitis

This disease, which is contracted by drinking sewage-contaminated water, or by eating raw shellfish or other food polluted faecally, is caused by the Hepatitis A virus. The incubation period is several weeks. Practicable methods for isolating culturing the virus are only just coming into use (Divizia et al 1989). Hepatitis A virus is now regarded as a member, Enterovirus 72, of the enterovirus group. This is mentioned, because those enteroviruses isolated most commonly from sewage and natural waters, such as poliovirus, coxsackievirus A and B and the echoviruses have rarely been implicated in water-borne disease outbreaks. There is now evidence from serology that a class of viruses responsible for hepatitis termed "non-A, non-B" may be spread by sewage-contaminated water (Ramalingaswami and Purcell 1988).

There is one published outbreak of clinically diagnosed hepatitis A in which accidental consumption of polluted recreational lake water was involved (Bryan et al 1974). Fourteen out of a troop of 30 boy scouts and accompanying adults contracted the illness four weeks after camping for 3½ days on an island in the middle of a lake in South Carolina. Food and drinking water were excluded as causes during the follow-up study. The lake water, on frequent occasions in that year, had shown 'gross contamination with coliform organisms.' When campers were questioned about drinking or accidentally swallowing lake water, there was a highly significant ($p = 0.007$) association between swallowing lake water and becoming ill.

2.3.3 Rotaviruses, the Norwalk agent and other viruses

It is now recognised that the majority of cases of gastroenteritis associated with recreational uses of water are probably caused by the rotaviruses, the Norwalk agent and the ill-defined small, round viruses. The illnesses have a short incubation period (24-48 hours) and are of short duration. The presence of viruses can be established by electron-microscopic examination of patients' faeces. Rotaviruses attack infants mainly. Methods for detecting rotaviruses in water are available and are being developed rapidly.

The retrospective epidemiological study of the Medical Research Council (1959) showed that poliomyelitis was not associated with bathing in polluted waters and there has been no cause subsequently to alter this opinion, although individual cases (eg Wakefield 1988) are cited. Many of the polioviruses which can be isolated form sewage and natural waters originate from the use of live strains in vaccination.

Norwalk virus was identified by serology as the pathogen causing headache, fever and myalgia among visitors to a recreational park in Michigan state (Baron et al 1982). A history of swimming in the park's lake was elicited with significantly greater frequency from 121 persons who were the first to fall ill in their family, compared with park visitors who remained well. The incubation period was about 4-77 hours. Secondary transmission of illness was observed in households.

Pharyngo-conjunctival fever, caused by Adenovirus type 4, was implicated in an outbreak at a swimming pool and the attack rate was significantly correlated with time spent in the water. Free chlorine levels were below 0.4 mg/l and the outbreak halted when they were raised to breakpoint (D'Angelo et al 1979).

2.3.4 Primary amoebic meningo-encephalitis

This disease, which is usually fatal, is caused by inhaling water containing pathogenic amoebae of the species Naegleria fowleri, which are able to multiply in warm waters contaminated with soil. These conditions occur in hot springs. Six cases have been known to have occurred in Britain, the last being an 11 year old who had bathed in water from the natural warm springs in Bath (Galbraith 1987).

2.3.5 Leptospirosis

Leptospirosis mainly occurs among persons directly or indirectly in contact with animal vectors, such as rodents, dogs, cattle and their urine; water and sewage may be indirectly associated with its transmission. For example, of the 90 cases reported in 1984 in the British Isles, 39 were among farm workers and those handling farm animals and their carcasses. Another 17 had a history of immersion in polluted water, comprising 5 canoeists and 12 others (of whom 2 died) who fell into or swam in water. Five others had contact with rats, 5 were cavers and one was a sewer worker (Waitkins 1986). It has been suggested that the coypu may have been a reservoir of infection in those East Anglian rivers where they were common, since 7 of 30 (24%) were found to be carrying leptospires (Anon 1986).

Harvey and Price (1981 and Appendix 1) record 76 infections in the period 1940-1980 in South Wales, 11 of whom had contact with natural waters; the rivers involved being the Taff, Towy and Teifi.

In December 1984 a person, who had accidentally fallen into Bristol Docks, died from Weil's disease (the severe from of leptospirosis). The causative organisms, Leptospira icterohaemorrhagiae was subsequently isolated from the water. In a survey of 23 water-skiers and windsurfers, who regularly used the docks, one middle-aged man was shown to possess leptospiral antibodies. He had had 'jaundice' symptoms at the age of nine years and a history of exposure to a variety of agencies other than the docks (Philipp et al 1989). The annual incidence of leptospirosis given above may be compared with the number of persons who are estimated to take part in outdoor swimming - 1.4 million of those aged 16 and over in 1983 - to gauge that the risks are small, but clinically significant.

2.3.6 Cryptosporidiosis

The development of methods for identifying the oocysts of the parasite, Cryptosporidium spp in faeces and for isolating from water have indicated that it is a significant cause of gastroenteritis in man and can be water-borne, as in the outbreaks causally linked with drinking water recently in San Antonio, Texas, in Carrollton, Georgia, in Ayrshire and in the Oxfordshire-Swindon area. The organism is a parasite which can affect farm animals and wildlife and therefore is to be expected to occur in natural waters from time to time and in sewage effluents. For example, 11 samples of river water from Washington State and California contained 2-112 oocysts/l (Ongerth and Stibbs 1987) and raw sewage from four works in Arizona an average of 5300 oocysts/l, reduced only to 1400/l in the chlorinated final effluents (Rose et al 1986). Rivers and irrigation channels contained 1.8-4800/l. It could be supposed that cryptosporidiosis could be associated with recreation in inland waters. This is partly confirmed in a retrospective case-control study, following an outbreak of 78 diagnosed cases in New

Mexico near Albuquerque. There was strong association between drinking surface water and illness and cases reported more swimming in surface waters in the four weeks prior to illness (Gallagher et al 1989).

2.3.7 Swimmer's itch

The schistosome parasites (blood flukes) have a complex life cycle, in which the adult fluke stage inhabits the blood vessels of vertebrate animals and the intermediate sporocyst stage, aquatic snails. Infected snails emit large numbers of mobile cercariae, which then endeavour to infect the primary mammalian host by puncturing wet skin or upon ingestion. Occasionally in Britain, outbreaks of itchy, pustular dermatitis have occurred amongst persons, who have bathed in lakes during warm weather. The symptoms are caused by cercariae of those schistosomes which have a primary host other than man, attempting to invade the immersed skin. A recent outbreak was recorded at a Suffolk water sports park and involved more than 65 people during July 1987. The feet and legs were most affected, but not the palms, soles or face. Symptoms were a prickly sensation within a few minutes of leaving the water, followed by a rash within 3 hours to 5 days later. The duration of the rash averaged 13 days. The lake was a weedy, shallow gravel pit and harboured large numbers of the giant pond snail, Lymnaea stagnalis, some of which were shown to be emitting cercariae of Trichobilharzia ocellata (a parasite of ducks) (Eastcott 1988). Action was taken at the lake to reduce the snail population and to control weed growth, including introducing carp.

2.3.8 Conjunctivitis and infections of the ear, nose and throat

Various epidemiological studies discussed in Section 2.4 have shown that swimmers, regardless of the quality of the water, may expect an increased incidence, over non-swimmers, of illnesses of the upper respiratory tract and conjunctivitis, even in properly maintained swimming pools and waters which are relatively unpolluted. Outer ear canal inflammation (otitis externa) is related to indoor pool use, where high air temperatures and relative humidity prevail. An outbreak of viral pharyngo-conjuctival fever in a swimming pool is discussed in Section 2.3.3.

2.4 THE METHOD AND SCOPE OF EPIDEMIOLOGY

Much of the information in Section 2.3 has resulted from national surveillance, which is important in indicating trends in disease and in highlighting problems for action. Collectively, individual reports will suggest and then strengthen the grounds for suspecting causal association, as set out in Table 1, but may not prove it beyond doubt. It is the function of epidemiology to establish causal relationship by statistically controlled trials. The methods of epidemiology consist of establishing a hypothesis of cause and effect and then setting out by experiment to prove or disprove it. As a result, a study can only set out to examine a single relationship or a very narrow range of related ones. Where the suspected risk of falling ill after exposure is small, as appears to be the case with the effect of bathing water quality on health, the size of the exposed and control groups has to be very large in order to be able to demonstrate significant association. Hence, epidemiological studies upon health effects of bathing are likely to be large and costly.

Two main types of epidemiological study can be recognised, the retrospective case-control study and the prospective cohort study. The main features and the merits of these approaches are given in the review by Lacey and Pike (1988) on water recreation and risk.

The case-control study is most often used as a sequel to national surveillance after an outbreak has been discovered. It compares the exposure history of two groups of people, those who have reported illness and those who have not reported illness (the 'control' group). The control group must be carefully selected from the same population as the case group in a way which ensures strict comparability in all ways apart from those directly linked to exposure to the suspected hazard. This was the approach used by the Medical Research Council (1959) in examining the relationship between poliomyelitis and sea bathing. Bathing histories of child victims, living in seaside towns, were obtained and compared with those of carefully matched controls, ie children of the same sex and as nearly as possible of the same age, living in the same locality. The bathing histories of the two groups were similar and there was no significant association between illness and bathing.

The prospective cohort study approach has been most widely used in subsequent epidemiological studies of bathing water quality and health. In this method, the illness rates are compared between exposed and non-exposed (control) groups. This type of study is prospective in that the cohorts or groups of people are selected before illness appears, whereas the case-control method is retrospective. Both of the methods which were tested at Langland Bay are examples of prospective cohort studies.

With both methods, the strength of proof is increased if the pathogenic agent can be isolated and identified, rather than the reporting of symptoms, since this provides a positive link with previous case in which the same pathogen was found and establishes infection. Epidemiology of bathing has long been hampered because the agents, now reasonably established as at least partly viral, were unknown. This has caused reliance to be placed on reporting or observation of symptoms, usually by the subjects themselves, without any clinical diagnosis, doubtlessly causing an over-estimation of infection.

2.5 EPIDEMIOLOGICAL STUDIES OF FRESHWATER RECREATION

2.5.1 US Public Health Service Studies

The US Public Health Service conducted three studies, two in freshwater (Lake Michigan, Ohio River and a nearby swimming pool) and a third in tidal waters of Long Island Sound (Stevenson 1953) - see Section 2.6.1. The paper of Stevenson (1953) gives an overall summary whereas the details were presented in individual reports from the former Environmental Health Center in Cincinnati, which are cited below.

In each of the freshwater studies, two beaches were selected in the same neighbourhood. They were chosen because they were known to differ in bacteriological quality, which however was known from surveys not to be prone to sudden variation and because they were used frequently by residents. The studies were set up firstly by extensive publicity and then by visits to households to elicit co-operation. Participating families were provided with a calendar, on which to record daily, swimming and illness experience. Illnesses recorded were eye, ear, nose and throat infections, gastrointestinal disturbances and skin irritations. At the beaches, samples were taken for estimation of total coliform bacteria (MPN method, acid and gas production in lactose broth) and observations were made of sanitary conditions, meteorology and bathing load. The data were analysed to detect prevalence of reported illness related to swimming experience and average water quality over the survey period and the delay between bathing and onset of symptoms. More specifically, a breakdown analysis was used to highlight illness incidence during and immediately after periods of poor or good bacteriological quality of the water.

The first study, (Smith, Woolsey and Stevenson 1951) took place on beaches ('North Beach', 'South Beach') of Lake Michigan adjacent to Chicago suburbs supporting upper and middle income residents. The second study (Smith and Woolsey 1952) was carried out at a riverside beach on the Ohio River at Dayton, Kentucky and at the nearby Tacoma Park swimming pool in Dayton, since no other clean freshwater site could be found in the area. The river site was on the inside of a bend in the river, which carried local polluting discharges, from about 120 000 people upstream, away from the bathing area. This beach has now been developed as a marina. The swimming pool had a capacity of 5700 m^3 (1.5 m US gal) and was equipped with pressure sand filters and chlorination to treat recirculated water.

The overall results are shown in Table 2. They are not altogether satisfactory since the 'number of persons in the study' and not the number of bathers is recorded and these values and the total illnesses recorded are the totals for both locations at Chicago and Dayton.

Table 2 - A summary of water quality and illness rates in bathers from the US Public Health Service studies (Stevenson 1953)

Location	Total Coliform (MPN/100 ml)		No of persons in study (and of swimmers)	Total illness recorded	Illness rates	
	Median (and extremes)	Standard deviation*			Per 1000 person-days of swimming	Non swimmer per 1000 person-days
(a) Total data						
Chicago (28 June - 28 August 1948)			5124 (?)			
North beach	91 (9.1-3500)	0.52		2237	7.1	3.7
South beach	190 (23-24 000)	0.52			8.3	5.6
Dayton, Ky (27 June - 31 July 1949)			7520 (2879)			
Ohio River	2700 (230-160 000)	0.36		2130	10.1	7.4
Pool	<1.8 (0-<3)	-			13.8	
Tidal water			9520 (4902)	3300		
New Rochelle	610 (110-141 000)	0.51	4590 (2412)		5.3	3.3
Mamaroneck	253 (36-202 000)	0.63	4930 (2490)		6.2	3.3
(b) Selected data for swimmers, Chicago, 3-day periods						
North beach:						
high MPN	730	-	(558)	55	9.9	-
low MPN	31	-	(832)	72	8.7	-
South beach:						
high MPN	2300	-	(566)	69	12.2	-
low MPN	43	-	(932)	79	8.5	-

* of mean of log MPN, calculated as (log upper quartile - log lower quartile)/1.35

Similarly it is not clear whether the total illnesses recorded are for persons (who may well have displayed more than one symptom) or for symptoms. On the other hand, the selected data for 3-day periods of high and low water quality refer to bathers only and to bathers reporting illness.

In the Chicago study, regardless of water quality, swimmers showed an increased rate of illness per 1000 person-days over non swimmers and a tendency for rates to rise with days of swimming experience for all types of illness separately or individually. The highest rate for all illnesses in natural waters was 13.4 per 1000 person-days for South Beach swimmers swimming on more than 24 days but this was exceeded for pool swimmers at Dayton swimming on 10-19 days where it was 32 per 1000 person-days.

In the Dayton study, pool swimmers had an incidence of 13.8 per 1000 person-days for all illnesses, of which eye, ear, nose and throat ailments comprised 68% and gastrointestinal only 15%. River swimmers had a lower total incidence, 10.1 per 1000 person-days, of which 53% were for eye, ear and respiratory ailments and 24% gastrointestinal. A third marine study carried out in Long Island Sound, New York is described in Section 2.6.1.

Certain findings, though barely significant, were used to develop water quality standards in the United States, Canada and probably elsewhere. At the Chicago South Beach significantly ($P<0.05$) higher illness rates were found on the three days when the median MPN was 2300/100 ml than in swimmers on the other three periods. However, the Ohio River data did not show any significance differences in total illness rates following swimming on days of highest and lowest MPN coliform levels. Despite this, river swimmers displayed 32% more gastroenteritis than would have been expected by chance ($P<0.05$) in comparison with pool swimmers. These findings were first drawn on by the National Technical Advisory Committee to the Secretary of the Interior (NTAC 1968) in recommending water quality criteria for primary contact recreation. These were formulated in terms of faecal coliform bacteria, which are more specifically related to faecal pollution than the older total coliform category. Subsequent work at the Ohio River site established a faecal coliform to total coliform ratio of about 400/2700 or 0.15 for this site (Geldreich 1966). It was felt that an appropriate standard would be at half the level giving a barely significant health effect, hence the NTAC recommended a geometric mean ('log mean') value of 200 faecal coliforms per 100 ml and an upper limit of 400 per 100 ml, not to be exceeded during any 30-day period.

The barely detectable health effect observed in these studies with total coliform levels of about 2300-2700 (median or geometric mean) is noteworthy. The original reports play down the significance of the findings. Thus at Chicago (Smith et al 1951), it was generally concluded that bathing in water with a median total coliform density of 180 per 100 ml presented no general hazard to public health. For the Ohio River, because of a sudden drop in swimmers after 10 July and the relatively few swimming more than once every three days, Smith and Woolsey (1952) considered that there was not enough exposure to draw definite conclusions about the effects of total coliform densities upon health of bathers.

2.5.2 Studies of the US Environmental Protection Agency in fresh waters

The later US studies (Cabelli 1983, Dufour 1982, 1984) differed from Stevenson's (1953) in that the aim at the outset was to develop for the US EPA a criterion for quality of bathing water based upon swimming-associated gastroenteritis. In these studies, beach-goers were approached by trained interviewers as they were about to leave the beach. Whenever possible family groups were enlisted and information recorded upon sex, age, race and ethnicity, if the participant swam and got his or her face and head wet, on length of time in the water, illnesses in the previous week and, for non-swimmers, the reason for not going in the water. Interviews were only at weekends and persons who had bathed in the previous five days were excluded from the survey. Participants were interviewed by telephone 8-10 days after the first interview. Those who had swum in the week following the first interview were excluded. Qualifiers were then questioned about the onset of symptoms between swimming and the follow-up interview. A distinction was made between total gastrointestinal (GI) symptoms and 'highly credible gastroenteritis' (HCGI) on the basis of advice given in the earlier studies by the Center for Disease Control, Atlanta Ga. The criteria for the latter were (1) vomiting or (2) diarrhoea with fever or disabling enough for the person to remain home, in bed or to seek medical advice, or (3) stomach ache or nausea accompanied by fever (Cabelli 1983).

The design of the studies aimed to overcome some of the deficiencies of the Stevenson (1953) studies. Firstly, swimmers were positively identified, rather than beach-goers. Secondly, there was a more specific identification of illness - 'highly credible gastroenteritis', rather than reporting of a variety of symptoms. Thirdly by restricting interviews to those bathing at the weekend, a better relationship could be established between reported illness and water quality at the time of bathing, and the blurring effect of multiple exposures on days of differing water quality could be controlled. The microbiological determinands used and the analytical methods were for narrow and homogeneous groups of bacteria, rather than for the imprecise 'total coliforms' and the methods were specifically developed by the US EPA for the purposes of the studies. Marine studies using these methods of epidemiology are described in Section 2.6.

Two sites were chosen at each of two freshwater lakes. Keystone Lake is about 15 miles from Tulsa, Oklahoma. One site (Beach W) was less than 3 miles from the point of discharge from a sewage works and the other (Beach E) about 5 miles. In 1979, when the pilot microbiological study was carried out to select the beaches, the sewage treatment was by two 'full retention' lagoons which discharged 76 m^3/d (20 000 US gal/d) of unchlorinated effluent. From April 1980 this was modified, so that approximately half the discharge was passed through one lagoon, then through an aeration basin and a chlorinator before discharge to the lake. The report states that the discharge of undisinfected sewage ceased but does not record what happened to the remaining half of the discharge.

At the second location, Lake Erie, both sites were in a State park on a peninsula north of the city of Erie. One (Beach B) was three-quarters of a mile from an outfall discharging 170 000 m^3/d (45 m US gal/d) of chlorinated activated-sludge effluent. The second beach (Beach A) was on the opposite side of the peninsula and was unaffected by point discharges. Both beaches were studied in 1979 and 1980 and Beach B only in 1982.

During the studies water samples were analysed for the following faecal indicators, faecal coliform bacteria (APHA 1976), Escherichia coli (method of Dufour et al 1981, membrane filtration) and enterococci including Streptococcus faecalis and S. faecium (method of Levin et al 1975, membrane filtration).

The results of the studies are summarised in Table 3. Of the 37 940 subjects only 9174 (24%) were non-bathers. It was found that, unlike the previous marine studies, most beach-goers would swim, this being particularly so at Keystone Lake. Because of this, data for non-swimmers at each of the two beaches at each lake have been pooled to provide larger control groups. The objectives of the study were accomplished, enabling the following conclusions to be drawn.

The first goal was to show whether swimmers in sewage-polluted freshwater showed a higher rate of gastroenteritis relative to non-swimmers. Table 3 shows that this was so in all nine comparisons but was statistically significant ($P<0.05$) only at Lake Erie Beach B in 1980 and 1981, when the geometric mean E. coli counts were the highest.

The second goal was to show whether a positive relationship existed between swimming-associated gastroenteritis and bacterial quality of the water, shown by regression of swimming-associated rates (S-NS in Table 3) on log geometric mean counts. There was no significant relationship between GI or HCGI associated with swimming and faecal coliform count, but relationships with E. coli or enterococcus count were significant. The best fit (correlation coefficient $r = 0.804$) was with E. coli count:

Table 3 – A summary of water quality and highly credible gastro-intestinal (HCGI) symptom rates in swimmers (S) and non-swimmers (NS), from the US EPA studies (Dufour 1984)

Lake, year and beach			Geometric/100 ml			No of subjects		HCGI Symptom rate/1000		
			Entero-cocci	*E. coli*	Faecal coliforms	S	NS	S	NS+	S-NS
Erie										
	1979	A	5.2	23	-	3020	1310	17.2	14.9	2.3
		B	13	47	-	2056	1039	19.5	14.9	4.6
	1980	A	25	137	37	2907	1436	16.5	11.7	4.8
		B	71	236	104	2427	1558	26.4*	11.7	14.7*
	1982	B	20	146	60	4374	1650	24.9*	13.9	11.0*
Keystone										
	1979	W	38.8	138	436	3059	551	20.6	15.5	5.1
		E	6.8	19	51	2240	419	16.0	15.5	0.5
	1980	W	23	52	230	5121	774	13.5	8.3	5.2
		E	20	71	234	3562	437	11.2	8.3	2.9

* Swimmers' symptom rate significantly different from non-swimmers' at $P<0.05$ level

\+ Pooling of non-swimmer's data between Beaches A and B, W and E in 1979 and 1980. Total subjects 37 940: swimmers 28 766 (Erie 14 784, Keystone 13 982); non-swimmers 9174 (Erie 6993, Keystone 2181)

HCGI rate/1000 = 0.940 (log *E. coli*/100 ml) -11.74 (1)

For enterococci, the regression equation had a correlation r = 0.744:

HCGI rate/1000 = 0.940 (log enterococci/100 ml) -8.28 (2)

Clearly, these findings achieve the second goal and also the third, which was to determine the best bacteriological indicator of risk. Because highly credible gastroenteritis is more reliable a criterion than total gastroenteritis of clinical illness where self-reporting is used, the best predictive equation - the one which results in highest precision - is obviously Equation 1.

The fourth goal was to compare the predictions of risk for freshwater with the relationships obtained by Cabelli (1983) in marine waters. The mean illness rate for HCGI associated with swimming was 15.2/1000 in marine waters compared with 5.7/1000 in freshwaters, ie 2.7 times greater, although the geometric mean counts of *E. coli* and enterococci were not significantly different. This was accounted for by arguing that the mortality rates of indicator bacteria are greater in saline waters than in freshwater, whereas the disease agents, which were considered to be viral, were less affected by salinity.

However a significant factor is not mentioned in this study - that except for Keystone Lake in 1979, the discharges of sewage effluent were chlorinated. Chlorination is more effective against faecal bacteria than viruses. The results of this study are therefore unlikely to apply to freshwaters which receive unchlorinated discharges. Under British conditions one would expect the illness rates to be less for a given bacterial count than predicted by Equations 1 and 2.

Another point which impedes comparison is the difference in microbiological methods used in these studies and those used in Britain, which follow the recommendations of 'Report 71' (Report 1982). Enumeration of *E. coli* was by delayed incubation of membrane filters upon mTEC medium (Dufour *et al* 1981), which was shown to be efficient in recovering exposure damaged cells and confirmed E. coli by urease activity with high specificity. The American term 'enterococci' is comparable with the British 'faecal streptococci', particularly when the latter are counted upon Slanetz and Bartley's medium at 44 °C with delayed incubation. Although there are no published comparable studies it seems likely that results for these two classes of bacteria would have been comparable had British methods for 'faecal streptococci' and 'thermotolerant coliform bacteria' been used. The lack of specificity of the faecal coliform test which was also used is shown by the observation that thermotolerant Klebsiella spp accounted for 17-73% of faecal coliform isolates from Beach B over a 15-day period.

2.5.3 Studies of Health and Welfare Canada

Pilot studies were conducted at 29 beaches of Lakes Ontario, Huron and Erie in 1979 to identify the best approaches for a study in 1980. In particular it was recommended that care should be taken to ensure a sufficient population of non-swimmers and that a minimum of 2000-2500 subjects each of swimmers and non-swimmers would be required for adequate statistical analyses (University of Toronto 1980). A pilot interview showed that 18.6% of 479 swimmers and 12.8% of 39 non-swimmers reported illness. The association with swimming is not significant. During the period 2 August - 10 October the mean air temperature was 22 °C and the mean water temperature 19 °C. This explains the high proportion of beach users who swam in these and the previous US EPA studies and also suggests that people might spend a longer time in the water than in Britain and therefore be more susceptible to illness.

In studies at two of the beaches, isolations were made of the protozoan Naegleria fowleri which were able to grow at 46 °C and killed mice inhaling them. They were therefore regarded as potentially pathogenic to man (see Section 2.3.4).

The full-scale study was carried out in 1980 at 10 Ontario beaches (Seyfried et al 1985a,b). No details of location or of any adjacent polluting discharges are given. Interviewers approached beach users at weekends and established age, sex, illness and swimming record over the previous few days and degree of contact with the water. Subsequent follow-up interviews were by telephone within 7-10 days of the first approach or by mail. Mail questionnaires were not as successful as telephone interviews because of a lower response rate and an exaggerated rate of reporting symptoms (mail 14.7% of bathers; telephone 7.0%). Between June and August 8402 persons, of whom 65% were swimmers, were interviewed on the beach and 6166 follow-up interviews took place by telephone. The final analysis was made on 2743 swimmers and 1794 non-swimmers. Of the swimmers, 1930 (71%) immersed their heads.

Crude analysis of the data (Seyfried _et al_ 1985a) showed that 6.96% of swimmers and 2.95% of non-swimmers reported symptoms, particularly respiratory (2.84 and 11.7% respectively) and gastrointestinal (1.53 and 0.39%). These proportions were little altered by adjustments for age, sex, contact person and swimming shortly before or after the interview. Swimmers who immersed their heads had a higher rate of ear infections (9.3%) compared with swimmers who did not (1.2%).

The second paper (Seyfried _et al_ 1985b) describes analysis of data adjusted for the factors given in the previous paragraph. A logistic regression analysis was carried out on a somewhat larger sample (3967 swimmers and 2105 non-swimmers). Water qualities were good and geometric mean counts were: faecal coliform bacteria, 76 per 100 ml, faecal streptococci, 43 per 100 ml, _Pseudeomonas aeruginosa_ 2.5 per 100 ml and staphylococci 151 per 100 ml. The presentation of illness rates differs here from previous studies discussed in that symptom experience is given as a logistic term, log $(p/(p-1))$, where p is the expected number ill as a fraction of the total population. This presentation is statistically more correct than an illness rate as a fraction of the total population, since the data is binomial (ie ill or not ill). The term $p/(p-1)$ is the odds of becoming ill, in the same way that a '100 to 1 outsider' is the odds of a racehorse not winning. At the low levels of incidences in this study, $p/(p-1)$ approximates very closely to the fraction of the total population reporting illness.

Significant relationships were found between total illness in bathers and counts of staphylococci, faecal coliforms and faecal streptococci and between staphylococci and eye and skin illnesses. The correlations were low and the most significant relation,

$$\text{Adjusted log } (p/(1-p) = 2.65 + 0.696 \text{ (log staphylococci per 100 ml)} \quad (3)$$

had a correlation coefficient of 0.439, showing that 81% of the information in the data was unaccountable.

2.5.4 Studies on Ontario beaches by Lightfoot

One of the Canadian workers (Lightfoot 1989; née Brown) carried out a similarly designed study at six Southern Ontario beaches. Unlike the Health and Welfare Canada studies none were located on the Great Lakes. Two were at inland lakes and the remainder were on small rivers, although no details are given. During the period of the investigation (June - August 1983) four of the six beaches were closed for bathing when the Ontario guideline value of 100 faecal coliform bacteria per 100 ml was exceeded. Only data for open beaches were presented.

The study was generally conducted and the results analysed as in the Seyfried _et al_ (1985a,b) studies. However the category of 'wader' was introduced and the second, follow-up interview was conducted by telephone. The twice daily bacteriological analyses were supplemented by _E. coli_, enterococci, _Campylobacter jejeuni_ and _Legionella_ and by enteroviruses.

In this study 12 028 beach users were approached by student interviewers, wearing distinctive T-shirts announcing the study. Usable data were obtained from 8420, comprising 6653 swimmers in water above knee depth, 574 waders and 1193 non-swimmers. The crude unadjusted illness rates for swimmers were 7.68 per 1000, for waders 41.8 per 1000 and for those not entering the water 19.3 per 1000. Respiratory and gastrointestinal illness predominated. The overall geometric mean coliform count at the open beaches was 398 per 100 ml.

Logistic regression modelling showed that swimmers were at significantly greater risk of falling ill than those not entering the water. However, logistic regression modelling generally revealed that there was no evidence to suggest that bacterial counts contributed to prediction of illness in swimmers and that important predictors were age, contact person (ie the person providing information at follow-up) and interviewer.

The results of this study are therefore controversial and lead one to conclude either that the variability in bacteriological quality of the waters was insufficient to provoke significant changes in symptom rates of bathers or that, the detailed multivariate statistical analysis has revealed serious drawbacks to way in which the interviewers and contact persons were used to obtain information on perceived health symptoms.

2.5.5 Enterovirus excretion by child swimmers and non-swimmers

This study (D'Alessio et al 1981) is valuable since it determined the proportions of swimmers amongst well children and those with an enteroviral like illness and related this information to excretion of enteroviruses. Children aged <1 year to 15 years old who attended a clinic in Madison, Wisconsin between 13 June and 1 September 1977 were interviewed to obtain the frequency and location of swimming in the previous fortnight. Pharyngeal and rectal swabs were examined for presence of enteroviruses. The majority of symptoms were respiratory, with or without fever and gastrointestinal. The city of Madison has 14 municipal beaches at 3 lakes. Sewage discharge is prohibited, but storm sewage and surface run-off water can enter the lakes. There are no municipal swimming pools but numerous privately-owned pools.

The results are displayed in Table 4 where the odds ratio is the odds of swimming among the ill to the odds of swimming among the well. The study population comprised 679 well children, 119 ill and excreting enterovirus and 107 ill non-excreters. Exclusive pool swimmers showed no significant increase in illness but beach swimmers had a significantly (P<0.0005) increased odds ratio, 3.41, of illness with excretion of enterovirus. The highest odds ratio, 10.63, of illness and excretion was in children less than four years old who exclusively swam at the beaches. Swimming history was not significantly different in the well or ill groups.

Table 4 - Relative risks of illness in children related to type of bathing (D'Alessio *et al* 1981)

Well children versus those:	Pool swimming only	Beach swimming only	All swimming
Ill, enterovirus isolated	1.58	3.41**	2.18*
Ill, enterovirus free	1.25	1.53	1.28

* $P<0.005$, ** $P<0.0005$

Relative risk (odds ratio) defined as $(p_i/(1-p_i)/(P_w/(1-p_w))$, where p_i is probability of swimming among the ill, p_w is the probability of swimming among the well.

It is a pity in this study that no details were given of the bacteriological monitoring which was carried out weekly by the city heath department. Since the city beaches are supervised, there is at least the implication that state standards were enforced and that the beaches would have been closed for bathing had they been exceeded. Hence, it is likely that the children would have bathed in water meeting the US Federal Guideline Standards, ie geometric mean of 200 faecal coliforms per 100 ml and 90% of samples not exceeding 400 per 100 ml over a 30-day period.

2.5.6 Shigellosis from swimming

In August 1974, 31 of 45 cases of Shigella sonnei dysentery were traced to swimming in an 8 km stretch of the Mississippi River at Dubuque, Iowa. This town of 62 000 residents discharged effluent after partial secondary treatment and chlorination into the river. A comparison of the first case in each family with matched controls from the same neighbourhood showed significant association with swimming ($P<0.0001$). A retrospective survey was then carried out of 60 families who had camped at a riverside park about 8 km downstream of the effluent outfall. Out of 262 contacts from 60 households, 20 persons reported illness and there was a strong association ($P<0.0001$) with swimming, but not with drinking water or eating. Other features revealed were a median incubation of about 3 days, median ages of 9 years (swimmers) and 15 years (camp users) and illness confined to swimmers who had immersed their heads or swallowed water. Water samples taken from the river in August showed a faecal coliform count of 400 000 per 100 ml in the park swimming area (Rosenberg et al 1976).

2.5.7 Pool use and outer ear canal inflammation

A retrospective study showed that Otitis externa (outer ear canal inflammation) was related to warm air and water (as in indoor pools), age less than 18 years, swimming and length of time swimming but not to bacteriological quality of the water (Calderon and Mood 1982).

2.5.8 Snorkel racing in Bristol Docks

The water in the Bristol Docks is maintained at a constant level by lock gates which are a barrier across the tidal Avon estuary. Since the Docks were closed for commercial shipping in 1974, the area has been redeveloped and recreational use encouraged. On 10 May 1981, 176 swimmers took part in a snorkel race; 11 out of 91 interviewed by telephone after the event reported illness, eight of them gastroenteritis. The event was repeated on 9 May 1982 when 205 participated. Questionnaires were sent subsequently to 199, of whom 91% responded and of whom 25% reported gastroenteritis and a further 11%, headaches, sore throats, shivering or muscular aches. On the day of the event water quality met the EEC bathing water Directive's standards for total and faecal coliform bacteria. A prospective cohort study was carried out for the next event on 8 May 1983, in which 21/77 swimmers reported gastroenteritis and only 1/75 family controls and 3/95 visitor controls. The association of illness with swimming was significant (df=2, P<0.001). Three water samples were taken during the event, all failed the EEC imperative standard for total coliforms (geometric mean 56 000 per 100 ml) and two that for Escherichia coli (1650 per 100 ml) (Philipp et al 1985).

2.5.9 Health hazards of windsurfing

In August 1984 the Windsurfer Western Hemisphere Championship was held on the St Lawrence River in the baie de Beauport, Québec City. On the eighth day of the event four out of eight water samples showed faecal coliform counts above 250 per 100 ml and it was estimated that these rose to about 1000 per 100 ml at high tide, when most of the races were held. On the ninth, final day, 79 competitors and 41 employees were interviewed to determine health effects; 45 competitors and eight employees reported at least one symptom. Windsurfers experienced relatively higher rates of gastroenteritis (5.5 times) and of all symptoms (2.9) than employees. Relative risk increased with the reported frequency of falling in the water (Dewailly et al 1986).

2.6 EPIDEMIOLOGICAL STUDIES OF MARINE WATER RECREATION

2.6.1 Study of the US Public Health Service in Long Island Sound

The tidal water study was carried out at the municipally-owned beaches of two residential communities, New Rochelle and Mamaroneck in Long Island Sound, New York (USDHEW 1961). The Hudson Park Beach at New Rochelle was divided by a rocky promontory into two stretches. Screened, chlorinated raw sewage was discharged to a deep water outfall in Long Island Sound. However, raw sewage from the bath house on the beach and from a private rowing club and storm sewage, were discharged near the beach. Beaches were closed when large overflows of raw sewage occurred. This happened on two consecutive days during the study. On the other hand, the Mamaroneck area was completely sewered. The sewage was screened and chlorinated before discharge through a two-mile long outfall in Long Island Sound. No storm sewage discharges occurred.

The tidal water study took place between 21 June and 31 August 1950 and the number of participants at each locality was equal. Of the 4900 swimmers, 2573 swam exclusively at the study beaches. The median coliform count was significantly greater at New Rochelle and individual values there were influenced tidally. The overall rates of illnesses in bathers and non bathers were the lowest of any of the three studies.

Although the total coliform counts at the two beaches differed significantly (geometric means: New Rochelle 815, Mamaroneck 398 MPN/100 ml), no significant differences was detected in illness rates in participants using either of the beaches exclusively, whether gastrointestinal, or eye, ear, nose and throat or of other illnesses taken together. At both beaches, illness rates in swimmers were greatest for those under 5 years old, decreasing with age and increased with number of days of swimming. In all age categories, eye, ear, nose and throat illnesses (3.7 per 1000 person-days) far exceeded gastroenteritis(0.9) and others (1.7). The greatest amount of swimming was done by 10-19 year olds, followed by 5-9 year olds, with very little by those aged 45 or over.

2.6.2 Studies of the US EPA

The overall US study (Cabelli 1983, Cabelli *et al* 1983) was conducted at three locations, New York City, Lake Pontchartrain, LA and Boston Harbour, MA. Two beaches, one 'relatively unpolluted', the other 'barely acceptable' were selected at each location. A fourth study was conducted on beaches at Alexandria, Egypt and involved residents and visitors from Cairo.

Only minor details were given about the beaches. The water in Lake Pontchartrain was brackish (about 5 percent sea water by volume) and although there were no discharges of sewage, it was thought that stormwater discharges could reach the beach from canals and bayous. A proportion of the discharges affecting the New York beaches were chlorinated. The Alexandria beaches were affected by numerous discharges from short outfalls.

Table 5 shows some of the overall features of the US studies.

Table 5 - An overall summary of the features of the US EPA marine studies (Cabelli 1983)*

Subjects used in analysis:	
Swimmers	16280
Non-swimmers	9162
Total subjects	25442
Bacterial counts, grand geometric means per 100 ml (and limits):	
Enterococci	25 (3.6 to 495 in 18 trials)
Escherichia coli	52.1 (7.0 to 3091 in 20 trials)
Symptom rates, highly credible gastroenteritis (grand average and limits):	
Swimmers (S)	28.7 (7.6 to 46.4)
Non-swimmers (NS)	12.9 (2.4 to 23.1)
Swimming-associated (S-NS)	17.3 (-0.5 to 34.5)

* Data calculated from his Table 6, except *E coli* - Table 8

The trials (ie study weekends) at individual beaches and the data from the whole study showed that the best correlation between water quality and highly credible gastroenteric (HCGI) symptoms was given by the enterococcus index. When the data were grouped by 18 combinations of trials with similar enterococcus counts, the relationship obtained was:

Swimming-associated HCGI rate/1000 = 12.17 log (enterococci/100 ml) + 0.20, $r = 0.75$

The fit between swimming-associated symptom rates for total and HCGI and counts of E coli was poor and not statistically significant.

The Alexandrian studies were conducted because the collective US policy of closing beaches not meeting standards prevented studies being carried out at unsatisfactory beaches and thus extending the range of the quality/health relationship. In these studies, carried out between 1976-1978 at four beaches, differences were found in the responses of Alexandrian residents and visitors from Cairo, in that the latter showed a greater susceptibility to swimming-associated vomiting and diarrhoea (relative to the mean counts of enterococci and E coli) up to a level of 200-300 E coli/100 ml. Children were more susceptible than adults. It was thought that the swimming population had acquired immunity to the disease agents. This point is apparent when the regression equations predicting the case rates per 1000 from swimming-associated diarrhoea and vomiting are compared with those for the US marine water studies.

For Cairo residents on Alexandria beaches:

Swimming-associated D+V rate/1000 = 20.29 (enterococci/100 ml) - 37.068, r = 0.88

For Alexandria residents on Alexandria beaches:

Swimming-associated D+V rate/1000 = 5.481 (enterococci/100 ml) - 4.842, r = 0.68

This shows that the slope of the line (a measure of susceptibility to infection) was greater for Cairo residents (20.29) than for Alexandria residents, bathing at Alexandria (5.481) and that the value for US bathers (12.7) was intermediate.

The Alexandrian studies were not used either in developing the first predictive equation for the US studies or in developing the health effects criteria for marine water, recommended by the US EPA (1986) and which are discussed in Section 3.2.1.

Some further conclusions from the US marine studies are as follows. At enterococcus counts of 70 and 10 per 100 ml respectively, the rates for total gastroenteritis and HCGI among swimmers were twice those for non-swimmers and were projected to be equal at an enterococcus count of 1/100 ml. This was taken to suggest that the infective agents were present in sewage in large numbers, were highly infective and/or were able to survive sewage treatment, disinfection and transport better than the enterococci. The importance of acquired immunity in modifying the symptom response to waters of differing quality was shown by the Alexandrian studies and by the greater susceptibility of children under 10 years. The illness associated with bathing in waters of varying quality was shown or inferred to be a relatively benign gastroenteritis with an incubation period of a few days only with an acute onset, short duration and few, if any, sequelae. Taken as a whole, the infectious agent was considered to be either the human rotavirus or the 'parvo-like' viruses (ie what would now be termed the Norwalk virus and the small, round viruses).

2.7 LATER STUDIES MODELLED UPON THE US EPA'S APPROACH

Later epidemiological studies have tended to follow the techniques adopted by Cabelli (1983) and Dufour (1984). Indeed, a model protocol has been adopted by the World Health Organization/United Nations Environmental Programme (WHO 1986) for use in studies of pollution in the Mediterranean Sea as part of the MEDPOL Phase II action. None of these studies has been as extensive as the US studies and only the outlines are considered below.

2.7.1 Aesthetic and health studies on Spanish beaches

In the summer of 1979 a study was carried out on 14 beaches in Málaga and 10 in Tarragona and 20 918 validly completed questionnaires were completed. A total of 29 questions were asked to establish personal details, swimming activities, perception of cleanliness of the beach and water and of untoward symptoms and the seeking of medical advice. Because holidaymakerss generally stayed at one resort and made daily trips to the local beach, but did not tour, no attempt was made to select groups exposed to water qualities on specific days or to conduct follow-up interviews some days later. Some of the conclusions of this study (Mujeriego et al 1982) are as follows.

The most frequent ailments reported were those collectively of the eyes, ears, nose and throat (3.25 percent) and of the skin (pimples, mycoses; 4.18 percent). Diarrhoea was reported by 0.8 percent of interviewees. Women reported a significant excess of skin ailments and men of ear infection. Head immersion was related to symptoms of the eyes and ears (Málaga beaches) and of the ears (Tarragona). Differences in symptom reporting were related to water quality classification. Paradoxically, morbidity rates for mycoses and for ear and eye infections in bathers were greater on satisfactory beaches than on unsatisfactory beaches in Málaga. With the exception of pimples, all symptoms were more prevalent among bathers at Málaga than at Tarragona, despite the beaches being satisfactory by WHO/UNEP criteria. A positive relationship (but of low, unspecified correlation) was found between enterococcus count and the rate of ear infection.

2.7.2 Brittany beaches

In this pilot study (Foulon et al 1983) 4921 holidaymakers were interviewed at 5 beaches over a 12-day period in 1979 to elicit personal details, bathing history and illness noticed in the previous four days. Only those who had spend at least 4 days at the beach were retained in the survey. A follow-up questionnaire card was given to participants to record illnesses contracted up to 30 days following the interview. Holidaymakers were classified as non-bathers, non head-immersing bathers and head immersers.

Non head-immersers reported significantly more eye, ear and skin complaints than non-bathers, but fewer abdominal pains. Head immersers reported more itching eyes, ear and throat symptoms and abdominal pains than non head-immersers. The differences in incidences of symptoms reported by bathers at polluted or non-polluted beaches were barely significant ($P<0.05$) only for skin irritations. In the follow-up questionnaire, a significantly ($0.05<P<0.01$) greater level of diarrhoea was reported by bathers at polluted beaches (27/959) than at unpolluted beaches (2/254). A drawback of this study was that microbiological monitoring of water quality did not exactly coincide with the days of the surveys.

2.7.3 Tel Aviv, Israel studies

In May-August 1983 waters were sampled and family groups interviewed at three Tel Aviv beaches (Fattal et al 1987). Two beaches were 3-5/km from an outfall and the third was remote from any discharge. In total, 2231 persons in 615 families were interviewed. Each family contained one person less than 10 years old and 499 subjects were 0-4 years old. Of the sample, 1174 were defined as swimmers, ie those who had immersed their heads, who had swallowed sea water or whose face had been splashed by waves. The questionnaire protocol generally followed the WHO (1986) guidelines.

Respondents were asked about socio-demographic details, bathing activities and about health for one week prior to interview. They were then given a follow-up interview by telephone about 3-4 days later to elicit subsequent health symptoms.

No significant excess of enteric and respiratory symptoms and skin infections by 'low' and 'high' counts of indicator bacteria was found between swimmers and non-swimmers in any age group, apart from the 0-4 year age group. 'High' meant faecal coliform bacteria <50/100 ml, enterococci <24/100 ml and E coli < 24/100 ml. In the 0.4 year age group, a significant excess of respiratory symptoms was found in swimmers compared with non-swimmers. Although counts of the three bacterial indicators were significantly correlated (eg faecal coliforms and E coli, r = 0.88; enterococci and E coli, r = 0.61), grouping of 'high' and 'low' counts by enterococci produced the highest association with illnesses in the 0.4 year age group. Enterococci were therefore judged as the most predictive indicator.

2.7.4 Hong Kong studies

Sea bathing is the most popular summertime activity at this city. There are 42 recognised beaches and a single popular beach may receive up to 1.5-3 million visitors in one season. A smaller study was conducted in 1986 (Hong Kong Government 1986) and a full-scale survey in 1987 (Cheung et al 1988, Holmes 1989). The WHO (1986) protocol was followed as far as possible.

The Phase I study was carried out at four beaches over 3 week ends (6 days). A total of 6639 beach-goers were interviewed about personal details, pretrial illnesses and swimming activities. They were then telephoned a day later to obtain information about swimming and food eaten at the weekend. A second telephone interview, 7-10 days after enlistment on the beach sought to obtain further health information and mid-week swimming after the beach interview. Water samples were taken every two hours between 0900 and 1700 on the days of beach interviews and analysed for eight microbiological indicators. Considerable press and radio coverage was given to the study. Successful follow-up interviews were given by 3869 bathers and 1245 non-swimmers, representing 77 percent success. Subsequently, only those swimmers who had a single swimming experience during the survey weekends were included in the analysis. This resulted in 3549 (70% of those successfully interviewed) responses being used in the analysis. Swimmers were about three times more numerous than non-swimmers, therefore in the comparisons, the non-swimmers from all four beaches were pooled.

When swimmers as a whole were compared with non-swimmers, they were found to have experienced significantly greater rates ($P<0.05$) of gastrointestinal symptoms, diarrhoea and total illness. When comparisons were restricted to individual beaches further significantly elevated swimming-associated responses were found but they are not clearly related to the bacterial count. The swimming-associated HCGI rates were 0.5-3.0 per 1000 swimmers which were lower than those found in the US EPA studies (Cabelli 1983, Dufour 1984).

In the following year, the procedures for the Phase II study were similar but 18 741 usable responses were obtained from a total of 24 308 interviews conducted at 9 beaches. For individual symptoms the rates reported by bathers were generally higher than for non-bathers. The HCGI rate for swimmers was 5 times that for non-swimmers and for gastroenteritis, skin, respiratory and total symptoms about 2-3 times. The HCGI rates were again lower (4.1/1000 overall) than found in the US EPA studies but more closely resembled those found at Alexandria (Cabelli 1983). Regression analysis provided the following relationship for predicting the count of E coli associated with a given risk:

$$\text{Log geometric mean } \underline{\text{E coli}}/100 \text{ ml} = 0.0922 \times \text{swimming-associated HCGI}/1000 + 1.382, \quad r=0.73$$

At the limit of acceptability used in Hong Kong, which is 60 percent compliance with the 1000 E coli/100 ml standard, the expected HCGI and skin symptom rates are about 15 cases per thousand bathers. This relationship is now used annually to rank the quality of water at Hong Kong's beaches with reference to predicted health risks. In this grading, note was taken that a geometric mean E coli count of 180/100 ml was a threshold at which swimming-associated gastroenteritis and skin symptoms became statistically significant at a rate of about 10 per 1000 bathers. The categories used are 'good' (bathing season geometric mean E coli $\leq$ 24/100 ml), 'acceptable' ($\leq$180), 'barely acceptable' ($\leq$610) and 'unacceptable' (>610) (Tam et al 1989).

2.7.5 Ocean health study - New Jersey Department of Health

The primary aim of this study (NJDOH 1989) was to determine whether discharges of chlorinated sewage or of storm water run-off were increasing the risk to health from swimming on the New Jersey coastline. A pilot study in 1987 aimed to assess the feasibility of the epidemiological techniques and the level of contamination. As a result, it was decided to carry out a single large epidemiological study in 1988 with a goal of 20 000 interviews, examining particularly HCGI.

At 10 weekends from June to September 1988 water samples were taken and beachgoers interviewed simultaneously at nine ocean beaches over a 150 Km stretch from Long Branch to Ocean City and at two inland lakeside beaches. Initially 23 458 households were contacted at the beach but many were rejected for not meeting various criteria such as unwillingness, pre-existing infectious illnesses, only adults at the beach or anticipated swimming elsewhere. The final study population was 5 378 households and 16 089 participants, with 11 447 ocean visitors and 4 642 lake visitors. The population was 54.5 percent female and 25 percent of ocean visitors and 37 percent of lake visitors were under 10 years old. Visitors were classified as 'got head wet' (ocean 45.3 percent, lakes 74.7 percent), 'waded' (32.3, 14.3) or 'not in the water' (22.4, 11.1). Follow-up, 3-4 days after the beach interview, was by telephone to confirm swimming status, health effects and other risk factors, such as foodstuffs consumed or contact with ill neighbours or friends.

Certain unusual circumstances were thought to have influenced the outcome of the study, such as unusually cold sea water (temperatures 13-21 °C) and 12 major pollution events affecting the coastline including washing ashore of household refuse and medical wastes and beach closures because of sewage contamination. There was much local concern and beach attendances were noticeably reduced. Even so, the bacteriological water quality during the study was extremely good (Table 6) and to some extent this was to be expected from chlorinated discharges of treated sewage.

Sore throat was the commonest symptom reported by ocean visitors (36/1000) and red, itchy eyes by lake visitors (56/1000). Children under 10 years, whether lake or ocean-going were affected more by all symptoms than older participants, particularly for HCGI and skin rashes. The rates for all symptoms in both lake and ocean-going participants was directly related to exposure, being least for those not entering the water and greatest for head immersers. Overall, swimming-associated HCGI rates were 12.2/1000. Because of the low levels of bacteriological indicators at the beaches (Table 4) it was not possible to relate water quality to symptom rates in bathers.

Table 6 - Geometric mean counts of faecal indicator organisms in chlorinated sewages, stormwaters and at the beaches, New Jersey Ocean Health Study

Sites and dates	Faecal indicators (per 100 ml)			
	Faecal coliforms	Enterococci	Coliphage f2 (male) -specific)	*Clostridium perfringens* spores
Chlorinated sewage, 9 works, summer 1987	6.5*	<1.7*	2800	422
Stormwater samples (15), April-June 1988	220	284	0.5	72
Ocean samples (76), beach weekends 1988	10	5	3	3
Lake samples (19), beach weekends 1988	25	10	9	3

* Medians

2.7.6 UK study of the Robens Institute, University of Surrey

A small public perception survey was carried out by the Robens Institute at two un-named English resorts over 6 weeks in July and August 1987 (Brown *et at* 1987), financed by the Greenpeace Environmental Trust. The first resort was known to be polluted by sewage discharges, which resulted in a faecal coliform count of 440/100 ml (geometric mean) during the study. The second resort yielded a geometric mean value less than 10/100 ml and was considered unpolluted. A total of 1903 people were interviewed concerning holiday habits, perception of pollution at the beach and health symptoms. There was no follow-up questionnaire. The reporting of symptoms by bathers (head-immersers, non head-immersers) at both beaches (first resort, 137 and 284 respectively; second resort, 117 and 122) was compared with that of 1243 non-swimmers pooled from both resorts. Swimmers (head immersed) at the first (polluted) resort showed significantly greater ($P<0.01$) reporting of general illness, stomach upset, nausea or diarrhoea than non-swimmers. This elevation was not significant for other symptoms.

2.8 DISCUSSION OF EVIDENCE

2.8.1 The strength of association

Table 7 lists those illnesses which have been reported in Section 2, either from outbreaks with case-control studies or from prospective epidemiology and attempts to gauge the strength of association with quality of the water. The criteria of Bradford Hill (1965) in Table 1 have been used.

The association is strongest in those cases where the pathogen has been isolated from the patients and the water, where the association between illness and exposure has been shown to be significant and where the water was known to be grossly polluted with sewage. Into this class fall typhoid fever, shigellosis, leptospirosis and viral infections such as respiratory with or without fever, gastroenteritis and hepatitis A. The two rarities in Britain are primary amoebic meningo-encephalitis and swimmer's itch, but these are substantiated from outbreaks elsewhere.

The major epidemiological studies of Sections 2.5.1 - 2.5.4 and of 2.7 have been carried out in waters meeting local bathing water standards or just failing to meet them, with the exception of the Alexandria and Hong Kong studies. In none of these (category 3 of Table 7) were the pathogens isolated and illness was reported by the subjects, but with some attempts to obtain credible diagnoses. The main conclusions are that the strengths of association between illness and water quality in bathers hardly reach statistical significance except when water is of 'barely acceptable' standard, or worse and that gastroenteritis is related to bacteriological quality, whereas infections of the eyes, ears, nose and throat are higher in bathers than in non-bathers, regardless of water quality. This latter category of disease is particularly related to swimming in properly maintained pools.

Finally, firm evidence is lacking to show a relationship between non-A non-B viral hepatitis or cryptosporidiosis in bathers swallowing polluted water, although it would seem likely at least by analogy.

Table 7 - A classification of illnesses reported in freshwater and marine recreation

Illness	Reference and particular remarks
1. Organisms isolated from patients and water, high degree of causal relationship:	
Typhoid fever	Medical Research Council (1959), Galbraith (1987), Harvey and Price (1981)
Shigellosis	Rosenberg *et al* (1981); *S. sonnei*
Leptospirosis	Waitkins (1986), Harvey and Price (1981)
Enteroviral illness	D'Alessio *et al* (1981); respiratory, with or without fever; gastroenteritis
Headache, fever, myalgia	Baron *et al* (1982); Norwalk virus infection confirmed by serology
Primary amoebic meningo-encephalitis	Galbraith (1987); hot spring, *Naegleria fowleri*
Swimmers' itch	Eastcott (1988); snail-infested pool, *Trichobilharzia ocellata*
2. Grossly polluted waters:	
Typhoid fever	Medical Research Council (1959), Galbraith (1987), Harvey and Price 1981)
Shigellosis	Rosenberg *et al* (1981)
Leptospirosis	Harvey and Price (1981), Waitkins (1986)
Gastroenteritis	Phillip *et al* (1985)
Hepatitis A	Bryan *et al* (1974)
3. Waters of acceptable or borderline quality:	
Gastroenteritis	Stevenson (1953), D'Alessio *et al* (1981), Cabelli (1983), Cabelli *et al* (1983), Foulon *et al* (1983), Dufour (1984), Seyfried *et al* (1985a), Dewailly *et al* (1986), Fattal *et al* (1987), Hong Kong Government (1986), Brown *et al* (1987), Cheung *et al* (1988), Holmes *et al* (1989), NJDOH (1989), Lightfoot (1989)
Ear and eye	Stevenson (1953), Mujeriego *et al* (1982), Foulon *et al* 1983, Mujeriego *et al* (1982) Seyfried *et al* (1985a), Lightfoot (1989) NJDOH (1989)
Skin irritation	Stevenson (1953), Mujeriego *et al* (1982), Foulon *et al* (1983) Lightfoot (1989)
Respiratory	D'Alessio *et al* (1981), Seyfried *et al* (1985a), Fattal *et al* (1987) Lightfoot (1989)
4. Chlorinated swimming pools:	
Ear, eye, nose and throat	Stevenson (1963), Smith and Woolsey (1952)

Outer ear inflammation (*Otitis externa*)	Calderon and Mood (1982)
Pharyngo-conjunctival fever	D'Angelo *et al* (1979); Adenovirus type 4, insufficient chlorination

5. Diseases for which the causal relationship is unproven:

Non-A non-B hepatitis	
Cryptosporidiosis	Gallagher *et al* (1989)

2.8.2 A comparison of the risks predicted by various epidemiological studies

The studies of Cabelli (1983) Dufour (1984), Seyfried *et al* (1985b), Lightfoot (1989) and Cheung *et al* (1988) all attempt to model risk of experiencing symptoms from the observed bacteriological quality of the water. Figures 1 and 2 attempt to display those relationships which reach statistical significance. The studies of Stevenson (1953) at the two Chicago beaches failed to detect an effect of total coliform count upon illness rates, because variability in water quality was small and presumably, because multiple bathing exposures throughout the season were not controlled. However the data of Table 2 for the high and low periods and overall do display a positive relationship and this is shown in Figure 1. Scrutiny will show that the studies are not directly comparable. For example different indicator bacteria were studied and between studies, different methods were sometimes used for the same determinand. Most certainly the populations were not homogeneous between studies and different illness criteria are used. The Stevenson (1953) study reports illness rate per 1000 person-days, Cabelli (1983) Dufour's (1984) and Cheung *et al* (1988) per 1000 persons. The two others (Seyfried 1985b, Lightfoot 1989) use multivariate probit analysis of bather data to control for various sources of error (reporter, subject, age, sex, bathing outside the study period, bather or non-bather). In Cabelli's, Dufour's and Cheung's studies the rates are for excess illness in bathers (highly credible gastroenteritis, swimming-associated) and the degree of control for external factors is not quoted, although alluded to.

The main feature of Figures 1 and 2 is that all the relationships are positive, ie the risk increases with the increase in bacterial count. What is not shown is the degree of scatter in individual points used to construct the relationships. It is also apparent that some of the studies were carried out in extremely clean waters. At least two studies (Stevenson 1951, New York, Dufour 1984) were carried out in waters receiving chlorinated final effluents. Because viruses are more resistant than faecal bacteria to chlorination, the risk relationship is altered, compared with waters receiving undisinfected discharges. In the latter case, the perceived risk would be lower for a given bacterial count than in the former.

Figures 1 and 2 also show the mean risk of illness in non-bathers. In the freshwater studies of Fig 1, except that of Seyfried and others (1985b), it was usually similar to, or even greater than that for bathers, even after correction for the non-bathing risk. These features again suggest that the degree of illness for bathers in waters of the quality studied were 'acceptable', by not being greatly elevated over those for non-bathers. Fig 2 however suggests that the risks for bathers in sea water were usually greater, even after correction for non-bathing risks, than for non-bathers.

A general impression is left that the data used, both in individual studies and collectively in Figure 1 display a great deal of 'noise' or uncontrolled variability. To some extent this is because no freshwater study was conducted in water of unsatisfactory quality. The single point for the Bristol Docks study (Philipp et al 1985) gives evidence for this view.

Fig 2 also displays differences in the susceptibilities of bathers to waters of varying quality at different locations. The three studies of Cabelli (1983) and the freshwater study of Dufour (1984) in Fig 1 are directly comparable. Thus, the Cairo visitors to Alexandria beaches showed greater susceptibility than Alexandria residents swimming at the same beaches. The higher levels of acquired immunity in people from poorer cities with greater crowding can explain the differences between the responses of the Egyptian and Hong Kong communities, compared with those of the US marine studies. Dufour (1984) comments on the higher swimming-associated HCGI rates in the US marine studies (Cabelli 1983) than in his own freshwater studies. This, he claimed, could be explained by the higher rates of decay in sea water of faecal indicator bacteria, used to judge water quality, compared with those of the viral pathogens responsible for HCGI symptoms. An unknown and unevaluated factor in the US and Canadian studies is the extent to which chlorination of effluents is practised. In the New Jersey study (Table 6, NJ DOH 1989), it is apparent that faecal bacteria were almost completely destroyed by chlorination of effluents, thereby removing their value as indicators of recent faecal pollution in sea water.

Some of the studies do not lend themselves to the comparative treatment of Figs 1 and 2. Table 8 compares the crude mean illness rates of swimmers and non-swimmers with the geometric mean counts of faecal bacteria. It shows again that the rates of illness vary from study to study over a wide range, both for bathers (0.86-156 per 1000), and to a lesser extent, for non-bathers (0.45-75). This may represent the success of interviewing techniques and the subjective reporting of illness by the subjects as well as real differences in underlying clinical illness . A common base is provided by measuring illness rates in bathers as a proportion of that in non-bathers (which, at low rates approximates closely to the 'odds ratio' of Figs 1 and 2). Table 8 shows that swimmers reported up to 8.3 times the rates of illness in non-swimmers, for different categories of symptom.

For the sake of completeness and to aid comparisons made in Section 3.4.2, the significant findings for perceived symptoms in the Phase I Pilot Studies at Langland Bay are included.

Table 8 - Geometric mean counts of faecal indicator bacteria and associated illness rates in some marine studies

Reference, and location and remarks	Bacteria (per 100 ml)	Illness and rate/1000			Ratio, $\frac{S}{NS}$
			Swimming (S)	Not swimming (NS)	
USDHEW (1960, Tables A-15 and A-16), chlorinated discharges					
New Rochelle, NY	815 TC	EENT	3.76	1.89	2.0
		GI	0.86	0.60	1.4
Mamaroneck, NY	398 TC	EENT	5.29	1.99	2.7
		GI	1.13	0.55	2.1
Foulon (1983), - Tables 3,6; Brittany	78 FC, 16 FS	EET	116	43	2.7
		GI	23	23	1.0
		Skin	68	23	3.0
Fattal *et al* (1987), Tel Aviv, Israel, 0-4 age group only:					
'Low beaches'	12 Ent	GI	11.4	9.0	1.3
'High beaches'	217 Ent	GI	22.1	13.3	1.7
Brown *et al* (1987) England:					
'Polluted beach'	440 EC	SU	88	44	2.0
		N	73	16	4.6
		D	44	8.0	5.5
'Unpolluted beach'	<10 EC	SU	20	44	0.45
		N	30	16	1.9
		D	10	8.0	1.3
NJDOH (1989) Ocean Study; chlorinated discharges	10 FC 5 Ent	HCGI	20.8	8.6	2.4
Cheung *et al* (1988) Hong Kong, Phase II	249 EC	HCGI	2.5	0.5	5.0
Langland Bay (1989) (a) Beach Survey; telephone follow-up; symptoms significantly more frequent in bathers	260 TC	Major	122	68	1.8
	158 FC	ET	77	31	2.5
	21 FS	Eye	29	7.3	4.0

(b) Cohort Study. Rates perceived 3 days following exposure (diarrhoea 3 weeks); symptoms significantly more frequent in bathers	36.8 TC	T 156	75	2.1
	19.6 FC	Ear 39	0.0	∝
	31.5 FS	Eye 62	7.5	8.3
		D 121	38	3.2

Notes: Bacteria: total coliforms TC, E coli EC, enterococci Ent, faecal streptococci FS.

Illnesses: ear and eye EE, nose N, throat T, ear and throat ET, gastroenteritis GI, stomach upset SU, diarrhoea D.

Illness rates are crude, unadjusted; in USDHEW (1960) studies, rates are per 1000 person-days of swimming, otherwise, per 1000 persons.

Swimmers are head-immersers.

A feature of the studies of Cabelli (1983), Dufour (1984), Seyfried et al (1985), Cheung et al (1988) and Lightfoot (1989) was an attempt to find the bacterial indicator showing highest correlation as a predictor of one or more different classes of symptom. There was however, no general agreement on the most satisfactory indicator to use. This is an example of empirical research, rather than research designed to test an hypothesis of disease. This type of research cannot, of itself, be expected to show a high degree of correlation, because the causal relationship of faecal indicator and risk involves three separate component relationships. No real constancy can be assumed between counts of faecal bacteria and of pathogens because the latter are excreted only when people are infected whereas the former are always present in faeces. Once excreted, the ratio of faecal indicator to pathogens will alter if their survival characteristics are different. The relationship between numbers of pathogens ingested and risk will vary depending upon pathogenicity and immunity of the subject. The relationship between counts of bacterial indicators and risk of illness will be least predictable when the identity of the pathogen is unknown and the illness is reported or perceived.

Hence the results of the studies shown in Figures 1 and 2 must be regarded as the best that could be achieved in the circumstances, rather than as definitive. They also indicate that it is unlikely that any universally applicable relationship exists.

2.8.3 Significant conclusions from the epidemiological studies reviewed

Certain conclusions are re-iterated so often in the studies reviewed earlier, that they must be regarded as having general validity under the test of consistency in Table 1. They also often display the features of biological gradient, plausibility and coherence. These conclusions are shown in Table 9 against the studies in which they have been found and relevant features of these studies. For completeness and to aid comparison, the significant conclusions from the Langland Bay Phase I Pilot Study have been included.

2.9 THE DERIVATION OF STANDARDS FOR AQUATIC RECREATION

2.9.1 Standards should be related to the type of recreation

It is immediately apparent that different types of recreation involve different degrees of bodily contact with water and different lengths of exposure. Hence the risks of acquiring illness and the degree of illness will be related both by the quality of water and the degree of contact with it. It is logical to classify the various uses of water according to the degrees of exposure, the extent of contact of the participant's body with the water and the risk of water being swallowed.

For example, North American policy largely derives from recommendations in a report by the National Technical Advisory Committee (NTAC 1968). This defined 'primary' and 'secondary contact recreation' as follows:

Primary contact recreation:

Table 9 - Conclusions from the epidemiological studies reviewed in Section 2

Conclusions	Qualifying remarks and investigation
Swimmers report a higher incidence illness than non-swimmers	Chicago, Lake Michigan, Ohio River and pool, Long Island Sound (Stevenson 1951) Brittany: eye, ear, nose and throat complaints (Foulon et al 1983), marine and freshwater US EPA studies (Cabelli 1983, Dufour 1984) Head immersion related to ear and eye infections (Mujeriego et al 1982) No relationship for waters with <25 enterococci/100ml (Fattal et al 1987) Differences not significant in Great Lakes pilot study (University of Toronto 1980) On Ontario beaches (Seyfried et al 1985a) In Ontario lakes and steams (Lightfoot 1989) Hong Kong beaches: gastroenteritis, total illness, diarrhoea (Hong Kong Government 1986, Cheung et al 1988, Holmes 1989) Two UK beaches: general illness, stomach upset, nausea and diarrhoea (Brown et al 1987) Langland Bay, 1989: ear, eye, throat in beach survey and cohort studies; diarrhoea less common in bathers (Beach Survey), but more common in bathers 3 weeks after exposure (Cohort Study)
The rate of illness is related to the degree or duration of exposure to water	Chicago, Lake Michigan, Ohio River and pool, Long Island Sound: rates rose with days of swimming experience (Stevenson 1953) Poorly chlorinated swimming pool, pharyngo-conjunctival fever (D'Angelo et al 1979) Negative relationship with number of days a week swimming (New York) or swimming events per day (Alexandria) (Cabelli 1983) Rates in head immersers >non head immersers > non-bathers (Foulon et al 1983) In windsurfers, St Lawrence River (Dewailly et al 1986) Ontario lakes: ear, respiratory and gastroenteritis symptoms greater in head immersers than non head immersers and non bathers (Seyfried et al 1985a) Langland Bay, 1989: beach study suggests that risk follows the order non-participants <waders <swimmers <divers <surfers, for major symptoms aggregated
Children bathing show a greater incidence of illness than older people	Under 5's >5-10 year olds > remainder: Alexandria (Cabelli 1983) In 0-4 year olds, significant excess of enteric and respiratory symptoms, compared with non-swimmers (Fattal et al 1987) Under 10's experienced more HCGI and skin rashes (NJDOH 1989) Langland Bay, 1989: 15-24 age group most susceptible to ear, throat, respiratory and all symptoms aggregated

Table 9 Cont/.....

Conclusions	Qualifying remarks and investigation
The rate of illness is related to the level of counts of faecal indicator bacteria	Higher illness rates on days when total coliform MPN >2300/100ml (Stevenson 1951) Ohio River swimmers (total coliform median MPN 2700/100ml) experienced higher gastroenteritis rates than pool swimmers, but *vice versa* for eye, ear, nose and throat symptoms (Stevenson 1953) Long Island Sound: no significant difference in symptoms for bathers at beaches with significantly different total coliform MPN's (815, 398/100ml) (Stevenson 1953, USDHEW 1960) US EPA studies in marine (Cabelli 1983) and freshwater (Dufour 1984) Brittany: diarrhoea (Foulon *et al* 1987) Mâlaga, Spain: morbidity rates for mycoses and ear and eye infections greater on satisfactory than on unsatisfactory beaches (Mujeriego *et al* 1982) Enterococcus count related to ear infection (Mujeriego 1982) Relationships not significant in Ontario lake and river study (Lightfoot 1989) Relationships not significant in New Jersey Ocean Health Study; low bacterial counts in sea and lakes (NJDOH 1989)
E coli or faecal coliform bacteria are not as satisfactory as other faecal indicator bacteria in correlation with illness rates	Enterococci superior, US marine waters (Cabelli 1983) Enterococci superior in grouping illness in 0-4 year olds Fattal *et al* (1987) *E coli* showed higher correlation (0.804) than enterococci (0.744) for HCGI in freshwater (Dufour 1984) Total staphylococci better than faecal coliforms and faecal streptococci for predicting total illness, eye and skin disease, Great Lakes (Seyfried *et al* 1985b)
Residents near the beach are less susceptible than visitors to swimming-associated gastroenteritis	Alexandria residents and Cairo visitors on Alexandria beaches (Cabelli 1983)
What are the most active age-groups for bathing?	10-19 years >5-9 years: Chicago, Lake Michigan (Stevenson 1953) 5-9 years >20-24 >10-14>15-19: Ontario lakes and rivers (Lightfoot 1989)

> "Activities in which there is prolonged and intimate contact with water, involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard, such as wading and dabbling by children, swimming, diving, water skiing and surfing."

Secondary contact recreation

> "Activities not involving significant risks of ingestion, including boating, fishing and limited contact incidental to shoreline activities."

Primary contact recreation involves the very real likelihood that water will be swallowed and that there will be contact of the water with the eyes, outer ears and nasal passages. Depending on the violence of contact there is also a risk that water will be forced into the auditory passages, nasal passages and sinuses. It is with such activities that the desirability and feasibility of water quality standards based upon medical and public health criteria needs to be considered. This is in addition to the need for a proper assessment of sanitary conditions, in particular the absence of discharges of sewage, farm wastes, treated effluents, storm sewage and urban run-of waters.

With secondary contact recreation there is a reasonable expectation of limited contact, largely accidental, with water. Such activities are angling, pleasure cruising, canoe touring, rowing and bankside activities. Dinghy sailing and sail-boarding when carried out by experts may fall into this category although the frequency of immersion increases with the inexperience of the participants. It is with such activities that water quality standards associated with preserving general amenity, aesthetics and preservation of aquatic life are appropriate. This approach will still have health implications. For example controlling rodents by bankside management or landscaping will reduce the risks from leptospirosis, for which rodents are the major vectors.

Most current standards are designed for primary contact recreation and some will be considered in detail.

2.9.2 US Standards and guidelines

It is instructive to see how the US have evolved health-related standards. In addition to defining the two categories of primary and secondary contact recreation, the National Technical Advisory Committee (NTAC 1968) also recommended minimum microbiological and other criteria for waters used in recreation. For general recreational use in waters not specifically designated for recreation, it recommended a faecal coliform average not exceeding 2000 per 100 ml with a maximum of 4000 per 100 ml. Where the water was designated for recreation other than primary contact, it recommended that the faecal coliform count should not exceed a 'log mean' (ie a geometric mean) of 1000 per 100 ml or exceed 2000 per 100 ml in 10 percent of samples. For primary contact recreation the recommendation was that, based upon not less than five samples taken over a 30 day period, the faecal coliform count should not exceed a log mean of 200 per 100 ml, or more than 10 percent of samples in any 30 day period exceed 400 per 100 ml.

These standards recognise that higher standards are required for waters specifically designated for recreation than those casually used and that the highest standards should apply where the chance of swallowing water is greatest, ie for primary contact recreation.

In 1976, the United States Environmental Protection Agency (US EPA 1976) adopted a faecal coliform standard for all recreational waters, fresh water and marine.

> "Fecal coliforms should be used as the indicator organism for evaluating the microbiological suitability of recreation as determined by multiple-tube fermentation or membrane filter procedures and based on a minimum of not less than five samples taken over not more than a 30-day period, the fecal coliform content of primary contact recreation waters shall not exceed a log mean of 200/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml."

This standard followed from the report by the US National Technical Advisory Committee (NTAC 1968) that a detectable risk to health was undesirable and that the standard should be set at one-half the level at which a health risk occurred and also that use of the water should not cause a detectable health effect more than 10% of the time. The 200/100 ml criterion follows from the study of health in bathers in the Ohio River at Dayton, Kentucky (Stevenson 1953) in which swimmers in water with a median total coliform density of 2700/100 ml showed a 32% excess of gastroenteritis compared with expectation over the whole group of swimmers (Ohio River and a chlorinated swimming pool). The 2700 total coliforms/100 ml were equated with about 400 faecal coliforms/100 ml (after further studies of their ratios at the Ohio River site). It also follows from an observation by Geldreich (1970) that there was a sharp increase in the percentage of freshwater samples containing salmonellae (level not given) when faecal coliform counts exceeded 200/100 ml.

In 1986 the US EPA published new criteria (US EPA 1986) based upon analysis of risk from the epidemiological studies of Cabelli et al (1979) and Cabelli (1983) in marine waters and of Dufour (1984) (Section 2.5.2). Table 10 details the fresh and marine water standards and the way in which they are calculated. They are two part standards, in which non-compliance is indicated when either the geometric mean is exceeded or the maximum allowable count for single samples. The latter criterion is related to the intensity of recreational use, and is defined in terms of upper confidence limits, being more stringent where use is more intensive. The degree of use criterion allows for natural variability, based upon an observed standard deviation of log counts of 0.4 in the Dufour (1984) studies. It is suggested that where variability is markedly different, the maximum allowable counts should be correspondingly re-defined.

The basis for these standards, which have guideline status, is that the risks associated in bathing in water meeting the US EPA's (1976) standards have been regarded as being 'acceptable', through

Table 10 - US EPA (1986) bathing standards for fresh water, as counts per 100 ml

			Maximum allowable count per 100 ml in single samples (4)			
	Acceptable swimming -associated gastro-enteritis rate per 1000 swimmers	Steady state geometric mean	Designed beach area 75 percentile	Moderate full body contact recreation 82 percentile	Lightly used full body contact 90 percentile	Infrequently used full body contact recreation 95 percentile
Freshwater:						
Enterococci	8	33(1)	61	89	108	151
E coli	8	126(2)	235	298	406	576
Marine water enterococci	19	35(3)	104	124	276	500

Notes

1. Geometric mean enterococcus count = antilog ((illness rate per 1000 + 6.28)/9.4)
2. Geometric mean *E coli* = antilog ((illness rate per 1000 + 11.74)/9.4)
3. Geometric mean enterococcus count = antilog ((illnessrate per 1000-0.20)/12.17)
4. Variability of counts are based on standard deviations of $\log_{10}$ counts of 0.4 for freshwater and 0.7 for marine water, based upon the US EPA studies (Cabelli 1983, Dufour 1984); each jurisdiction should establish the log standard deviation for its own conditions

long-standing usage. The relationships of Dufour (1984) have been used to predict the associated illness rates from bathing in water at the levels of the 1976 standards and these rates have been used to re-define the bacterial standards.

2.9.3 Canadian standards

In the the Guidelines for Canadian recreational water quality (anon 1983), the epidemiological research of the US EPA is used to propose the following standard.

"A maximum geometric mean of not less than 5 samples taken over a 30-day period is set at 200 faecal coliforms/100 ml. The exact risk associated with bathing in water of this quality is still not well established, but probably corresponds to about a 0.12 to 1.5 per cent chance of contacting gastrointestinal illness, on the basis of epidemiological data. It does not give any estimate of the risk associated with pathogens from non-faecal sources or very long-lived organisms.

In addtion to the above limit, any sample yielding more than 400 faecal coliforms/100 ml should be further investigated. Minimum action consists of immediate resampling of the site."

This applies to fresh and marine waters. The minimum action of immediate resampling is thought to overcome the practical problem of having to close the beach for recreation, when the exceedence is caused by temporary conditions, such as bad weather.

2.9.4 The European Economic Community Bathing Water Directive

The Council Directive (1976) concerning the quality of bathing water (76/160/EEC) applies to bathing waters, ie,

> "...to all running or still fresh water, or parts thereof and sea water in which: (a) bathing is explicitly authorised by the competent authorities of each Member State, or (b) bathing is not prohibited and is traditionally practised by a large number of bathers".

Five microbiological parameters are defined (Table 11) and these apply to 'bathing areas', ie to any place where bathing water is found and throughout the 'bathing season' which means,

> "... the period during which a large number of bathers can be expected, in the light of local custom and any local rules which may exist concerning bathing and weather conditions".

Hence, there is nothing to prevent the designation of any inland water as falling within the monitoring and compliance required by this Directive should bathing be permitted and not prohibited and should it prove to be popular. However, at present, all British waters designated for monitoring under this Directive are marine.

The Directive is not exclusively concerned with protecting public health and there are apparently no official statements relating compliance to any acceptable degree of risk. The microbiological standards are not derived from epidemiology and appear primarily as a desire to harmonise conditions between Member States. Other aims are to protect the environment, reduce pollution of bathing water and to provide objective information on bathing water quality to a public increasingly aware of environmental issues.

Table 11 - Microbiological quality requirements of the EC bathing water directive

Measurement (and unit)	Limit value* G	I
Total coliforms (/100 ml)	500	10 000
Faecal coliforms (/100 ml)	100	2 000
Faecal streptococci (/100 ml)	100	-
Salmonella (/litre)	-	0
Enteroviruses (/10 litres)	-	0

* Compliance levels: I, 95%, or G, 80% (faecal streptococci 90%) for samples taken during the bathing season

It must be noted that these standards refer to bathing. From what has been said in Section 2.9.1, it will be realised that risks for sports involving less contact with water, such as dinghy sailing and angling will carry lower risks to health and those involving primary contact with water, greater risks.

The Directive (1976) permits a number of methods of microbiological analysis to be used. Some recommended for coliform bacteria are seriously defective in WRc's experience for enumerating stressed organisms and the procedure which WRc recommends is that of membrane filtration using either 0.4% enriched adsorbed Teepol broth, or its replacement, 0.1% sodium lauryl sulphate broth, with resuscitation for 4 h at 30 °C followed by incubation for 14 h at 44 °C (Stanfield and Irving 1983).

It must be emphasised that the methods of analyses used in North America do not correspond with those used in the United Kingdom. If allowance is made for the differences between respective analyses it is likely that the European 95 percentile standard of 2000 faecal coliforms per 100 ml provides a similar or slightly higher failure rate than the North American geometric mean of 200 faecal coliforms per 100 ml, if the upper 90 percentile limit of 400 per 100 ml is ignored. The total coliform procedures as used in Stevenson's (1953) studies, will, depending upon source, reveal a high proportion of lactose fermenting strains lacking sanitary significance (Geldreich 1970).

There is no consistency between the levels of compliance for the various determinands. For example, experience shows that compliance with the imperative (I) values for total or faecal coliforms will not guarantee absence of salmonellas in 1 litre or of enteroviruses in 10 litres. In a survey for the Department of the Environment, enteroviruses and rotaviruses were found in 10 litre samples in sea water at 'clean' and dirty beaches (Carrington <u>et al</u> 1989). For example, at Pembrey-Cefn Sidan, a beach remote from pollution, the faecal coliform count was only 5/100 ml (median) but the median rotavirus count was 3 ff/10l and enteroviruses were present in 10/16 samples of 101. In published data (Dart 1983), for 80 samples of water of 5-10 litres volume taken from 10 raw water intakes within Thames Water in 1981/82 enteroviruses were detected in 68 (85%) and none would have met the imperative requirement for enteroviruses to be absent from 10 litres, in 80% of samples.

SECTION 3 - THE PHASE I PILOT STUDIES AT LANGLAND BAY, 1989

This section is the one that will be of most interest to the lay reader. The two studies will be described in general terms, presenting their setting-up design and results, followed by a discussion, placing the results into context with those of the previous studies throughout the world and then with recommendations for future work. Details of organisation and results are given in the two Appendices provided by the sub-contractors and the scientific reader in search of further information is directed to these. This section will also attempt to describe in simple terms, the statistical methods which have been used and the reasons why they were used.

3.1 SETTING-UP

3.1.1 Organisation

Sections 1.1 and 1.2 of this report describe the outlines of the Phase I Pilot Studies. The Department of the Environment contracted the Water Research Centre to manage the studies and to engage sub-contractors to carry out the two trials of epidemiological methods. These were

(a) The Robens Institute of Industrial and Environmental Health and Safety, University of Surrey, Guildford, GU2 5XH, for the prospective survey ('Beach Study') of holidaymakers on the beach of their own volition and of their perceived health symptoms. The project leader was Professor R Balarajan of the Epidemiology and Public Health Research Unit, assisted by a microbiological team led by Dr D Wheeler, with Ms C Emes and Ms R Smith in the field. The final report of this survey to WRc is given in entirety as Appendix A to this report.

(b) St David's University College, University of Wales, Lampeter, Dyfed, SA48 7ED, for the controlled exposure 'Cohort Study', in which health effects were examined in matched bathing and non-bathing groups of healthy adult volunteers by clinical examination and questionnaire before and after exposure. This study was carried out by Dr D Kay, assisted by Mr M Wyer and advised by Mr F Jones (Managing Director, Altwell Ltd, Runcorn WA7 1SJ) and by Dr R Stanwell-Smith (Consultant Epidemiologist, Communicable Disease Surveillance Centre, Colindale London NW9 5DF). The final report of this study to WRc is given in entirety as Appendix B.

WRc concluded sub-contracts with the above by early June 1989, but the search for a suitable site commenced in anticipation, at the same time that detailed plans of the experimentation were being drafted by the two subcontractors and WRc.

For some time prior to the concluding of research contracts, the scientists responsible for the Cohort Study had convened an ad-hoc working party to discuss their strategies. This comprised key water industry microbiologists and environmental health officers from coastal authorities. WRc was represented. During the planning and execution of the Cohort Study, this working party acted as a focus for enrolling support and for organising and briefing those executing the study.

WRc convened a small steering group comprising the senior scientists involved in both studies to co-ordinate effort and hold regular meetings with each party respectively at (a) Guildford and (b) London/Lampeter/Runcorn to oversee progress and reporting. These activities were additional to meetings of the Department's Working Group on the Possible Health Risks of Bathing in Water Contaminated by Sewage, which continued to meet to review progress.

The contract awarded to WRc by the Department was on a 'shared-cost' basis. An element, amounting to 13 percent of the total cost of carrying-out the programme, was subscribed from the WRc Environmental Research Programme 1989/90, Project Reference 5.2.1a, Development of Microbial Standards. Responsibilities for this project were transferred to the new National Rivers Authority on 1 September 1989.

3.1.2 Choice of site

WRc were requested under the terms of their contract with the Department to locate a suitable site acceptable to the Department and with its approval. The requirements considered desirable for carrying out both types of study at the same beach were as follows:

(a) a large number of bathers, to satisfy the need to recruit 4000 subjects during the Beach Survey;

(b) a beach well defined geographically, to ease the needs of the Beach Survey and of defining the bathing and non-bathing areas for the Cohort Study exposures. It was thought that a long stretch of beach without defined limits or one divided by rocks or natural features would be unacceptable;

(c) nearness to a large town or resort with easy road and rail communications. This would ease transport of samples to laboratories and provide both a high influx of bathers and a base for recruiting volunteers for the Cohort Study;

(d) microbiological quality of water to meet the bacteriological standards of the EEC bathing water Directive (Community Directive 1976). It was considered that it would not be ethical to expose adult volunteers to waters which did not comply with accepted public health and environmental standards. This requirement was one of the bases upon which the submission for ethical approval of the Cohort Study design was made.

(e) Co-operation and approval of the studies by the local authority and of the local health authority.

Advice on suitable sites was taken from DoE and from certain regional water authority staff, particularly concerning expected bather densities at different periods of the tourist season and upon microbiological records at key resorts. Additionally, past records of the results of microbiological monitoring under the EEC bathing water Directive for resorts were inspected. It was concluded that a successful Beach Survey, in terms of recruiting sufficient subjects, would need to be carried out from the last week in July, until the Summer Bank Holiday, ie coinciding with school holidays in England and Wales. The bather records indicated that numbers of persons upon beaches and of bathers could fall by ten-fold in weeks outside of this period.

WRc informally, through environmental health contacts on the Cohort Study working party and formally by letters to selected Chief Environmental Health Officers and a private beach owner, sought co-operation with the local interests. Positive responses were provided by two local authorities in West Wales. On 5 July the Public Protection Committee of Swansea City Council gave its approval for carrying out the study at Langland Bay. This beach was acceptable to the Department and the location was publicised in a Press Release on the same day.

Throughout the studies, Swansea City Council, through the offices of the Chief Environmental Health Officer, Mr E Ramsden and his Chief Pollution Officer, Mr H Morgan, gave invaluable support, particularly for siting the mobile laboratory of the Robens Institute at Langland Bay, for providing accommodation, staff for interviewing and facilities for recruiting and examining volunteers for the Cohort Study and providing facilities on the day of the Cohort Study.

The design and protocol for the Cohort Study was submitted, in advance, to the Royal College of Physicians' Committee on Ethical Issues in Medicine (see Appendices I and II to the Cohort Study Report, Appendix B to this report). These details were also submitted for local ethical approval to Dr B N C Littlepage, Chief Administrative Medical Officer of West Glamorgan Health Authority. Approval and useful advice was given in both cases.

3.2 METHODS OF STUDY

3.2.1 Langland Bay and the Swansea area

Langland Bay is one of several resorts on the South coast of the Gower Peninsula. It is about 9 km by road, south-west from the city centre of Swansea and is popular with day trippers from Swansea and South Wales, as well as with seasonal tourists. Swansea is traditionally an industrially based city but has considerable residential development in its suburbs and tourist centres are based at The Mumbles, Oystermouth, Limeslade, Langland and Caswell. Sewage from a contributory resident population of 170 000 (design dry weather flow 45500 $m^{3/d}$) is pumped to the short sea outfall at Mumbles Head (National Grid Reference SS636871), where it is given preliminary treatment by 'Screezer' and is retained in tidal storage tanks before release to the outfall which discharges at low water mark (Welsh Water Authority 1984). Langland Bay is located about 2 km south-west of the short outfall.

The bacteriological quality of the water is assessed weekly during the bathing season and during 1987 and 1988 it met the mandatory requirements for total and faecal coliform bacteria (10 000 and 2 000 per 100 ml respectively in 95 percent of samples).

A schematic map of the beach is given in Fig 3. At high tide the water's edge is about 500 m long and is bounded a promenade and a considerable number of beach huts. These are three sets of steps on to the foreshore. Refreshment facilities are limited to two kiosks and there is a life-guard station. At low water a considerable expanse of sand is exposed and the beach becomes contiguous with the small Rotherslade Bay at the eastern end.

3.2.2 Microbiological monitoring and analysis

Both sub-contractors agreed to standardise methods of analysis for total and faecal coliform bacteria (presumptive and thermotolerant coliforms) and for faecal streptococci using British standard methods (Report 1983). Membrane filtration methods were adopted as follows:

(a) Total coliforms. Incubation upon 0.2% sodium lauryl sulphate broth for 4 h at 30 °C followed by 14 hours at 37 °C.

(b) Faecal coliforms. As (a) but incubation for 4 hours at 30 °C, followed by 14 hours at 44 °C.

(c) Faecal streptococci. Incubation upon Slanetz and Bartley's medium for 4 h at 37 °C followed by 44 hours at 44 °C.

Both sub-contractors agreed to make sub-samples available to WRc upon demand for quality control checks upon analysis.

The programmes of analyses were as follows:

(a) Beach survey Samples taken every two hours between 0800 and 1800 from three stations, corresponding to the lines normal to the western, central and eastern steps down to the beach (Fig 3). Samples were taken at the standard 30 cm depth required in the EEC bathing water Directive. The sampling was carried out on the 20 days of interviews of holidaymakers between 1-30 August 1989. Additionally on five days (3, 8, 15, 22, 30 August) single samples were taken from the three stations and analysed for total staphylococci, Salmonella spp, Cryptosporidium spp, Giardia lamblia, cytopathic enteroviruses and rotaviruses. Sample volumes submitted for virological analyses were 10 litres in each case. These additional analyses were carried out by The Water Quality Centre of Thames Water. Routine microbiological analyses were carried out by Robens Institute staff in their mobile laboratory in the Langland Bay car park.

(b) Cohort Study. On the day of the Cohort Study (2 September 1989) extensive sampling was made in the zone used by the bathing subjects (Fig 3) during the time of exposure, 1200-1500. The exposure area was marked out on shore by posts and parallel tapes at 20 m intervals into six strips normal to the shore line. Samples were taken synchronously every 20 minutes in each strip of water at three depths (surf zone, 30 cm and chest height). There were nine such samplings, generating 180 samples. Additionally 18 samples were taken offshore by inflatable boat. These samples were analysed for total and faecal coliform bacteria, faecal streptococci, Staphylococcus aureus and Pseudomonas aeruginosa. During the exposure period, 15 samples were taken from the 30 cm depth zone and analysed for cytopathic enteroviruses and rotaviruses in 10 litre amounts. The microbiological sampling and analyses were conducted by water industry microbiologists, many working voluntarily, in laboratory facilities provided by the University College, Swansea. Virological analyses were carried out by Welsh Water's Virology Unit at Gowerton, Swansea.

(c) Additional analyses by Welsh Water During the period 1 August - 2 September 1989, Welsh Water carried out intensive monitoring of water quality at Gower beaches, additionally to that required under the Bathing Water Directive. At Bracelet Bay, Limeslade Bay, Caswell Bay, Oxwich Bay and Port Eynon this was daily. At Langland Bay, east and west ends, triplicate samples were taken three times daily at about 1100, 1400 and 1700. All these samples were examined for total and faecal coliform bacteria and for faecal streptococci.

3.2.3 Beach Survey

The approach used took into account experiences from the previous UK study (Brown et al 1987), but was closely based upon that devised by Cabelli (1983) and Dufour (1984) and adopted for the WHO/UNEP Mediterranean guidelines (WHO 1986). It is an approach which needs care, since subjects' responses to questions about bathing history and symptoms are used to assess the degree of exposure to water and the likelihood that the subjects did experience illness. Initial pilot studies by Cabelli (1983) showed that there would be negligible response to a request for subjects to visit a clinic some days after interview to establish their state of health. Instead, on the advice of the Center for Disease Control, Cabelli's questions were designed to establish 'highly credible gastroenteritis'. In the Beach Survey, the questionnaire was designed to elicit a broader range of symptoms, namely gastrointestinal, respiratory, ear and throat and eye.

A market research organisation was engaged to carry out beach interviews. This had the benefits, compared with using University staff, of cost-efficiency and in using interviewers who would not have an interest in the outcome. Primary interviews to elicit socio-demographic factors, recreational history, food habits and health were conducted at the beach, the target being 2000 interviews with individuals or family groups. This yielded 4045 usable records. About a week later a sample of 791 subjects were interviewed by telephone to obtain information on further illness, any medication taken and visits to the doctor. Postal interview was not used.

3.2.4 Cohort Study

The cohort of volunteers was recruited from residents in the Swansea area. Initial attempts were centred upon staff at the Guildhall and the University College, but responses were low (50). Two weeks before the date of the study, the decision was taken to publicise the study in a positive manner and to seek recruits from the general public. This meant that it was necessary to abandon the media silence and to encourage volunteers by involving local and national news media. Silence had hitherto been maintained to avoid prejudicing the outcome of the Beach Survey by unwelcome publicity. WRc organised a press briefing session at a seafront hotel which was attended by over 30 representatives of press, radio and television. Recruitment in Swansea was rapid thereon and a total of 465 registered. Pre-exposure interviews, collection of faecal samples and swabbing of ears and throat were conducted 2-3 days before exposure.

On the exposure day, 2nd September, low water occurred at 1435 (spring tide) leaving a considerable expanse of foreshore exposed and ensuring maximum separation between the group of non-swimmers and the swimmers (Fig 3). The water temperature was 17 °C and the weather conditions overcast - hazy sun. Subjects were transported to the beach from the City Centre, allocated randomly on arrival to bather or non-bather groups, questioned and assigned to a supervisor, who recorded their activities during the exposure period. Bathers stayed in the water for at least 10 minutes and were asked to immerse completely at least three times. Bathers and their supervisors were assigned to one of the six strips of water sampled so that it was possible to identify each bather with the prevailing quality of water in the area in which he or she bathed. After exposure, all participants received a packed lunch (meat or vegetarian). A sample of the lunches were submitted for bacteriological analysis.

Post-exposure interviews and clinical sampling of faeces, ear and throat were conducted 3 days after the exposure. A fourth, postal questionnaire and faecal sample was taken three weeks after exposure. The four questionnaires were wide-ranging in their coverage and elucidated social, health and environmental factors, to check upon consistency of the data and to assess the most efficient ways of obtaining this information for use in future, full-scale studies.

Ear and throat swabs taken before and after exposure were examined by the Preston Public Health Laboratory to provide microbiological evidence of infection. They were examined for E coli and coliform bacteria, Streptococcus faecalis, β-haemolytic streptococci, Staphylococcus aureus and Pseudomonas aeruginosa.

The first and second faecal specimens were examined for evidence of infection by Salmonella spp, Campylobacter spp, Cryptosporidium spp, and cysts and ova of intestinal parasites. The third sample was examined for enteroviruses and for parasitic cysts and ova. All positive results initiated viral analysis of the first and second faecal samples.

3.2.5 Statistical methods used

Statistical design is used with the aims of avoiding bias in the interpretation of results and to aid economical design of the size and scale of an experiment, so that it is neither too large or too small to achieve a significant outcome and that the significance of the results can be specified, ie the odds that the result was not due to chance and was as a result of a real relationship. The data obtained are in a form suitable for statistical analysis, allowing real trends to be distinguished from random variability and errors of measurement and the level of significance to be determined. Only with such methods can the results of studies such as these be made credible to the scientific and medical community.

The reviews of previous studies show that the rates at which bathers report symptoms are at most, a few percent of subjects and that those rates are not greatly elevated above those reported by non-bathers. This means that epidemiological studies to detect health effects must involve large numbers of people. Secondly, because illnesses in holidaymakers can be caused by factors other than bathing - such as exposure in crowds, unwise or over-eating, or can be influenced by stress and physical fatigue - the studies must be conducted with matched, exposed and non-exposed (control) groups, to eliminate the effects of other factors.

The principal techniques of statistical analysis which have been used in the two studies are as follows:

(a) Chi-square (X^2) test of contingency This provides a measure of 'goodness of fit' of two or more independent sets of observations, both of which can take two or more discrete forms. Specifically, in this study, the method for '2 x 2 tables' is used. For example, subjects existed in two categories, bathers and non-bathers; each of these could either become ill or remain well, giving four separate classes. Perfect fit would exist if, for example, all bathers become ill and all non-bathers remained well. In real life this agreement never happens and all four possible outcomes will result. The test measures the relationship of the observed pattern of results to that expected by chance, expressing the results as a statistic χ^2. The higher the value of χ^2, the less the results are likely to be caused by chance. In general, a result showing a probability of being caused by chance in 1 out of 20 trials ($p = 0.05$) is regarded as barely significant.

(b) Exact probability (Fisher's exact test) The χ^2 test cannot be used when the numbers of subjects showing one (or more) of the four possible outcomes is less than 5. Fisher's test provides a way of calculating directly the probability of an outcome (and more severe outcomes) being due to chance.

(c) Linear regression analysis This is a very commonly used technique for displaying the relationship between two sets of measurements, such as rate of illness and bacteriological counts in seawater. For example in the studies of Cabelli (1983), Dufour (1984) and Cheung *et al* (1988), the rate of illness (the dependent or predicted variable, y) is predicted from measurements of the independent variable (x) the logarithm of the bacterial count, giving an equation of the form which yields a straight line:

$$y = bx + a$$

The coefficient b, is termed 'the slope of the line' and measures the increase in y for a one unit increase in x. The term, a is a constant, since it is the value of y when $x = 0$. Regression generates a statistic, r, the correlation coefficient. When the fit is perfect, all the values of x and y lie on the straight line and $r = \pm 1$. The value of r provides a measure of the fit of the points to the model equation and the value of r^2 is the proportion of the total information (variance in the dependent variable) which is accounted for by the model equation.

(d) Logistic regression This widely available method of analysis was first used in bathing epidemiology by Seyfried et al (1985b) and then by Lightfoot (1989). It features in the analyses of the Beach Survey data. In this, the natural logarithm of the odds of falling ill (the independent variable, ln (p/(1-p)) is predicted from more than one independent variable, such as bacteriological count, intensity of water activity, sex and age. This provides a model of the form

$$\ln (p/(1-p)) = a + B_1x_1 + B_2x_2 \ldots\ldots\ldots B_nx_n$$

In this equation, p is the probability of falling ill (expected number ill/total population examined), a is a constant term (the value of ln (p/(1-p)) when the sum of the successive terms B_1x_1 to B_nx_n is zero and the coefficients B_1 to B_n are the slopes for each of the independent variables x_1 to x_n (ie they indicate the amount by which in (p/(1-p)) increases for a unit increase in the respective values of x_1 to x_n. In this type of analysis, the independent variables can either be continuous (eg bacterial counts) or discreet (eg bather, non-bather, with values of 1 and 0) and can be used in a mixture. The model enables an independent variable (eg bathing, bacterial count) to predict the odds of falling ill, if all the remaining independent variables are held constant. The model therefore enables the effects of concomitant variables such as age, sex, visitor/non visitor to be controlled. In the Beach Study report (Appendix A) reference is made to the 'odds ratio' (OR). This is the predicted ratio of the odds of falling ill in an exposed group to that in the control, unexposed group.

A key text book dealing with the statistical application of logistic linear models is that by McCullagh and Nelder (1989).

(e) Geometric means and medians If a collection of bacterial counts, obtained from numerous samples of water taken from one spot over a length of time, are examined, it will be found that most of the values are comparatively small while a few are very much larger. In other words, the counts are said to be positively skewed, or are asymmetrically distributed about the central value (the median) and do not fit the bell-shaped normal distribution. A practical consequence of this is that the average value is higher than the median, being distorted, and that statistical tests, which assume a normal distribution cannot be used. Empirically it is found that taking logarithms of the values yields data which are normally distributed approximately. The antilog of the average of the log counts is a statistic called the geometric mean and for a distribution of this type (a log-normal distribution) the median value and the geometric mean should be identical. If some of the values are below or above detectable limits, the geometric mean cannot be calculated and the median (or 50 percentile value) provides a good approximation.

The standards for recreational waters in the US and Canada are partly expressed in terms of the geometric mean, because of its value for measuring central tendency of bacterial counts.

3.3 RESULTS

3.3.1 Beach survey

On the 20 survey days between 1 - 30 August, 4045 people were interviewed on the beach, of whom 70 percent were holidaymakers rather than people living locally, and of whom 75 percent were agreeable to participating in a telephone follow-up questionnaire. The number of successful telephone follow-up interviews was 791, or 19.6 percent of those interviewed on the beach. In both cases information for children was given by their parents and data were not collected for children under 5 years old.

Under 45's comprised 3105, or 77%, of those interviewed on the beach. The male/female ratio was approximately 1 except for 15 - 24 year-olds (more males) and 25 - 44 year-olds (more females).

Those who had entered the water comprised 48 percent of those interviewed and of these 56 percent either swam, dived or went surfing and 44 percent only waded in the sea. Of the surfers, 61 percent lived locally.

Illnesses reported were grouped into four categories: gastrointestinal, respiratory, ear and throat and eye. A general group, those suffering 'major symptoms' was compiled from subjects reporting one or more of the four categories of symptom.

Table 12 presents the overall, unadjusted rates of reporting symptoms determined in the beach interview and by the telephone follow-up. For all symptoms, the rates of reporting were greater at telephone follow-up and the decision was taken to analyse this data more fully. Table 9 also shows that those entering the water reported symptoms at higher rates than those not entering the water, with the single exception of gastroenteritis reported at telephone interview. Ear and throat symptoms were commonest in those entering the water (7.7 percent) and gastroenteritis was reported most frequently (3.9 per cent) by those not entering the water. In both interviews the percentages of subjects treating themselves (self-medication) was almost identical to the percentages reporting one or more of the four types of major symptom. About a quarter to a sixth as many sought medical advice as reported major symptoms and there was little difference between those who had been in the water and those who had not, who saw a doctor.

Table 12 - A comparison of the percentage rates of reporting symptoms at the beach and in the telephone follow-up for those entering the water or not*

Symptom or action	Questioned on beach Entered water	 Did not	Telephone interview Entered water	 Did not
Major symptoms	8.0	4.1	12.2	6.8
Gastroenteritis	2.2	1.7	3.2	3.9
Ear and throat	4.2	2.1	7.7	3.1
Respiratory	1.8	0.76	1.9	1.2
Eye	2.5	0.71	2.9	0.73
Self-medication	8.0	4.3	12.2	9.4
Consulted doctor	1.5	1.0	1.9	1.7
Table number of subjects interviewed	1916	2117	377	413

The data were then examined by logistic regression analysis, which has the advantage over other forms of analysis used in studies of this kind, that all the interview responses are used and that the different factors (independent variables) which might influence reporting of illness can be examined simultaneously. The relative health effects, comparing exposed and non-exposed groups, are presented as the odds ratios which are predicted by the modelled regression equations (see Section 3.2.5(d)). In Tables 16 - 21 of Appendix A, where these analyses are presented, the odds of falling ill for various activities have been predicted and compared with that for no activity (ie not entering the water) to yield the odds ratio (OR).

The 'Estimate' is the $\log_e$ value of the odds ratio, and takes the value of zero for 'no water activities' in the tables since the odds ratio for comparing no activities with no activities is 1, ie $\log_e 1 = 0$. The 'Estimate' is subject to the error in the predictability of the model equation. This is because the fit of the equation to the data is always imperfect. 'SE' is a term called the standard error of estimate which describes this lack of precision in the estimate and this is used to define the 95 percent confidence interval ('95% CI') for the estimate.

Of the odds ratios for water activities to no water activities, only those for major symptoms (1.90, 95% CI 1.14 - 3.17), ear and throat symptoms (2.77, 1.40 - 5.50) and eye symptoms (3.71, 1.03 - 13.35) are significantly different from the base level 1.00. Within each of these symptoms the odds ratios for female do not depart significantly from the base level 1.00 for males (Appendix A, Tables 16, 18 - 21).

Within the category of major symptoms (Appendix A, Table 17) the odds ratios for wading (1.26, 0.64 - 2.49), swimming (2.34, 1.27 - 4.32), diving (3.00, 0.92 - 9.73) and surfing 3.07, 1.13 - 8.35) show a progressive increase with increased degree of contact with water. However only those for swimming and for surfing are significantly greater than the base value of 1.00 for no participation in water activities. Further breakdown analyses, activity within the five categories of symptoms. It is noted that odds ratios are multiplicative on travelling through the dichotomies. However two points must be made. The products of successive odds ratios are always related to the base group and the effect of multiplying such ratios, which have already wide confidence limits is to increase the errors and the likelihood that the derived value is not significantly different from odds ratio for the base group. One example will be taken.

In Appendix A, Figure 11 and Table 16, the odds ratio for major symptoms and water activity (1.90) has been multiplied by the odds ratios for the seven age groups to obtain separate values for age groups participating or not participating in water activities. However, only the odds ratio for the 15 - 24 age group (2.82, 1.3 - 6.03) differs significantly from the base value of 1.00 for males of 5 - 14, so the valid conclusion is that it is only the 15 - 24 age group which reported a significantly elevated rate of major symptoms.

Other significant odds ratios are age group 15 - 24 (2.75, 1.28 - 5.90) in major symptoms categorised by exposure (Appendix A, Table 17), age group 15 - 24 (3.98, 1.31 - 12.08) in ear and throat symptoms, categorised by exposure (Table 19) and age group 15 - 24 (9.38, 2.23 - 39.51) in respiratory symptoms categorised by exposure (Table 20).

The geometric mean bacterial counts observed during the 20 days of sampling and beach interviews are compared in Table 13 with the values obtained during the programme of intensive monitoring by Welsh Water. The times and locations of the two sampling programmes did not coincide exactly and their is a tendency for the counts obtained by the Robens Institute to exceed those of Welsh Water, but by not greater than a factor of 2.4. To some extent, this may be because it was possible to analyse samples in the mobile laboratory, without any transport delays. The data show that the water quality was generally good and that the imperative 95 percentile values of 10 000 total coliforms per 100 ml and 2000 faecal coliforms per 100 ml, in the bathing water Directive (Council Directive 1976) were not exceeded during the periods of study (Figs 3 - 5).

Table 13 - A comparison of geometric mean counts (and range) of faecal bacteria (per 100 ml) obtained by the Robens Institute and by Welsh Water at Langland Bay*

Faecal bacteria	Beach survey, Robens Institute*	Intensive monitoring, Welsh Water+	
		East	West
Total coliforms	260	143 (10-2600)	186 (20-8000)
Faecal coliforms	158	65 (10-1680)	71 (10-2700)
Faecal streptococci	29	24 (<1- 836)	31 (1-1704)

* Obtained on 20 days between 1 - 30 August 1989; 18 samples daily from 3 locations, every 2 hours from 0800-1800.

\+ Obtained between 31 July - 2 September, from 2 locations sampled in triplicate, 18 samples daily; ranges in parentheses.

3.3.2 Cohort Study

Of the 465 persons who registered for the study initially, 276 completed the schedule of questionnaires, clinical examinations and exposure, a success rate of 59 percent. Of the latter, 46 percent were female and approximately one-quarter fell into each of the age groups 18 - 24, 25 - 34 and 35 - 44 years old. Subjects who reported for the trial were assigned randomly to the bather and non-bather cohorts, 58.6 percent of bathers were male and 50.4 of non-bathers. This distribution was not significant. There was a similar age structure to the bather and non-bather cohorts, each comprising 133 subjects. Of all participants, 83.5 percent resided in the area of the West Glamorgan Health Authority and 73.3 percent in Swansea. Only 31 (11 percent) resided outside of Wales.

The most frequent class of bathing activity reported was 1 - 3 times per month in the summer (36.8 percent), followed by those who reported bathing from 4 to more than 7 times monthly (35.0%). Only 3.8 percent reported daily swimming and 22.9 percent never swam. It is interesting that the bathing cohort included 16.5 percent who reported never swimming in the summer and 33.1 percent who said that they never visited a beach.

The rates of perceived illness (Table 14) were much higher than in previous studies (see Table 8 and Figures 1 and 2). Those shown (eye, ear, throat; three days after exposure and diarrhoea, three weeks after exposure) were reported at a significantly higher rate by bathers. The perceived symptoms were not associated significantly with the results of clinical examination of the swabs and faecal samples. There was no significant association between water quality experienced by the bathers and perceived symptoms.

Table 14 - Attack rates for symptoms which were perceived by the cohort subjects three days* after exposure (2 September 1989) and which were significantly different between bathing and non-bathing cohorts

Symptom perceived	Probability level +	Attack rates (%)		Ratio B/NB
		Bathers(B)	Non bathers(NB)	
Sore throat	0.04	15.6	7.5	2.1
Ear infection	0.03	3.9	0.0	∝
Eye	0.02	6.2	0.75	8.3
Eye, or ear, or throat	0.00	21.3	8.3	2.6
Ear or throat	0.01	18.1	7.5	2.4
Diarrhoea*	0.01	12.1	3.8	3.2

* After 3 weeks for diarrhoea
\+ Coventionally, $p>0.05$ = not significant, $0.05>p>0.01$ = barely significant, $p<0.01$ = significant

The water quality experienced by the bathers between 1200 and 1500 on 2 September 1989 was good and no sample exceeded the mandatory criteria for total and faecal coliform bacteria in the Directive (1976). Table 15 compares the geometric mean counts for the main sampling exercise with those derived from the examination of duplicates and corresponding samples taken at Langland Bay East station by Welsh Water.

3.3.3 Relationships with press and television

Following the Department's press release of 17 May (DoE 1989), announcing the Phase I Pilot Study, there was intense speculation concerning the form that the studies would taken. Interest heightened around the time of publication of the 'Blue Flag' awards for beaches (23 May), with the revelation that polioviruses had been detected in waters taken from certain beaches receiving this award and an announcement that a major UK company was to market chlorine for disinfecting sewage before discharge.

Table 15 - Geometric mean counts of faecal indicator bacteria taken at Langland Bay during the period of the bathing exposure, 2 September 1989

Sampling exercise and details	Counts (per 100 ml) and range* Total coliforms	Faecal coliforms	Faecal streptococci
Main; 1200-1500, every 20 min, 3 depths, 6 locations, total 180	36.8 (0-1434)	19.6 (0-1310)	31.5 (0-196)
18 samples, split into duplicates	66,43	45,22	45,45
Welsh Water 3 samples at c. 1430, Langland Bay East station	56	32	17

* Ranges in parentheses

WRc announced the choice of Langland Bay on 5 July in collaboration with the Department's Press Office. This confirmed the 'suspicions' of certain newspapers that 'guinea pig' volunteers were to be paid to swim in sewage and risk illness and the subject formed the basis of a contrived interview on a national 'disc jockey' radio programme, inviting those interested in 'a free dose of diarrhoea' to phone WRc for details.

A more constructive note was struck by the Western Mail (2 August) which featured the Chief Pollution Officer of Swansea City, Mr Huw Morgan, appealing for volunteers for the Cohort Study and by the South Wales Evening Post (3 August) which featured Mr J Elfred Jones, Chairman of Welsh Water taking a dip at Langland Bay ("Come on in - the water's lovely").

By mid-August press enquiries to WRc had become intense and it was also necessary to publicise the Cohort Study to encourage recruitment. WRc held a successful press briefing in the Osbourne Hotel overlooking Rotherslade and Langland Bays on 18 August and this was followed by an opportunity to photograph the beach. This was attended by national and local pressmen (13), television (11) and radio (3) reporters and a further 'live' interview was given by telephone.

The publicity undoubtedly encouraged registration for the Cohort Study and engendered public sympathy with the objectives. To avoid bias, no interviewing of holidaymakers was carried out on 18 August.

A further press briefing was held on the beach during the Cohort Study (2 September) with the objectives of informing the press about the study and diverting enquiries and photographers away from those conducting the study.

3.4 DISCUSSION

3.4.1 Validating the epidemiological procedures

The first and foremost objective of the Phase I Pilot Study was to test and validate the two types of epidemiological method for determining the risks, if any, to the health of bathers in coastal water contaminated by sewage. There are three questions which must be answered:

(a) were the two methods workable in the field, or were there serious logistic difficulties?

(b) what were the supposed health effects it was desired to measure and what was the nature of the study groups who were exposed to risk?

(c) what scale would be appropriate for full-scale experiments in order to be reasonably certain of detecting significantly the size of risk?

3.4.1a Logistics

To answer the first question, the objectives of the Beach Survey were to conduct 2000 interviews with individual or with family groups, over 20 interview days in August. Just over 4000 were recruited, but at a beach where 70 percent of people on the beach were holidaymakers, there for the duration of their holiday, a problem was multiple interviewing. Those who had been previously interviewed were discarded from the survey by the interviewers. The weather in August was unusually fine, except for the third week. Even so, a particular effort had to be made by the interviewers in the final week, including the long weekend of the Bank Holiday (28 August) to meet the target of 4000 acceptable records.

Another factor which caused concern was the publicity given to the Pilot Study by press and television. This was initially hostile and may have caused subjects to prejudge the risks. To create a favourable climate for the Pilot Study and encourage recruitment for the Cohort Study, WRc held a press briefing at Langland Bay on 18 August. While this succeeded in its purpose, the interviewers and Robens Institute staff were seriously concerned about the introduction of bias into subject's responses. In the event, it was found that the data obtained on telephone follow-up interview with people at home, was more consistent internally than that obtained on the beach. The Robens Institute team have recommended that in future studies, the beach interview should be short and designed merely to obtain details on the subjects and that telephone follow-up interview should be used to obtain the health data.

The major problem with the Cohort Study was with recruiting sufficient volunteers. At the outset, it had been proposed informally to recruit students for a trial immediately before 'going down' at the end of the Summer Term. This proved to be impossible for a number of reasons, such as occurring too early in the period of the contract to organise, bathing in unusually cold water in early June and the choice of an unrepresentative cross section of adults. Recruitment in late June - early July in University College, Swansea and in the City Guildhall staff was very poor, even though personal contacts were made and over

2500 handbills were circulated to employees. Other unquantifiable factors may have been hostility to the study by news media and the fact that people were undecided about signing-up for an event on a Saturday afternoon too far ahead to have immediacy of appeal. A major factor in recruitment was a vigorous and positive news campaign, launched at the press briefing on 18 August, in which the message fostered was for participants to 'have a fun-day out and to do something for the environment'. Recruitment stands in the City Centre shopping precincts were successful and most of the people who registered had heard about the study on television or had read about it in local newspapers.

The Cohort Study needed well-briefed teams for conducting interviews and taking of clinical samples, for sampling and for marshalling and supervising subjects on the beach. The enlistment of positive support by Swansea City Council's Officers and their staff was a vital factor, for providing interview rooms, arranging transport to the beach and providing facilities at the beach, as well as assisting with recruitment. The study also depended upon the efforts of water industry microbiologist, most of whom gave voluntary service.

The Cohort Study was critically dependent upon the selected day being fine. It was chosen for a day of spring tide and for low water at a convenient time. In a future study, it will be necessary to consider contingency plans in case of bad weather. One consequence of bad weather will be failure of volunteers to turn up on the day, whereas postponement will erode the value of the pre-exposure questionnaire and clinical sampling, if the study is delayed by more than a day or so.

A final factor is the success of enlisting volunteers to complete the course. The drop-out rate was 41 percent between enlisting for the study and finishing the course of interviews and examinations. Planning of recruitment will need to take this into account. The subsequent dropout rate was very low, once subjects had attended for the first interview.

3.4.1b Health effects and study groups

The health perception questionnaires used in both studies were designed to elicit the subjects' perception of symptoms of the eye, ear, nose and throat, respiratory difficulties, symptoms associated with highly credible gastroenteritis (diarrhoea, fever, nausea and vomiting) and skin irritations, together with questions to determine whether the subjects took medical advice or took medicine (beach survey). In this respect, both studies used the approaches based upon Cabelli's (1983) and the WHO (1986) Mediterranean protocol. This should ensure that comparisons can be made between a British study and those using similar techniques which have preceded it.

A difficulty of this approach is that it determines the subjects' perception of illness and not clinical illness. Allied to this is the extent to which the interviewer or local publicity of the risks of bathing in polluted water can influence perception. Also, the interviewer/respondent effect upon responses was found to be the most significant factor in determining risk in Lightfoot's (1989) study. However, her study was conducted in waters meeting local standards, where water quality may have had little influence, in comparison with interviewing techniques. These objections can be largely overcome by careful design of questionnaire and by professional interviewing by persons without interest in the outcome. Interviewers were specifically requested to avoid news correspondents and interviewing was stopped at the time of the press briefing. Both studies used questionnaires with internal checks on quality of information and consistency of reporting. Since the telephone follow-up interview introduces no eye-to-eye contact, is dispassionate and contacts the subject at home after a time for reflection on the holiday, it would appear to have advantages over beach interview and is indeed a feature of the Cabelli (1983) method.

A minor criticism of the beach interview method is that it reports perceived symptoms and not clinical illness. It should however be recognised that illness presents itself in a wide gradation of severity, so that there will always be a matter of opinion in the diagnosis by the physician.

Finally, the Greenpeace study (Brown et al 1987) showed that persons on the beach were aware of visible pollution. Since visible pollution from sewage contamination (slicks, faecal solids, dejecta from sewage) is usually highly correlated with high counts of faecal bacteria (unless the sewage is disinfected), it is likely that such signs may reinforce perception of illness, or unease. This merely states that perception is a complex matter, but should not be dismissed as being unreliable or non-specific.

It is a major purpose of the Cohort Study method to determine a link between reporting of symptoms and diagnosis of infections of the ears, nasopharynx and of the bowels by looking for agents associated with infection. Despite perceived symptom rates among bathers, which were higher than reported in other studies or in the beach survey, there was no positive association between the results of the clinical examinations for pathogens and perception. This indicates that any such association was too low to be detected in this pilot study, or that the agents responsible could not be isolated.

The two studies embraced different classes of subjects. Because of ethical requirements, the Cohort Study was confined to healthy adults over 18 years old. It was found that a high proportion were local residents (73 percent lived in Swansea) and this was because of the local recruiting campaign. On the other hand, the method of randomly assigning people to bather or non-bather groups on arrival at Langland Bay did mean that the two groups contained persons who reported not swimming or visiting a beach in the summer months. It might be supposed that these would lack acquired immunity to waterborne infection and would therefore report symptoms with higher frequency than regular visitors.

The beach survey revealed patterns which have featured in previous studies. Thus the main groups of beach-goers were under 45 years old. A high proportion of these interviewed were willing to be interviewed by telephone. Unlike studies in warmer waters, the proportions of beach-goers who entered the water to those who did not were nearly equal, a factor which will ease the task of achieving adequately sized control groups. Because most of the interviewees (70 percent) were holidaymakers, the problems of multiple exposure to water is not easily overcome. It was avoided by Cabelli (1983) and Dufour (1984) by interviewing at weekends only and selecting only weekend visitors and not those staying for several days. This will give rise to difficulty under British conditions in recruiting sufficient volunteers. On the other hand, in a large enough study, the problem vanishes if one of the objectives is to relate perceived attack rates to bathing frequency (see Stevenson 1953).

3.4.1c Size of future studies

The number of subjects required to be certain of demonstrating a statistically significant relationship, or effect, depends upon the excess attack rate in the exposed group, compared with the control (or with the odds ratio). It is also influenced by the chances of mis-reporting a relationship where none exists, or vice versa. The required size of study has been calculated by both sub-contractors as follows:

(a) Beach Survey of 16 000 subjects across 10 beaches should render it possible to detect an odds ratio of 1.25 with a baseline incidence (control group) of 3.5 percent (Appendix A, pp 38-39 and Table 27).

(b) Cohort Study of 1 800 - 3 000 subjects at ten beaches, recruiting twice this number to allow for 'drop-outs', assuming the clinical attack rates observed at Langland Bay (Appendix B, Appendix XII).

Both these calculations assume that the studies will be carried out at a variety of beaches displaying a sufficient gradation of bacteriological quality to enable the second objective to be achieved - the determination of the correlation between bacteriological quality and risk of contracting illness.

3.4.2 Health effects and microbiological quality of water

The second objective was to establish the relationships, if any, between microbiological quality of coastal waters and the risk to health of bathers. It will be apparent that a correlation or linear model of the types shown by Figs 1 and 2 can only be obtained if there are a succession of studies, each in waters differing in median quality, or if in a sufficiently large single study, the water quality varies widely and bathers are individually exposed to water of particular qualities. Neither of these apply to the Phase I Pilot Studies. However, both studies have succeeded in measuring the levels of attack rates at Langland Bay and these should serve as single points on the graph of water quality <u>versus</u> risk.

The significant health effects revealed in the two studies were derived from perception of symptoms and are as follows:

(a) in the Beach Survey, telephone follow-up interviews showed that those entering the water showed a higher proportion of all ('major') symptoms (odds ratio 1.9), ear and throat symptoms (2.77) and eye symptoms (3.7). In the Cohort Study perception of ear, eye and throat symptoms three days after exposure were significantly higher in bathers compared with non-bathers and gastroenteritis 3 weeks after exposure;

(b) the most susceptible age group for ear and throat, respiratory and for all symptoms in the Beach Survey was 15 - 24;

(c) in the Beach Survey, there was a suggestion that the rates of all symptoms together increased with degree of exposure in the order non-participant <wader <bather <diver <surfer.

Reference to Table 9 shows that these findings agree with those reviewed in earlier studies. They thus show the merits of strength of association, consistency, biological gradient and plausibility (Table 1).

Surprisingly diarrhoea or other symptoms associated with HCGI (Cabelli 9183) did not show significance in the Beach Survey. One reason is probably that the quality of water at Langland Bay was generally high throughout the studies. Indeed, no effect of water quality on attack rates was found.

The preponderance of symptoms of eyes, ears nose and throat, relative to gastroenteritis or HCGI, has been noted in the sea water studies at New York (Stevenson 1953), Spain (Mujeriego et al 1982), Brittany (Foulon 1983) and New Jersey (NJDOH 1989). It was also a feature of freshwater studies, such as the chlorinated pool swimmers at Dayton, KY, and Ohio River swimmers (Stevenson 1953) and at the Ontario beaches (Seyfried et al 1985a, Lightfoot 1989). The Dayton studies (Stevenson 1983) make the conclusion that regardless of water quality, bathers show a greater excess of symptoms of the eyes, ears, nose and throat and this may be a general conclusion.

The attack rates for perceived symptoms in bathers at Langland Bay are high, compared with those recorded in other studies (Table 8, Figs 1 and 2). However, the eye, ear and throat rates are comparable with those recorded in the Brittany studies (Foulon 1983). If the ratios of rates for swimmers to non-swimmers are considered (Table 8), the values obtained in the Beach Survey (a larger, more representative cross-section of the community than in the Cohort Study) are comparable with those in other studies. This latter comparison eliminates differences in susceptibility and inherent disease rates between different populations of bathers.

Finally, both studies contain information upon bathing or beach-going without water activity and health effects at more than one point in time-two (beach and telephone follow-up interview) in the case of the Beach Survey and four (pre-exposure, exposure day, 3 days and 3 weeks post-exposure) in the case of the Cohort Study. This can present an opportunity for correcting for health trends in the population (exposed and unexposed) as a whole. In other words, did the background level of health of the population improve or deteriorate over the period of observation? This point has been considered by WRc in reviewing the two reports (Appendices A and B). The additional analysis involved would not alter the conclusions obtained but it is felt that it is a point which should be considered in future studies. It is one which is amenable to logistic regression analysis and generalised linear modelling.

SECTION 4 - CONCLUSIONS

4.1 LITERATURE SURVEY

1. An exhaustive survey of the literature on waterborne disease has shown that the following serious illnesses have been associated with bathing in grossly polluted waters: typhoid fever, shigellosis, leptospirosis, gastroenteritis and Hepatitis A. Causal relationships are likely but unproven for non-A non-B hepatitis and for cryptosporidiosis.

2. The complaints which are most often reported by bathers in waters conforming to existing microbiological standards, or those barely meeting them are gastroenteritis (with diarrhoea, fever, nausea or vomiting), those of the eye, ear, nose and throat, respiratory symptoms and skin irritations.

3. In chlorinated swimming pools, infections most commonly reported are of the eye, ear, nose and throat and outer ear inflammation (otitis externa).

4. The results of marine and freshwater epidemiological studies on the risks to health from recreation in waters of differing microbiological quality have been extensively reviewed. An attempt has been made to present their findings on a common basis so that they can be compared and so that the results of the Phase I Pilot Studies can be placed in context. The overall consensus views of these studies are as follows:

(a) swimmers report a higher incidence of illness than non-swimmers;

(b) the rate of reporting illness by swimmers and others using the water for sport is related to the degree or duration of exposure to the water;

(c) children or those under 24 years old report a greater incidence of illness after bathing than older participants;

(d) the rate of reporting illness, particularly gastroenteritis, is related to the level of counts of faecal indicator bacteria in the water at the time of bathing;

(e) there is no general consensus upon the most suitable faecal indicator to use for predicting the rate of symptom reporting by bathers;

(f) there is a wide divergence in the rates of attack for various symptoms in different studies or in similar studies by the same investigators at different locations, which suggest that acquired immunity and/or socio-economic factors affect the susceptibilities of the populations to illness;

(g) microbiological standards, based upon acceptable risk, determined by epidemiology, have been formulated by the US EPA and by the Hong Kong Government. Standards based on earlier studies of the US Public Health Service, are in force in Canada. The microbiological standards of the EEC bathing water Directive 76/160/EEC do not have such a basis, but they are accepted and are used for indicating a need for improvements in quality and for design of marine treatment schemes.

4.2 PHASE I PILOT STUDIES AT LANGLAND BAY

1. Two methods for investigating the relationships between bathing in the sea and the health risks associated with water of the prevailing microbiological quality were evaluated in a pilot study at Langland Bay, Swansea in August - September 1989. These were (a) a survey of 4045 holidaymakers on the beach, followed by telephone interview about 7 days later on a sample of 791 subjects to elicit perceived health effects and (b) a controlled Cohort Study in which 276 healthy adult volunteers were divided equally into swimming and non-swimming cohorts; perceived symptoms being elicited before and after exposure and validated against clinical examination of ear and throat swabs and faecal samples for evidence of infection.

2. The following conclusions were made about the logistics of the two methods:

   (a) despite the fine summer, there was difficulty in obtaining 4 000+ subjects for interview on a relatively small beach over the 20 interview days in August. About 70 percent of those interviewed were holidaymakers, and not local day-trippers, so that there were problems with avoiding multiple interviews and the allied problem of multiple bathing exposure could not be resolved;

   (b) about half the people on the beach went into the water and, of these, about half immersed themselves completely;

   (c) a high proportion (75 percent) of family groups on the beach were willing to participate in a telephone follow-up interview;

   (d) the data obtained from the telephone follow-up interview was more consistent than that obtained in the primary beach interview;

(e) considerable and favourable local publicity on television and in newspapers was essential to aid recruitment for the Cohort Study. Most of those who volunteered had learned of the trial from the news media. On the other hand, the media publicity given to the Cohort Study was considered undesirable for the beach survey, since it could bias reporting of symptoms;

(f) a drop-out rate of about half is to be expected between initial recruitment of volunteers for the Cohort Study and completing the programme of interviews, exposure and clinical examinations;

(g) the co-operation of the Swansea City Council and its Officers was found to be vital, particularly in the organisation of the Cohort Study.

3. The following conclusions were made concerning the health effects observed during the two trials:

(a) in the Beach Survey, a higher rate of reporting symptoms was recorded at the telephone follow-up interview than at the initial beach interview;

(b) the follow-up interview to the beach survey showed that the commonest symptoms reported by those entering the water were of the ear and throat (7.7 percent; non-bathers 3.1 percent), whereas gastroenteritis was reported most by those not entering the water (3.9 percent; bathers 3.2 percent). The numbers reporting one or more of the four major groups of symptoms (bathers 12.2 percent, non-bathers 6.8 percent) were almost identical with those treating their symptoms by medicine (bathers 12.2 percent, non-bathers 9.4 percent). Of those reporting one or more of these symptoms only a sixth to a quarter saw a doctor about them;

(c) the symptoms which were found to differ significantly between bathers and non-bathers in the Beach Survey were one or more of the major groups of symptoms (odds ratio 1.90), ear and throat (2.77) and eye (3.71);

(d) within the category of reporting one or more major symptoms, there appeared to be a progressive increase in risk with degree of water activity; not entering the water <wading < swimming < diving < surfing. However only swimming (odds ratio 2.34) and surfing (3.07) differed significantly from the base value for no activity (1.00);

(e) examination by age groups showed that only among the 15 - 24 year old group were rates of reporting ear and throat symptoms (odds ratio 3.98), respiratory symptoms (9.38) and one or more major symptoms (2.75);

(f) during the Beach Survey period, 1 - 30 August, the water quality on survey days remained good and within the requirements of the EEC bathing water Directive. Geometric mean counts for the survey days were (per 100 ml) total coliforms 260, faecal coliforms 158, faecal streptococci 29;

(g) amongst the 276 subjects participating in the Cohort Study, bathers reported significantly higher rates of eye (bathers 6.2 percent, non-bathers 0.75 percent), ear (3.9, 0.0) and throat symptoms (15.6, 7.5) than non-bathers, three days after exposure and diarrhoea (12.1, 3.8), 3 weeks after exposure. There was no significant association between perceived symptoms and clinically diagnosed infection of the ears, throat or the intestines;

(h) during the Cohort Study exposure on 2 September the water quality was good and geometric mean counts (per 100 ml) were: total coliforms 36.8, faecal coliforms 19.6, faecal streptococci 31.5;

(i) neither in the beach survey, nor in the cohort study was there apparent any significant effect of water quality upon symptom rates;

(j) although the crude rates of reporting symptoms in the Phase I Pilot Study are high in comparison with those obtained in other studies, those for eye, ear and throat symptoms are comparable with those obtained in an earlier study in Brittany. The ratios of attack rates between bathers and non-bathers found in the Beach Survey are similar to those in previous studies.

SECTION 5 - RECOMMENDATIONS

1. Greatly extended studies will be needed if it is desired to determine the relationship between risks to health and bathing in waters of different microbiological quality. The size of these studies will depend upon differences in attack rates between bathers and non-bathers which it is desired to detect with statistical significance. In general the size and cost of the study increases disproportionately as the differential rate decreases. Size estimates have been calculated for both types of study, as follow:

(a) Beach Surveys at a number of beaches, involving a total of 16 000 subjects, for detecting an odds ratio of 1.25 of illness in bathers compared to non-bathers, with a baseline incidence of 3.5 percent in the unexposed population;

(b) Cohort Studies involving a total of 1 800 - 3 000 subjects at a number of beaches, assuming the clinical attack rates determined at Langland Bay.

2. The type of study using healthy volunteers ('Cohort Study') will be needed, if it is desired to investigate the relationship between perception of symptoms and clinical illness.

3. The two types of study cannot be undertaken simultaneously at the same beaches, since the recruitment publicity needed for the healthy volunteer approach, will probably bias the results of a prospective beach survey by heightening the public's perception of symptoms.

ACKNOWLEDGEMENTS

The progress of the Phase I Pilot Studies was steered by the Department of the Environment's Working Group on the Possible Health Risks of Bathing in Water Contaminated by Sewage.

The Beach Survey was conducted by a team led by Professor R Balarajan of the University of Surrey. Microbiological work was conducted by Ms C Emes and R Smith under the supervision of Dr D Wheeler. The Cohort Study was conducted by Dr D Kay (St David's University College, Lampeter, Mr F Jones (Attwell Ltd, Runcorn), Dr R Stanwell-Smith (Bristol and Weston Health Authority and latterly Communicable Disease Centre, Colindale) and Mr M Wyer (SDUC, Lampeter). The Cohort Study was advised by an *ad hoc* steering group.

The assistance of Swansea City Council and of its Chief Environmental Health Officer, Mr E Ramsden and Chief Pollution Officer, Mr H Morgan is gratefully acknowledged. Dr B N C Littlepage, Chief Administrative Medical Officer of the West Glamorgan Health Authority gave his approval and advice on the carrying-out of the studies.

Dr R Grantham (now with the National Rivers Authority, South-West Region), Drs C Pattison and C Chubb (National Rivers Authority, Welsh Region) and Mr J E Saunders (Welsh Office) gave specific local advice in the setting-up stages of the project. Data from extensive microbiological monitoring of Gower beaches during the pilot study was kindly provided by the National Rivers Authority, Welsh Region.

The author acknowledges the statistical advice given by his colleague Mr R F Lacey and assistance with literature searches and analysis of microbiological data by Dr P S Gale.

The author has valued discussions upon the conduct of epidemiological experiments and the supply of reports and information by Professor V J Cabelli (University of Rhode Island, Kingston RI, USA), Dr A P Dufour (US EPA, Cincinnati OH, USA, Professor R Mujeriego (University of Barcelona, Spain), Mr W H S Cheung (Environmental Protection Department, Hong Kong) and of Dr J Harrington and Mr D. Bennett (Sydney Water Board, Australia).

Relations with the press, radio and television and the organising of the two press briefing days were managed by Mr R I Odell, WRc Corporate Relations, assisted by Mr J Bray and Mrs S Smith.

REFERENCES

APHA (1976) Standard methods for the examination of water and wastewater, 14th ed. American Public Health Association, Washington DC.

ANON (1983) Guidelines for Canadian Recreational Water Quality. Catalogue no H46-20/1983E. Canadian Government Publishing Centre, Ottawa KIA OS9, Canada, p17.

ANON (1986) The coypu as a rodent reservoir of leptospira infection in Great Britain. PHLS Communicable Disease Report CDR 86-01 (3 January 1986), p3.

BARON R C, MURPHY F D, GREENBERG H B, DAVIS C E, BREGMAN D J, GARY G W, HUGHES J M and SHONBERGER L B (1982) Norwalk gastrointestinal illness. An outbreak associated with swimming in a recreational lake and secondary person-to-person transmission. American Journal of Epidemiology 115, 163-172.

BRADFORD HILL A (1965) The environment and disease: association or causation? Proceeding of the Royal Society of Medicine 58, 295-300.

BROWN J M, CAMPBELL E A, RICKARDS A D and WHEELER D (1987) Sewage pollution of bathing water. The Lancet ii, 1208-1209.

BRYAN J A, LEHMANN J D, SETIADY I F and HATCH M H (1974) An outbreak of Hepatitis-A associated with recreational lake water. American Journal of Epidemiology 99, 145-153.

CABELLI V J (1983) Health effects criteria for marine recreational waters. EPA-600/1-80-031. US Environmental Protection Agency, Health Effects Research Laboratory, Research Triangle Park, North Carolina 27711, 98pp.

CABELLI V J, DUFOUR A P, McCABE L J and LEVIN M A (1983) A marine recreational water quality criterion consistent with indicator concepts and risk analysis. Journal, Water Pollution Control Federation 55, 1306-1314.

CALDERON R and MOOD E W (1982) An epidemiological assessment of water quality and "swimmer's ear". Archives of Environmental Health 37, 300-305.

CARRINGTON E G, MERRETT H and STACKHOUSE C (1989) Sewage discharges as a source of rotavirus (MDE 9213) - Final Report. WRc Report DoE 2353-M. Water Research Centre, Medmenham.

COUNCIL DIRECTIVE (1976) Council Directive of 8 December 1975 concerning the quality of bathing water (76/160/EEC). Official Journal of the European Communities, 5 February 1976, No L31/1.

CHEUNG W H S, KLEEVENS J W L, CHANG K C K and HUNG R P S (1988). Health effects of beach water pollution in Hong Kong. In: Pollution in the Urban Environment, POLMET 88, edited P Hills et al. Vincent Blue Copy Co, Hong Kong.

D'ANGELO L J, HIERHOLZER J C, KEENLYSIDE R A, ANDERSON L J and MARTONE W J (1979) Pharyngo-conjunctival fever caused by Adenovirus Type 4: report of a swimming pool - related outbreak with recovery of virus from pool water. The Journal of Infectious Diseases 140, 42-47.

D'ALESSIO D, MINOR T E, ALLEN C I, TSIATIS A A and NELSON D B (1981) A study of the proportions of swimmers among well controls and children with enterovirus-like illness shedding or not shedding an enterovirus. American Journal of Epidemiology 113, 533-541.

DART M C (1983) Thames Water Statistics 1982. Manpower Data Unit, Thames Water Authority, Reading, E1.1 and E3.1.

DEWAILLY E, POIRIER C and MEYER F M (1986) Health hazards associated with windsurfing on polluted water. American Journal of Public Health 76, 690-691.

DIVIZIA M, DE FILIPPIS P, DI NAPOLI A, VENUTI A, PERIX-BERCOFF R and PANA A (1989) Isolation of wild-type hepatitis-A virus from the environment. Water Research 23, 1155-1160.

DOE (1989) Water Research Centre to carry out bathing water study. News Release 285, 17 May 1989. Department of the Environment, London.

DUFOUR A P (1982) Fresh recreational water quality and swimming-associated illness. In: Proceedings, Second National Symposium on Municipal Wastewater Disinfection, Orlando, Florida, 26-28 January 1982. US Environmental Protection Agency, Cincinnati, Ohio 452658, 21pp.

DUFOUR A P (1984) Health effects criteria for fresh recreational waters. EPA 600/1-84-004. US Environmental Protection Agency, Cincinnati, Ohio 452658.

DUFOUR A P, STRICKLAND E R and CABELLI V J (1981) Membrane filter method for enumerating Escherichia coli. Applied and Environmental Microbiology 41, 1152-1158.

EASTCOTT H R (1988) Swimmers' itch, a surfacing problem. An outbreak at a Suffolk watersports park. PHLS Communicable Disease Report CDR 88/12 (25 March 1988), 3-4. Unpublished.

FATTAL B, PELEG-OLEVSKY E, AGURSKI T and SHUVAL H I (1987) The association between seawater pollution as measured by bacterial indicators and morbidity among bathers at Mediterranean bathing beaches of Israel. Chemosphere 16 (2/3), 565-570.

FOULON G, MAURIN J, NGUYEN NGOC QUOI and MARTIN-BOYER G (1983) Étude de la morbidité humaine en relation avec la pollution bacteriologique des eaux de bagnade en mer. Etude préliminarie. Revue Francaise des Sciences de l'Eau 2, 127-143.

GALBRAITH N S, BARRETT N J and STANWELL-SMITH R (1987) Water and disease after Croydon: a review of waterborne and water-associated disease in the United Kingdom 1937-1986. Journal of the Institution of Water and Environmental Management 1, 7-21.

GALLAGHER M M, HERNDON J L, NIMS L J, STERLING C R, GRABOWSKI D J and HULL H H (1989) Cryptospiridosis and surface waters. American Journal of Public Health 79, 39-42.

GELDREICH E E (1966) Sanitary significance of fecal coliforms in the environment. Water Pollution Control Research Series No WP-20-3. US Government Printing Office, Washington DC.

GELDREICH E E (1970) Applying bacteriological parameters to recreational water quality. Journal, American Water Works Association 62, 113-120.

HARVEY R W S and PRICE T H (1981) Observations on infections associated with South Wales natural waters. Journal of Applied Bacteriology 51, 369-374.

HOLMES P R (1989) Research into health risks at bathing beaches in Hong Kong. Journal of Water and Environmental Management 3, 488-495.

HONG KONG GOVERNMENT (1986) Epidemiological studies related to beach water pollution in Hong Kong: a preliminary report. Environmental Protection Department Technical Report No EPD/TP17/86, Hong Kong Government.

LACEY R F and PIKE E B (1989) Water recreation and risk. Journal of the Institution of Water and Environmental Management 3, 13-21.

LEVIN M A, FISCHER J R and CABELLI V J (1975) Membrane filter technique for enumeration of enterococci in marine waters. Applied Microbiology 30, 66-77.

LIGHTFOOT N E (1989) A prospective study of swimming-related illness at six freshwater beaches in Southern Ontario. PhD thesis, University of Toronto.

MEDICAL RESEARCH COUNCIL (1959) Sewage Contamination of Bathing Beaches in England and Wales. MRC Memorandum No 37. HM Stationery Office, London, 24pp.

MOORE B (1960) The risk of infection through bathing in sewage polluted water. In: Proceedings, 1st International Conference on Waste Disposal in the Marine Environment, edited by E A Pearson. Pergamon Press, Oxford, p29-38.

MOORE B (1974) The case against microbial standards from bathing waters. In: International Symposium on Discharge of Sewage from Sea Outfalls, London, 28 August 1974, edited A L H Gameson. Paper No 11, Pergamon Press, Oxford.

MOORE B, PERRY E L and CHARD S T (1952) A survey by the sewage swab method of latent infection in an urban area. Journal of Hygiene, Cambridge 50, 137-156.

McCULLAGH P and NELDER J A (1989) Generalised Linear Models, 2nd Edition. Chapman and Hall, London.

MUJERIEGO R, BRAVO J M and FELIU M T (1982) Recreation in coastal waters: public health significance. In Proceedings, IVes Journées Études de Pollutions, Cannes. CIESM Secretariat, Monaco. p585-594.

NJDOH (1989) Ocean health study. A study of the relationship between illness and ocean beach water quality. New Jersey Department of Health (no address).

NTAC (1968) Water Quality Criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. April 1, 1968. Federal Water Pollution Control Administration, Washington DC, p7-14.

ONGERTH J E and STIBBS H T (1987) Identification of Cryptosporidium oocysts in river water. Applied and Environmental Microbiology 53, p672-676.

PHILIPP R, EVANS E J, HUGHES A O, GRISDALE S K, ENTICOTT R G and JEPHCOTT A E (1985) Health risks of snorkel swimming in untreated water. International Journal of Epidemiology 14, p624-627.

PHILIPP R, WAITKINS S CAUL O, ROOME A, McMAHON S and ENTICOTT R (1989) Leptospiral and Hepatitis A antibodies amongst windsurfers and water-skiers in Bristol City Docks. Public Health 103, p123-129.

PHLS (1959) Sewage contamination of coastal bathing waters in England and Wales. A bacteriological and epidemiological study. By the Committee on Bathing Beach Contamination of the Public Health Laboratory Service. Journal of Hygiene, Cambridge 57, p435-472.

RAMALINGASWAMI V and PURCELL R H (1988) Waterborne non-A, non-B hepatitis. The Lancet 571-573.

REPORT (1983) The Bacteriological Examination of Drinking Water Supplies 1982. Reports on Public Health and Medical Subjects No 71. Her Majesty's Stationery Office, London.

ROSENBERG M L, HAZLET K K, SCHAEFER J, WELLS J G and PRUNEDA R C (1976) Shigellosis from swimming. Journal of the American Medical Association, 236, 1849-1852.

ROSE J B, CIFRINO A, MADORE M S, GERBA C P, STERLING C R and ARROWOOD M J (1986) Detection of Cryptosporidium from wastewater and freshwater environments. Water Science and Technology, 18, 233-239.

ROYAL COMMISSION ON ENVIRONMENTAL POLLUTION (1984) Tenth Report. Tackling Pollution - Experience and Prospects. Cmnd 9149. Her Majesty's Stationery Office, London 233pp.

SEYFRIED P L, TOBIN R S, BROWN N E and NESS P F (1985a) A prospective study of swimming-related illness. I. Swimming-associated health risk. American Journal of Public Health 75, 1068-1070.

SEYFRIED P L, TOBIN R S, BROWN N E and NESS P F (1985b) A prospective study of swimming-related illness. II. Morbidity and the microbiological quality of water. American Journal of Public Health 75, 1071-1075.

SHUVAL H (1974) The case for mircobial standards for bathing beaches. In: International Symposium on Discharge of Sewage from Sea Outfalls, London, 28 August 1974, edited ALH Gameson. Paper No 10, Pergamon Press, Oxford.

SMITH R S and WOOLSEY T D (1952) Bathing Water Quality and Health. II. Inland river. US Federal Security Agency, Public Health Service, Environmental Health Center, Cincinnati.

SMITH R S, WOOLSEY T D and STEVENSON A H (1951) Bathing Water Quality and Health. I. Great Lakes. US Federal Security Agency, Public Health Service, Environmental Health Center, Cincinnati.

STANFIELD G and IRVING T E (1983) Investigations of sewage discharges to some British Coastal Waters. Chapter 3. Bacteriological enumeration procedures, Part 1. Technical Report TR 192, Water Research Centre, Medmenham, 92pp.

STEVENSON A H (1953) Studies on bathing water quality and health. American Journal of Public Health 43, 529-538.

TAM T Y, KO K C, YUNG H and BROOM M (1989) Bacteriological water quality of bathing beaches in Hong Kong, 1989. Environmental Protection Department Technical Report EPD/TR5/89, Hong Kong Government.

UNIVERSITY OF TORONTO (1980) A Study of Disease Incidence and Recreational Water Quality in the Great Lakes - Phase 1. Report 81-EHD-67. Health and Welfare Canada, Ottawa KIA OL2.

USDHEW (1960) Bathing water quality and health. III Coastal Water. A study of bathing water quality in Long Island Sound at Westchester Country, NY and its relation to bathers, 1950. US Department of Health, Education and Welfare, Public Health Service, Cincinnati, Ohio. 134pp.

USEPA (1976) Quality Criteria for Water. US Environmental Protection Agency, Washington DC, 42-50.

USEPA (1986) Ambient Water Quality Criteria for Bacteria. EPA 440/5-84-002. US Environmental Protection Agency, Washington DC, 18pp.

WAITKINS S A (1986) Leptospirosis in man, British Isles: 1984. British Medical Journal 292, (17 May 1986), 1324.

WAKEFIELD J A (1988) Coastal pollution - aesthetics and/or health. In: Marine Treatment of Sewage and Sludge. Thomas Telford, London, 45-55.

WHO (1975) Guides and Criteria for Recreational Quality of Beaches and Coastal Waters. Report on a Working Group, Bilthoven, 28 October - November 1974. World Health Organisation, Regional Office for Europe, Copenhagen, 1975, 31pp.

WHO (1986) Correlation between coastal water quality and health effects. Report on a joint WHO/UNEP meeting, Follonica, 21-25 October 1985. World Health Organisation, Regional Office for Europe, Copenhagen, 44pp.

WRc (1990) Design Guide for Marine Treatment Schemes. Vol I. Introduction. Water Research Centre, Swindon.

Figure 1 - Observed risks of illness in non-swimmers compared with those predicted in swimmers from bacterial counts in the water

Notes:

Risk is described both as case rate per 1000 subjects and as odds ratio, p/(1-p) where p is the proportion of group members falling ill and (1-p) the proportion of the group members remaining well. The odds ratio is more correct, since the data is binominal (eg ill or not ill).

The curves indicate the limits of bacterial counts in the original data, but are extrapolated (broken lines) to predict risks for bacterial counts of 10 000 per 100 ml. Bacteria are: FC, faecal coliforms; TC, total coliforms; Ec, E. coli; Ent, enterococci; TS, total staphylococci. The references, the predictive equations and features are summarised below; counts are per 100 ml and logarithms are decimal based, unless stated:

Stevenson (1953) Derived from Chicago data, Table 2. All illnesses.
Rate/1000 person-days = 1.611 log TC + 5.341

Dufour (1984) Swimming-associated, highly credible gastroenteritis
Rate/1000 persons = 9.40 log Ent -6.278
= 9.397 log Ec -11.74

Seyfried et al (1985b) All illnesses
log (p/(1-p)) = -2.65 + 0.696 log TS
= -1.4441 + 0.1818 log FC

Lightfoot (1989) All illnesses
$\log_e (p/(1-p)) = -4.752 + 0.347 \log_{10} FC$
$= -4.671 + 0.325 \log_{10} EC$
$= -6.044 + 0.560 \log_{10} TS$

Philipp et al (1985) Single observation. Gastroenteritis.

Fig. 1- Observed risks of illness in non-swimmers in five studies, compared with those predicted in swimmers from bacterial counts in the water.

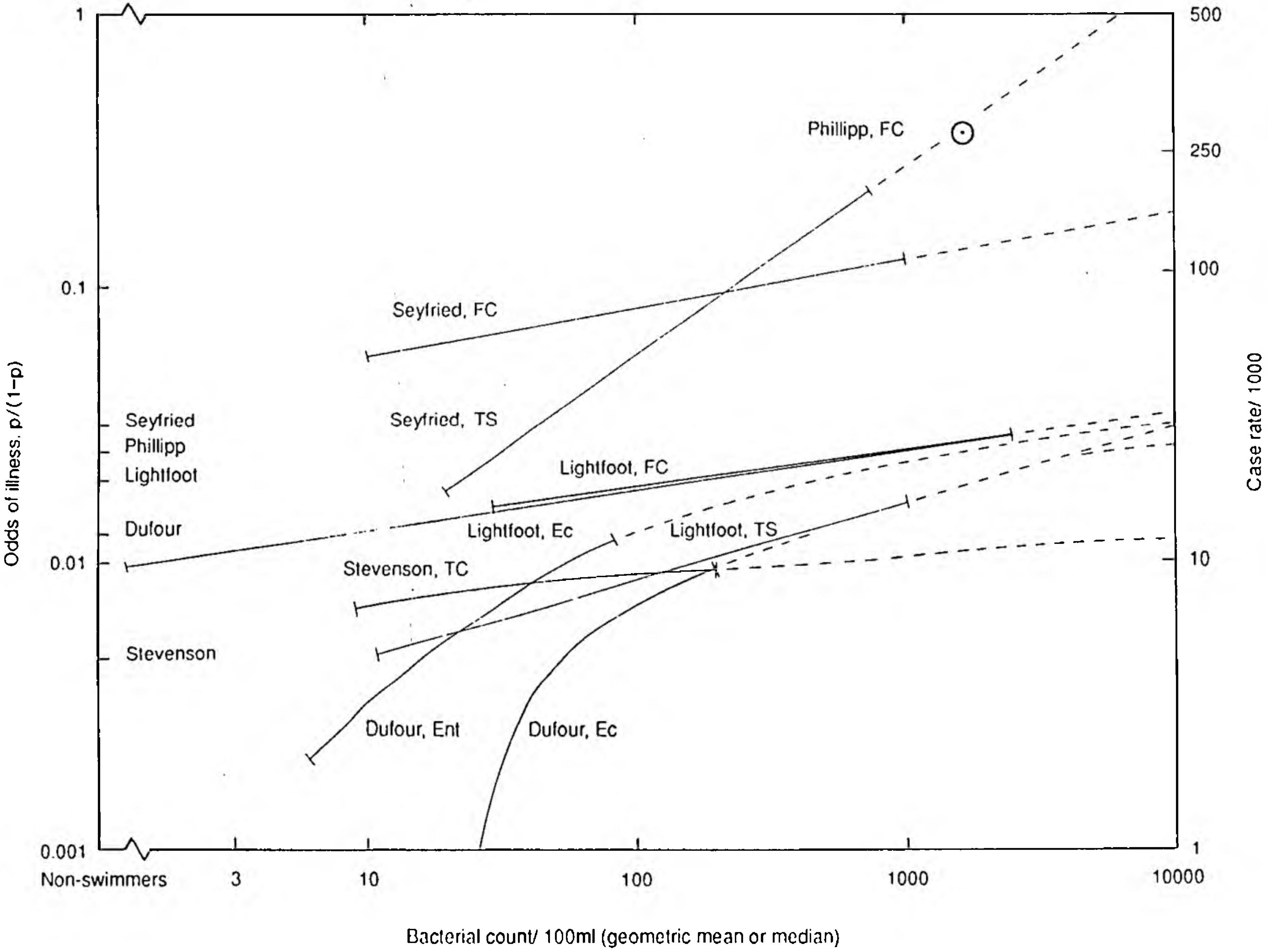


Figure 2 - Observed risks of highly credible gastroenteritis in non-swimmers compared with swimming-associated risks predicted from bacterial counts in seawater

Notes:

All predicted rates are for swimming-associated HCGI, ie swimmer rate minus non-swimmer rate. The derivation of the odds of falling ill and of the curves is as given in Figure 1. Bacterial indicators are Ent, enterococci and Ec, *Escherichia coli*. The references, predictive equations and features are summarised below. Counts are per 100 ml and logarithms are decimal-based.

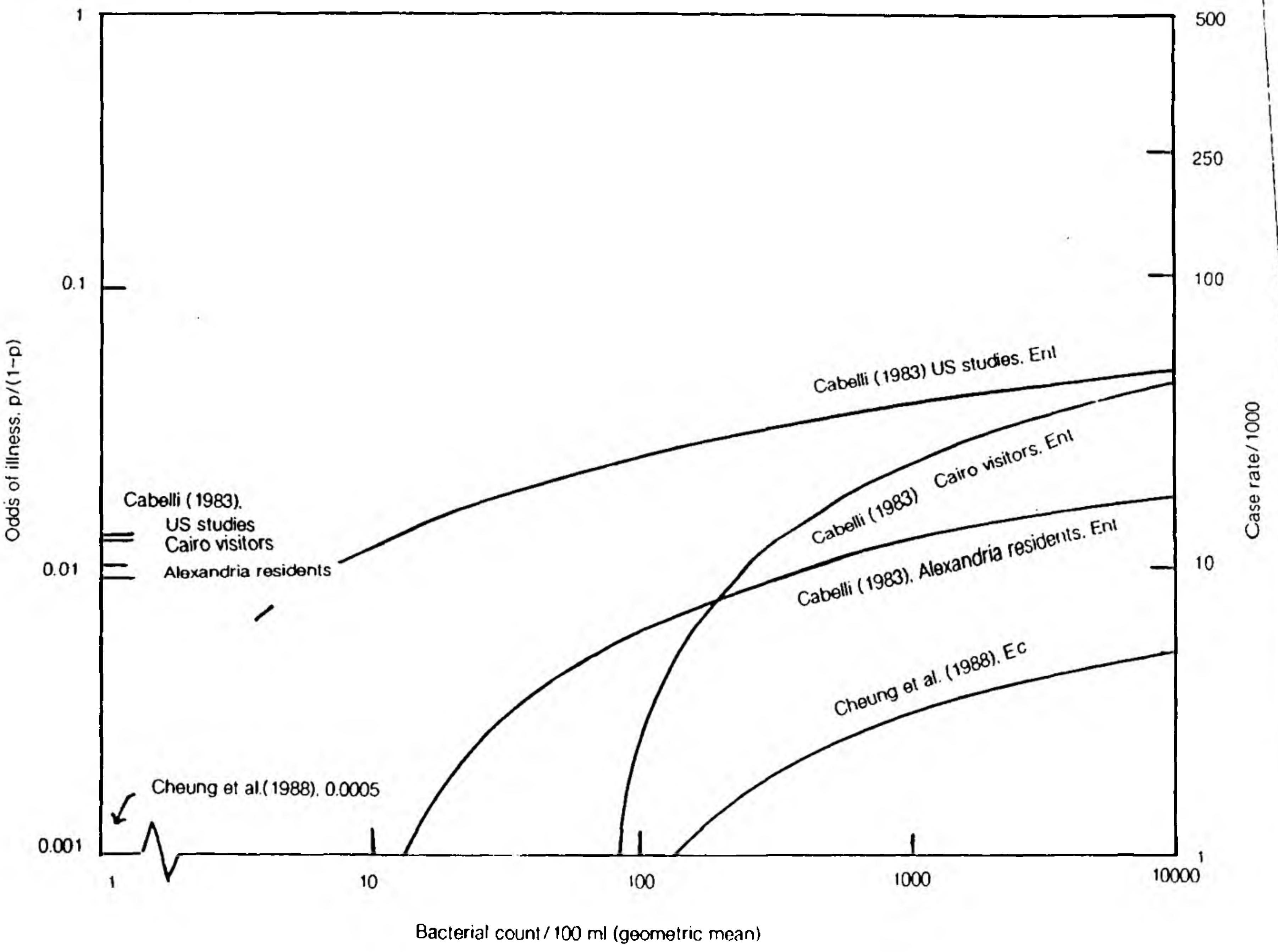
Cabelli (1983), US studies: New York City, Lake Pontchartrain LA and Boston Harbour MA. Swimming-associated HCGI:
Rate/1000 persons = 12.17 log Ent + 0.02

Cairo visitors to Alexandria beaches:
Rate/1000 persons = 20.29 log Ent - 37.068

Alexandria residents bathing on Alexandria beaches:
Rate/1000 persons = 5.481 log Ent - 4.842

Cheung *et al* (1989). Data included from 7 beaches in Phase II study and 4 from Phase I (Hong Kong Government 1986).
Regression equation calculated from their data.
Rate/1000 persons = 2.131 log EC - 3.383

Fig. 2. Observed risks of highly credible gastro-enteritis in non-swimmers, compared with swimming-associated risks predicted from bacterial counts in seawater.



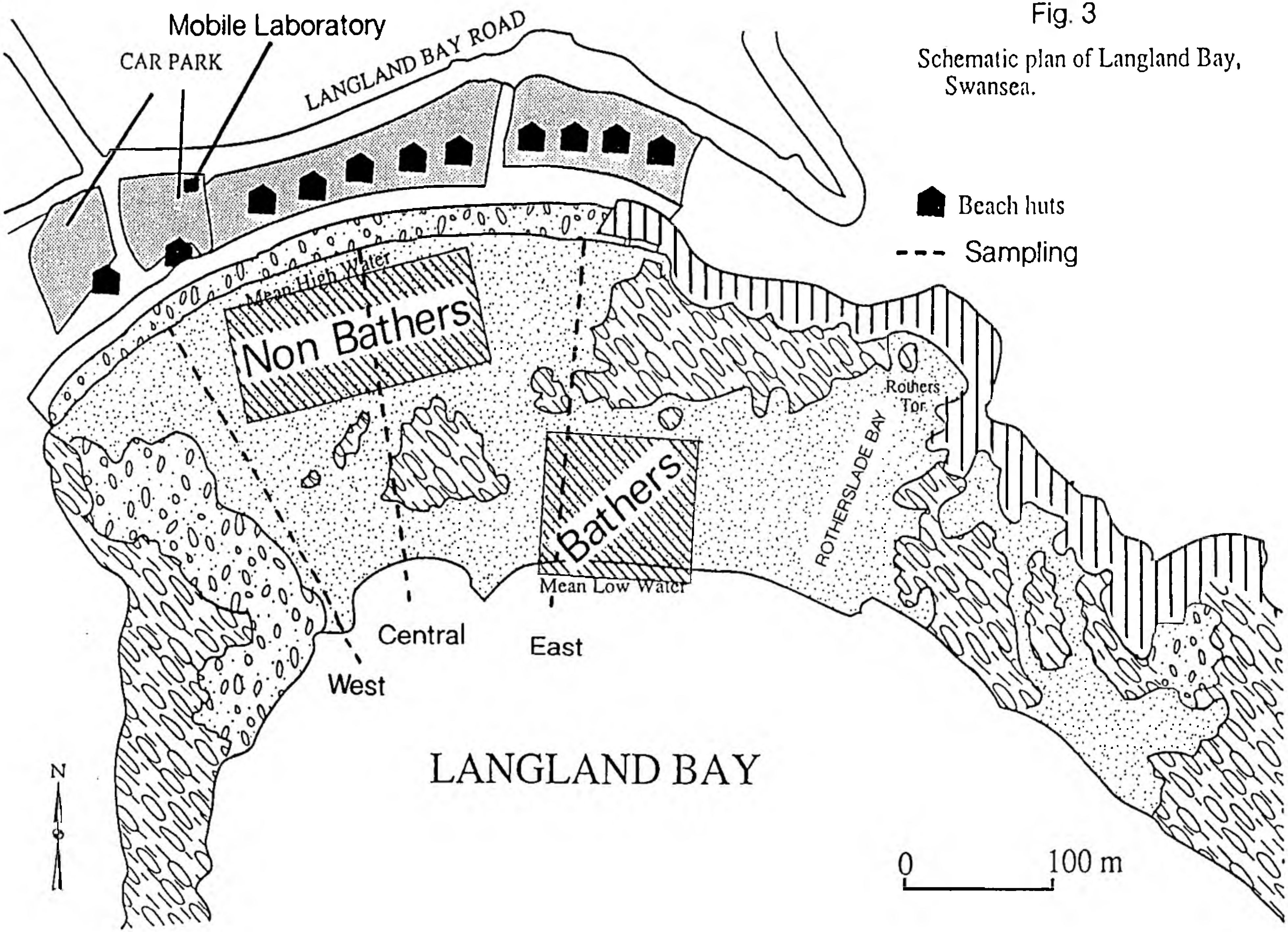


Fig. 3

Schematic plan of Langland Bay, Swansea.

FIG 4 : FREQUENCY DISTRIBUTION FOR TOTAL COLIFORM BACTERIA AT LANGLAND BAY EAST AND WEST, TRIPLICATE SAMPLES, THRICE DAILY, 31 JULY - 2 SEPT, 1989.

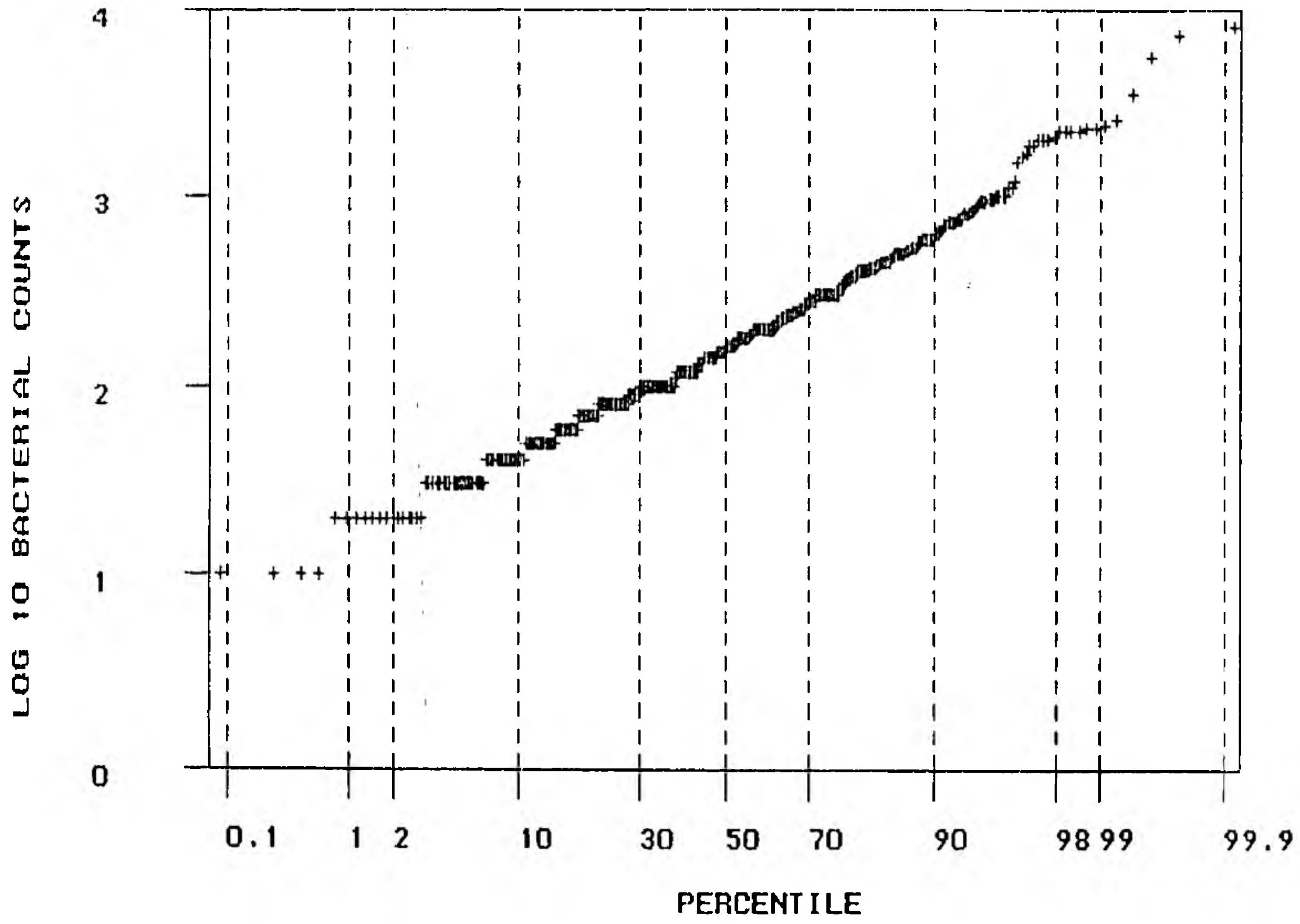


FIG 5. FREQUENCY DISTRIBUTION FOR FAECAL COLIFORM BACTERIA AT LANGLAND BAY, EAST AND WEST, TRIPLICATE SAMPLES, THRICE DAILY, 31 JULY - 2 SEPT, 1989.

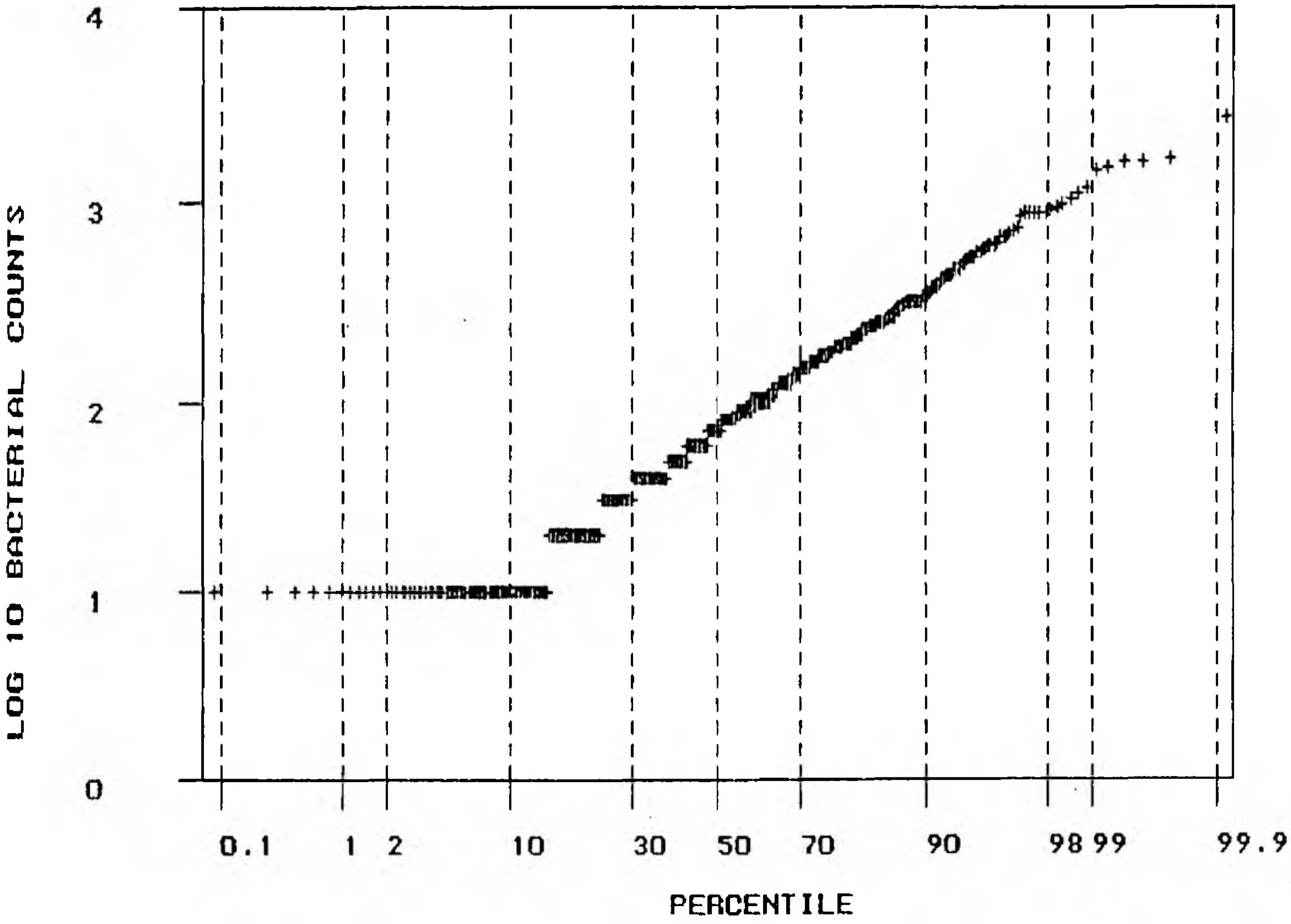
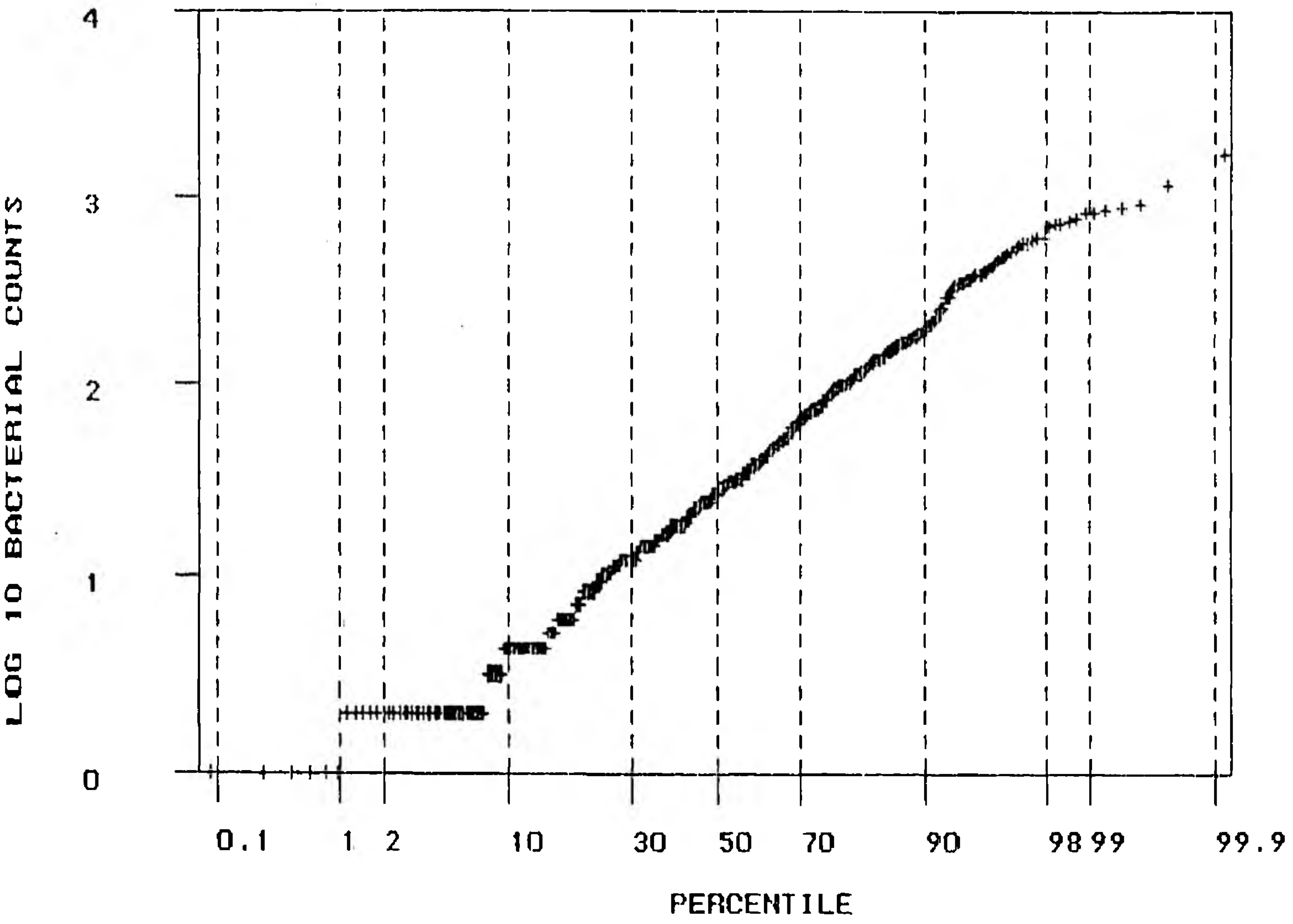


FIG 6. FREQUENCY DISTRIBUTION FOR FAECAL STREPTOCOCCI BACTERIA AT LANGLAND BAY, EAST AND WEST, TRIPLICATE SAMPLES, THRICE DAILY, 31 JULY - 2 SEPTEMBER, 1989.



APPENDIX A

HEALTH RISKS ASSOCIATED WITH BATHING IN THE SEA RESULTS OF A PILOT STUDY IN LANGLAND BAY

Final Report to the Water Research Centre,
March 1990

by R Balarajan,
Epidemiology and Public Health Research Unit,
University of Surrey, Guildford GU2 5XH.

UNIVERSITY OF SURREY
ROBENS INSTITUTE

HEALTH RISKS ASSOCIATED WITH BATHING IN THE SEA

RESULTS OF A PILOT STUDY IN LANGLAND BAY

Correspondence to Professor R Balarajan
Epidemiology and Public Health Research Unit
University of Surrey
Guildford
GU2 5XH

March 1990

ACKNOWLEDGEMENTS

I wish to acknowledge the help of Miss Alison Bishop, Dr. David Machin and Dr. David Wheeler in the preparation of this report and Mrs S. Cranham for typing the manuscript.

Professor R Balarajan
Epidemiology and Public Health Research Unit

March 1990

CONTENTS

ABSTRACT

Aim

To conduct a pilot study to investigate the possible risks from bathing in sea water through a follow-up study of bathers and non-bathers at a beach resort.

Setting

Langland Bay, Wales. August 1989.

Design

A random sample of beach users was interviewed (n = 4045) to obtain information on their sociodemographic characteristics, bathing habits, water activities, food habits, and health status. 791 individuals (20% of the sample) were followed-up a week later through a telephone interview to obtain information on their health status. Contingency tables were studied and a logistic regression analysis was carried out to derive odds ratios by exposure to water activity for gastrointestinal, respiratory, ear/throat, and eye symptoms, and for aggregated symptoms, adjusting for age and sex.

Results

The findings of the pilot study revealed a significant excess of self-reported illness for aggregated symptoms, and individually for symptoms of the eye and ear/throat. The numbers were too small to detect risks for gastrointestinal illness. Risks increased with the type of water activity, and were highest in those participating in surfing, followed by diving, swimming, and wading. Individuals aged 15-24 were at greatest risk. Food comsumption did not have a significant contribution to risk.

Conclusion

It is possible to establish the relative risks of bathing in British seas through a large follow-up study (16,000 individuals) of bathers and non-bathers, relating reported illness to beach characteristics.

Recommendation

It is recommended that such a follow-up study is conducted covering 1600 individuals from ten different beaches across the country. It is feasible to do this in the summer of 1990 if the study is commissioned by mid April. The estimated costs are £356k.

AIMS OF THE STUDY

- To conduct a pilot study to investigate the possible risks from bathing in sea water in this country through a follow-up study of bathers and non-bathers at a beach resort.
- To establish the feasibility of such a design for a definitive study, and if found feasible to develop a detailed study proposal with costs.
- To establish the feasibility of simultaneously monitoring the microbiological environment in order to establish associations, if any, between morbidity levels and the concentration of potential pathogens.

INTRODUCTION

One of the most important current debates on the subject of microbiological disease transmission concerns the risks to health of bathing in sewage-contaminated water. Much of the present discussion relating to effluent emission standards and water quality objectives centres on whether the "precautionary principle" should be adopted. This principle, which was adopted by the second North Sea Conference in 1987 and endorsed by the UK Secretary of State in the recent third Conference, means that if the risks are not understood, there should be a presumption against the discharge of potentially harmful or accumulative contaminants. This approach is now espoused by the majority of European countries.

There is now sufficient evidence from studies conducted in North America and elsewhere that it is possible to sensibly quantify the hazards of recreational contact with sewage. The problem for the regulator is that standards for water quality must have "clearly defined and scientifically credible supporting criteria" (Watershed 89 Declaration - Wheeler et al, 1989). The only rational way therefore to establish the real benefit of a particular approach for protecting the public and the environment is to conduct scientific studies to quantify risks.

In 1976 the European Community published its bathing water directive in an attempt to encourage member states to clean up their beaches (CEC, 1976). The bacteriological and virological standards specified are summarised below.

MICROBIOLOGICAL STANDARDS OF THE EUROPEAN COMMUNITY BATHING WATER DIRECTIVE

Parameter	Guide Level	Mandatory Level*	Minimum Sampling Frequency
Total Coliforms per 100 ml	500	10,000	Fortnightly
Faecal Coliforms per 100 ml	100	2,000	Fortnightly
Faecal Streptococci per 100 ml	100	-	Discretionary
Salmonella per litre	-	0	Discretionary
Enteroviruses pfu per 10 litres	-	0	Discretionary

(* 95 % of samples should contain less than the mandatory levels)

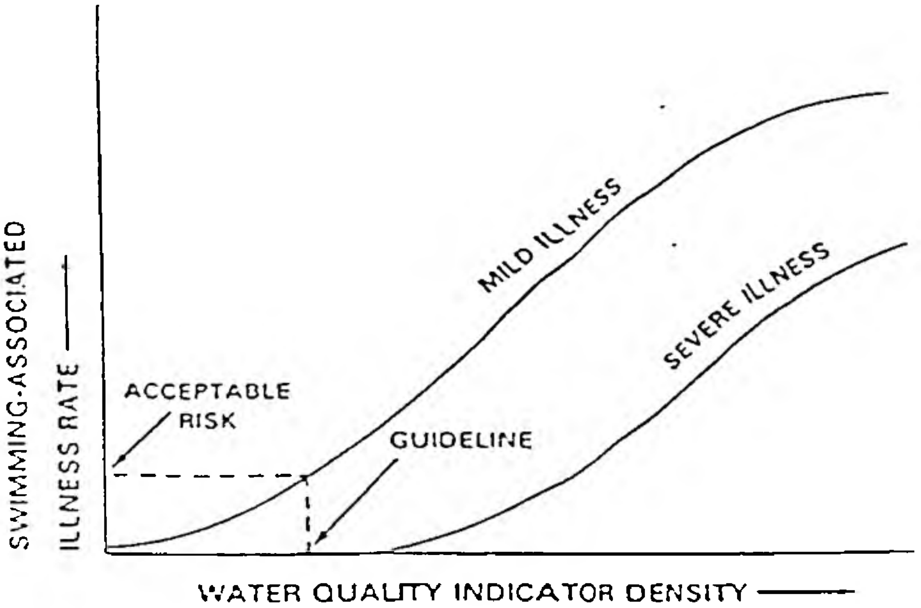
As with most microbiological standards for water quality, greatest reliance was placed on the bacterial indicators of faecal pollution - in particular the faecal and total coliforms. Since the directive was originally drafted, it has become clear that both bacterial and viral standards may not be optimal indices of risk from recreational contact with sewage- contaminated waters.

Some naturally occurring bacteria (in particular the marine vibrios) may also cause infection in swimmers in the absence of sewage pollution. However, the agents of most interest are those associated with sewage pollution, and in particular the viruses which are responsible for faecal-oral infections such as gastroenteritis (Wheeler, 1990). Viruses which may be present in sewage are summarised below together with the ailments with which they are associated.

HUMAN ENTERIC VIRUSES WHICH MAY BE PRESENT IN POLLUTED WATER (Rao & Melnick, 1986)

Virus Group	Number of serotypes	Disease caused
Enteroviruses:		
Poliovirus	3	Paralysis, meningitis, fever
Echovirus	34	Meningitis, respiratory disease, rash, fever, gastroenteritis
Coxsackievirus A	24	Herpangina, respiratory disease, meningitis, fever, hand, foot and mouth disease
Coxsackievirus B	6	Myocarditis, congenital heart anomalies, rash, fever, meningitis, respiratory disease, pleurodynia
New enterovirus types 68-71	4	Meningitis, encephalitis, respiratory disease, rash, acute haemorrhagic conjunctivitis, fever
Hepatitis A (enterovirus 72)	1	Infectious hepatitis
Norwalk virus	2	Epidemic vomiting and diarrhoea, fever
Rotavirus	4	Gastroenteritis, diarrhoea
Reovirus	3	Unknown
Parvoviruses:		
Adeno-associated virus	3	Unknown
Adenovirus (faeces & urine)	>30	Respiratory disease, conjunctivitis, gastroenteritis
Cytomegalovirus (urine only)	1	Infectious mononucleosis, hepatitis, pneumonitis, immunological deficiency syndrome
Papovavirus, SV40 like (urine only)	2	Associated with progressive multi-focal leukoencephalopathy and immunosuppression

As can be readily observed, not all of the viruses are enteroviruses and not all cause gastroenteritis. Some are responsible for more serious ailments, including hepatitis, and meningitis. The importance of viruses in the marine recreational environment derives from two factors: their potentially long-term survival and their relatively low infective doses. Typical survival characteristics of enteric viruses and bacteria are illustrated in Figure 1.



Graphic representation of the desired recreational water quality criteria. It is assumed that only an extremely small risk of "serious" illness will be accepted.

Figure 1. Dose response curves established by epidemiological investigation and their relationship to microbiological standards (after Cabelli et al, 1984).

The pre-eminence of viral risks underscores the need for indices of sewage pollution which adequately accommodate the difference in behaviour between bacteria and viruses. Because faecal streptococci survive better in the marine environment than coliform bacteria, they may provide a more appropriate indication of disease risk (Dufour, 1984).

Quantifying the Risks

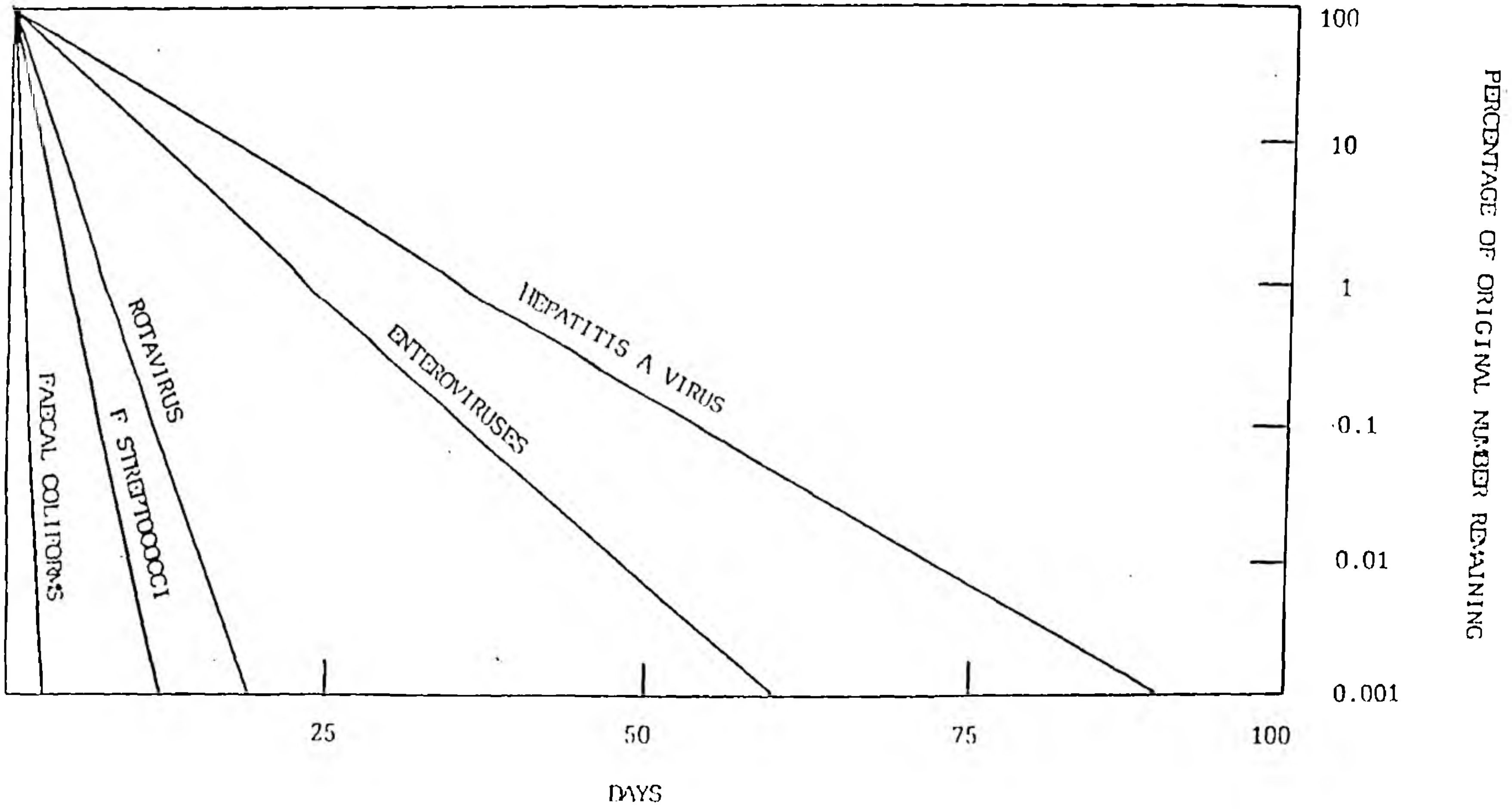
Bathing-associated gastroenteritis is caused by a variety of agents with unknown seasonal and spatial distribution and unknown infective dose. Most of the viruses listed above are not amenable to isolation from the aquatic environment and may even present difficulties in detection in faecal specimens. Thus, one viable approach is to use an epidemiological instrument which is sensitive enough to detect the characteristically low prevalence of symptoms associated with bathing and (regardless of the actual agents involved) correlate these with an index of pollution. Low prevalence may be detected by recruiting large numbers of exposed and non-exposed persons present on the beach of their own volition, these persons being carefully defined as bathers or non-bathers.

Both groups are questioned about their bathing habits, diet, and a number of other social and health factors. After 7-10 days respondents are telephoned at home and requested to give details of their health, together with any symptoms they have experienced in the intervening period. Bathing-associated elevations in reporting rates are established for a range of water qualities and these build into a dose-response curve correlating elevation of symptoms with level of sewage pollution. In the case of sewage pollution, the index of risk will normally be a bacterial indicator of faecal contamination, for example thermotolerant coliforms or faecal streptococci. The objective is to construct a dose-response curve which allows degree of risk to be quantified in terms of degree of exposure to pollution. The concept, as applied by the US Environmental Protection Agency, is illustrated in Figure 2.

The Future for Bathing Water Quality Standards in Europe

The European Commission is considering a review of the standards contained within the bathing water directive. Such a review should take on board the developments in our understanding of the risks of bathing in seawater contaminated by sewage, in particular the results of studies currently being sponsored by UK's Department of the Environment. It is almost certain that new standards for bathing water quality will be based on more robust indicator systems. However, before new standards are elaborated, it will be necessary to conduct epidemiological studies to support those standards. In preparation for the full-scale investigation of health risks associated with bathing in sewage-contaminated water following the WHO/UNEP methodology, a pilot project was undertaken in South Wales in the summer of 1989. The findings of that study are described in this report.

Figure 1. Typical survival characteristics of faecal indicator bacteria and human enteric viruses in seawater (adapted from Sattar, 1981; Dufour, 1984; Goyal *et al*, 1984; Gerba and Goyal, 1986; Rao and Melnick, 1986 and Gerba, 1988).



BACKGROUND TO THE STUDY

In November 1988, the UK Department of the Environment convened a Working Group on the "Possible Health Risks of Bathing in Water Contaminated by Sewage". The Group were asked to advise the Department on strategies for establishing "what level of sewage contamination of bathing waters (measured by various indicator organisms) gives a measurable risk of contracting minor illnesses".

Further meetings of the Group in 1989 enabled the Department of the Environment to come to a view on the most appropriate types of pilot study to be commissioned for the 1989 bathing season. It was decided that the UK Water Research Centre (WRC) would be contracted to manage two studies following completely different methodologies in order to compare their applicability in UK coastal resorts.

In June 1989, the WRC contracted the Robens Institute to undertake a "Beach Survey Study". The approach was to be based on a document prepared by WRC entitled "Proposal for Pilot Epidemiological Study of Effects of Bathing in Seawater" (PRS 2073-M) and submitted to the Department of the Environment following consultation with the Robens Institute in January 1989. In broad terms the study design was in line with the WHO/UNEP methodology elaborated in connection with the Mediterranean Pollution Monitoring and Research Programme (WHO/UNEP, 1977; WHO/UNEP, 1986). It combines cross-sectional data gathering among individuals who are present at the bathing water site of their own volition with a telephone or postal follow-up to ascertain details of health outcomes.

Langland Bay, Wales, was designated as the location of the study. The target was to conduct 2000 beach interviews, up to 400 telephone follow-up interviews, and up to 1000 postal follow-up interviews in the period 01 - 31 August 1989. In addition, microbiological analysis for a period of four weeks with a minimum of 12 samples per day were to be analysed for indicator bacteria from three sites along the beach. In addition, a minimum of twenty samples were to be taken for bacterial pathogens, viruses and parasites during the survey period.

The second approach commissioned by the Department of the Environment via WRC was based on a "healthy volunteer" protocol proposed by Altwell Ltd and Lampeter College (Jones et al, 1988), and a report on the outcome of this study is available.

The main purpose of the two studies conducted at Langland Bay was to examine the comparative viability of two epidemiological approaches for assessing the risks to health from bathing in sewage-contaminated seawater. The reason for conducting two different but related studies at the same resort was to test the proposition that perceived symptoms could be partially validated by clinical microbiology. Thus by combining the output from the survey (WHO/UNEP) method with that of the volunteer study of Altwell, the gastroenteric and other symptoms detected by both studies could be subjected to comparison with clinical findings. Professor Balarajan at the University of Surrey was invited to coordinate the follow-up study of bathers and non bathers.

The output of the study and the original targets set by the WRC are shown below.

CRITERION	TARGET	OUTPUT
Beach Interviews	2000	4045
Telephone Follow-ups	Up to 400	791
Postal Follow-ups*	Up to 1000	0
Microbiological Samples (Indicator Bacteria)	240	360
Microbiological Samples (Pathogens)	20	15
Weeks of Fieldwork	4	5

* Since telephone follow-up proved to be a viable technique for data-gathering, the budget for postal follow-ups was diverted into maximising the output from the telephone method.

METHODS

The study was designed according to the terms of reference and took the form of a cross-sectional survey by interview of people at the beach. The study was conducted in Langland Bay, Wales, in August 1989. The subjects included both local residents and holiday- makers, and covered all age groups other than 0-4 year olds. Information about children was obtained from their parents.

4045 individuals were interviewed on a one to one basis using a questionnaire. Data was collected on sociodemographic factors, length of stay at the beach resort, type of water activity, bathing habits, food habits, and health status. 791 individuals (20% of the sample) were followed-up a week later through a telephone interview whereby information was obtained on further illness, self-medication, and consultation with a general practitioner.

Subjects who took part in water activities were treated as the exposed group and the others as non-exposed. After preliminary analysis the type of water activity was examined in a hierarchical manner from surfing to diving, swimming and wading.

Information was available on the occurrence of a large variety of symptoms. After preliminary analysis they were combined to form four relevant groups, namely gastrointestinal symptoms, respiratory symptoms, ear and throat symptoms, and symptoms relating to the eye. These four groups were also aggregated and analysed as a category referred to as 'major symptoms' to create sufficient numbers for detailed analysis.

The health risk assessment was based on the follow-up study of 791 individuals. The health status assessed at the beach for the total study population of 4045 was used to test for consistency. Contingency tables were prepared for health status by a series of variables such as age, sex, type of respondent, length of stay at the beach, food habits, etc.

After the preliminary analysis it was decided to use the logistic regression method to devise odds ratios adjusted for age and sex, for 'major symptoms', gastrointestinal, respiratory, ear and throat, and eye symptoms for exposure to water activity. Odds ratios for 'major symptoms' were also examined by type of water activity, which included surfing, diving, swimming and wading.

A case control analysis was also carried out within the follow-up study, using subjects who reported illness as cases. Two controls matched for age, sex and day of interview were selected for each case. The analysis again covered gastrointestinal, respiratory, ear and throat, and eye symptoms, and the aggregated category of 'major symptoms'. The logistic regression method was preferred to the case-control analysis, as it uses the information on all 791 individuals.

The number of microbiological samples for indicator bacteria (thermotolerant coliforms, total coliforms, faecal streptococci and total vibrios) was greater than originally allowed for, but it was thought valuable to obtain data for the entire bathing day (08.00 - 18.00) rather than restricting the time-span to the period 10.00 - 16.00. In contrast, owing to an unexpected price rise, the number of samples for pathogen analysis (Rotavirus, Total Enterovirus, Giardia, Cryptosporidium, Salmonella and Staphylococcus) had to be reduced from 20 to 15.

Analyses of faecal indicator bacteria were undertaken in the field according to standard protocols (Anon, 1982). The WRC was responsible for quality control of field measurements, and the Robens Institute complied with the necessity to provide duplicate samples for analysis on request. Analyses for pathogens were undertaken by the Water Quality Centre of Thames Water which provides certificated statements of analysis in order to comply with the provisions of their quality control accreditation.

The water quality was not related to health status in view of the design and the small size of the study.

RESULTS

Altogether 4045 interviews were conducted at Langland Bay between 1st August and 1st September 1989. The instrument used for the survey is shown in the Appendix. Seventy-five percent of those interviewed were willing to be contacted by telephone for the follow-up. This response did not differ significantly by age or sex.

Age-Sex Distribution

3105 (77%) of those interviewed were below the age of 45 (Table 1). The male/female ratio varied by age, being approximately 1:1 for those aged 5-14, 45-54 and 65+. In the 15-24 age category there were more males, the reverse being true for 25-44 and 55-64 (Figure 3). The age distribution of the follow-up group did not differ significantly from the total study population (Table 2).

Figure 3
Age And Sex Distribution
Of The Respondents

Type of Respondent

The majority (70%) of those interviewed were holiday-makers (Table 3), and this was true for all age groups (Table 3) (Figure 4). The follow-up sample was similar (Table 4) (Figure 5).

Type of Activity

Almost half (48%) of those interviewed entered the water, of which only 56% did active swimming, diving or surfing (Table 5). In terms of individual activity surfing attracted more locals than holiday-makers, with 61% of surfers being locals (Figure 6). This pattern generally prevailed also in the follow-up sample (Table 6).

Reported Illness

In the follow-up study 9.4% reported major symptoms. In the non- exposed group reporting of illness was 6.8% for the 'major' symptoms as opposed to 12.2% in the exposed (Table 7). Reporting varied by age in the exposed and non-exposed groups. In the non-exposed group reporting was highest in the 15-24 year olds followed by age groups 25-34 and 5-14. In the exposed the peaks were again highest at ages 15-24 followed by 25-34, 35-44 and 5- 14. Reporting levels were in general greater for the exposed than for the non-exposed. The same information for the beach interview is given in Table 8.

Reported illness for major symptoms varied by type of activity (Table 9) with the highest level for surfing (18.2%) and the lowest level for wading (8.3%), those with no activity reporting 6.8%. A dose-response type of relationship emerged for major symptoms (Figure 7).

For individual symptoms the levels of reporting in the exposed by type of activity and the non-exposed are given in Tables 10-13. The reporting of gastrointestinal symptoms was 3.2% in subjects exposed to risk and 3.9% in those not exposed, with an overall figure of 3.5% for the total study group. The occurrence of ear/throat symptoms was 7.7% in the exposed and 3.1% in the non- exposed (5.3% in the total group). Respiratory symptoms were reported by 1.9% of exposed subjects and 1.2% of the non-exposed (1.5% in the total group). Eye symptoms were reported by 2.9% of the exposed and 0.7% of the non-exposed (1.8% in the total group). Thus, for all symptoms except gastrointestinal illness, the levels of reported illness were generally higher in the exposed than in subjects not exposed (Figure 8). Reported levels of ear/throat and eye symptoms were highest in subjects participating in surfing and diving.

Figure 4
Type Of Respondent By Age

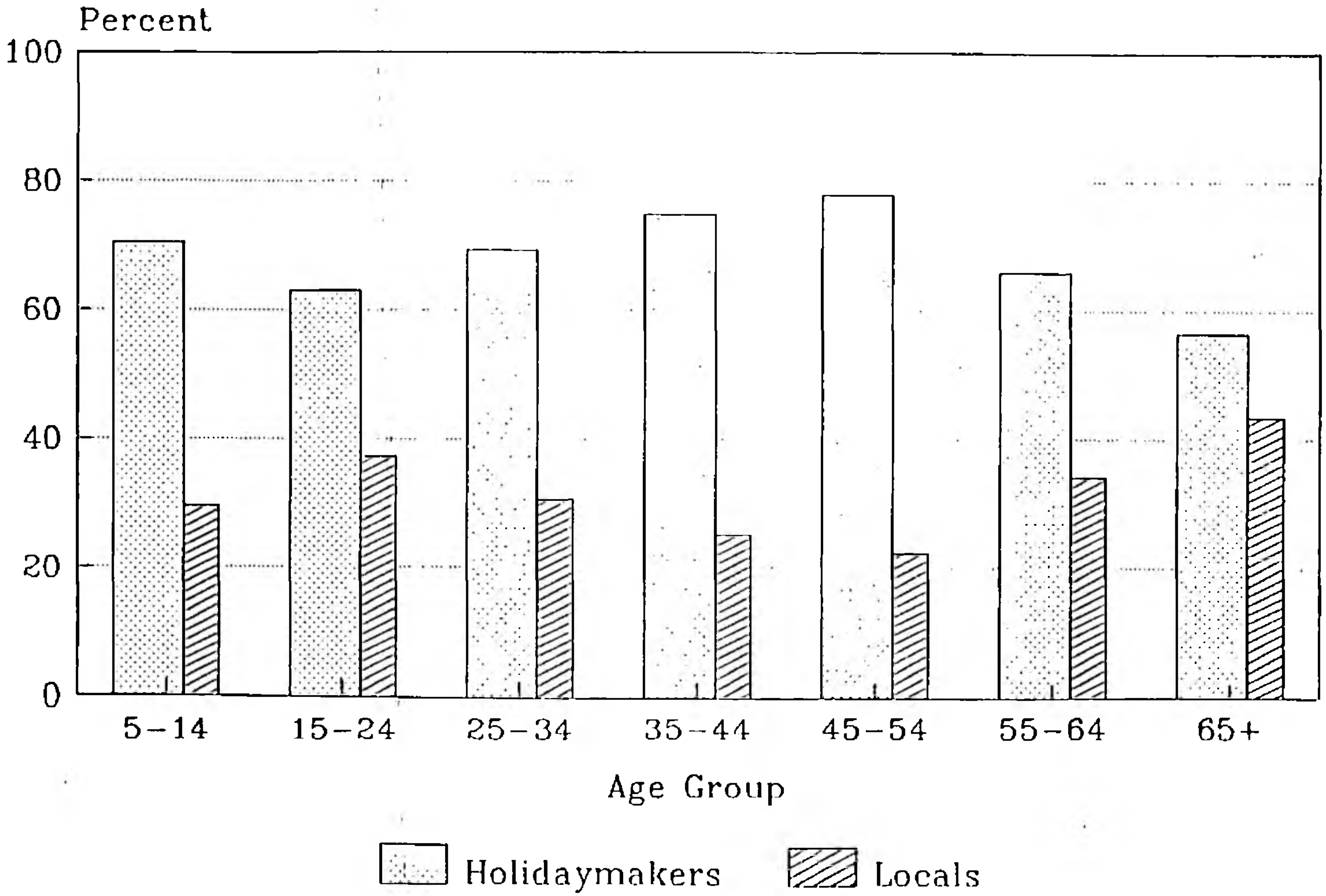


Figure 5
Type Of Respondent By Age
(Follow-Up Study)

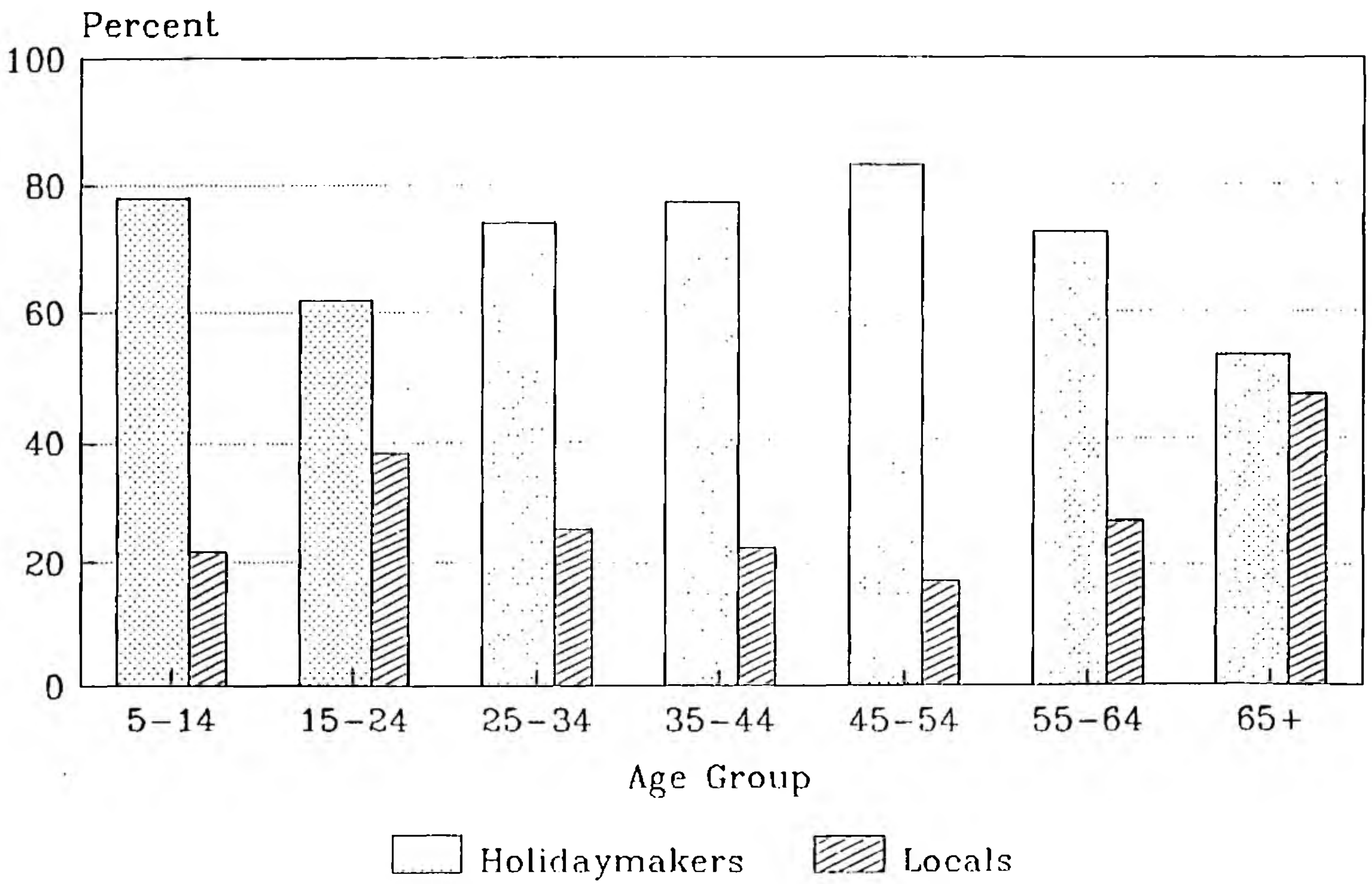


Figure 6
Type Of Respondent By
Type Of Activity

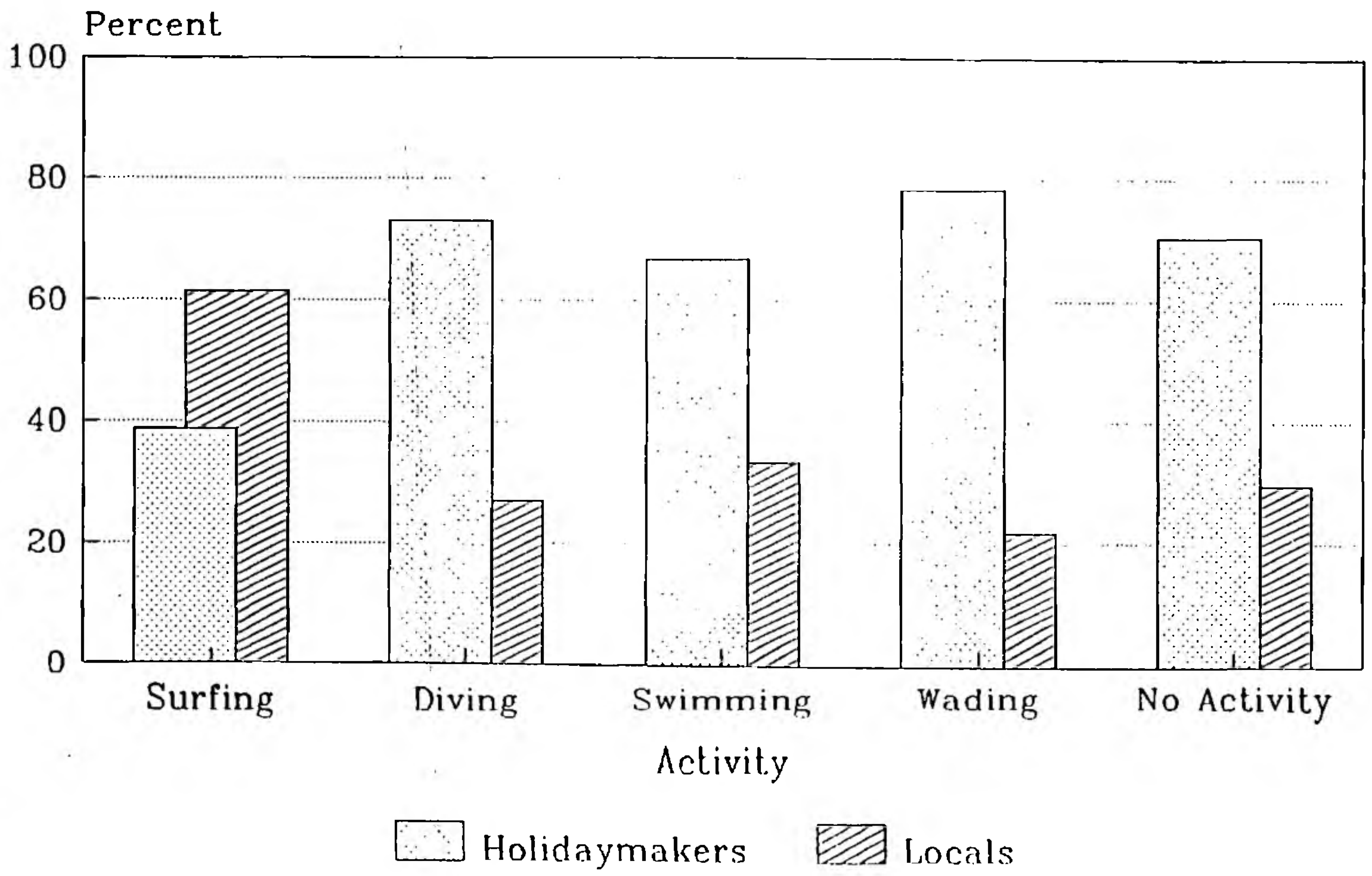


Figure 7
Type Of Activity By Reporting Of Major Symptoms (Follow-Up Study)

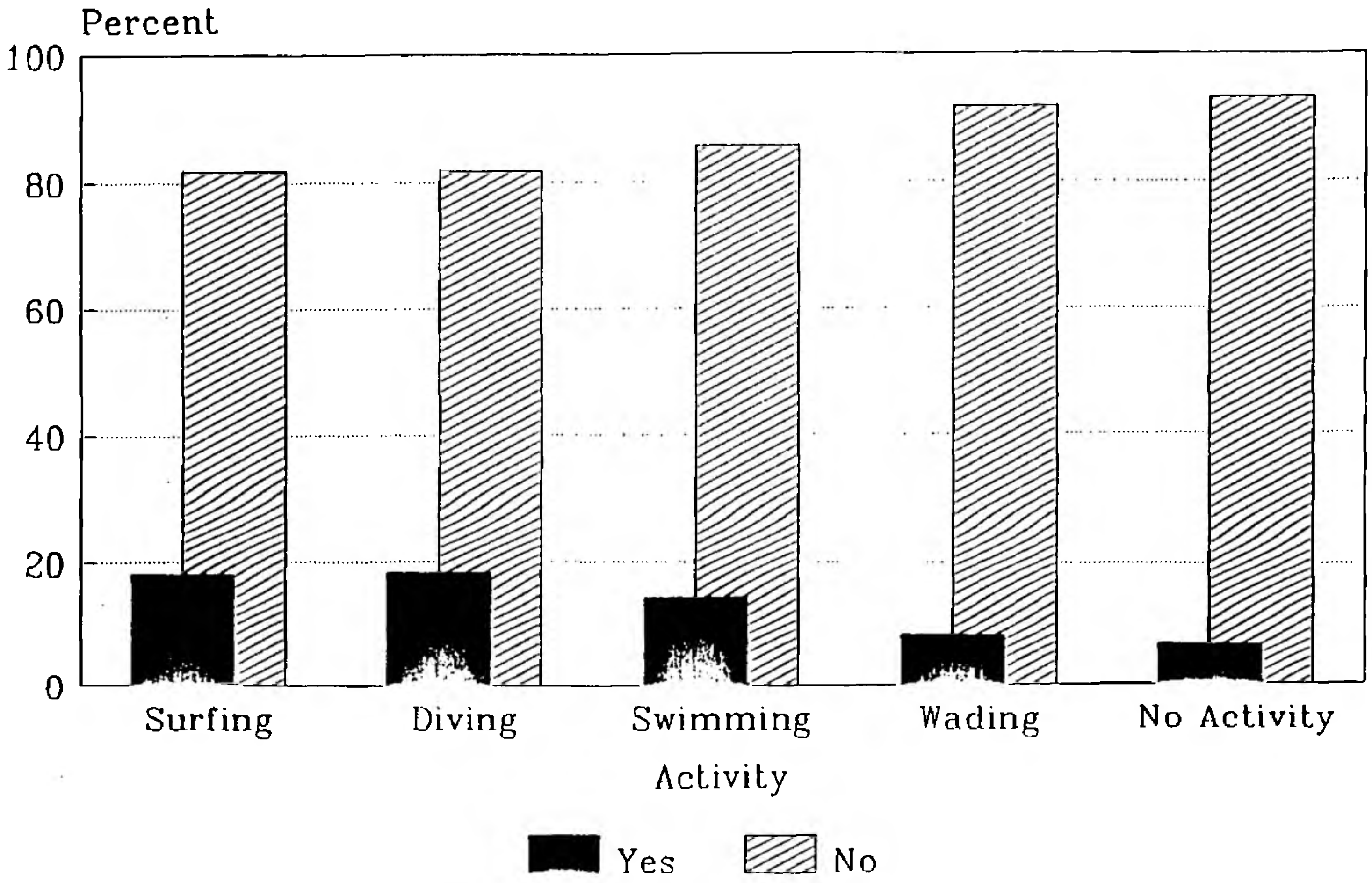
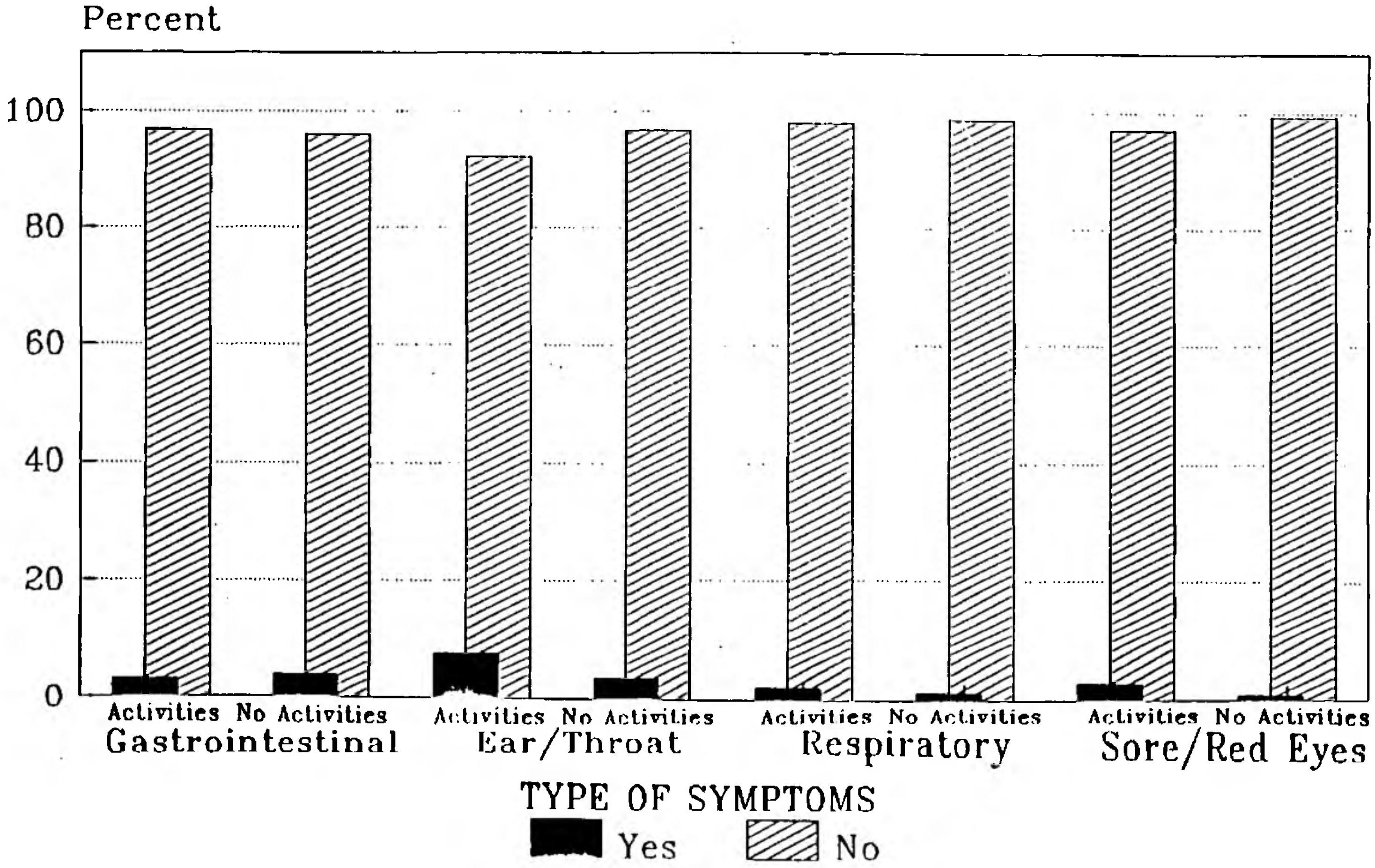


Figure 8
Type Of Activity By Reporting Of Symptoms (Follow-Up Study)



The numbers were insufficient to investigate the type of activity by individual symptoms.

Self-Medication

In the follow-up group self-medication was higher in the exposed (12%) than in the non-exposed (9%) (Figure 9), with the highest level (21%) among those who took part in surfing (Table 14).

GP Consultation

The proportions consulting a doctor were similar (1.9% and 1.7% among the exposed and non-exposed respectively, Table 15). There were insufficient numbers to examine consultation by type of symptoms or to examine this outcome in any detail.

Logistic Regression Analysis

Table 16 shows the findings in terms of odds ratios for participation in water activity. After allowing for age and sex, major symptoms were almost twice as common (OR 1.90, 95% CI 1.14-3.17) in subjects who participated in water activity.

Health risks did not vary between the sexes in this pilot study. Age, however, played a significant role, with the probability of reporting illness being highest in the 15-24 age group (OR 2.82, 95% CI 1.32-6.03). The risk associated with water activity was therefore accentuated in the young. The model being multiplicative, the risk of major symptoms among those aged 15-24 participating in water activity was about five-fold. Odds ratios for major symptoms were raised also at ages 25-34 and 35-44. Subjects aged 5-14 were used as the base line for the analysis, and in relation to this group the odds ratios for those aged 45 and over was less than 1, with risks decreasing with increasing age thereafter.

Analysis by type of activity using the same model shows a dose- response type of relationship between type of activity and major symptoms (Figure 10). Reported illness was highest among subjects who went surfing (OR 3.07, 95% CI 1.13-8.35), being three times greater than in those not exposed (Table 17). The risk of reported illness associated with surfing among young people aged 15-24 was about eight-fold. The risk of illness was high also among divers (OR 3.00, 95% CI 0.92-9.73) and swimmers (OR 2.34, 95% CI 1.27-4.32). The risk for those exposed is compared by age with those not exposed in Figure 11.

Results of the logistic regression analysis by individual symptoms (Tables 18-21) show a significant excess of ear/throat symptoms (OR 2.77, 95% CI 1.40-5.50) and eye symptoms (OR 3.71, 95% CI 1.03-13.35), and a non-significant excess of respiratory

Figure 9
Type Of Activity By Doctor Consultation & Self-Medication (Follow-Up Study)

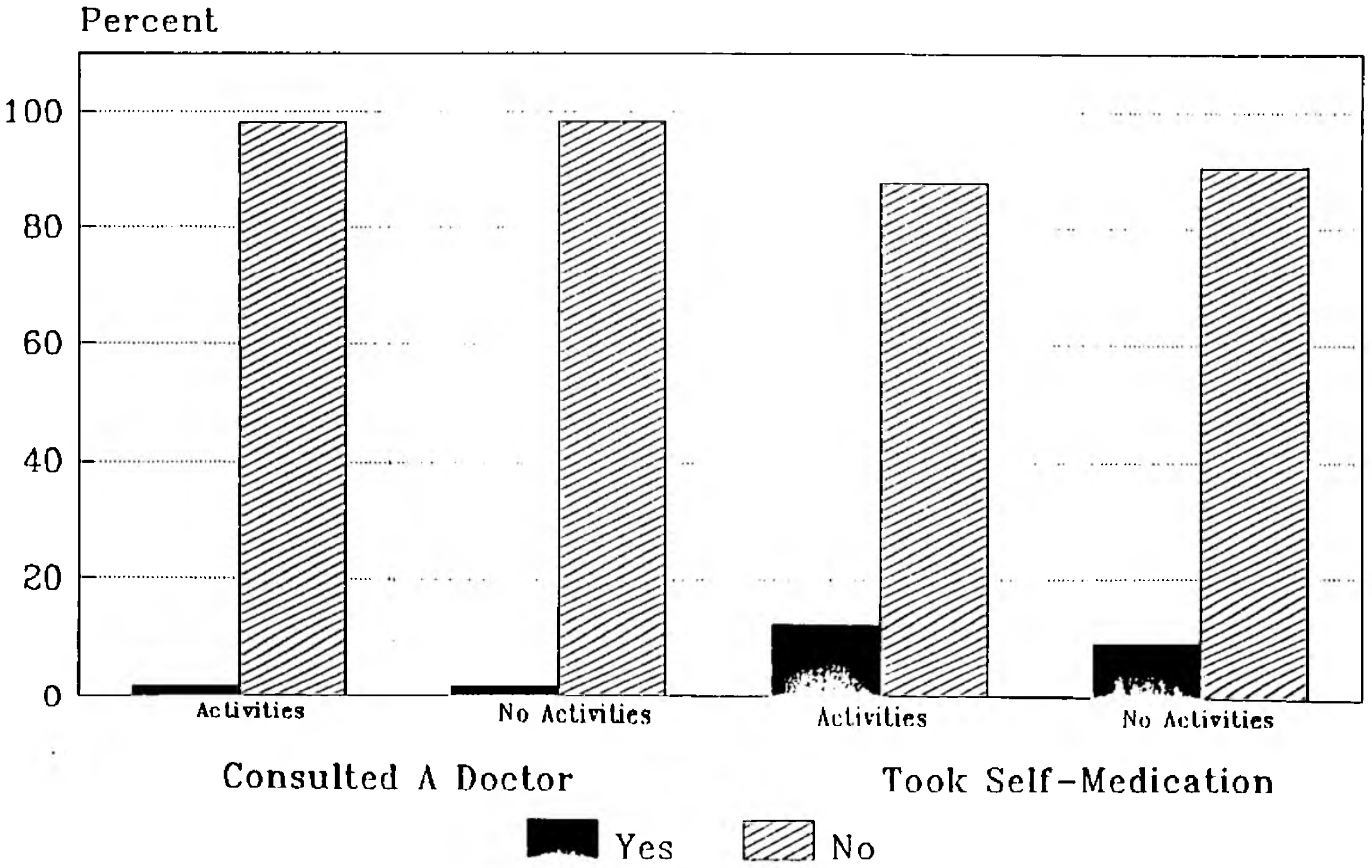


Figure 10
Major Symptoms
Odds Ratio For Each Activity

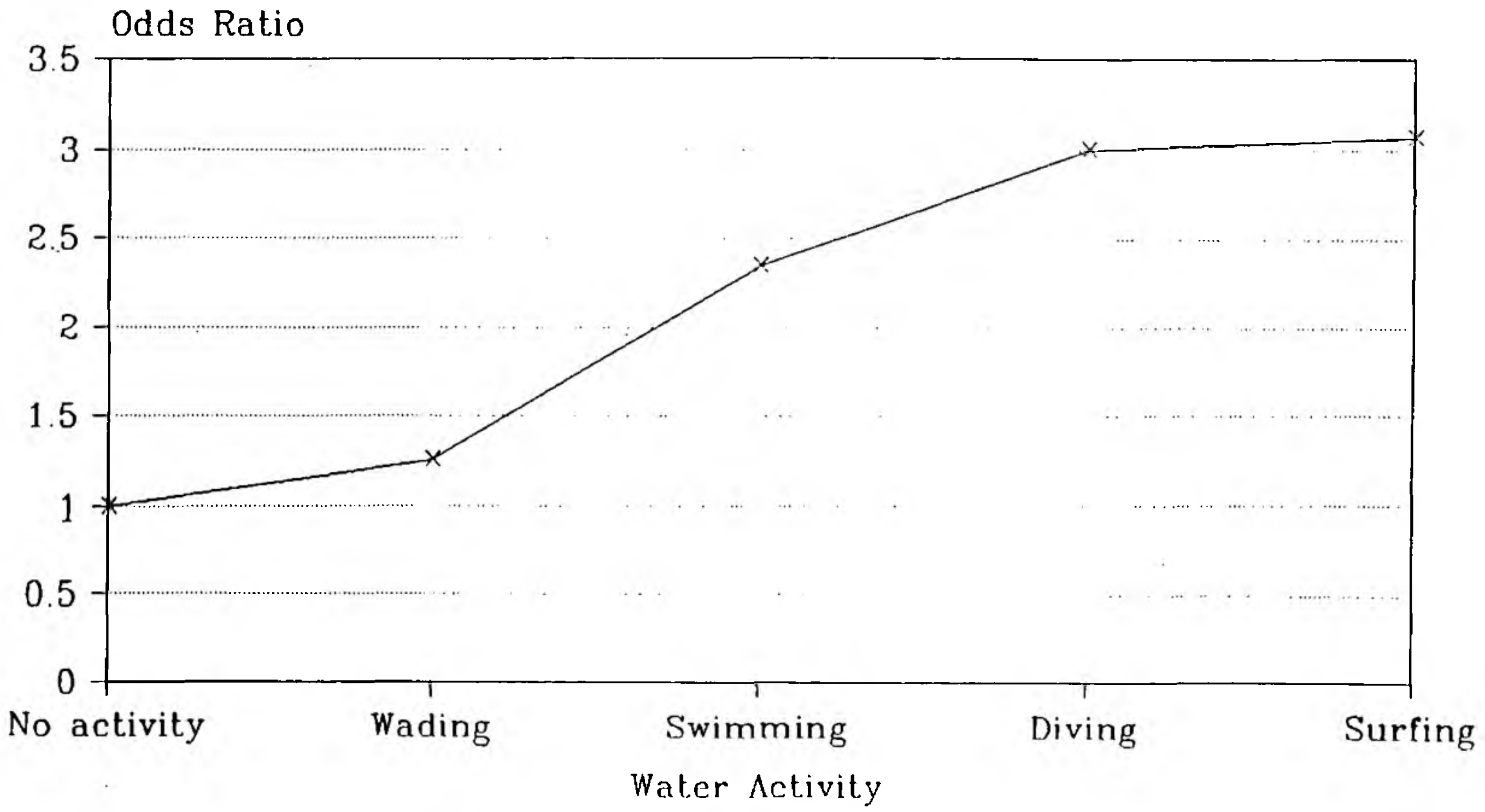
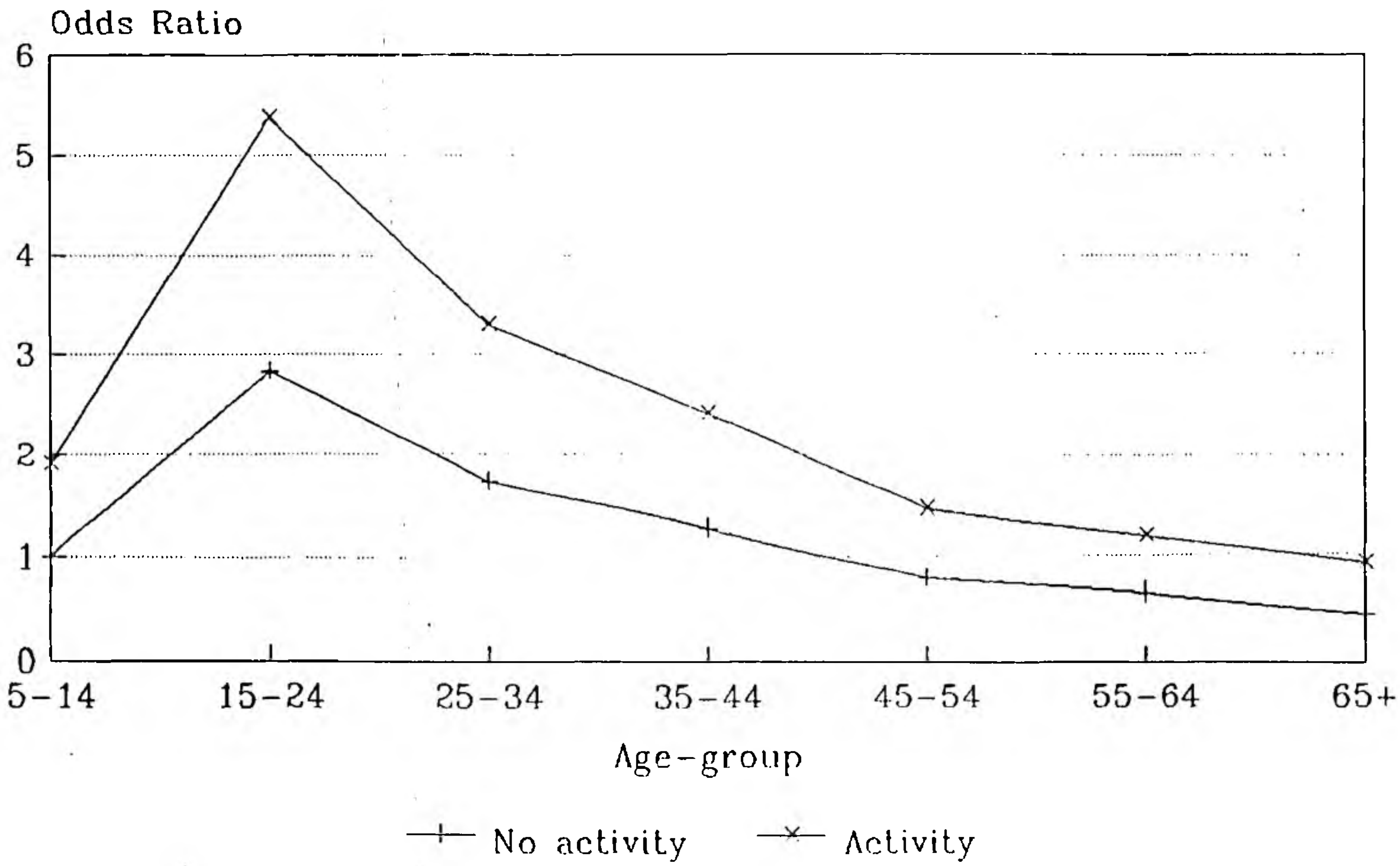


Figure 11
Major Symptoms
Odds Ratio For Each Age Group

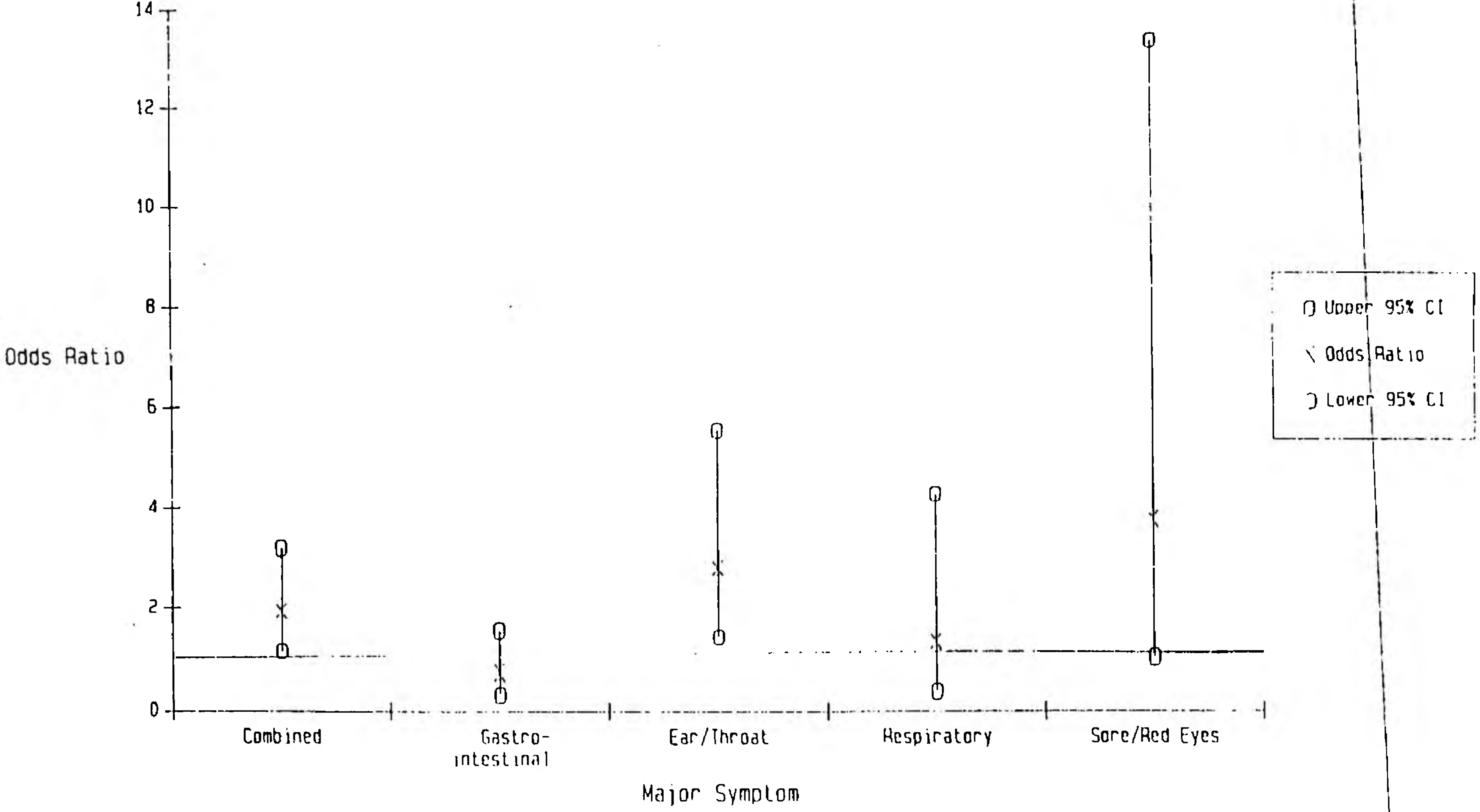


illness (OR 1.27), in subjects participating in water activities. The results did not show an excess of gastrointestinal tract illness among respondents entering the sea. An excess of more than 1.5 was unlikely from the findings of this study. Small numbers precluded the examination of a dose-relationship with individual illnesses relating to gastrointestinal, respiratory and other symptoms. These findings relating risk of symptoms to activity are presented graphically in Figure 12.

Comparisons with the Main Study Population

Levels of reported illness in the follow-up study are compared with those among subjects interviewed at the beach in Table 22. Reporting rates among the exposed for each of the symptom groups were consistently higher in the follow-up survey, being 50% higher for the category of major symptoms. A consistent pattern was evident between the follow-up sample and the total study population for the different types of symptoms. In both groups reporting levels among the exposed were highest for ear and throat symptoms, followed by gastrointestinal, eye, and respiratory symptoms. Levels of self-medication and consultation with a general practitioner among those participating in water activities were again higher in the follow-up group, with an increase of 53% and 27% respectively (Table 23).

Figure 12 Major Symptoms
Odds Ratios With 95% CI For Those Participating
In Water Activities



RESULTS: Microbiological Monitoring

Results of analyses for indicator bacteria are presented in Figures 13-21 and Tables 24 and 25. Figures 13-15 illustrate weekly geometric means for the three most important indicator bacteria, combining the results for all three sample sites. Figures 16-18 show the same data expressed as combined daily geometric means for all three sites. Figures 19-21 illustrate the distribution of thermotolerant coliform densities with respect to state of tide at the three separate sites (West, Central and East). Tables 24 and 25 summarise the daily and weekly geometric mean indicator densities respectively, together with the maxima and minima obtained for all three sites.

Results for the pathogens are summarised in Figures 22 and 23 and Table 26. Copies of certificates of analysis are included as an annex to this report.

It may be readily observed that the variation in microbiological quality observed at Langland Bay had both temporal and tidal dimensions. Typical daily ranges of bacterial indicator densities were 1 - 2 log orders of magnitude. Nevertheless, there was remarkable consistency in daily geometric means, particularly in weeks one, two, four and five. Results in the third week exhibited greater variability due to the impact of adverse weather conditions. Thus, at least for Langland Bay, it appears reasonable to accord a bacteriological indicator "score" to an individual day or week without accepting unreasonable ranges of bacteriological water quality. The data do tend to confirm that peak levels of indicator bacteria are obtained around high water, but again, the distribution is not so marked as to represent a major source of interference with the calculation of daily or weekly geometric mean scores.

As might be expected, the results of pathogen analysis did not provide such a consistent pattern, either on a daily or weekly basis. Results for the five sampling occasions were pooled for each of the three sites (arithmetic means being incorporated into graphical representations). However, it is clear that levels of both enteric virus and staphylococci were significant and thus subject to informed interpretation. In contrast, levels of parasites and salmonellae were low, in most cases verging on the limit of detection. Rotaviruses were detected in one-third and enteroviruses in 40% of all samples.

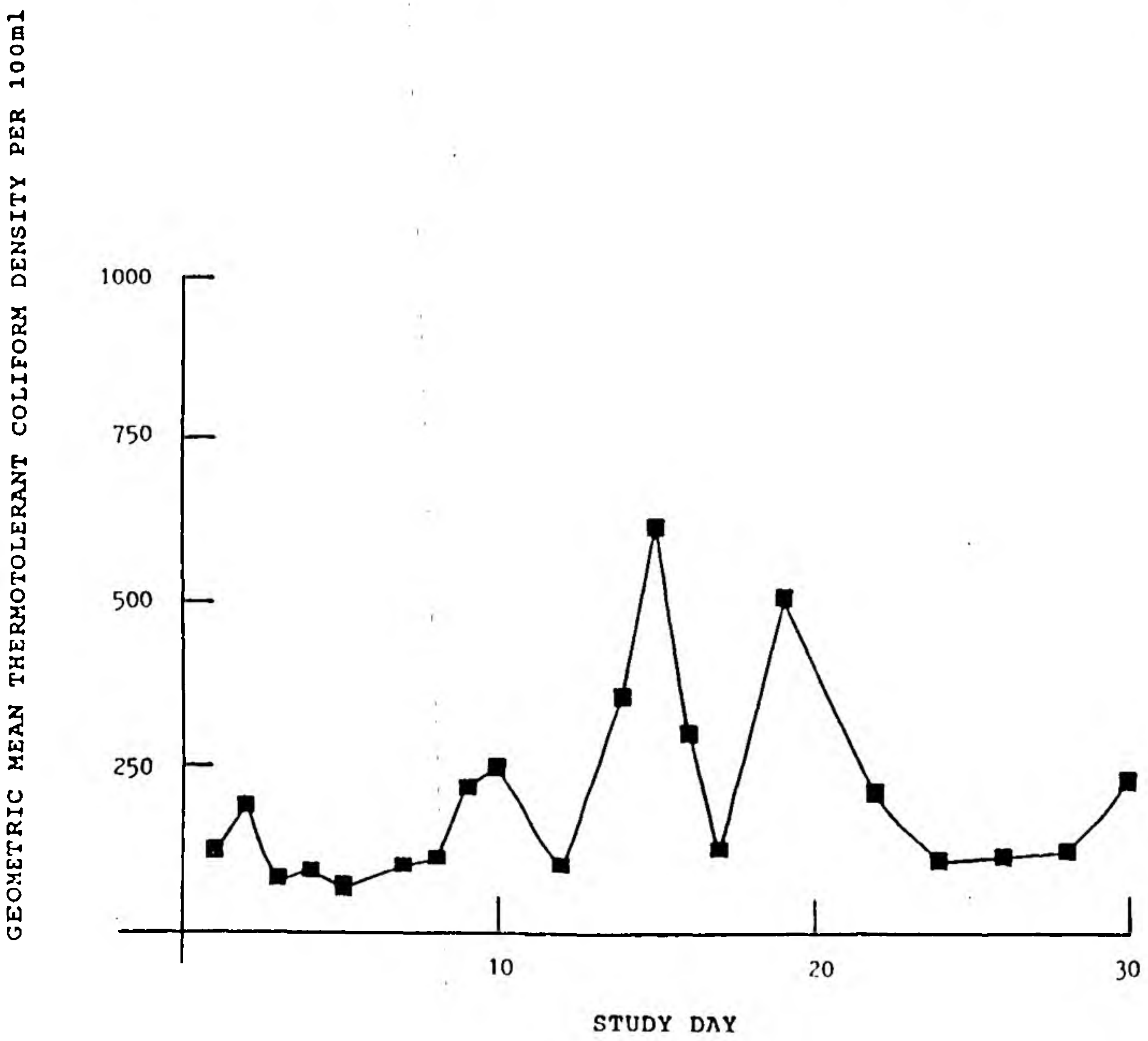


Figure 13 Geometric mean thermotolerant coliform densities by study day : combined results of three sample sites. Study day also corresponds to date in August 1989.

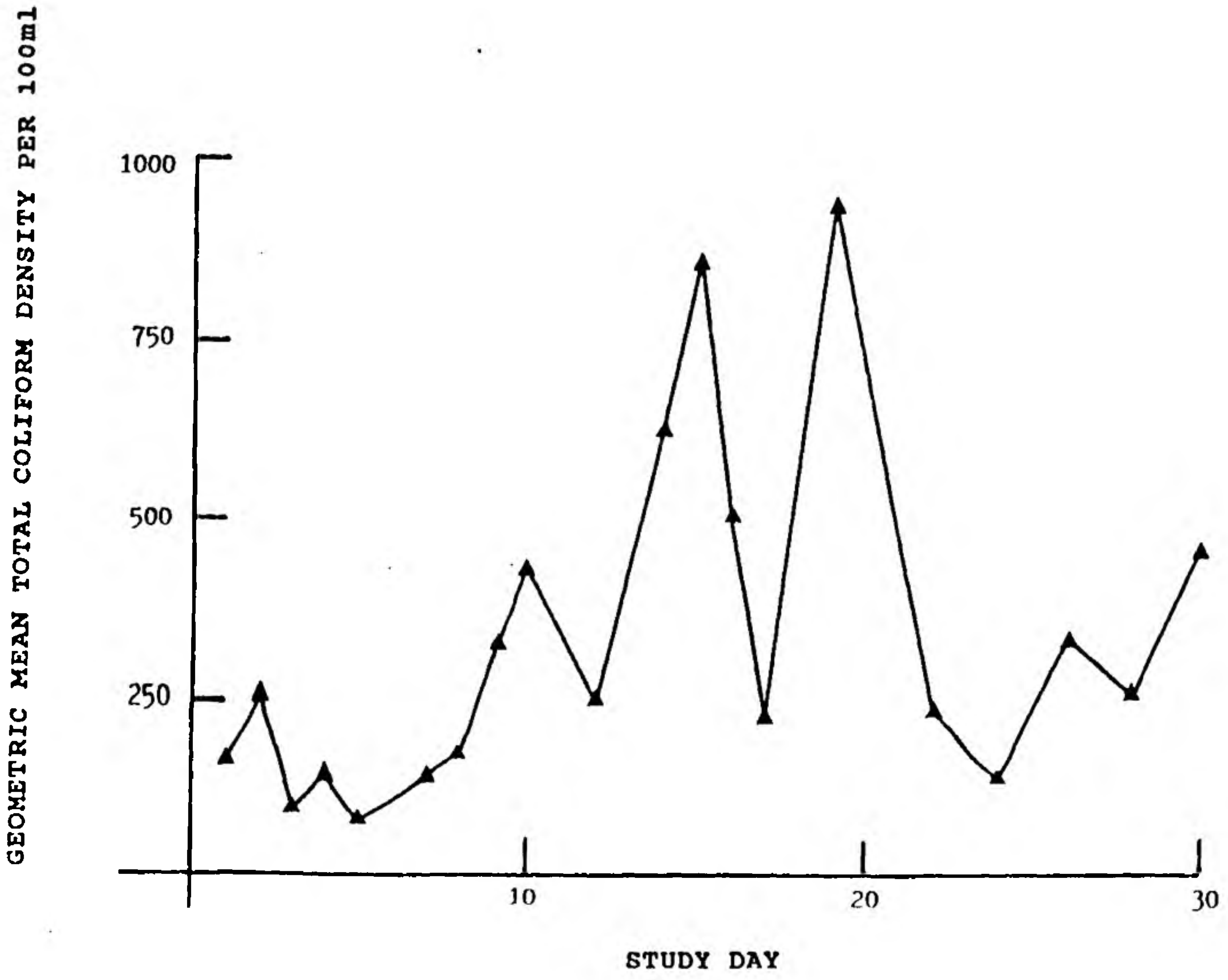


Figure 14 Geometric mean total coliform densities by study day : combined results of three sample sites. Study day also corresponds to date in August 1989.

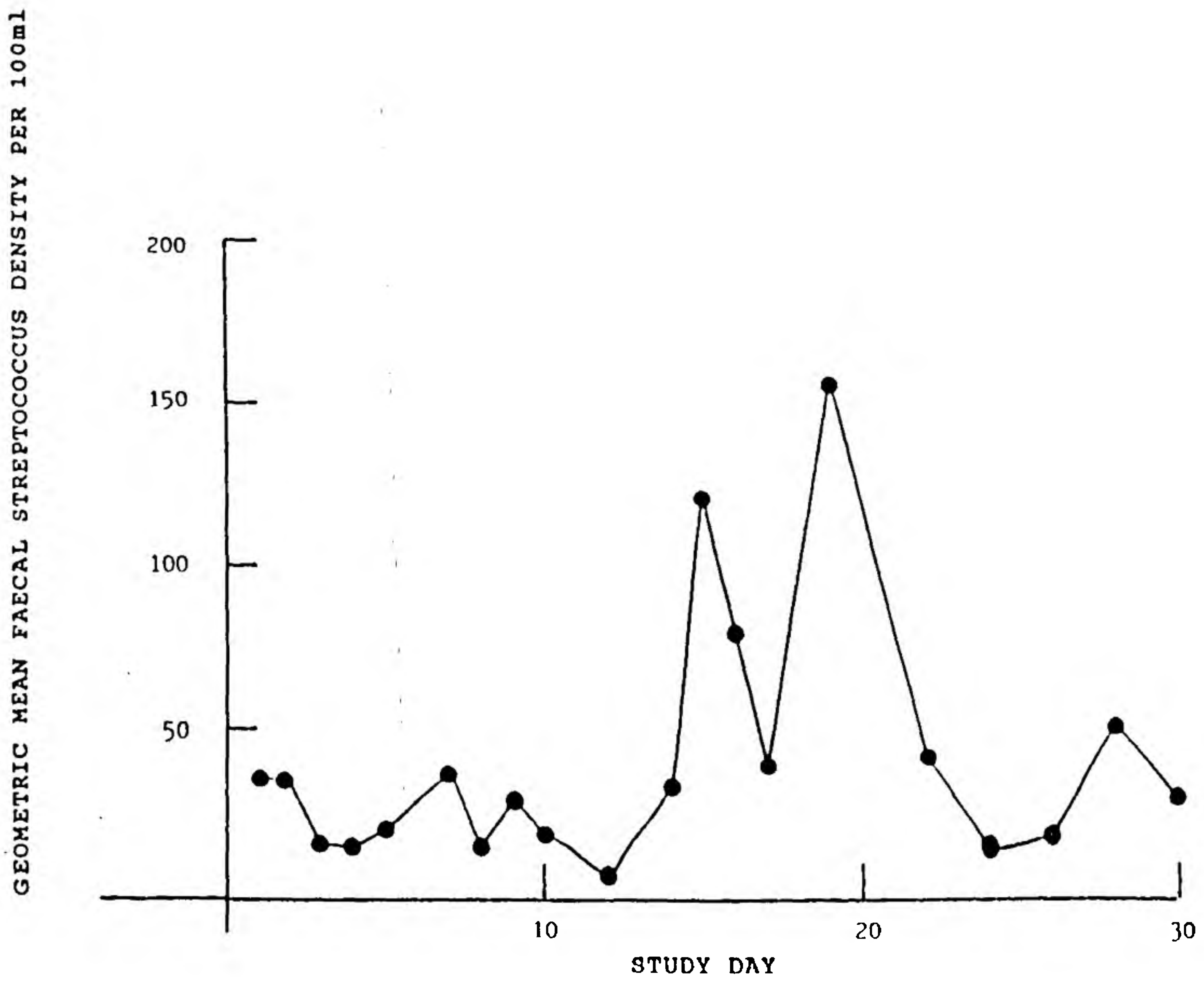


Figure 15 Geometric mean faecal streptococcus densities by study day : combined results of three sample sites. Study day also corresponds to date in August.

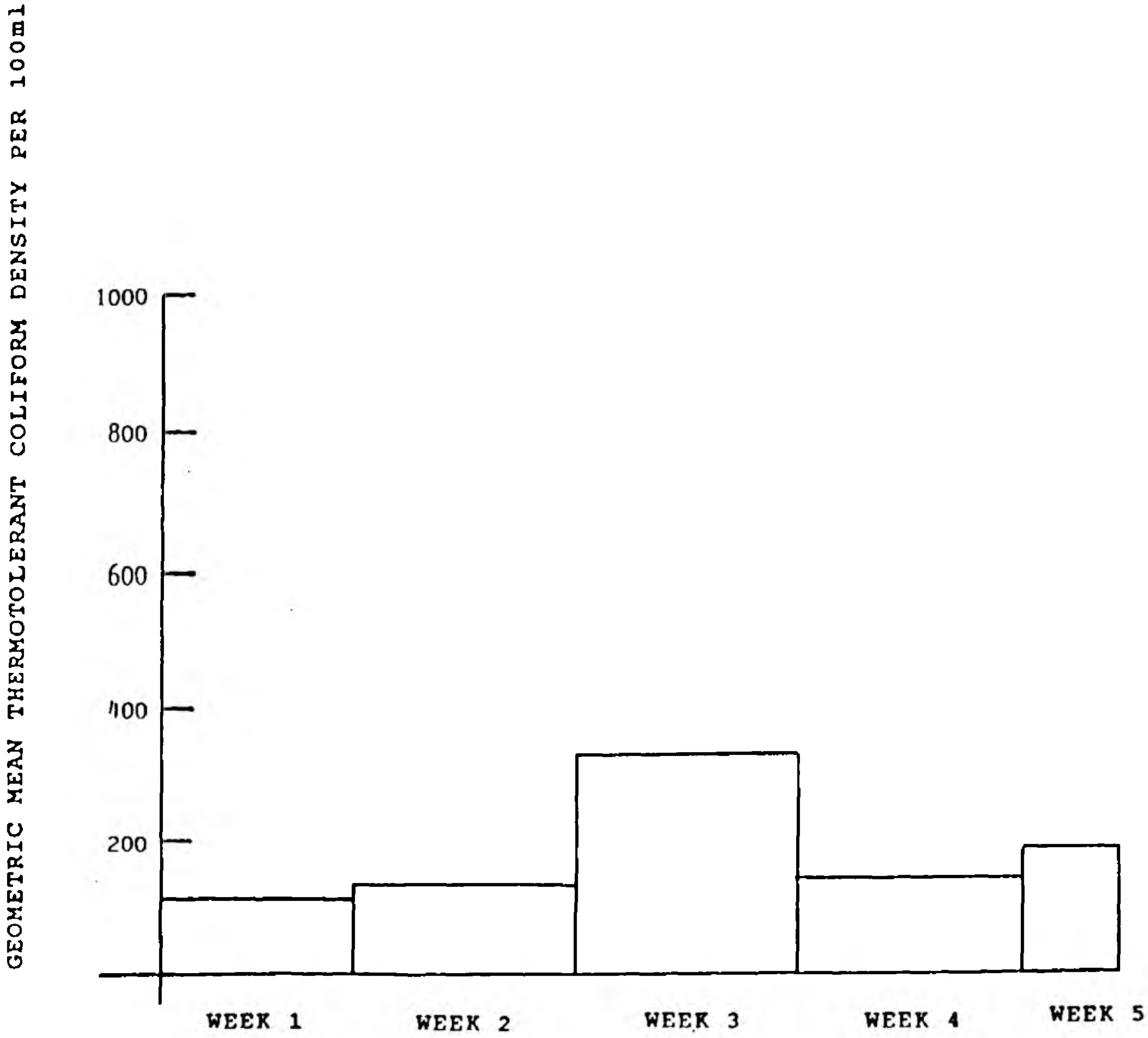


Figure 16 Geometric mean thermotolerant coliform densities by week : combined results of three sample sites.

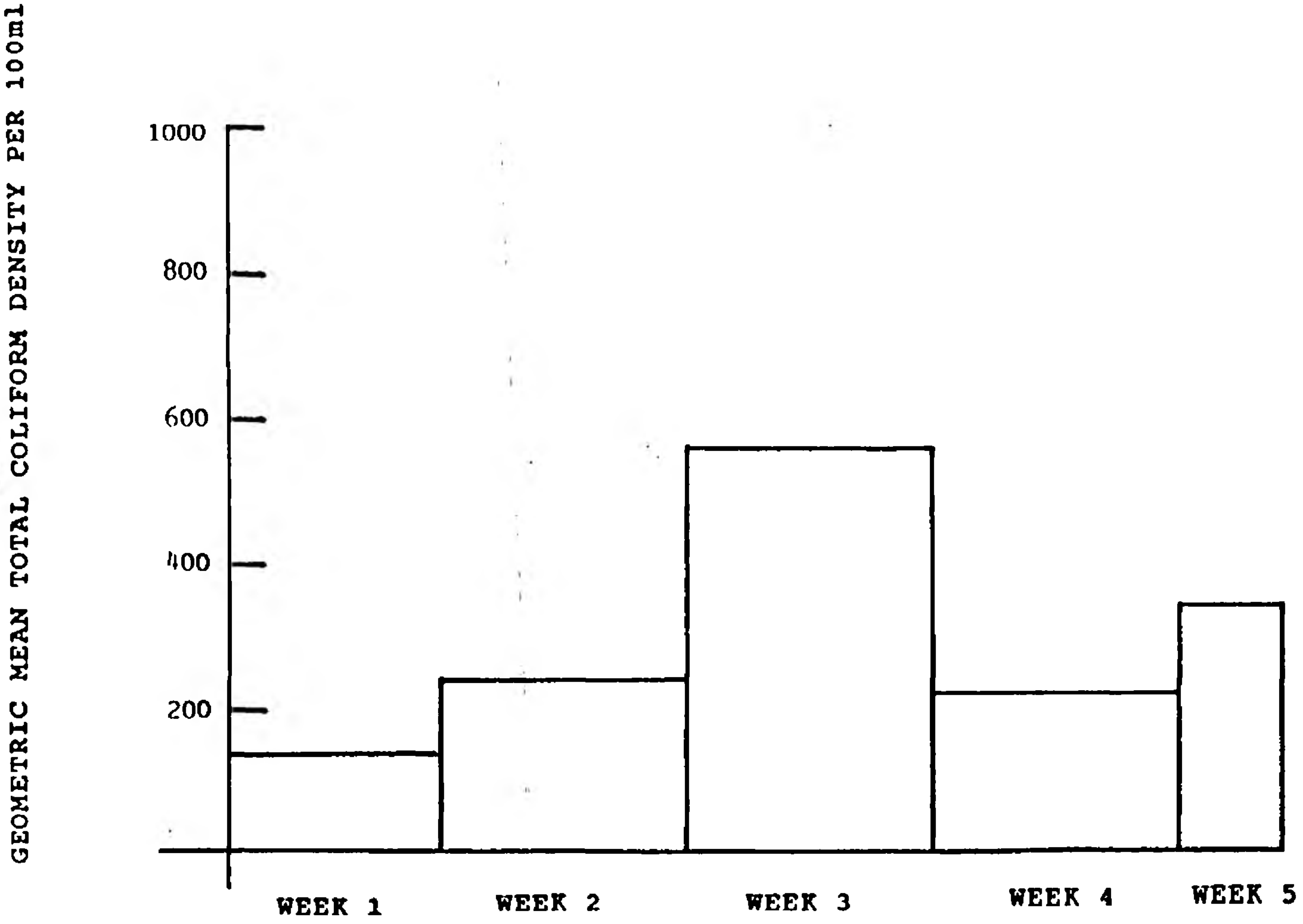


Figure 17 Geometric mean total coliform densities by week : combined results of three sample sites.

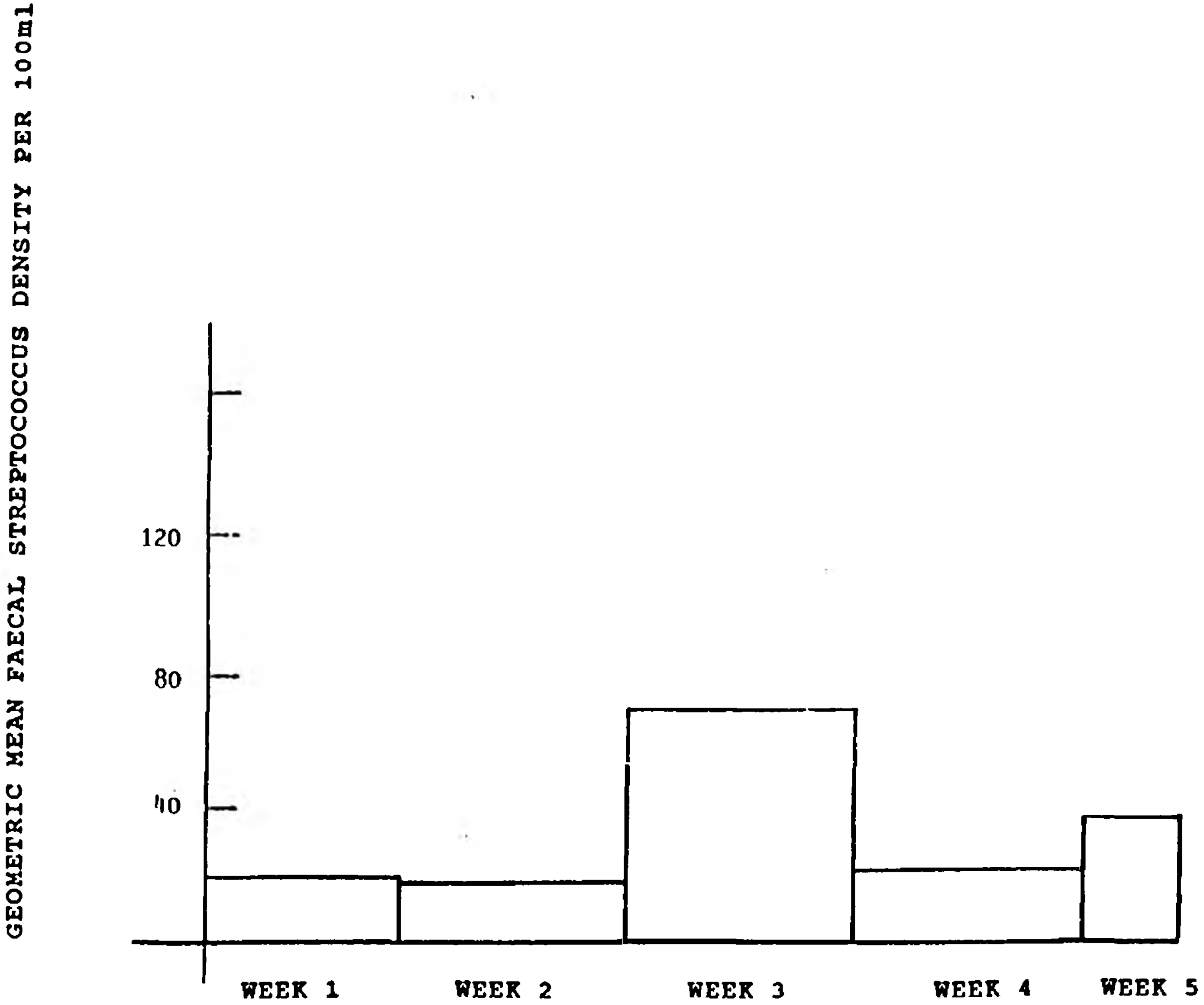


Figure 18 Geometric mean faecal streptococcus densities by week: combined results of three sample sites.

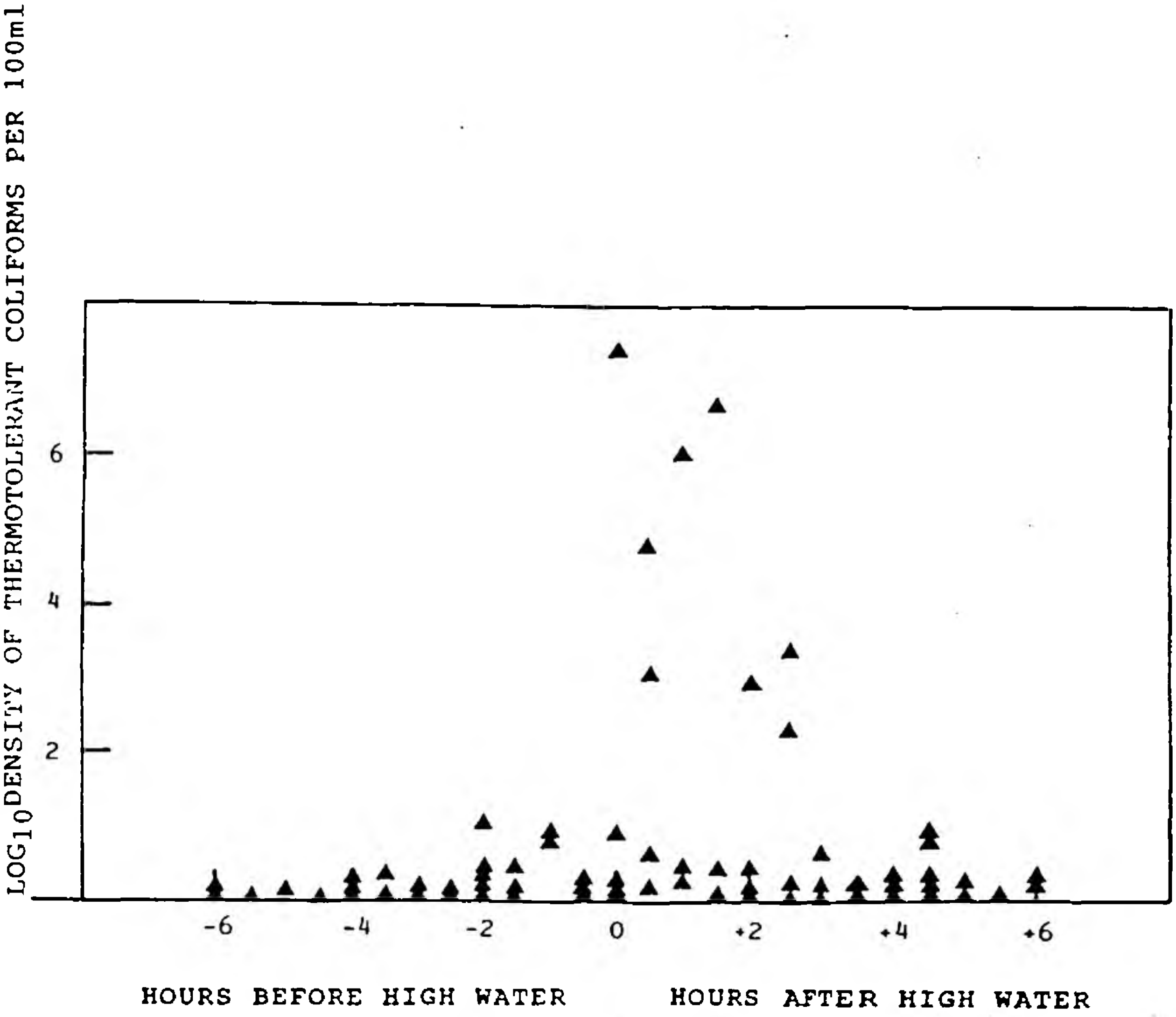


Figure 19 Distribution of thermotolerant coliform densities with respect to state of tide (hours ± high water) : sample site W (west).

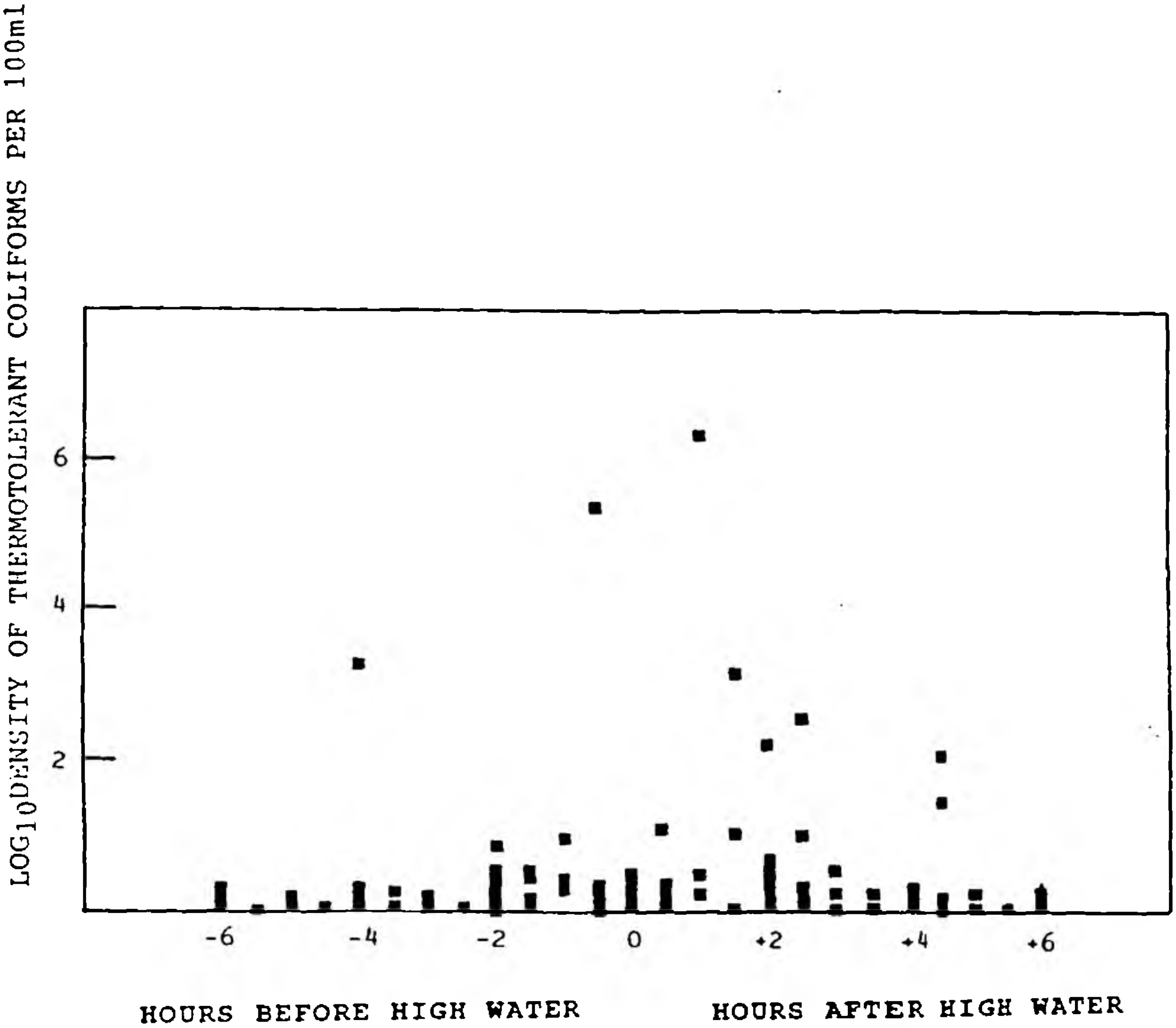


Figure 20 Distribution of thermotolerant coliform densities with respect to state of tide (hours ± high water) : sample site C (central).

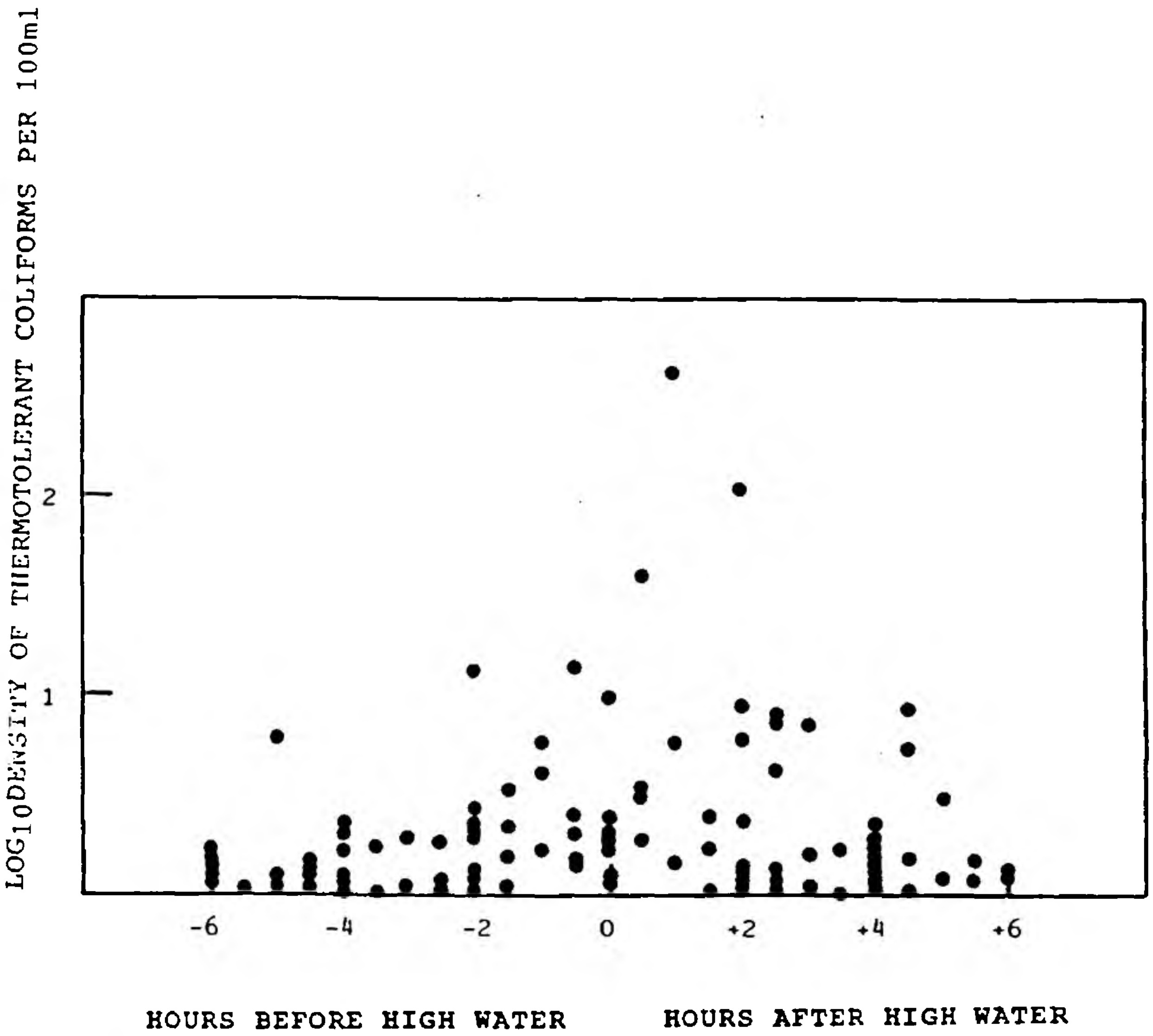


Figure 21 Distribution of thermotolerant coliform densities with respect to state of tide (hours ± high water) : sample site E (east).

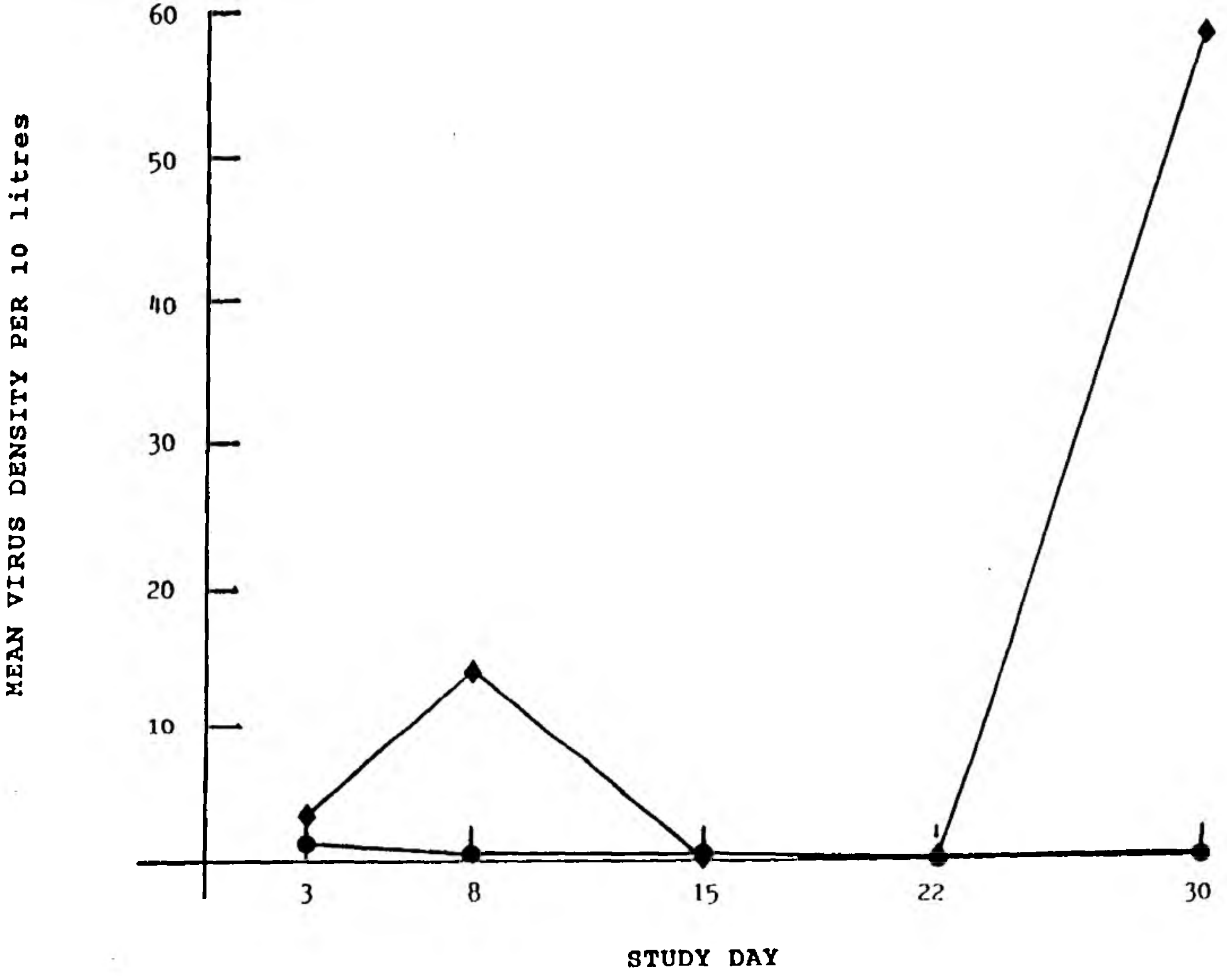


Figure 22 Arithmetic mean enterovirus pfu ( ) and rotavirus fffu ( ) densities for three sample sites on five occasions during study.

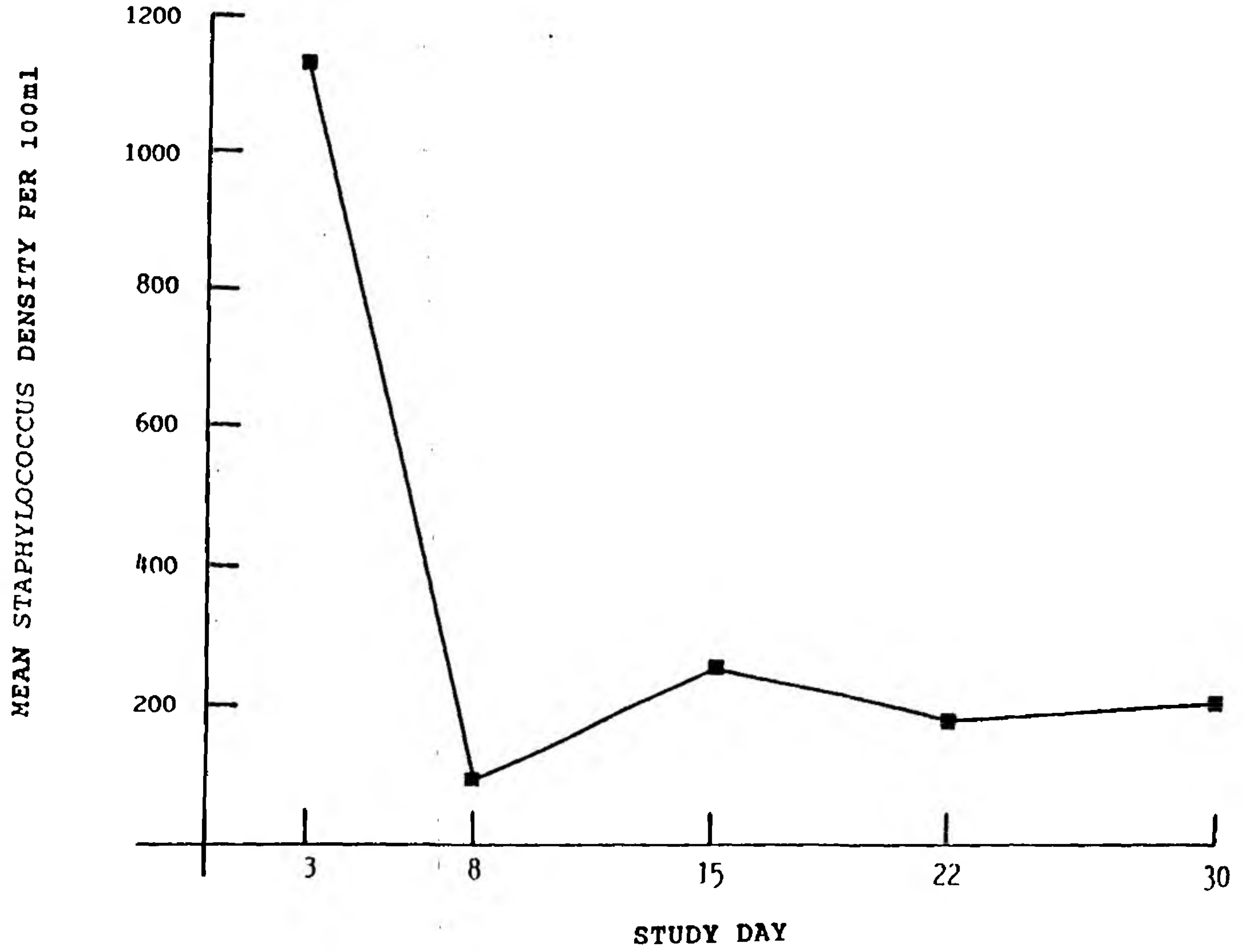


Figure 23 **Arithmetic mean total** Staphylococcus **densities for three sample sites on five occasions during study.**

CONCLUSION

The study showed that it is feasible to conduct a large interview survey at a beach resort with a successful telephone follow-up. The findings showed a significant excess of self-reported illness from an aggregate of major symptoms, and individually for eye and ear/throat symptoms. The numbers were too small to reveal any risks for gastrointestinal symptoms. Self-medication was marginally higher in subjects exposed to water. Risks increased with the type of water activity, and were particularly high for surfing, suggestive of a dose-response type of relationship, although this was restricted to all aggregated symptoms. The age-associated risk was highest in young people aged 15-24, a finding consistent with expectations. The reported level of illness is again consistent with studies conducted elsewhere.

The plausible findings with a good degree of internal consistency lend credibility to the study design. With a larger sample size it would be possible to relate levels of exposure to specific symptoms especially for gastrointestinal disease. The levels of illness would be related to the microbiological environment over a series of beaches selected for their varying levels of pollution.

In the light of our experience with this pilot study, we would alter the design to cover more beaches of varying quality, with a total follow-up at each beach. The instrument would be shorter, saving interview time, and the analysis conclusive based on the new estimations of sample sizes as determined by the results of the pilot study.

The pilot study gave an estimated OR of 0.69 for gastrointestinal tract illness in those who were exposed. However, the 95% confidence intervals of 0.31-1.53 based on 28 cases are consistent with a possible 50% increase. The overall proportion of beach users who reported gastrointestinal tract illness at telephone interview was 3.5%. Table 27 gives the total numbers of beach users required to detect an OR ranging from 1.1-1.5 with test size $\alpha = 0.05$, power $1-\beta = 0\text{-}90$ for values of the background prevalence of gastrointestinal tract illness varying from 0.01 to 0.05.

The preferred option would be to opt for 16,000 cases across ten beaches. If 1600 interviews were obtained for each of the ten beaches then, assuming the baseline prevalence of 3.5% and pooling the data, it should be possible to detect an OR of 1.25 with $\alpha = 0.05$ and $1-\beta = 0.90$. As ten morbidity measurements would be available from ten different beaches, it provides the opportunity to have ten points to test association with microbiological indicators. Beaches recruited to the study should cover the whole spectrum of beaches including those known to be of poor quality.

The cost of this option is shown in Table 28 along with the cost for studies to detect risks higher than 1.25, namely 1.3, 1.4 and 1.5. The recommended option would cost £356k and as the capacity to detect the excess moves from 1.25-1.5, the cost declines to £131k for detecting an excess of 1.5. The cheapest option would only detect a risk of 1.5 and would reduce the study to three beaches making available only three points for comparison with water quality.

The strengths and weaknesses of the two pilot studies are presented in Table 29. Based on the results of the pilot study, it would seem appropriate to take the follow-up study of bathers and non-bathers forward in preference to a trial.

In summary, with a larger follow-up study it is feasible to establish the relative risks of bathing in British seas, especially when reported illness levels are examined in association with microbiological assessment of the water.

RECOMMENDATIONS

A definitive study to be conducted in the summer of 1990 to establish the risks of bathing in British sea waters. The study design would include ten beaches selected for their varying water quality. In each beach 1600 individuals would be interviewed, giving a total study population of 16,000. All study subjects would be followed up by telephone for an assessment of health status, with corroborative evidence obtained for reported illness as far as possible. The study size should make it possible to detect a relative risk for gastrointestinal disease of 1.25 ($\alpha = 0.05$ and $1-\beta = 0.90$). This should also give ten points to test for association with the different microbiological measurements for the ten beaches.

The costs for the entire proposal would be £356k and it is feasible to carry out the study to completion in the summer of 1990 provided a decision is taken by mid April. If this is not possible then the study could be phased over two years, with five beaches surveyed in 1990 and a further five beaches surveyed in 1991, the cost being distributed over two financial years.

REFERENCES

Cabelli VJ, Dufour AP, McCabe LJ, Levin MA (1984). A marine recreational water quality criterion consistent with indicator concepts and risk analysis. Journal of the Water Pollution Control Federation 55, 1306-1314.

CEC (1976). Council Directive of 8 December 1975 concerning the quality of bathing water (76/160/EEC). Official Journal of the European Communities L31.

Dufour A P (1984). Bacterial indicators of recreational water quality. Canadian Journal of Public Health 75, 49-56.

Jones F, Kay D, Stanwell-Smith R and Barrow G I (1988). Research Proposal and Strategy on Coastal Bathing Related Disease Incidence. A Prospective Epidemiological Pilot Survey. Warrington : Altwell Ltd.

Rao V C and Melnick J L (1986). Environmental Virology. Wokingham : Van Nostrand Reinhold.

Watershed 89 Declaration. In : Watershed 89 - The Future for Water Quality in Europe (eds Wheeler D, Richardson M L and Bridges J). Volumes I & II. Oxford: Pergamon.

Wheeler D (1990). Pollution of Beaches by Viruses. Memorandum to the House of Commons Select Committee on the Environment Inquiry on Pollution of Beaches. London : HMSO (forthcoming).

World Health Organization/United Nations Environment Programme (1977). Health Criteria and Epidemiological Studies Related to Coastal Water Pollution. Nairobi : UNEP.

World Health Organization/United Nations Environment Programme (1986). Correlation between Coastal Water Quality and Health Effects. Long-term Programme for Pollution Monitoring and Research in the Mediterranean Sea (MEDPOL Phase II). Nairobi : UNEP.

TABLE 1

AGE BY SEX

	AGE (Years)							
SEX	5-14	15-24	25-34	35-44	45-54	55-64	65 +	TOTAL
Male	458	327	274	424	233	142	70	1928
Female	449	262	406	505	213	200	70	2105
TOTAL	907 (22.5)	589 (14.6)	680 (16.9)	929 (23.0)	446 (11.1)	342 (8.5)	140 (3.5)	4033 (100)

Percentages in parentheses

TABLE 2

AGE BY SEX (FOLLOW-UP STUDY)

	AGE (Years)							
SEX	5-14	15-24	25-34	35-44	45-54	55-64	65 +	TOTAL
Male	80	46	44	77	47	24	20	338
Female	98	48	79	125	47	42	12	451
TOTAL	178 (22.6)	94 (11.9)	123 (15.6)	202 (25.6)	94 (11.9)	66 (8.4)	32 (4.1)	789 (100)

Percentages in parentheses

TABLE 3

TYPE OF RESPONDENT BY AGE

	AGE (Years)							
TYPE OF RESPONDENT	5-14	15-24	25-34	35-44	45-54	55-64	65 +	TOTAL
Holidaymakers	639 (70.5)	370 (62.8)	471 (69.3)	695 (74.8)	347 (77.8)	225 (65.8)	79 (56.4)	2826 (70.1)
Locals	268 (29.5)	219 (37.2)	209 (30.7)	234 (25.2)	99 (22.2)	117 (34.2)	61 (43.6)	1207 (29.9)
TOTAL	907 (100)	589 (100)	680 (100)	929 (100)	446 (100)	342 (100)	140 (100)	4033 (100)

Percentages in parentheses

TABLE 4

TYPE OF RESPONDENT BY AGE (FOLLOW-UP STUDY)

	AGE (Years)							
TYPE OF RESPONDENT	5-14	15-24	25-34	35-44	45-54	55-64	65 +	TOTAL
Holidaymakers	139 (78.1)	58 (61.7)	91 (74.0)	156 (77.2)	78 (83.0)	48 (72.7)	17 (53.1)	587 (74.4)
Locals	39 (21.9)	36 (38.3)	32 (26.0)	46 (22.8)	16 (17.0)	18 (27.3)	15 (46.9)	202 (25.6)
TOTAL	178 (100)	94 (100)	123 (100)	202 (100)	94 (100)	66 (100)	32 (100)	789 (100)

Percentages in parentheses

TABLE 5

TYPE OF RESPONDENT BY TYPE OF ACTIVITY

	ACTIVITY						
TYPE OF RESPONDENT	Surfing	Diving	Swimming	Wading	Activities	No Activities	Total
Holidaymakers	70 (38.7)	84 (73.0)	525 (66.7)	657 (78.2)	1336 (69.5)	1493 (70.4)	2829 (69.9)
Locals	111 (61.3)	31 (27.0)	262 (33.3)	183 (21.8)	587 (30.5)	629 (29.6)	1216 (30.1)
TOTAL	181 (100)	115 (100)	787 (100)	840 (100)	1923 (100)	2122 (100)	4045 (100)

Percentages in parentheses

TABLE 6

TYPE OF RESPONDENT BY TYPE OF ACTIVITY (FOLLOW-UP STUDY)

	ACTIVITY						
TYPE OF RESPONDENT	Surfing	Diving	Swimming	Wading	Activities	No Activities	Total
Holidaymakers	16 (48.5)	21 (95.5)	115 (74.7)	127 (75.6)	279 (74.0)	309 (74.8)	588 (74.4)
Locals	17 (51.5)	1 (4.5)	39 (25.3)	41 (24.4)	98 (26.0)	104 (25.2)	202 (25.6)
TOTAL	33 (100)	22 (100)	154 (100)	168 (100)	377 (100)	413 (100)	790 (100)

Percentages in parentheses

TABLE 7

MAJOR SYMPTOMS BY AGE BY ACTIVITY (FOLLOW-UP STUDY)

MAJOR SYMPTOMS	AGE (Years)							
ACTIVITIES	5-14	15-24	25-34	35-44	45-54	55-64	65 +	TOTAL
YES	12 (9.5)	9 (20.9)	10 (16.9)	12 (14.1)	2 (6.3)	1 (4.2)	-	46 (12.2)
NO	114 (90.5)	34 (79.1)	49 (83.1)	73 (85.9)	30 (93.8)	23 (95.8)	8 (100)	331 (87.8)
TOTAL	126 (100)	43 (100)	59 (100)	85 (100)	32 (100)	24 (100)	8 (100)	377 (100)
NO ACTIVITIES	5-14	15-24	25-34	35-44	45-54	55-64	65 +	TOTAL
YES	3 (5.8)	8 (15.7)	5 (7.8)	6 (5.1)	3 (4.8)	2 (4.8)	1 (4.2)	28 (6.8)
NO	49 (94.2)	43 (84.3)	59 (92.2)	111 (94.9)	59 (95.2)	40 (95.2)	23 (95.8)	384 (93.2)
TOTAL	52 (100)	51 (100)	64 (100)	117 (100)	62 (100)	42 (100)	24 (100)	412 (100)

Percentages in parentheses

TABLE 8

MAJOR SYMPTOMS BY AGE BY ACTIVITY

MAJOR SYMPTOMS	AGE (Years)							
ACTIVITIES	5-14	15-24	25-34	35-44	45-54	55-64	65 +	TOTAL
YES	51 (8.0)	36 (13.3)	29 (8.9)	26 (6.4)	4 (2.9)	7 (6.7)	1 (2.9)	154 (8.0)
NO	585 (92.0)	235 (86.7)	296 (91.1)	383 (93.6)	132 (97.1)	98 (93.3)	33 (97.1)	1762 (92.0)
TOTAL	636 (100)	271 (100)	325 (100)	409 (100)	136 (100)	105 (100)	34 (100)	1916 (100)
NO ACTIVITIES	5-14	15-24	25-34	35-44	45-54	55-64	65 +	TOTAL
YES	6 (2.2)	31 (9.7)	13 (3.7)	20 (3.8)	10 (3.2)	5 (2.1)	2 (1.9)	87 (4.1)
NO	265 (97.8)	287 (90.3)	342 (96.3)	500 (96.2)	300 (96.8)	232 (97.9)	104 (98.1)	2030 (95.9)
TOTAL	271 (100)	318 (100)	355 (100)	520 (100)	310 (100)	237 (100)	106 (100)	2117 (100)

Percentages in parentheses

TABLE 9

TYPE OF ACTIVITY BY 'MAJOR' SYMPTOMS (FOLLOW-UP STUDY)

	MAJOR SYMPTOMS		
ACTIVITY	YES	NO	TOTAL
Surfing	6 (18.2)	27 (81.8)	33 (100)
Diving	4 (18.2)	18 (81.8)	22 (100)
Swimming	22 (14.3)	132 (85.7)	154 (100)
Wading	14 (8.3)	154 (91.7)	168 (100)
Activities	46 (12.2)	331 (87.8)	377 (100)
No Activities	28 (6.8)	385 (93.2)	413 (100)
TOTAL	74 (9.4)	716 (90.6)	790 (100)

Percentages in parentheses

TABLE 10

TYPE OF ACTIVITY BY GASTROINTESTINAL SYMPTOMS (FOLLOW-UP STUDY)

	GASTROINTESTINAL SYMPTOMS		
ACTIVITY	YES	NO	TOTAL
Surfing	-	33 (100)	33 (100)
Diving	1 (4.5)	21 (95.5)	22 (100)
Swimming	5 (3.2)	149 (96.8)	154 (100)
Wading	6 (3.6)	162 (96.4)	168 (100)
Activities	12 (3.2)	365 (96.8)	377 (100)
No Activities	16 (3.9)	397 (96.1)	413 (100)
TOTAL	28 (3.5)	762 (96.5)	790 (100)

Percentages in parentheses

TABLE 11

TYPE OF ACTIVITY BY EAR/THROAT SYMPTOMS (FOLLOW-UP STUDY)

	EAR/ THROAT SYMPTOMS		
ACTIVITY	YES	NO	TOTAL
Surfing	6 (18.2)	27 (81.8)	33 (100)
Diving	3 (13.6)	19 (86.4)	22 (100)
Swimming	12 (7.8)	142 (92.2)	154 (100)
Wading	8 (4.8)	160 (95.2)	168 (100)
Activities	29 (7.7)	348 (92.3)	377 (100)
No Activities	13 (3.1)	400 (96.9)	413 (100)
TOTAL	42 (5.3)	748 (94.7)	790 (100)

Percentages in parentheses

TABLE 12

TYPE OF ACTIVITY BY RESPIRATORY SYMPTOMS (FOLLOW-UP STUDY)

	RESPIRATORY SYMPTOMS		
ACTIVITY	YES	NO	TOTAL
Surfing	-	33 (100)	33 (100)
Diving	-	22 (100)	22 (100)
Swimming	6 (3.9)	148 (96.1)	154 (100)
Wading	1 (0.6)	167 (99.4)	168 (100)
Activities	7 (1.9)	370 (98.1)	377 (100)
No Activities	5 (1.2)	408 (98.8)	413 (100)
TOTAL	12 (1.5)	778 (98.5)	790 (100)

Percentages in parentheses

TABLE 13

TYPE OF ACTIVITY BY SORE/RED EYES (FOLLOW-UP STUDY)

	SORE/RED EYES		
ACTIVITY	YES	NO	TOTAL
Surfing	2 (6.1)	31 (93.9)	33 (100)
Diving	1 (4.5)	21 (95.5)	22 (100)
Swimming	6 (3.9)	148 (96.1)	154 (100)
Wading	2 (1.2)	166 (98.8)	168 (100)
Activities	11 (2.9)	366 (97.1)	377 (100)
No Activities	3 (0.7)	410 (99.3)	413 (100)
TOTAL	14 (1.8)	776 (98.2)	790 (100)

Percentages in parentheses

TABLE 14

TYPE OF ACTIVITY AND SELF-MEDICATION (FOLLOW-UP STUDY)

	SELF -MEDICATION		
ACTIVITY	YES	NO	TOTAL
Surfing	7 (21.2)	26 (78.8)	33 (100)
Diving	2 (9.1)	20 (90.9)	22 (100)
Swimming	19 (12.3)	135 (87.7)	154 (100)
Wading	18 (10.7)	150 (89.3)	168 (100)
Activities	46 (12.2)	331 (87.8)	377 (100)
No Activities	39 (9.4)	374 (90.6)	413 (100)
TOTAL	85 (10.8)	705 (89.2)	790 (100)

Percentages in parentheses

TABLE 15

TYPE OF ACTIVITY AND CONSULTING A DOCTOR (FOLLOW-UP STUDY)

	CONSULT A DOCTOR		
ACTIVITY	YES	NO	TOTAL
Surfing	-	33 (100)	33 (100)
Diving	1 (4.5)	21 (95.5)	22 (100)
Swimming	2 (1.3)	152 (98.7))	154 (100)
Wading	4 (2.4)	164 (97.6)	168 (100)
Activities	7 (1.9)	370 (98.1)	377 (100)
No Activities	7 (1.7)	406 (98.3)	413 (100)
TOTAL	14 (1.8)	776 (98.2)	790 (100)

Percentages in parentheses

TABLE 16

LOGISTIC REGRESSION ANALYSIS USING DICHOTOMISED EXPOSURE AND AGE AND SEX FOR MAJOR SYMPTOMS

VARIABLE		ESTIMATE	S.E	OR	95% CI
EXPOSURE	**No Water Activities**	**0.00**		**1.00**	
	Water Activities	**0.64**	**0.26**	**1.90**	**1.14 - 3.17**
CONSTANT		-2.88	0.37		
SEX	Male	0.00		1.00	
	Female	0.00	0.25	1.00	0.61 - 1.64
AGE	5 - 14	0.00		1.00	
	15 - 24	1.04	0.39	2.82	1.32 - 6.03
	25 - 34	0.55	0.39	1.73	0.80 - 3.72
	35 - 44	0.24	0.37	1.27	0.61 - 2.64
	45 - 54	-0.27	0.54	0.77	0.27 - 2.21
	55 - 64	-0.45	0.65	0.64	0.18 - 2.29
	65 +	-0.76	1.03	0.47	0.06 - 3.54

TABLE 17

LOGISTIC REGRESSION ANALYSIS INCLUDING ACTUAL EXPOSURE AND AGE AND SEX, ILLUSTRATING THE "DOSE RESPONSE" RELATIONSHIP FOR MAJOR SYMPTOMS

VARIABLE		ESTIMATE	S.E	OR	95% CI
EXPOSURE	**No Water Activities**	**0.00**		**1.00**	
	Wading	**0.23**	**0.35**	**1.26**	**0.64 - 2.49**
	Swimming	**0.85**	**0.31**	**2.34**	**1.27 - 4.32**
	Diving	**1.10**	**0.60**	**3.00**	**0.92 - 9.73**
	Surfing	**1.12**	**0.51**	**3.07**	**1.13 - 8.35**
CONSTANT		-2.98	0.38		
SEX	Male	0.00		1.00	-
	Female	0.10	0.26	1.11	0.67 - 1.84
AGE	5 - 14	0.00		1.00	
	15 - 24	1.01	0.39	2.75	1.28 - 5.91
	25 - 34	0.63	0.40	1.88	0.87 - 4.10
	35 - 44	0.30	0.38	1.36	0.65 - 2.84
	45 - 54	-0.20	0.54	0.82	0.28 - 2.37
	55 - 64	-0.41	0.65	0.66	0.18 - 2.38
	65 +	-0.72	1.03	0.49	0.06 - 3.66

TABLE 18

LOGISTIC REGRESSION ANALYSIS USING DICHOTOMISED EXPOSURE AND AGE AND SEX FOR GASTROINTESTINAL SYMPTOMS

VARIABLE		ESTIMATE	S.E	OR	95% CI
EXPOSURE	**No Water Activities**	**0.00**		**1.00**	
	Water Activities	**-0.37**	**0.41**	**0.69**	**0.31 - 1.53**
CONSTANT		-3.97	0.61		
SEX	Male	0.00		1.00	
	Female	-0.29	0.39	0.75	0.35 - 1.60
AGE	5 - 14	0.94	0.64	2.56	0.73 - 8.95
	15 - 24	1.37	0.64	3.95	1.13 - 13.85
	25 - 44	0.35	0.61	1.42	0.43 - 4.69
	45 +	0.00		1.00	

TABLE 19

LOGISTIC REGRESSION ANALYSIS USING DICHOTOMISED EXPOSURE AND AGE AND SEX FOR EAR/THROAT SYMPTOMS

VARIABLE		ESTIMATE	S.E	OR	95% CI
EXPOSURE	No Water Activities	0.00		1.00	
	Water Activities	1.02	0.35	2.77	1.40 - 5.50
CONSTANT		-3.02			
SEX	Male	0.00		1.00	
	Female	-0.09	0.33	0.92	0.48 - 1.74
AGE	5 - 14	-0.82	0.62	0.92	0.27 - 3.13
	15 - 24	1.38	0.57	3.98	1.31 - 12.08
	25 - 34	0.85	0.51	2.35	0.86 - 6.38
	35 - 44	0.00		1.00	

TABLE 20

LOGISTIC REGRESSION ANALYSIS USING DICHOTOMISED EXPOSURE AND AGE AND SEX FOR RESPIRATORY SYMPTOMS

VARIABLE		ESTIMATE	S.E	OR	95% CI
EXPOSURE	No Water Activities	0.00		1.00	
	Water Activities	0.24	0.61	1.27	0.38 - 4.22
CONSTANT		-4.92	0.72		
SEX	Male	0.00		1.00	
	Female	-0.16	0.59	0.85	0.27 - 2.70
AGE	5 - 14	1.29	0.78	3.65	0.79 - 16.90
	15 - 24	2.24	0.73	9.38	2.23 - 39.51
	25 +	0.00		1.00	

TABLE 21

LOGISTIC REGRESSION ANALYSIS USING DICHOTOMISED EXPOSURE AND AGE AND SEX FOR SORE/RED EYES

VARIABLE		ESTIMATE	S.E	OR	95% CI
EXPOSURE	No Water Activities	0.00		1.00	
	Water Activities	1.31	0.65	3.71	1.03 - 13.35
CONSTANT		-6.06	1.11		
SEX	Male	0.00		1.00	
	Female	0.32	0.56	1.37	0.45 - 4.14
AGE	5 - 44	1.18	1.02	3.26	0.44 - 24.00
	45 +	0.00		1.00	

TABLE 22

COMPARISON OF REPORTED INCIDENCE BETWEEN FOLLOW-UP STUDY AND BEACH INTERVIEW

MAJOR SYMPTOMS					GASTROINTESTINAL SYMPTOMS				
	Follow-up		Beach			Follow-up		Beach	
	%	n	%	n		%	n	%	n
Activities	12.2	(46)	8.1	(155)	Activities	3.2	(12)	2.2	(43)
No Activities	6.8	(28)	4.1	(87)	No Activities	3.9	(16)	1.7	(37)

RESPIRATORY SYMPTOMS					SORE/RED EYES				
	Follow-up		Beach			Follow-up		Beach	
	%	n	%	n		%	n	%	n
Activities	1.9	(7)	1.8	(34)	Activities	2.9	(11)	2.4	(47)
No Activities	1.2	(5)	0.8	(16)	No Activities	0.7	(3)	0.7	(15)

EAR/THROAT SYMPTOMS				
	Follow-up		Beach	
	%	n	%	n
Activities	7.7	(29)	4.3	(82)
No Activities	3.1	(13)	2.1	(44)

TABLE 23

COMPARISON BETWEEN FOLLOW-UP STUDY AND BEACH INTERVIEW IN REPORTED SELF-MEDICATION AND CONSULTATION WITH A GENERAL PRACTITIONER

SELF- MEDICATION			CONSULTATION WITH A GENERAL PRACTITIONER		
	Follow-up % n	Beach % n		Follow-up % n	Beach % n
Activities	12.2 (46)	8.0 (153)	Activities	1.9 (7)	1.5 (28)
No Activities	9.4 (39)	4.3 (92)	No Activities	1.7 (7)	1.0 (21)

TABLE 24

WEEKLY GEOMETRIC MEANS, MAXIMA AND MINIMA FOR BACTERIAL INDICATORS: COMBINED RESULTS OF THREE SAMPLE SITES. RESULTS EXPRESSED IN CFU PER 100ml. [NB FAECAL COLIFORMS = THERMOTOLERANT COLIFORMS].

	FAECAL COLIFORMS			TOTAL COLIFORMS			FAECAL STREPTOCOCCI		
WEEK	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
1	111	950	< 10	136	7200	< 10	20	752	< 2
2	132	5350	< 10	240	5350	20	18	2354	< 2
3	331	7420	10	555	11400	20	70	1680	2
4	142	870	< 10	218	2720	40	21	392	2
5	187	6660	< 10	335	6780	30	37	3192	2

TABLE 25

DAILY GEOMETRIC MEANS, MAXIMA AND MINIMA FOR BACTERIAL INDICATORS: COMBINED RESULTS OF THREE SAMPLE SITES. RESULTS EXPRESSED IN CFU PER 100ml. DAYS OF STUDY ALSO CORRESPOND TO DATES IN AUGUST 1989. [NB FAECAL COLIFORMS = THERMOTOLERANT COLIFORMS].

	FAECAL COLIFORMS			TOTAL COLIFORMS			FAECAL STREPTOCOCCI		
STUDY DAY	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
1	119	950	30	160	950	30	35	752	< 2
2	192	780	< 10	255	7200	20	34	248	< 2
3	68	300	< 10	97	580	< 10	15	160	2
4	85	520	20	147	1310	20	14	144	2
5	58	260	< 10	74	300	< 10	19	306	< 2
7	96	3030	< 10	138	3040	20	36	2354	< 2
8	103	1120	< 10	173	4000	30	14	712	2
9	211	5350	50	311	5350	80	28	864	6
10	251	930	80	429	930	190	18	52	2
12	84	330	10	240	620	60	6	40	< 2
14	359	7420	70	623	7420	160	31	896	4
15	619	6360	110	855	11400	190	120	1680	22
16	313	2300	80	497	5750	80	78	1600	10
17	113	1150	10	212	3390	20	37	596	2
19	501	4750	40	937	11200	100	154	1664	18
22	196	850	40	229	860	40	40	392	4
24	96	870	< 10	136	870	40	13	74	2
26	149	430	40	330	2720	80	17	92	6
28	115	6660	< 10	247	6780	30	51	3192	4
30	227	1050	20	455	2080	50	28	2120	2

TABLE 26

RESULTS OF MONITORING FOR ENTERIC VIRUSES, BACTERIA AND PARASITES ON FIVE OCCASIONS DURING THE STUDY PERIOD. RESULTS ARE THE ARITHMETIC MEAN OF ANALYSES FROM THREE SITES.

STUDY DAY	03	08	15	22	30
Total Enterovirus pfu per 10 litres	1.33	0.67	0.67	< 1	< 1
Total Rotavirus fffu per 10 litres	3.33	14	< 1	< 1	58.7
Staphylococcus spp per 100ml	1128	98	260	186	213
Salmonella spp per litre	< 1	< 1	< 1	1	< 1
Cryptosporidium per litre	< 40	< 6.67	< 10	< 6.67	< 6.67
Giardia lamblia per litre	< 10	< 10	< 10	< 10	< 20

TABLE 27

ESTIMATION OF SAMPLE SIZE FOR A DEFINITIVE STUDY

	ODDS RATIO					
πo	1.1	1.2	1.25	1.3	1.4	1.5
0.01	357000	103000	69000	50000	30000	20000
0.02	147000	46000	31000	23000	14000	10000
0.03	82000	28000	19000	14000	8500	6000
0.035	65000	23000	16000	12000	7500	5000
0.04	53000	19000	13000	10000	6000	4500
0.05	36000	14000	9500	7500	4500	3500

TABLE 28

SAMPLE SIZES AND CORRESPONDING COSTS FOR A DEFINITIVE STUDY

	ODDS RATIOS			
	1.25	1.3	1.4	1.5
TOTAL STUDY SAMPLE	16,000	12,000	7,500	5,000
NUMBER OF BEACHES	10 beaches 1600/beach	8 beaches 1500/beach	5 beaches 1500/beach	3 beaches 1700/beach
COST	356k	276k	184k	131k

TABLE 29

COMPARISONS OF THE TWO PILOT STUDIES

Follow-up study of bathers and non-bathers	Randomised trial (not blind)
Natural experiment	Experimental situation not truly representative of the real life situation
Could cover beaches with high pollution	Restricted to selected beaches
Feasible to be carried out in Great Britain	
Could cover all groups at risk especially 15-24 where risk is highest	Restricted age groups
Reporting bias +	Reporting bias + + +
Could draw conclusions on risk to the population as any other epidemiological study	

APPENDIX

RAS 1086

COLS 1234	5678
1086	7

LANGLAND BAY SURVEY
- IN STREET STUDY -

NAME: ______________________

ADDRESS: ______________________

____

____

POST CODE: ______________________

TELEPHONE NUMBER: ______________________

OCCUPATION OF HEAD OF HOUSEHOLD:

Job Title: ______________________

Rank Grade: ______________________

No. of people responsible for: ______

Industry: ______________________

Qualifications: ______________________

____

INTERVIEWER'S DECLARATION:
I declare that the interview was carried out in accordance to the written instructions, with the person named above who was previously unknown to me.

INTERVIEWER'S SIGNATURE:

____

INTERVIEWR'S NAME (PLEASE PRINT)

____

INTERVIEWER'S NUMBER: ______________________

DATE: __________ / __________ 1989

BEST TIME TO TELEPHONE

____

____

SEX: (9)

Male	1
Female	2

EXACT AGE LAST BIRTHDAY:

WRITE IN:	(10)	(11) Years

SOCIAL CLASS: (12)

AB	1
C1	2
C2	3
DE	4

PRESENCE OF CHILDREN IN HOUSEHOLD: (13)

Children aged 0-15 years present	1
No children aged under 15 present	2

WILLING TO BE CONTACTED BY TELEPHONE: (14)

Yes	1
No	2

WILLING TO COMPLETE A DIARY (15)

Yes	1
No	2

DATE OF INTERVIEW:

DATE		MONTH	
(16)	(17)	(18)	(19)

TIME OF INTERVIEW:

HOURS		MINUTES	
(20)	(21)	(22)	(23)

Good morning/afternoon/evening I am from Research and Auditing Services Limited who are conducting a survey on health and environmental issues for the University of Surrey. Please could you spare me about ten minutes to answer a few questions:

Can I just check whether you have been interviewed on this study before?

	CODE	GO TO
Yes	1	CLOSE
No	2	Q.1

Are you on holiday at this resort?

	(24)	
Yes	1	Q.3.
No	2	Q.2.

ASK Q2 OF ALL ANSWERING 'NO' AT Q1. OTHERS GO TO Q.3.

Are you a local resident or a daytripper?

	(25)	
Local Resident	1	Q.7.
Day Tripper	2	Q.3.

ASK Q3 OF ALL HOLIDAYMAKERS/DAYTRIPPERS. OTHERS GO TO Q.7.

When did you arrive at this resort?

DATE		MONTH	
(26)	(27)	(28)	(29)

And how many more days are you likely to spend at this resort?

(30)	(31)

days

Have you been to any other seaside resort immediately before coming to this one? IF YES NOTE NAME OF RESORT BELOW

	(32)	
Yes	1	
No	2	

RESORT(S) ______________________________

____

And how many days did you spend there?

(33)	(34)

ASK ALL
SHOW CARD A

I would now like to ask you a few questions about the food that you have been eating during the last 3 days.

7(a) Have you eaten any of the items on this list having prepared them yourself? Code below then go to Q.7(b).

7(b) And have you eaten any of them in the last 3 days having bought them in the resort at a restaurant/cafe/hot-dog stand etc? Code below.

		Q.7(a) PREPARED BY SELF	Q.7(b) BOUGHT
ICE CREAM		(35)	(36)
	Yes	1	1
	No	2	2
CHICKEN		(37)	(38)
	Yes	1	1
	No	2	2
EGGS		(39)	(40)
	Yes	1	1
	No	2	2
HOT DOGS		(41)	(42)
	Yes	1	1
	No	2	2
HAMBURGERS		(43)	(44)
	Yes	1	1
	No	2	2
SALAD		(45)	(46)
	Yes	1	1
	No	2	2
SHELLFISH (i.e. PRAWNS/COCKLES)		(47)	(48)
	Yes	1	1
	No	2	2

ASK Q.7(c) IF SHELLFISH EATEN AT Q.7(a) OR Q.7(b). OTHERS GO TO Q.8

7(c) And what type of shellfish did you eat?

I would now like to ask you a few questions about your health.

		CODE	GO TO
Were you in good health when you came to this resort?		(49)	
	Yes	1	Q.11(a)
	No	2	Q.9.
Do you have any long standing illness disability or infirmity that has troubled you over a period of time or that is likely to affect you over a period of time?		(50)	
	Yes	1	
	No	2	Q.10
During the last two weeks, have you had to cut down on any of the things you usually do because of illness or injury?		(51)	
	Yes	1	
	No	2	Q.11(a)

11(a) Have you had any of the following illnesses/symptoms whilst you have been at this resort? CODE BELOW THEN SEE NOTE ABOVE Q.11(b).

ASK Q11(b) AND Q11(c) FOR EACH ILLNESS/SYMPTOM HAD AT Q11(a).
IF NONE GO TO Q.12.

11(b) And how many days did it last? CODE BELOW THEN GO TO Q11(c).

11(c) And did you take some medicine that was not prescribed by a doctor, for the illness/symptom or did you consult a doctor?

SYMPTOMS	11(a) YES	11(b) DURATION IN DAYS	11(c) SELF MEDICATION	11(d) CONSULT DOCTOR	
Runny nose	(52) 1	(53) (54)	(55) 1	(56) 1	
Sore throat	(57) 1	(58) (59)	(60) 1	(61) 1	
Sore or red eyes	(62) 1	(63) (64)	(65) 1	(66) 1	
Ear infection	(67) 1	(68) (69)	(70) 1	(71) 1	
Nausea/sickness	(72) 1	(73) (74)	(75) 1	(76) 1	(80) ①
Vomiting	(9) 1	(10) (11)	(12) 1	(13) 1	
Diarrhoea	(14) 1	(15) (16)	(17) 1	(18) 1	
Indigestion	(19) 1	(20) (21)	(22) 1	(23) 1	
Wheezing/breathing difficulties	(24) 1	(25) (26)	(27) 1	(28) 1	
Cough	(29) 1	(30) (31)	(32) 1	(33) 1	
Skin rash	(34) 1	(35) (36)	(37) 1	(38) 1	
Itching	(39) 1	(40) (41)	(42) 1	(43) 1	
Sunburn	(44) 1	(45) (46)	(47) 1	(48) 1	
Headache	(49) 1	(50) (51)	(52) 1	(53) 1	
Backache	(54) 1	(55) (56)	(57) 1	(58) 1	
Aches in your joints	(59) 1	(60) (61)	(62) 1	(63) 1	
Fever	(64) 1	(65) (66)	(67) 1	(68) 1	
Cuts/bruises	(69) 1	(70) (71)	(72) 1	(73) 1	
Stings	(74) 1	(75) (76)	(77) 1	(78) 1	(80) ②

GO TO Q.12(a)

<u>ASK ALL</u>
<u>SHOW CARD B</u>

2(a) Now I would like to know which, if any, of the activities on this card you have taken part in or done in the sea at Langland Bay over the last three days. Code below then see note below.

Ask Q.12(b) to Q.12(d) for each activity carried out at Q.12(a)

2(b) For how long did you go....(Activity/ies at Q.12(a) today? Code below then go to Q.12(c).

2(c) For how long did you go .... (Activity/ies at Q.12(a) yesterday? Code below then go to Q.12(d).

2(d) And for how long did you go...... (activity/ies at Q.12(a) the day before yesterday. Code below.

	SWIMMING	DIVING	PADDLING/ WADING	SURFING/ WIND SURFING/ WATER SKIING
	(9)	(10)	(11)	(12)
Q.12(a) Taken part in last 3 days	1	1	1	1
Q.12(b) Time Today	(13)	(14)	(15)	(16)
Less than 30 mins	1	1	1	1
Between 30-60 mins	2	2	2	2
more than 60 mins	3	3	3	3
Did not take part/ Do	4	4	4	4
Q.12(c) Time Yesterday	(17)	(18)	(19)	(20)
Less than 30 mins	1	1	1	1
Between 30-60 mins	2	2	2	2
More than 60 mins	3	3	3	3
Did not take part/ Do	4	4	4	4
Q.12(d) Time day before yesterday	(21)	(22)	(23)	(24)
Less than 30 mins	1	1	1	1
Between 30-60 mins	2	2	2	2
More than 60 mins	3	3	3	3
Did not take part/ Do	4	4	4	4

	CODE	GO TO
13. When you are in the sea do you usually:	(25)	
(a) swim with head above water	1	
swim with head under water	2	
	(26)	
(b) wade without dipping head in the water	1	
wade with dipping head in water	2	
ASK Q.14 OF THOSE WHO HAVE NOT BEEN SWIMMING/IN SEA AT Q.12(a) OTHERS GO TO CLASSIFICATION		
14. Are you likely to swim on this beach?	(27)	
Yes	1	CLOSE
No	2	Q.15
ASK Q.15 IF 'NO' TO Q.14. OTHERS CLOSE		
15. What is the reason for your not swimming here at Langlands Bay?	(28)	
Can't swim	1	
	(29)	
Health reason	1	
	(30)	
Water not warm enough	1	
	(31)	
Other (CODE AND WRITE IN) ____________________ ____________________	1	
	(80)	
	①	

THANK RESPONDENT AND GO TO CLASSIFICATION

1088
1274

1778

/T

ASK ALL

I would like to ask you a few questions about the food that you ate at Langland Bay after your interview.

Did you eat any of these items that I'm going to read out having prepared them yourself? Code below then go to Q.1(b).

And did you eat any of them having bought them in the resort at a restaurant/cafe/hot-dog stand etc? Code below.

		Q.1(a) PREPARED BY SELF	Q.1(b) BOUGHT
ICE CREAM		(13)	(14)
	Yes	1	1
	No	2	2
CHICKEN		(15)	(16)
	Yes	1	1
	No	2	2
EGGS		(17)	(18)
	Yes	1	1
	No	2	2
HOT DOGS		(19)	(20)
	Yes	1	1
	No	2	2
HAMBURGERS		(21)	(22)
	Yes	1	1
	No	2	2
SALAD		(23)	(24)
	Yes	1	1
	No	2	2
SHELLFISH (i.e. PRAWNS/COCKLES)		(25)	(26)
	Yes	1	1
	No	2	2

ASK Q.1(c) IF SHELLFISH EATEN AT Q.1(a) OR Q.1(b). OTHERS GO TO Q.2

) And what type of shellfish did you eat?

____

____

____

____

2(a) Have you had any of the following illnesses/symptoms after you were interviewed and while you were still at that resort? CODE BELOW THEN SEE NOTE ABOVE Q.2(b).

ASK Q2(b) AND Q2(c) FOR EACH ILLNESS/SYMPTOM HAD AT Q2(a).
IF NONE GO TO Q.3.

2(b) And how many days did it last? CODE BELOW THEN GO TO Q2(c).

2(c) And did you take some medicine that was not prescribed by a doctor, for the illness/symptom or did you consult a doctor?

SYMPTOMS	2(a) YES	2(b) DURATION IN DAYS	2(c) SELF MEDICATION	2(d) CONSULT DOCTOR
Runny nose	(27) 1	(28) (29)	(30) 1	(31) 1
Sore throat	(32) 1	(33) (34)	(35) 1	(36) 1
Sore or red eyes	(37) 1	(38) (39)	(40) 1	(41) 1
Ear infection	(42) 1	(43) (44)	(45) 1	(46) 1
Nausea/sickness	(47) 1	(48) (49)	(50) 1	(51) 1
Vomiting	(52) 1	(53) (54)	(55) 1	(56) 1
Diarrhoea	(57) 1	(58) (59)	(60) 1	(61) 1
Indigestion	(62) 1	(63) (64)	(65) 1	(66) 1
Wheezing	(67) 1	(68) (69)	(70) 1	(71) 1
Cough	(72) 1	(73) (74)	(75) 1	(76) 1
Skin rash	(9) 1	(10) (11)	(12) 1	(13) 1
Itching	(14) 1	(15) (16)	(17) 1	(18) 1
Sunburn	(19) 1	(20) (21)	(22) 1	(23) 1
Headache	(24) 1	(25) (26)	(27) 1	(28) 1
Backache	(29) 1	(30) (31)	(32) 1	(33) 1
Aches in your joints	(34) 1	(35) (36)	(37) 1	(38) 1
Fever	(39) 1	(40) (41)	(42) 1	(43) 1
Cuts/bruises	(44) 1	(45) (46)	(47) 1	(48) 1
Stings	(49) 1	(50) (51)	(52) 1	(53) 1

(80) ①

GO TO Q.3

<u>ASK Q.3. IF CONSULTED DOCTOR AT ALL AT 2(a) TO 2(d) OTHERS GO TO Q4(a).</u>

You say that you had to consult a doctor about your illnesses/symptoms. I am going to read out a list of tests and I would like you to say for each whether you had that test or not for any of your illnesses/symptoms?

READ OUT

	Blood Test	(54) 1	
	Urine Test	(55) 1	
	Stool/Faecal/Excrement Test	(56) 1	
	Throat Swab	(57) 1	
	Nasal Swab	(58) 1	
	Ear Swab	(59) 1	Q.4(a)

ASK ALL

Did you spend any days after the original interview on any other beach?

	(60)	
Yes	1	Q.4(b)
No	2	
Don't know/ Can't remember	3	Q.5(a)

ASK Q.4(b) OF ALL SAYING 'YES' AT Q.4(a). OTHERS GO TO Q.5(a)

And where was that?

____

____

____

Q.4(a)

ASK ALL

Did you spend any days on Langland Bay Beach after the original interview took place?

	(61)	
Yes	1	Q.5(b)
No	2	
Don't know/ Can't remember	3	Q.6(a)

ASK Q.5(b) OF ALL SAYING 'YES' AT Q.5(a). OTHERS GO TO Q.6(a).

5(b) And on how many days following the interview did you actually visit or spend some time on Langland Bay Beach?

(62)	(63)	
		days

/T

ASK ALL

Now I would like to know which, if any, of the following activities you took part in at Langland Bay over the last three days. of your holiday there? Code below then see note below.

Ask Q.6(b) to Q.6(d) for each activity carried out at Q.6(a)

For how long did you go....(Activity/ies at Q.6(a) on the last day? Code below then go to Q.6(c).

For how long did you go .... (Activity/ies at Q.6(a) on second to last day? Code below then go to Q.6(d).

And for how long did you go...... (activity/ies at Q.6(a) on the third to last day. Code below.

	READ OUT	SWIMMING	DIVING	PADDLING/ WADING	SURFING/ WIND SURFING/ WATER SKIING
		(64)	(65)	(66)	(67)
Q.6(a)	Taken part in last 3 days	1	1	1	1
Q.6(b)	LAST DAY	(68)	(69)	(70)	(71)
	Less than 30 mins	1	1	1	1
	Between 30-60 mins	2	2	2	2
	More than 60 mins	3	3	3	3
	Did not take part/ Do	4	4	4	4
	DK/CR	5	5	5	5
Q.6(c)	SECOND LAST DAY	(72)	(73)	(74)	(75)
	Less than 30 mins	1	1	1	1
	Between 30-60 mins	2	2	2	2
	More than 60 mins	3	3	3	3
	Did not take part/ Do	4	4	4	4
	DK/CR	5	5	5	5
Q.6(d)	THIRD LAST DAY yesterday	(76)	(77)	(78)	(79)
	Less than 30 mins	1	1	1	1
	Between 30-60 mins	2	2	2	2
	More than 60 mins	3	3	3	3
	Did not take part/ Do	4	4	4	4
	DK/CR	5	5	5	5

ASK Q.7 OF ALL WHO WENT SWIMMING ETC AT Q.6(a)
OTHERS CLOSE.

		CODE	GO TO
7.	When you were in the sea on those last 3 days did you usually:	(9)	
	(a) swim with your head above water	1	
	swim with your head under water	2	
		(10)	
	(b) wade without dipping your head in the water	1	
	wade with dipping your head in water	2	
		(80)	
		6	

THANK RESPONDENT AND GO TO CLASSIFICATION

Thames Water

THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
12th October, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	03-08-89	03-08-89	03-08-89
Laboratory Sample Number:	C14081	C14082	C14083
Date of Sample Registration:	03-08-89	03-08-89	03-08-89
Staphylococci spp., /100ml	3000 *	300 *	84 *
Salmonella, no./l	< 1	< 1	< 1
Cryptosporidium, no./l	< 100	< 10	< 10
Giardia llamblia, no./l	< 100	< 10	< 10
Enterovirus, PFU/10l	2 -	1 #	1 -

C14081 - 3/A/C
C14082 - 3/A/E
C14083 - 3/A/W

* *Staphylococcus aureus* not isolated

\- Poliovirus = P.1
\# Coxsackievirus group B = CB.5

R Bird

For R.J.Vincent, Laboratories Manager

Thames Water

THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
12th October, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	15-08-89	15-08-89	15-08-89
Laboratory Sample Number:	C14622	C14623	C14624
Date of Sample Registration:	15-08-89	15-08-89	15-08-89
Staphylococci spp., /100ml	360 *	220 *	200 *
Salmonella, no./l	< 1	< 1	< 1
Cryptosporidium, no./l	< 10	< 10	< 10
Giardia llamblia, no./l	< 10	< 10	< 10
Enterovirus, PFU/10l	0	2 #	0

C14622 - 12/A/C
C14623 - 12/A/E
C14624 - 12/A/W

* *Staphylococcus aureus* not isolated

\# Coxsackievirus group B = CB.5

For R.J.Vincent, Laboratories Manager

New River Head Laboratories, 177 Rosebery Avenue, London EC1R 4TP
[illegible]

Thames Water
THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
12th October, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	08-08-89	08-08-89	08-08-89
Laboratory Sample Number:	C14319	C14320	C14321
Date of Sample Registration:	08-08-89	08-08-89	08-08-89
Staphylococci spp., /100ml	90 *	84 +	120 *
Salmonella, no./l	< 1	< 1	< 1
Cryptosporidium, no./l	20	< 10	< 10
Giardia llamblia, no./l	< 10	< 10	< 10
Enterovirus, PFU/10l	1 #	1 -	0

C14319 - 7/A/C
C14320 - 7/A/E
C14321 - 7/A/W

* *Staphylococcus aureus* not isolated
\+ *Staphylococcus aureus* (presumptive) = 56

\# Coxsackievirus group B = CB.5
\- Coxsackievirus group B = CB.4

For R.J.Vincent, Laboratories Manager

Thames Water

THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
12th October, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	30-08-89	30-08-89	30-08-89
Laboratory Sample Number:	C14998	C14999	C15000
Date of Sample Registration:	30-08-89	30-08-89	30-08-89
Staphylococci spp., /100ml	80 *	400 *	160 *
Salmonella, no./l	< 1	< 1	< 1
Cryptosporidium, no./l	20	< 20	< 20
Giardia llamblia, no./l	< 20	< 20	< 20
Enterovirus, PFU/10l	0	0	0

C14998 - 20/A/C
C14999 - 20/A/E
C15000 - 20/A/W

* *Staphylococcus aureus* not isolated

For R.J.Vincent, Laboratories Manager

Thames Water

THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
12th October, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	22-08-89	22-08-89	22-08-89
Laboratory Sample Number:	C14807	C14808	C14809
Date of Sample Registration:	22-08-89	22-08-89	22-08-89
Staphylococci spp., /100ml	240 *	50 *	270 *
Salmonella, no./1	1	1	1
Cryptosporidium, no./1	< 10	< 10	20
Giardia llamblia, no./1	< 10	< 10	< 10
Enterovirus, PFU/101	0	0	0

C14807 - 16/A/C
C14808 - 16/A/E
C14809 - 16/A/W

* Staphylococcus aureus not isolated

For R.J.Vincent, Laboratories Manager

THE WATER QUALITY CENTRE

New River Head, 173 Rosebery Avenue, London EC1R 4TP
Telephone: 01-833 6105 Fax: 01-833 6279 Telex: 267216 TWMTLB G

The Water Quality Centre is a trading name of
Thames Water Enterprises Limited
Registered in England and Wales No. 2334941
Registered Office Nugent House, Vastern Road, Reading RG1 8DB

Part of the Thames Water Plc. Group

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
12th October, 1989

Dear Mr. D. Wheeler,

Please find enclosed our Certificates of Analysis for water samples delivered to our laboratories between the 3rd August and the 30th August, 1989.

The rotavirus results should follow in a couple of weeks. Please accept my apologies for the delay.

I hope you find this satisfactory. If you have any queries regarding these results please do not hesitate to contact me.

Yours sincerely,

Indira Basu (Scientific Assistant).

Thames Water

THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
15th November, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	03-08-89	03-08-89	03-08-89
Laboratory Sample Number:	C14081	C14082	C14083
Date of Sample Registration:	03-08-89	03-08-89	03-08-89
Rotavirus, FF/10L	10	0	0

C14081 - 3/A/C
C14082 - 3/A/E
C14083 - 3/A/W

HL Evans

For R.J.Vincent, Laboratories Manager

New River Head Laboratories, 177 Rosebery Avenue, London EC1R 4TP
Telephone: 01-833 6105 Fax: 01-833 6279 Telex: 267216 TWMTLB G

Thames Water

THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
15th November, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	08-08-89	08-08-89	08-08-89
Laboratory Sample Number:	C14319	C14320	C14321
Date of Sample Registration:	08-08-89	08-08-89	08-08-89
Rotavirus, FF/10L	28	14	0

C14319 - 7/A/C
C14320 - 7/A/E
C14321 - 7/A/W

AC Evans
For R.J.Vincent, Laboratories Manager

Thames Water

THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
15th November, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	15-08-89	15-08-89	15-08-89
Laboratory Sample Number:	C14622	C14623	C14624
Date of Sample Registration:	15-08-89	15-08-89	15-08-89
Rotavirus, FF/10L	0	0	0

C14622 - 12/A/C
C14623 - 12/A/E
C14624 - 12/A/W

A C Evans

For R.J.Vincent, Laboratories Manager

New River Head Laboratories, 177 Rosebery Avenue, London EC1R 4TP
Telephone: 01-833 6105 Fax: 01-833 6279 Telex: 267216 TWMTLB G

Thames Water

THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
15th November, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	22-08-89	22-08-89	22-08-89
Laboratory Sample Number:	C14807	C14808	C14809
Date of Sample Registration:	22-08-89	22-08-89	22-08-89
Rotavirus, FF/10L	0	0	0

C14807 - 16/A/C
C14808 - 16/A/E
C14809 - 16/A/W

A C Evans

For R.J.Vincent, Laboratories Manager

Thames Water

THE WATER QUALITY CENTRE

Certificate of Analysis

Mr. D. Wheeler
Robens Institute
University of Surrey
Guildford
Surrey GU2 5XH

IRB/P21734
15th November, 1989

Results of the Analysis of Water Samples From:- Bathing Waters

Date of Sample:	30-08-89	30-08-89	30-08-89
Laboratory Sample Number:	C14998	C14999	C15000
Date of Sample Registration:	30-08-89	30-08-89	30-08-89
Rotavirus, FF/10L	168	0	8

C14998 - 20/A/C
C14999 - 20/A/E
C15000 - 20/A/W

For R.J.Vincent, Laboratories Manager

New River Head Laboratories, 177 Rosebery Avenue, London EC1R 4TP
Telephone: 01-833 6105 Fax: 01-833 6279 Telex: 267216 TWMTLB G

APPENDIX B

THE LANGLAND BAY CONTROLLED PILOT COHORT STUDY

Final Report to the Water Research Centre,
December 1989

By: F Jones (Attwell Ltd, Runcorn)
D Kay (St David's University College, Lampeter)
R Stanwell-Smith (Communicable Disease Surveillance Centre, Colindale, London NW9)
and M Wyer (St David's University College, Lampeter)

THE LANGLAND BAY CONTROLLED COHORT PILOT STUDY

FINAL REPORT

F. Jones, D. Kay, R. Stanwell-Smith and M. Wyer

December 1989

THE LANGLAND BAY CONTROLLED COHORT EPIDEMIOLOGICAL PILOT STUDY

FINAL REPORT

F. Jones, D. Kay, R. Stanwell-Smith and M. Wyer

Frank Jones is Senior Research Consultant, St David's University College, University of Wales, Lampeter, Dyfed SA48 7ED and Managing Director, Altwell Ltd., Units 6+8, Howard Court, Manor Park, Runcorn Cheshire WA7 1SJ. (0928 576969 TEL; 0928 576116 FAX)

David Kay and Mark Wyer are Senior Lecturer and Research Fellow, respectively, at St David's University College, University of Wales, Lampeter, Dyfed SA48 7ED. (0570 422351 EXT 249; 0570 423423 FAX)

Rosalind Stanwell-Smith is a Consultant Epidemiologist at the Communicable Disease Surveillance Centre, Colindale, London NW9 5DF. (01 200 6868 TEL; 01 200 7868 FAX)

This report is submitted in completion of Contract ET 9511 between the Water Research Centre and St David's University College, University of Wales, Lampeter.

December 1989.

FINAL REPORT ON THE LANGLAND BAY CONTROLLED COHORT EPIDEMIOLOGICAL PILOT STUDY

SECTIONS

LIST OF FIGURES 20-43

LIST OF TABLES

LIST OF PLATES

APPENDICES

1. SUMMARY

The reported study was a pilot investigation of the feasibility of a controlled cohort protocol for surveys of possible bathing related illness associated with recreational waters in the UK. The investigation was conducted in the late summer of 1989 at Langland Bay, near Swansea, South Wales.

Over 400 adult volunteers were recruited, of whom 276 eventually participated in the study. Volunteers were principally drawn from residents of and visitors to the city of Swansea. The 276 volunteers were randomly allocated to bathing and non-bathing groups, following pre-exposure interviews and clinical tests. Volunteers were interviewed again on the day of exposure (2.9.89) and at 3 days after exposure at which time the clinical tests were repeated. Environmental conditions and food intake were similar for both groups, with the exception that bathers were required to enter the sea and immerse their heads on at least three occasions during normal bathing activities over a minimum period of 10 minutes. Non-bathers used the beach but did not enter the water at any stage. Indeed, they were requested not to do so over the following three weeks.

Viral and bacterial water quality on the day of exposure was relatively *good*. Faecal coliform concentrations in water samples were generally less than 100 $100ml^{-1}$ with a geometric mean value of 19 $100ml^{-1}$ (based on 180 samples). Enteroviruses and rotaviruses were identified in three of fifteen samples examined for viruses. Synchronous samples were collected at six stations over a 100m stretch of beach with three depths sampled at each station.

Perceived illness in both groups was higher than that reported in previous investigations. This may be partly attributable to the use of detailed personal follow-up interviews and the wide range of health enquiry included in the questionnaires. Contingency table analysis identified significantly higher rates of perceived symptoms in the bather group over the non-bather group for sore throat, eye infection and ear infection three days after exposure and for diarrhoea three weeks after exposure (see Table 7.1). Bather observation sheets kept by supervisors on the beach were used to define a mean water quality experienced by each bather (see Appendix IV). There was no significant difference in the mean $\log_{10}$ water quality experienced by the bathers reporting symptoms and bathers with no post-exposure perceived symptoms (see Table 7.4) except that mean $\log_{10}$ total coliform organisms in the surf zone was higher for those who did <u>not</u> report symptoms.

There was no statistically significant difference, at the 95% level, between the bather and non-bather groups for any of the post-exposure clinical tests on ear swabs, throat swabs and faecal samples although the proportion of positive samples was higher in the bather group (see Tables 8.1-8.3). Furthermore, no significant difference could be found between the mean $\log_{10}$ water quality experienced by those bathers with positive sample results, when compared with those whose results were negative (see Table 8.4).

The pilot investigation demonstrated that a controlled cohort methodology is both ethically and logistically feasible. The higher perceived attack rates reported by subjects during detailed medical interviews suggests significant under-reporting in previous perception studies, which have tended to use less rigorous methods of data acquisition such as telephone follow-up. The perceived symptoms were not clinically confirmed by the faecal samples and swabs, but the size of the pilot study was too small to determine whether reported symptoms were related to immersion in seawater of the quality observed. A larger national study is now required to provide information on a wider range of sea water quality and environmental conditions. Such data could provide the basis for appropriate advice on bathing from UK and possibly other beaches in Europe, and for advice to ministers in this important area of environmental management.

2. INTRODUCTION

This investigation resulted from a joint research proposal, submitted to the DoE in January 1988 by St David's University College and Altwell Ltd, which set out a potential research protocol for the implementation of a controlled cohort examination of the possible health effects of bathing in coastal waters. In August 1988 all Maritime district Councils and relevant resource agencies were contacted by the authors with a view to the implementation of a controlled cohort study in the 1989 bathing season. Contributions from these collaborating bodies allowed the establishment of a steering group which has guided this controlled cohort epidemiological investigation. In the Autumn of 1988 the Department of the Environment (DoE) established an advisory group to examine this area and review the available research protocols for UK epidemiological investigations. Following the advice of this group, the DoE commissioned the Water Research Centre (WRc) to manage two pilot scale studies, the first involving a disease perception study which would broadly follow the protocol designed by Victor Cabelli of the USA, and the second involving the controlled cohort investigation involving medical and clinical examination of a volunteer subject group.

This report describes the controlled cohort pilot study conducted at Langland Bay on 2nd September 1989. The objective of this study was to

(i) *test and validate epidemiological procedures for determining the risks, if any, to the health of bathers in coastal water contaminated by sewage, and*

(ii) *establish the relationship, if any, between microbiological quality of coastal waters and the risk to health of bathers.*

Item (i) in the terms of reference above is, perhaps, the most significant since this is the first controlled cohort study using a volunteer group with full medical supervision and follow-up. If, in the light of the Langland Bay experience, this method is judged feasible by the international scientific community it will overcome many of the problems now recognised in the USEPA protocol originally designed by Prof. Victor Cabelli (Cabelli *et al.*, 1982; Cabelli, 1989). It is the objective of this report to present the results of this experiment and to describe the problems encountered in this first implementation of the controlled cohort protocol so that lessons can be incorporated to future investigations at the design stage.

3. LITERATURE REVIEW

3.1 Early United Kingdom Research

The first UK research into the health effects of coastal bathing was initiated by the Public Health Laboratory service in the 1950s and reported jointly in 1959 by the PHLS (1959) and MRC (1959). This investigation was a retrospective examination of two major notifiable diseases namely, poliomyelitis and enteric fever. The study aimed to retrospectively establish links between instances of sea bathing and these two illnesses. This task requires that all subjects have a reliable recollection of their bathing history and that water quality data exists describing the bathing locations in question. Only four cases of paratyphoid fever were attributed to sea bathing in the study period 1956-1958 (PHLS, 1959:495) and these were associated with bathing in waters of very poor bacteriological quality. Poloimyelitis could not be scientifically or medically linked to coastal bathing. All environmental samples examined for viruses were negative. This result is to be expected, given the methodology available at the time.

These findings led the PHLS Committee to conclude that;

"bathing in sewage polluted sea water carries only a negligible risk to health, even on beaches that are aesthetically very unsatisfactory"

(PHLS, 1959:468)

This conclusion goes far beyond the data on which it is founded. That is on very small numbers of two notifiable diseases. It is not valid to make such sweeping statements about bathing related diseases in general from these very limited findings and this survey work of the 1950s is even less relevant today with the additional water-borne infections that have been identified.

The PHLS research has, nevertheless, been the foundation rock for official statements by the UK competent authorities in the intervening period (Kay and McDonald, 1986a,b; HMSO, 1985a,b). For example, a Welsh Water spokesman stated to the 1984-5 Commons Welsh Affairs Committee on coastal sewage pollution;

"A committee of the MRC conducted epidemiological studies relating to polio and enteric fever between 1955 and 1959 and it was their conclusion that there was no significant risk to health 'unless waters were so fouled as to be aesthetically revolting' This conclusion was accepted by the United Kingdom government and has been the basis of national policy since its publication."

(HMSO, 1985c:25)

Other agencies have increasingly come to question the validity of policy based on the PHLS retrospective research. For example, the Royal Commission on Environmental Pollution stated in its tenth report;

"it is now necessary to modify the reliance placed on a report published almost a quarter of a century ago."

(HMSO, 1984:87)

The reason for this re-assessment of the PHLS research stemmed, in part, from *prospective* studies being undertaken in the United States which had begun to examine a much broader set of diseases.

3.2 North American Research

In North America an alternative approach has been taken to defining the link between bathing water quality and health. The method includes a prospective research design in which bather and non-bather cohorts are defined at the beach and then contacted later to establish the disease attack rates in both the bather and non-bather cohorts. This approach was pioneered by Victor J Cabelli of the USEPA (Cabelli *et al.*, 1975, 1982,1983; Cabelli, 1989). Using this protocol Cabelli and his co-workers established statistically significant bathing related attack rates of gastroenteritis amongst bathers in the United States. They went on to suggest functional relationships between attack rate (dependent variable) and the bacterial water quality (predictor variable). These data suggested that enterococci were the best faecal indicator available for the prediction of swimming associated disease risk. Based upon these studies the North American nations have established water quality criteria which are used as a beach management tool. For example the City of Toronto will close its freshwater beaches on the shores of Lake Ontario when the 10 day running geometric mean *E. coli* value exceeds 100 $100ml^{-1}$. In other parts of Canada and the USA beaches are closed when the five samples taken in one month exceed a geometric mean value of 200 $100ml^{-1}$ *E. coli.*

Several other investigations have used Cabelli's experimental protocol to investigate bathing related disease attack rates. Dufour (1982, 1983, 1984) was able to establish significant relationships between both enterococci and disease attack rates at US freshwater bathing sites. Faecal coliform concentrations, however, exhibited no correlation with disease attack rates in the bather population. In Canada, Seyfried (1985a,b) examined the excess bathing related disease incidence at Ontario freshwater bathing sites. She found significantly higher rates of disease amongst bathers which correlated best with total staphylococci (Health and Welfare Canada, 1980). More recently Lightfoot (1989) has completed a PhD thesis on epidemiological investigations at Ontario beaches. She has provided the most comprehensive statistical assessment to date of confounding factors inherent in the Cabelli research protocol. Her study is of particular importance since it concluded that;

"there was no evidence to suggest that bacterial count contributed to the prediction of illness in swimmers. Instead, age, contact person, and interviewer, most frequently tended to be important."

There is little evidence from the present study to support the belief that the bacterial water quality indicators investigated herein index the short-term risk of becoming ill from swimming"
(Lightfoot, 1989:208)

The contact person (i.e. respondent) and interviewer effects are of particular importance. The relationships between these factors and reported (or perceived) symptomatology suggests that the results generated by the Cabelli protocol should be treated with great caution, if not scepticism, by those with specific environmental management and public health responsibilities. For example, whilst Lightfoot was able to identify higher crude morbidity rates amongst bathers (i.e. 76.8/1000) than non-bathers (i.e. 41.8/1000), there was no relationship between bacterial indicator concentrations and disease attack rates at the six southern Ontario freshwater bathing sites studied.

Lightfoot has completed the most recent and detailed attempt to replicate the Cabelli protocol. She has applied statistical tests (logistic regression modelling) to identify the confounding factors and she has found the method to be flawed. This study is important in highlighting a problem which may invalidate many previous prospective investigations. The design flaw inherent in most previous studies is that they have sought to measure disease **perception** not **incidence**. Medical and clinical follow up of the reported symptomatology has been attempted by several workers but never achieved because of the dispersion of the cohort group after the initial recruitment on the beach. Lightfoot makes a number of significant recommendations and comments.

"It is possible that the utilisation of medical and laboratory confirmation might have altered the results which were based on the reporting of illness."
(Lightfoot, 1989:206) and

"future investigators will be well advised to attempt recording of duration of exposure for individuals, and to carry out more frequent water sampling each day than was possible in the present study."
(Lightfoot, 1989:207) and

"Yet another potential source of bias in this study is that illness was reported by contact persons, and not confirmed by clinicians and laboratory testing. .... It may prove beneficial for investigators of swimming related illness to compare results from the two methods of reporting (i.e. contact person versus the use of clinicians and laboratory results)"
(Lightfoot, 1989:223-226)

A further recent North American study is worthy of some comment. This was completed by the New Jersey Department of Health in the 1988 bathing season at nine ocean beaches and two lake beaches (New Jersey Department of Health, 1988, 1989). The first interim report was made available in March 1989. A total of 16,089 (i.e. 72% ocean and 29% lake) people participated in this Cabelli style perception survey. Swimmers consistently reported higher symptom attack rates than non-swimmers and the symptoms reported in order of importance were; (i) red, itchy eyes (mainly lake bathers), (ii) sore throat (mainly ocean bathers), (iii) skin rash, (iv) credible gastrointestinal symptoms and (v) ear infections. The Authors of the New Jersey interim report state that;

"Overall, the findings indicate that there was no increase in illness associated with sewage or stormwater runoff at any of the study beaches.
(New Jersey Department of Health, 1989:i) and

"It is likely that the illness rates observed resulted from factors other than sewage contamination and may have been

primarily person-to-person transmission of viruses."

(New Jersey Department of Health, 1989:iv)

Water quality during the New Jersey study was relatively *good* in terms of the bacterial indicator concentrations and this factor may explain the lack of any consistent relationship between water quality and symptom attack rates. In summary, the New Jersey research indicates that there is a statistically significant relationship between bathing (i.e. head immersion) and symptom attack rates but it failed to establish any relationship between the water quality indicators chosen and disease in the bathers.

There are several reasons why it would be scientifically inappropriate for the competent UK authorities to simply transfer the results of these North American studies to the unique UK coastal environment.

3.2.1 The chlorination factor

The first is that the New York city beaches used by Cabelli and the New Jersey discharges often experienced chlorination of the effluents. chlorination reduces bacterial indicator concentrations (i.e. *E. coli*) by several orders of magnitude. Virus concentrations are not reduced to the same extent. Hence, fairly low indicator concentrations could be associated with high viral infection attack rates where the disease is caused by viral rather than bacterial infection. It is certainly probable that most gastroenteritis contracted in the nearshore zone is of viral origin. The bathing related disease attack rates identified by Cabelli at the US beaches are therefore likely to be higher at any given indicator concentration because of the chlorination factor.

3.2.2 Inconsistency of results

Attempted replications of the Cabelli style experiments have produced a range of different indicators and dose response relationships in the bather cohort (see Table 3.1). The extent to which this is due to the respondent and interviewer effects identified by Lightfoot is not clear. However, the overall failure to replicate the Cabelli findings casts doubt on this research protocol and suggests that it is unlikely to provide a firm policy foundation for UK competent authorities. However, The Cabelli protocol is the best that overseas workers have been able to achieve and it has therefore been adopted by the WHO of investigations in this area (WHO, 1988,1986, 1977). It is probably prudent therefore for initial UK investigations to incorporate a rigorous and epidemiologically sound implementation of the Cabelli style protocol whilst at the same time seeking to rectify the clear faults in this method which are outlined above and seeking to devise more scientifically valid methodologies to provide a firm base for UK policy decisions.

3.3.3 Inappropriate indicators

Most previous studies have examined the easily measure bacterial indicators in the nearshore zone. These indicators may not be the main aetiological agents of disease associated with bathing. The use of indicator organisms is based on assumptions relating to the survival of both the indicators and related pathogens. Several authors have recently questioned these assumptions by suggesting that viral pathogens might survive for very long periods in marine sediments (Colwell, 1987; Grimes, 1986) and by noting the lack of expected correlations between *E. coli* concentrations and viral contamination (Tyler, 1986). The epidemiological significance of these survival estimates and mechanisms is as yet unknown. However, the public perception of risk is based on the knowledge of pathogen presence.

3.3 Other prospective studies

Several prospective studies have attempted to replicate the Cabelli protocol in Egypt (El Sharkawi and Hassan, 1982) Israel (Fattal *et al.*, 1986). Other studies in Spain (Mujeriego *et al.*, 1982) and France (Foulon *et al.*, 1983) have addressed the problem with a perception approach and achieved varying levels of success (see Table 3.1).

The most extensive study, to date, outside North America has been undertaken in Hong Kong (Holmes, 1988, 1989; Cheung *et al.*, 1988; Hong Kong Government, 1986,1988). This investigation identified very low attack rates of gastrointestinal symptoms (4.1/1000 bathers) at pollution levels much higher than those experienced in the USA. The Hong Kong studies implicated skin complaints as the most common bathing related symptom and they suggested that indicator concentrations above 180 *E. coli* $100ml^{-1}$ and 1000 staphylococci $100ml^{-1}$ were associated with statistically significant morbidity amongst the bathing cohort.

3.4 Recent UK prospective investigations

The first UK prospective investigations in this area were commenced in the summer of 1989 at Langland Bay near Swansea (DoE, 1989; WRc, 1989). This pilot investigation was funded by the DoE , the NRA and WRc. The University of Surrey was contracted to test the Cabelli protocol. A controlled cohort study, using volunteers principally recruited from the city of Swansea, was contracted to the University of Wales and is reported here. The former (Cabelli protocol) study followed an earlier pilot investigation completed in the South of England during the 1987 bathing season which was sponsored by Greenpeace (Brown *et al.*, 1987).

The controlled cohort investigation, outlined in this report, sought to avoid many of the criticisms of the prospective perception studies identified by Lightfoot and in broad terms if followed the methodology first suggested by the WHO (1972:13) i.e..

"Ideally, the best hope of progress in this field would seem to lie in carefully planned prospective studies in volunteer populations of adequate size. If such populations could be randomly divided into comparable groups of persons who did and did not bathe, but shared all other activities and exposures to environmental hazards, so much the better. The populations would need to be observed at close quarters by teams that included clinicians, public health workers, epidemiologists and microbiologists."

4. COHORT RECRUITMENT AND ORGANISATION

4.1 Ethical issues in recruitment

It is necessary to obtain the approval of the relevant ethical committees prior to recruitment. Submissions to the Royal College of Physicians Committee for Research on Health Volunteers (RCP) included a statement of the protocol (Appendix I) and a subject information sheet (Appendix II). These documents were also submitted for local ethical consideration to Dr B Littlepage of West Glamorgan Health Authority. Instructions for staff involved in recruitment were prepared as suggested by RCP (Appendix II). The preparation of these documents was based on the recommendations contained in Royal College of Physicians (1986).

4.2 Recruitment methods

The cohort of volunteers was initially recruited from Swansea residents in August 1989. Initial recruitment efforts were centred on (i) Guildhall staff who are all employed by the City of Swansea and (ii) staff of University College Swansea. These *workplace* recruitment efforts produced very low rates of return and were not fruitful. The methods used involved individual letters and subject information sheets which were sent to all staff on each site (approximately 2,500). This resulted in less than 50 positive replies from UCS and the Guildhall. It is possible that this exercise failed because staff were being approached by a colleague (i.e. Huw Morgan in the Guildhall and David Kay at UCS). It *may* have been more fruitful if DK had approached Guildhall staff and HM the UCS.

The failure of workplace recruitment required an alternative approach, i.e. recruitment from the general public. It was not possible, however, to commence this operation until after the WRc press conference on 18th August. To this date, the controlled cohort group were maintaining total media silence to ensure that the perception work of the Robens institute was not compromised by excessive media interest. It would have been desirable to commence public recruitment earlier and this illustrates the basic incompatibility of the two approaches when applied at the same site.

Public recruitment involved using display boards in the central shopping area (i.e. the Quadrant Centre) and the local sports centre. This exercise coincided with positive local publicity in the Western Mail, the Swansea Evening News (Plate 4.1), Swansea Sound and BBC Wales. The display boards were staffed by the project team and the Pollution Control department of Swansea City Council. Most members of the public had heard of the project through the media and using this method it was possible to recruit 50-100 volunteers per day. Each volunteer was given a copy of the subject information sheet approved by the ethical Committee of the Royal College of Physicians. Volunteers were each contacted, after initial recruitment, by staff of the Pollution Control Section of Swansea City Council to arrange the time of the first medical interview at the Guildhall. This reinforced the recruitment and ensured that volunteers had time to check their time commitments during the experiment.

A drop-out rate of 10-15% was expected from initial recruitment of volunteers to the first medical interview with an estimated subsequent loss of 5%. It was decided, therefore, to recruit 450 volunteers to accommodate the expected drop out rates and allow 400+ volunteers for the experiment. A total of 465 volunteers were recruited in the initial exercise. This number declined through the course of the experiment as outlined in Table 4.1. The initial drop-out rate was higher than expected but subsequent declines were pleasingly low. The lesson of this phase in the experiment was that a 50% decay rate from recruitment to the first medical interview should be expected. It is a easy matter to accommodate this with higher levels of initial recruitment which seem feasible given the willingness of Swansea residents to take part in the study.

4.3 Logistics

Pre and post-exposure medical interviews were conducted in a large assembly room provided by Swansea City Council. Considerable effort was devoted to the design and organisation of a booking system for the pre-exposure medical interviews and examinations. The objective of this booking system was to minimise the time commitment of the volunteers by reducing the size of any queues. It also allowed each volunteer to confirm their wish to take part in the experiment and make the necessary arrangements for the subjects to receive the first faecal sample pot which was, generally, brought to the first medical interview. Five medics and ten interviewers were available for the first session. Completion of the first questionnaire (green) form took about 20 minutes. Though a long time was required for this first interview, it did have the effect of cementing commitment to the project which was evident in the very low drop out rates at subsequent stages. The staffing level provided was sufficient to prevent unacceptable time delays for the volunteers and it was decided that a formal booking system was not required for the second (i.e. post-exposure) medical interview (Plate 4.2).

After the pre-exposure interview at Swansea City Council, subjects were allocated, using random number statistical tables, to either the bather or non-bather groups. Lists of subjects and the relevant supervisors were then printed on blue or red paper for distribution at the beach to bathers and non-bathers respectively.

A limited number of the subjects were not Swansea residents. Most of these were volunteers from the North West of England and were medically examined by one of the selected medical team who resided in the North West. Others were fairly evenly spread throughout the UK. Members of this sub-group of volunteers arranged for clinical samples to be taken by a medic in their home region and then posted the PINK and BLUE questionnaire forms to the project office in SDUC.

Transport was provided for the subjects from Swansea City centre to Langland Bay (a 10-15 minute journey). On arrival at the beach subjects were allocated to the bather or non-bather groups and they were given the number of their individual supervisor on a blue or red list of all subjects. Supervisors were identified by colour-coded, numbered tee-shirts (blue for bather supervisors and red for non-bather supervisors). Each subject was therefore required to find one of ten supervisors in a small area of beach who was wearing a numbered tee-shirt.

The non-bathing area was clearly marked with red tape and signs (Figure 4.1 and Plate 4.3) which also contained and inflatable castle kindly supplied by Swansea City Council. The 100 m bathing area was marked with 20 m distance signs and blue tapes pegged from each marker into the water. This arrangement maintained accurate positioning for the samplers and, in addition, it allowed supervisors to locate their subjects for the analysis of potential correlations between water quality at particular stations and bather morbidity patterns. All bathers were supervised in the water and a diary sheet of their activities kept by their individual supervisor (Appendix IV). A significant problem which should be noted at this point is the difficulty of subject identification once in the water. Colour-coded, numbered arm bands were used in the Langland Bay experiment but they were not successful and swimming caps may offer a more practical means of identification in future studies. Swimmers all remained in the waters for at least 10 minutes and they were observed to immerse their heads in the water on at least three occasions. After the beach interview and, where appropriate water immersion, all subjects were free to collect their packed lunch and take a relaxing picnic on the beach. Subjects were transported back to Swansea by bus. The whole experiment was completed in a 3 hour period between 12.00 noon and 15.00 pm.

5. QUESTIONNAIRE DESIGN AND ANALYSIS

Four questionnaires were used at different stages of the study (see Appendix VI). The aim of the questionnaires was to investigate social, health and environmental factors in the cohort before and after exposure. A supplementary aim of the questionnaire design was to investigate the most efficient means of assessing these factors for future studies, including the extension of the pilot to a national survey of health and sea bathing. A series of questions were included for each factor incorporating alternative wording to validate different approaches and examine possible bias in the subjects' responses. Where possible, similar questions to those used in the modified Cabelli design study were incorporated, with the aim of producing questionnaires suitable for either type of survey in subsequent research.

Investigation of social factors involved recording demographic details such as age, sex, social class, size of household and district of residence. The general health enquiry covered a wide range of symptoms, chronic illness, drug therapy and immunization history prior to exposure, with dates and duration of any recent illness or symptoms. Post-exposure health enquiries used similar symptom-illness questions with dates of onset and duration. Environmental factors explored relevant work or recreational exposures, particularly sea and freshwater bathing and water sports, in addition to detailed questions on tobacco and alcohol consumption. Recent travel within the UK or abroad was also recorded. Dietary history before and after exposure, included a list of food and drink items associated with an increased risk of gastrointestinal infection, such as unpasteurized (raw) milk; hamburgers; bought sandwiches; raw eggs products and pate.

Three questionnaires were administered by personal interview (at 2-3 days before exposure; on the day of exposure; and 3 days after exposure). The fourth questionnaire was posted to all cohort participants for completion three weeks after the beach exposure with a reply paid envelope for return.

Identical questionnaire sets were used for the bathers and non-bathers and neither interviewers nor participants knew their allocated group prior to exposure. The questionnaires for each stage were printed on different coloured paper for ease of identification and analysis.

Questionnaire design included a coding column and pre-coded options to be ticked by the interviewer (or respondent in the postal questionnaire). A coding frame was devised for the few 'open-ended' questions or where the range of answers had not been anticipated. All questionnaires were checked for consistency of coding prior to computer input and analysis. This was carried out at SDUC using a custom designed fixed format template for accurate data input and the SPSSx package for data analysis (SPSS, 1989).

6. ENVIRONMENTAL QUALITY

6.1 Bacterial water quality, Langland bay summer 1989

Results of analysis of 19 bathing water samples from Langland Bay (sample point 37200) for the 1989 bathing season are summarised in Table 6.1 and Figure 6.1 for Faecal coliform, Faecal streptococci, and Total coliform. All values refer to concentration per 100 ml of water. Table 6.2 shows these data in relation to the EC Directive for bathing waters (76/160/EEC). For the three microbiological criteria, Langland Bay passed the EC directive at the Imperative level (applicable to Faecal coliform and Total coliform only) but failed at the Guide level using the 1989 data available at the time of the study.

6.2 Bacterial water quality, Langland bay 2/9/89

Intensive sampling took place in the bathing area shown in Figure 4.2 during the exposure period, i.e.12.00 noon to 15.00 hrs BST, on 2/9/89. Summary statistics for the entire set of 180 samples is shown in Table 6.3, for Total coliform, Faecal coliform, Faecal streptococci, *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Analytical techniques for these parameters are outlined in Appendix VII. Sampling took place at six shore locations, at 20 m intervals for the 100 m stretch of shoreline, and three depth locations. The depth locations were; (i) in the surf zone, (ii) at the EC recommended water depth of 30 cm and (iii) at chest depth. The third location represented the zone where bathers would immerse their heads and swim. Samples were taken at each depth and shore location at intervals of approximately 20 minutes. Nine such sampling runs were made during the course of the afternoon, each generating 18 samples (Figures 6.1 to 6.4). The water quality, for the parameters listed above, is summarised in Table 6.4 for the three sampling depths. An additional set of 18 samples were taken further off shore, by boat (Table 6.5).

Bacterial water quality on the afternoon of 2/9/89 was relatively "*good*", with the sample set for the 30cm depth location passing the EC directive at the imperative and guide levels for Faecal and Total coliform concentrations (Table 6.6). However, the sample set did not comply with the Guide level for Faecal streptococci (Table 6.6).

6.3 Viral water quality, Langland Bay 2/9/89

During the afternoon 15 samples were taken from the 30 cm depth zone, at various locations, and analysed for enteroviruses and rotaviruses (Appendix VIII). Results were expressed as plaque forming units (pfu) per 10 litres of water and are listed in Table 6.7. The low occurrence of viruses precludes any meaningful statistical analysis. The presence of any enterovirus would, however, indicate a failure to comply with the EC directive for this parameter.

7. PERCEIVED SYMPTOM ATTACK RATES

The four questionnaire surveys defined in Appendix VI were conducted to examine the subjects' perception of their disease symptoms over the course of the experiment. This provides a comparison with previous perception studies, outlined in Section 3. The collection of perception data as an integral part of the controlled cohort study allows for the first clinical confirmation, or otherwise, of perceived symptoms in a study of bathing related disease incidence.

Contingency table analysis was undertaken to determine if statistically significant differences in symptom attack rates were present between the bather and non-bather groups. Where the expected frequency of any contingency table cell were less than 5, a Fisher's exact test was employed. In all other cases a Chi square (χ^2) test was applied. Raw attack rates for <u>both</u> bathers <u>and</u> non-bathers are presented for 23 single and grouped symptoms in Figure 7.1. Table 7.1 shows the statistical significance of differences between the bather and non-bather groups and Figure 7.2 presents a graphical contingency table illustrating the attack rates for all *significant* symptom differentials between the bather and non-bather groups. Figure 7.3 shows the relative significance of bather/non-bather perceived symptom differentials for all 23 symptoms. The cut-off significance level was alpha (α) =0.05, below which the null hypothesis, that there was no significant difference in the attack rates between the two groups, was accepted.

Significant differences in the perceived symptom attack rates were observed for sore throat, ear infection and eye infection after three days and for diarrhoea after three weeks. The gross attack rates for these symptoms were high when compared to previous international studies. Table 7.2 shows the Langland perceived crude attack rates and Table 7.3 shows some comparative attack rates from recent overseas investigations.

It is evident from Table 7.3 that the perceived attack rates, observed in the Langland investigation, are high in comparison with previous perception studies. This is not surprising in view of the methodological differences in perception data acquisition between the Langland controlled cohort study and all previous perception investigations. In all previous studies, disease attack rates were defined by telephone based questionnaire interview of *respondents* which represent a sub-group of the total cohort population. In the Langland study, the first three questionnaires were completed by project staff during detailed medical interviews with all subjects . The final questionnaire which maintained a similar format to the first three was completed by the subjects then posted to the project office. Response rates for each stage in this process are shown in Table 4.1. It is likely that the more detailed interview of every subject employed in the Langland investigation has resulted in higher crude symptom reporting rates.

In addition to the bather/non-bather comparisons of perceived symptom attack rates, the impacts of water quality on perceived symptoms amongst bathers was studied. This was made possible by the intensive environmental sampling and the diary sheets kept for all bathers by the beach supervisors. Each bather could be allocated to a time and location for their bathing activity and a mean water quality could be defined for each location. Whilst, in UK terms, the indicator concentrations were low, there was considerable inter-bather variability in the water quality experienced. Student's t analysis was therefore applied to test the hypothesis that there was a statistically significant difference in the mean $\log_{10}$ indicator concentrations experienced by those bathers reporting symptoms and those bathers not reporting symptoms. This analysis was completed for each of the three sampling depths and four indicators namely; total coliform, faecal streptococci, *Pseudomonas aeruginosa* and faecal coliform organisms. In all cases no statistically significant difference could be found except for total coliform organisms in the surf zone. In this case, however, the mean $\log_{10}$ total coliform concentration experienced by bathers not reporting symptoms was higher than that experienced by bathers reporting symptoms (see Table 7.4).

8 . CLINICAL SYMPTOM ATTACK RATES

8.1. Ear and throat swabs

Ear and throat swabs prior to (swab 1) and after the exposure day (swab 2) were used to provide microbiological evidence of clinical infection. The organisms were coliforms (including *Escherichia coli*), *Streptococcus faecalis*, (groups A and B) Beta haemolytic streptococci, *Staphylococcus aureus* and *Pseudomonas aeruginosa* .

Contingency table analysis was utilised to determine statistically significant differences in attack rates between the bather and non-bather cohort groups. Comparisons were made for each of the organisms, except for haemolytic streptococci which occurred in low abundance. This bacterium was combined with *Streptococcus faecalis* to produce a composite variable, streptococci. The Chi square (χ^2) statistic was used for the comparisons unless the expected frequency for a cell was below five, when Fisher's exact test was employed. The significance values (p) for this analysis are shown in Table 8.1 and the resultant percentage confidence values presented graphically in Figure 8.1. As with the perceived symptom analysis, α was set at $<= 0.05$ (95% confidence) for rejection of the null hypothesis that there were no significant differences between the two groups.

With the exception of coliform or presence of any determinand on the first ear swab, no significant differences between the two cohort groups were detected for individual or combinations of bacteria. Crude attack rates, i.e. the number of subjects with a positive occurrence divided by the number of subjects in the group, are shown in Table 8.2 and illustrated in Figures 8.2, for bather, and Figure 8.3 for non-bathers.

8.2 Faecal samples

The first and second stool samples, corresponding to the pre and post exposure interviews, were examined for for *Salmonella sp.*, *Campylobacter sp.*, *cryptosporidia sp.* and cyst, ova and parasites. The third sample was assayed for enteroviruses, cysts, ova and parasites. The results are shown in Table 8.3. The low numbers for both microbial and viral determinands detected precluded statistical analysis for significant differences between the bather and non-bather groups. Subjects who exhibited a positive result for any microbial parameter were all positive on the first (pre-exposure) sample i.e. no cohort member exhibited a positive result after exposure following a negative result in the pre-exposure faecal samples

8.3 Water quality and clinical symptoms

The analysis of any relationship of clinical results to water quality was carried out in the same manner as for perceived symptoms. t-tests were performed on the bather group to analyse for significant differences between the mean water quality experienced by bathers with positive swab results (group 2) and the mean water quality for the group with negative swab results (group 1) (Table 8.4). All water quality variables were $\log_{10}$ transformed for parametricity. The results generally suggest no significant difference between the two groups, at $\alpha <= 0.05$. However, bathers with a positive result for *Staphylococcus aureus* on the second throat swab appear to have experienced a significantly higher mean total coliform concentration in the bathing water, in comparison to those bathers exhibiting no *Staphylococcus aureus* on this swab (Table 8.4 (h)). Both bathers with enteroviruses experienced approximate water quality with 0 pfu for enteroviruses and rotaviruses.

8.4 Clinical and perceived symptom relationships

Symptoms and other evidence of health were analysed in three ways; (i) positive reporting of a symptom or illness on a questionnaire, (ii) microbiological evidence of an infection from swab and stool samples (iii) the combination of perceived and microbiological evidence. Taking the perceived symptoms showing a significant difference between the bather and non-bather groups at three days; i.e. ear and throat symptoms, and the associated clinical samples, venn diagrams were used to illustrate the three symptom levels (Figures 8.4 and 8.5). Contingency table analysis of the clinical results was then performed on the groups reporting a symptom (Table 8.5).

Of the five cases with positive enteroviruses in the final faecal sample only one reported any of the credible gastrointestinal perceived symptoms. This symptom was diarrhoea, reported on the final questionnaire.

9. CONCLUSIONS

The controlled cohort methodology has proven to be feasible. To that extent the pilot investigation been successful. This pilot scale investigation was not designed to provide definitive public health information. Two significant conclusions can be drawn.

First the medical questionnaire used was more detailed than in any previous study. In the execution of Cabelli style perception experiments it is often impossible to employ a detailed questionnaire in **either** beach interviews **or** telephone follow-up because the subjects will not devote the required time to the study. This probably explains the higher rates of perceived symptom reporting experienced in this study. We conclude from this dichotomy that the morbidity patterns uncovered by any perception exercise will depend on the questions posed and the manner in which they are structured.

Second there was no statistically significant evidence from the clinical samples that bathing in the waters of Langland Bay on 2nd September 1989 had any adverse effect on health. This finding fails to confirm the validity of the perceived data gathered from the same group This presents a dilemma to the competent authorities in Britain which can only be properly resolved by taking this proven methodology to full scale implementation.

10. LESSONS FOR FUTURE WORK

10.1. Recruitment

A 50% fallout rate should be expected from the initial recruitment to the first medical interview. However, subsequent fallout is very small (see Table 4.1). Recruitment is hindered by parallel perception studies implemented at the same location which require minimum publicity. The main lesson of the recruitment exercise is that sufficient time is essential and a professional, planned approach to cohort recruitment is required.

10.2 Medical Interviews

These should include some medical assessment of the subjects made during the medical examination. For example, the numbers of inflamed throats could have been recorded at the time that the medics were taking swab samples. In future studies, the use of additional physiological tests should be considered to enhance the data base on the medical and demographic status of the cohort.

10.3 Clinical Samples

More consideration is required of the optimum sampling and re-sampling times to ensure maximum recoveries. This requires an input, at the planning stage of future work, by the PHLS.

10.4 Medical Questionnaire

A consistent approach by the interviewers is essential. Training of interviewers, including realistic rehearsal interviews, is therefore important and should be costed into future epidemiological studies. Appropriate psychological and market research inputs should be included in any proposed modifications to the study questionnaires.

10.5 Logistics

On-site computer and printing facilities are essential for cohort allocation and rapid data processing in the period after the first medical interview and before the cohort exposure day. At the study beach there must be a clearly identified marshalling point with cover for reception of the cohort. Bather identification using arm bands is difficult and additional attention to this aspect is required.

10.6 Timing

It is vital that sufficient time is made available for the planning and implementation of future work. The 1989 pilot studies were, to some extent, rushed due to the late decision taken in May 1989 to fund the work. If this research is to go to full scale in 1990, a much earlier decision would be required to allow sufficient time for staff recruitment and organisation.

10.7 External liaison

Greater attention is needed to appropriate and early liaison with subjects' GPs. A national survey will require correspondence with all MOsEH/CCDCs to alert them that their district residents may be involved.

11. REFERENCES

Anon (1985) Leptospirosis in man, British Isles 1984. *Public Health Laboratory Service, Communicable Disease Report, CDR 85/36.* London.

Barrow, G.I. (1981) Microbial pollution of coasts and estuaries: the public health implications. *Water Pollution Control 80(2)*, 221-230.

Brown, J.M., Campbell, E.A. Rickards, A.D. and Wheeler, D. (1987) *The public health implications of sewage pollution of bathing water.* Published by the University of Surrey, Robens Institute.

Cabelli, V.J., Levin, M.A., Dufour, A.P. and McCabe, L.J. (1975) *The development of criteria for recreational waters.* In Gameson, A.L.H. (Ed.) *Discharge of sewage from sea outfalls.* Pergamon. 63-74

Cabelli, V.J., Dufour, A.P., McCabe, L.J. and Levin, M.A. (1982) Swimming associated gastroenteritis and water quality. *American Journal of Epidemiology 115(4)*, 606-616.

Cabelli, V.J., Dufour, A.P., McCabe, L.J. and Levin, M.A. (1983) A marine recreational water quality criterion consistent with indicator concepts and risk analysis. *Journal of the Water Pollution Control Federation 55*, 1306-1314.

Cabelli, V.J. (1989) Swimming associated illness and recreational; water quality. *Water Science and Technology 21(2)*, 13-21.

Cheung, W.H.S., Kleevens, J.W.L., Chang, K.C.K. and Hung, R.P.S. (1988) Health effects of beach water pollution in Hong Kong. *Proceedings of the Institution of Water and Environmental Management.*

Proceedings of the Annual Conference 376-383.

Colwell, R.R. (1987) Microbiological effects of ocean pollution . Paper 23 *International Conference on Environmental Protection of the North Sea.* 19p.

Denness, B. (1987) *Sewage disposal to the sea.* Sons of Neptune Ltd. Scarborough. 68p.

Department of the Environment (1989) *The quality of UK Bathing waters improves.* Environment News Release 96 21.2.89. 19p.

Department of the Environment (1989) *Water Research Centre to carry out bathing water study.* Environment News Release No. 285 17th May. 2p.

Dufour, A.P. (1982) *Fresh recreational water quality and swimming associated illness.* Second National Symposium on Municipal Wastewater Disinfection, Orlando Florida. January 26-28, 21p.

Dufour, A.P. (1983) *Microbiological recreational water quality objectives.* Paper presented at the First National Conference on Recreational Water Quality and Human Health. Canadian Public Health Association. Oct. 27-28, Toronto, Ontario.

Dufour, A.P. (1984) Bacterial indicators of recreational water quality. *Canadian Journal of Public Health 75*, 49-56.

EEC (1976) Council Directive of 8 December 1975 concerning the quality of bathing water (76/160/EEC). *Official Journal L/31*, 1-7.

EEC (1979) Council Directive on the quality required for shellfish waters (79/923/EEC) *Official Journal L281*, 47-52.

EEC (1988) *Quality of bathing water 1983-1986.* Fifth Report EUR11588. Directorate General for Environment, Consumer Protection and Nuclear Safety. 139pp.

Ellis, J.B. and Stanfield G. (1987) *Bacterial quality of marine bathing waters: a comparative assessment of North American and European standards.* Water Research Centre Report PRS 1595-M. 20p.

El Sharkawi, F. and Hassan, M.N.E.R. (1982) The relation between the state of pollution in Alexandria swimming beaches an the occurrence of typhoid among bathers. *Bull High Inst. pub. Hlth Alexandria 12*, 337-351.

Fattal, B., Peleg-Olevsky, T. Agurshy and Shuval, H.I. (1986) *The association between sea-water pollution as measured by bacterial indicators and morbidity of bathers at Mediterranean beaches in Israel.* Chemosphere.

Foulon, G., Maurin, J., Quoi, N.N. and Martin-Bouyer, G. (1983) Etude de la morbidite humaine en relation avec la pollution bacteriologique des eaux de baignade en mer. *Revue francaise des SCIENCES DE L'EAU 2(2)*, 127-143.

Galbraith, N.S., Barrett, N.J. and Stanwell-Smith, R. (1987) Water and disease after Croydon: a review of water-borne and water associated disease in the U K 1937-86. *Journal of the Institution of Water and Environmental Management 1(1)*, 7-21.

Garrett, P. (1987) Bathing water - time for change. *Water Bulletin 284*, 6-7.

Grimes, J.D. (1986) *Assessment of ocean waste disposal. Task 5 Human health impacts of waste constituents II Pathogens and antibiotic - and heavy metal -*

resistant bacteria. Final report submitted to the Congress of the United States Office of Technology Assessment Contract No 533-2685.0. 132p.

Health and Welfare Canada (1980) *A study of disease incidence and recreational water quality in the great lakes phase I.* Report 81-EHD-67. 161p.

H.M.S.O. (1985a) *House of Commons Committee on Welsh Affairs Coastal sewage pollution in Wales.* Minutes of Evidence 16.1.85. H.M.S.O. London. 118-167p.

H.M.S.O. (1985b) *House of Commons Committee on Welsh Affairs Coastal sewage pollution in Wales.* Report and Proceedings Vol I and II. 12.12.85. H.M.S.O. London. 27p.

H.M.S.O. (1985c) *House of Commons Committee on Welsh Affairs Coastal sewage pollution in Wales* Minutes of Evidence 5.12.84. H.M.S.O. London. 117p.

H.M.S.O. (1984) *Royal Commission on Environmental Pollution Tenth Report. Tackling Pollution-Experience and Prospects.* Cmnd. 9149 HMSO London. 233p.

Holmes, P.R. (1988) *Bathing beach pollution research and control in Hong Kong.* Presented at the IWEM conference Eastbourne 28.9.88. 8p. mimeographed.

Holmes, P.R. (1989) Research into health risks at bathing beaches in Hong Kong. *Journal of the Institution of Water and Environmental Management 3,* 488-495.

Hong Kong Government (1986) *Epidemiological studies related to beach water pollution in Hong Kong: a preliminary report.* Hong Kong Government Environmental Protection Agency Technical Memorandum Report No EPD/TP17/86. November, 27p.

Hong Kong Government (1988) *Microbioogical water quality of bathing beaches* Hong Kong Government Environmental Protection Department. 57p.

Jones, F. and Godfree, A.F. (1989) Recreational and amenity aspects of surface waters: the public health implications. *Water Science and Technology 21(3),* 137-142.

Jones, F. and Kay, D. (1989) Bathing waters and health studies. *Water Services 93(1117)* 87-89.

Jones, F. and Watkins, J. (1985) The water cycle as a source of pathogens. *Journal of Applied Bacteriology Symposium Supplement 1985,* 27S-36S.

Jones, F. (1981) Bacterial pollution of marine waters from the disposal of sewage sludge to sea. *Water Science and Technology 14,* 61-70.

Kay, D. (1988) Coastal bathing water quality: the application of water quality standards to Welsh beaches. *Applied Geography 8,*117-134.

Kay, D., Wyer, M.D., McDonald, A.T. and Woods, N. (1989) *The application of water quality standards to UK bathing waters.* Research Report for a WRc funded project.

Kay, D. and McDonald, A.T. (1986) *Risk recreation and regression: a study of the Toronto beaches.* Leeds University Working Paper. 17p.

Kay, D. and McDonald, A.T. Enteric bacterial entrainment in a recreational channel following reservoir releases used competitive canoeing. *Cambria 9(2),* 61-68.

Kay, D and McDonald, A.T. (1980) Reduction of coliform bacteria in two upland reservoirs: the significance of distance decay relationships. *Water Research 14*, 305-318.

Kay, D. and McDonald, A.T. (1986a) Bathing water quality: the significance of epidemiological research in the British context. *European Water and Sewage 90(1085)*, 321-328.

Kay, D and McDonald, A.T. (1986b) Coastal Bathing Water Quality. *Journal of Shoreline Management 2*, 259-283.

Lightfoot, N.E. (1989) *A prospective study of swimming related illness at six freshwater beaches in Southern Ontario*. Unpublished PhD Thesis. 275p.

M.R.C. (1959) MEDICAL RESEARCH COUNCIL Sewage contamination of bathing beaches in England and Wales. *Medical Research Council Memorandum No. 37*, 32p.

McDonald, A.T., Kay, D. and Jenkins, A. (1982) Generation of faecal and total coliform surges in the absence of normal hydrometeorological stimuli. *Applied and Environmental Microbiology 44(2)*, 292-300.

McDonald, A.T. and Kay, D. (1981) Enteric bacterial concentrations in reservoir feeder streams: baseflow characteristics and response to hydrograph events *Water Research 15*, 1981, 861-968

M.R.C. (1959) MEDICAL RESEARCH COUNCIL Sewage contamination of bathing beaches in England and Wales. *Medical Research Council Memorandum No. 37*, 32p.

Mujeriego, R., Bravo, J.M. and Feliu, M.T. (1982) Recreation in coastal waters public health implications. *Vier Journee Etud. Pollutions, Cannes, CIESM*. pp. 585-594.

New Jersey Department of Health (1988) *A study of the relationship between illness in swimmers and ocean beach water quality*. New Jersey Health Dept. March 1988. 167p.

New Jersey Department of Health (1989) *A study of the relationship between illness in swimmers and ocean beach water quality interim summary report*. New Jersey Health Dept. March 1989. 54p.

P.H.L.S. (1959) PUBLIC HEALTH LABORATORY SERVICE. Sewage contamination of coastal bathing waters in England and Wales: a bacteriological and epidemiological study. *Journal of Hygiene, Cambs. 57(4)*, 435-472.

Royal College of Physicians (1986) Research on healthy volunteers. *Journal of the Royal College of Physicians 29(4)*, 17p.

Seyfried, P.L., Tobin, R., Brown, N.E. and Ness, P.F. (1985a) A prospective study of swimming related illness. I Swimming associated health risk. *American Journal of Public Health 75(9)*, 1068-1070.

Seyfried, P.L., Tobin, R., Brown, N.E. and Ness, P.F. (1985b) A prospective study of swimming related illness. II Morbidity and the microbiological quality of water. *American Journal of Public Health 75(9)*, 1071-1075.

Shuval, H.I. (1986) *Thalassogenic diseases*. UNEP Regional Seas Reports and Studies No. 79.

Sockett, P.N., West, P.A. and Jacob, M. (1985) Shellfish and Public Health. *PHLS Microbiology Digest 2(2)*, 29-35.

SPSS (1989) *Statistical Package for the Social Sciences. McGraw Hill.*

Stevenson, A.H. (1953) Studies of bathing water quality and health. *American Journal of Public Health 43*, 529-538.

Tyler, J. (1985) Occurrence in water of viruses of public health significance. *Journal of Applied Bacteriology Vol 59*. Symposium Supplement, 37S-46S.

Water Research Centre (1989) *Press Release*. 18th August 1989.

West, P.A., Wood, P.C. and Jacob, M. (1985) Control of food poisoning risks associated with shellfish. *Journal of the Royal Society of Health 105(1)*, 15-21.

West, P.A. (1989) The human pathogenic vibrios - A public health update with environmental perspectives. *Epidemiology and Infection 103*, 1-34.

White, W.R. and Godfree, A.F. (1985) Pollution of freshwaters and estuaries. *Journal of Applied Bacteriology Symposium Supplement 14*, S67-S79.

WHO (1988) World Health Organisation Mediterranean Action Plan. *Epidemiological studies related to environmental quality criteria for bathing waters, shellfish growing waters and edible marine organisms. (Activity D).* MAP Technical Reports Series No. 20 UNEP Athens. 156pp.

W.H.O. (1986) *Correlation between coastal water quality and health effects*. World Health Organisation Copenhagen. 44p.

W.H.O./U.N.E.P. (1977) *Health criteria and epidemiological studies related to coastal water pollution.* WHO Copenhagen.

W.H.O. (1972) *Health criteria for the quality of recreational waters with special reference to coastal waters and beaches.* Ostend Belgium. 13-17th March. 26p.

12. ACKNOWLEDGEMENTS

This project was funded by the Department of the Environment, the Welsh Office, and the Water Research Centre. Staff of the DoE, Water Environment Division are thanked for their assistance at all stages of the project. Dr. E.B. Pike, and the staff of the WRc public relations section, deserve particular thanks for their handling of the media during the study which allowed the research team to concentrate on the task in hand. Members of the DoE advisory group are thanked for the constructive suggestions at the design stages of this project.

Cohort recruitment was conducted by staff of the Pollution Control section of Swansea City Council and University of Wales, Lampeter, with professional advice and assistance from Mrs C. Pownall of Oxford Conferences Ltd. Medical interviews were conducted in the Guildhall by Gary Belger, Anne Delahunty, Paula Gray, Sarah Maxwell and Sue Pitt.

Laboratory media and sterile sampling equipment were supplied by Oxoid Ltd, Basingstoke, Gelman Sciences, Northampton and Northern Media, Hull. Laboratory facilities and technical assistance were provided by the University of Swansea, School of Biological Sciences. Laboratory analyses were completed by Helen Dawson, Alan Godfree, John Watkins and Dick White.

Field sampling and cohort supervision on 2nd September at Langland Bay were completed by Clare Ashcroft, Teresa Bristow, Ray Castle, Anne Delahunty, Lynne Howgate, Jayne Hughes, Alan Longford, Adrian McDonald, Gary O'Neill, Keith Osborn, Sue Pitt, Kate Philips, Mandy Rix, Chris Thomas, Paul West and Dick White.

Expert views on the controlled cohort protocol were provided by Victor Cabelli, Wallace Cheung, Alfred Dufour, Badri Fattal, Edwin Geldreich, Nancy Lightfoot, Adrian McDonald, Sue Pitt and George Ruben.

Clinical samples were analysed by PHLS Preston and the packed lunches were examined by PHLS Swansea. The virology unit of Welsh Water collected and analysed the seawater samples. Packed Lunches were supplied by Sutcliff's caterers to the City of Swansea. Safety cover on 2nd September was provided by the Lifeguard service of Swansea City Council and the St John's Ambulance Brigade. The *then* Welsh Water Authority (now NRA Wales) conducted additional sampling of adjacent locations during the summer of 1989 and assisted with sample transport on 2nd September.

This project could not have been completed successfully without the assistance a full support of Swansea City Council and we wish to thank the Public Protection Committee, the Chief Environmental Health Officer, Eddie Ramsden, and, in particular, the staff of the Environmental Health, Pollution Control Section, who have given freely of their time and expertise throughout this study. To Huw Morgan, Penny Davies, Richie Westlake, Howard Williams and their dedicated team of professional staff go our sincere thanks. We owe a special debt to Sylvia Morgan who help and encouragement was greatly appreciated.

We owe particular thanks to the individuals and organisations who have provided support for the establishment of a steering group which has helped design this research protocol. We are grateful to the Royal Society of Health, the ex-South West, Welsh and Yorkshire Water water authorities; Castle Point, Ceredigion, Cleethorpes, Havant, East Yorkshire, Gt Yarmouth, Rother, Scarborough, Southend and Waveney district councils.

Finally we wish to express our sincere gratitude to the people of Swansea and all our volunteers who cheerfully gave of their time and various clinical samples without complaint, thus making this experiment an enjoyable experience for all involved.

FIGURES

Figure 4.1 Schematic map of the Langland Bay study site

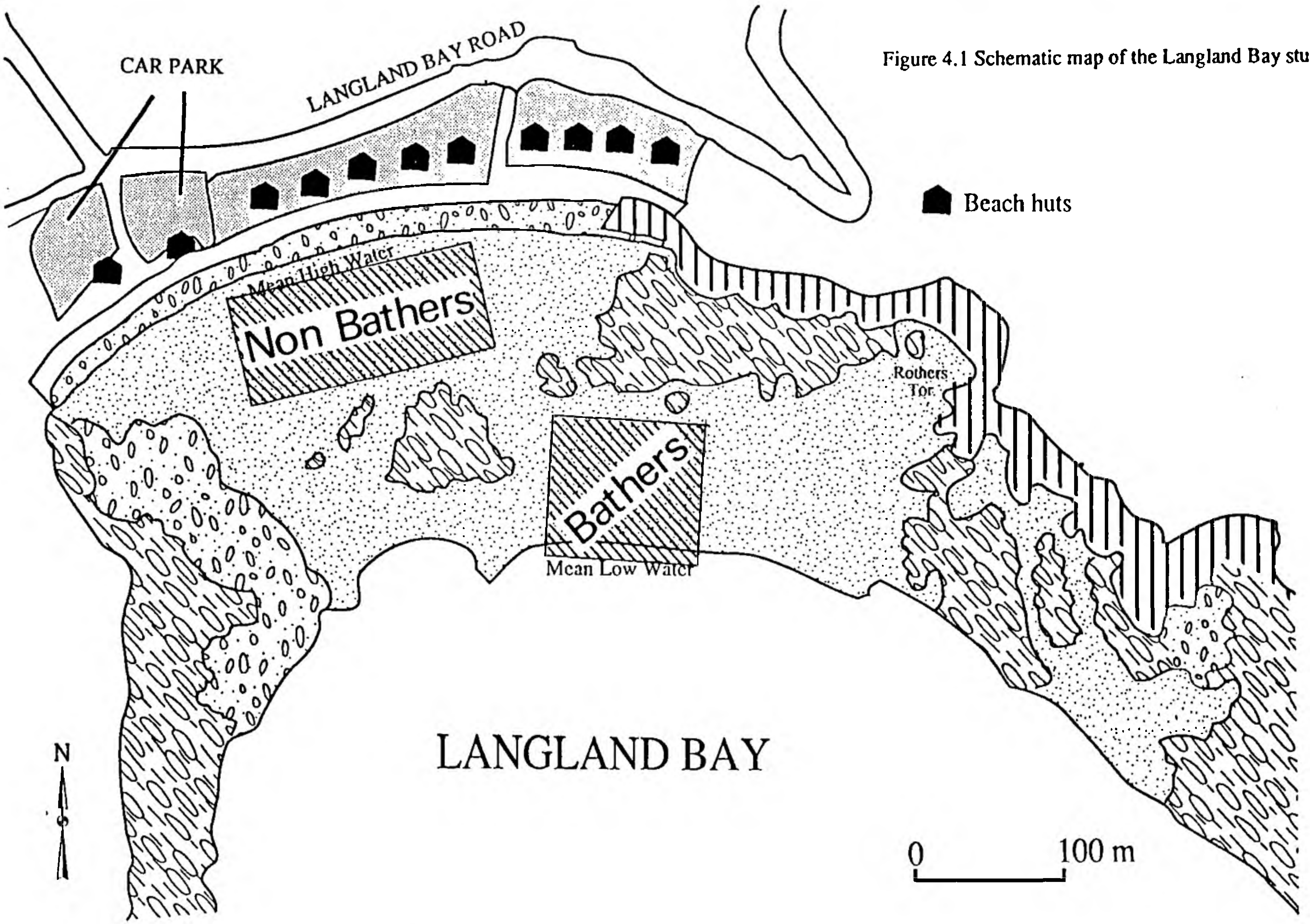


Figure 6.1 Concentrations of indicators (per 100 ml), Langland Bay, summer 1989.

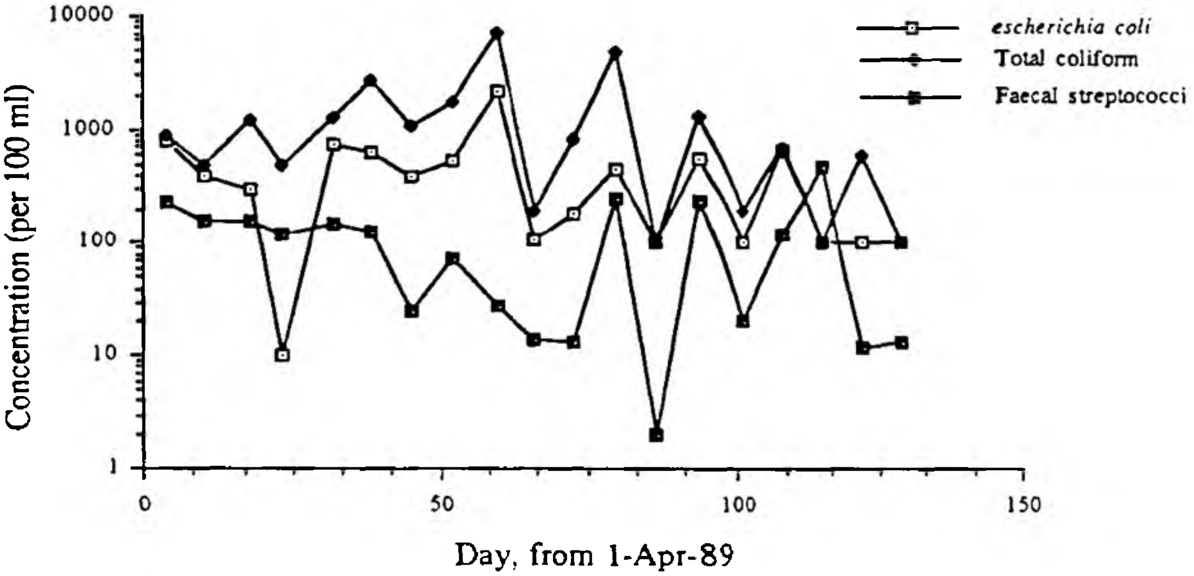
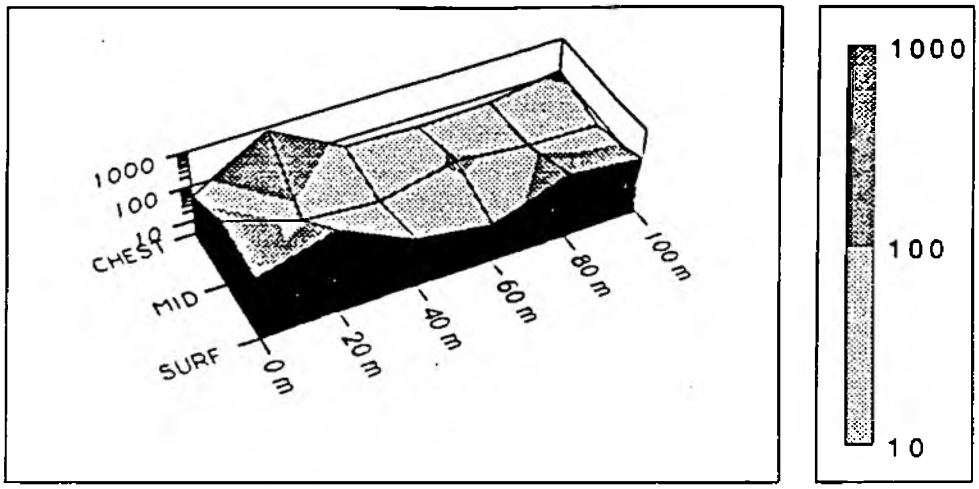
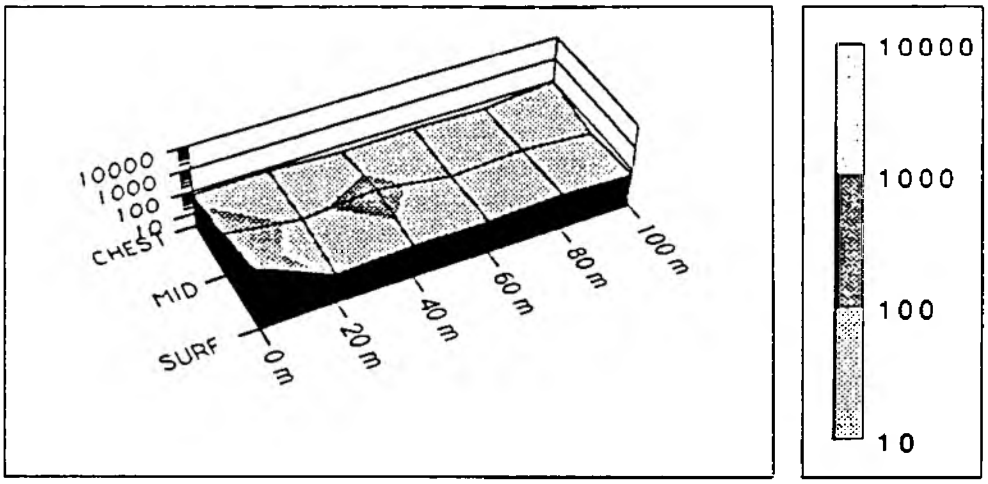


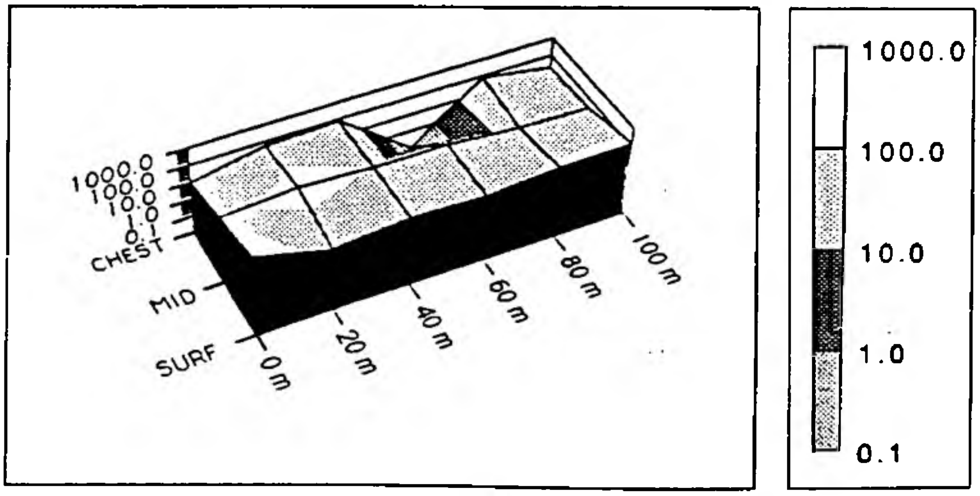
Figure 6.2 Total coliform, Langland Bay 2/9/89, 12.00-15.00 BST



(a) Total coliform (per 100 ml), 12.00



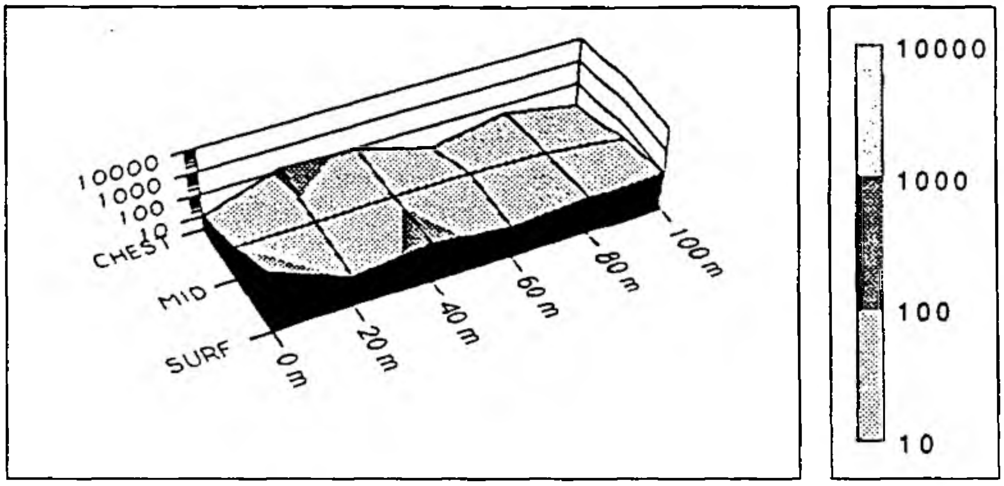
(b) Total coliform (per 100 ml), 12.30



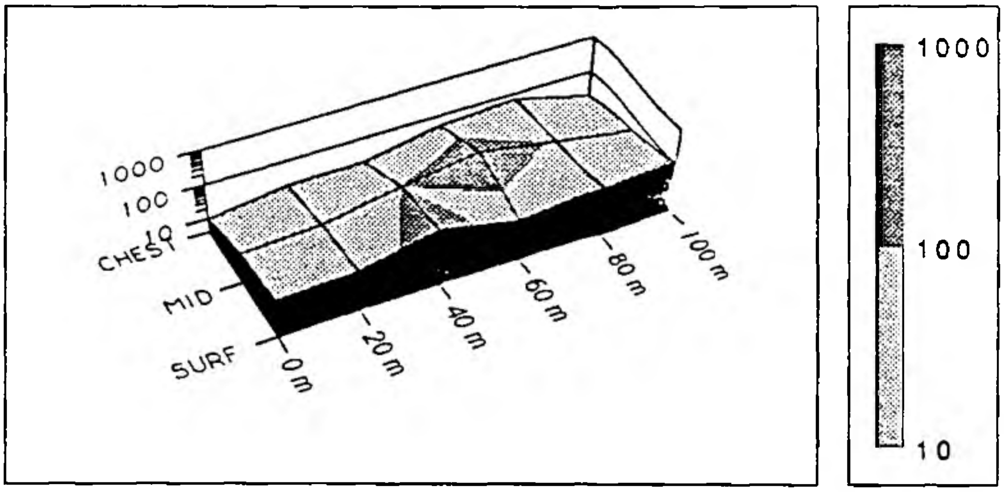
(c) Total coliform (per 100 ml), 13.00

Figure 6.2 continued

(d) Total coliform (per 100 ml), 13.20



(e) Total coliform (per 100 ml), 13.40



(f) Total coliform (per 100 ml), 14.00

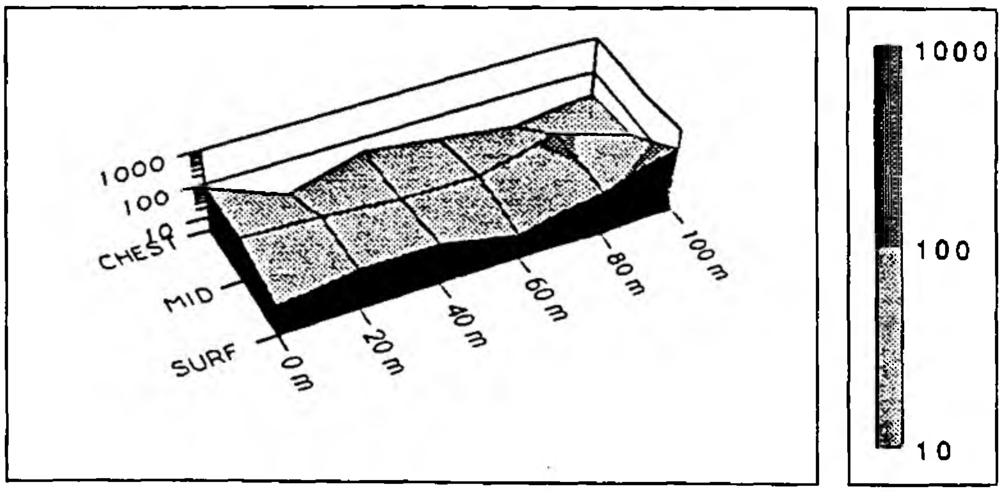
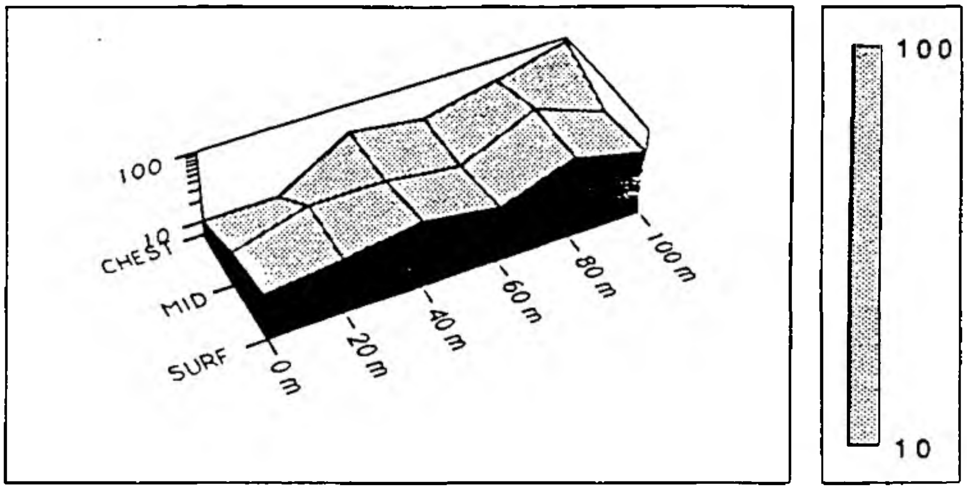
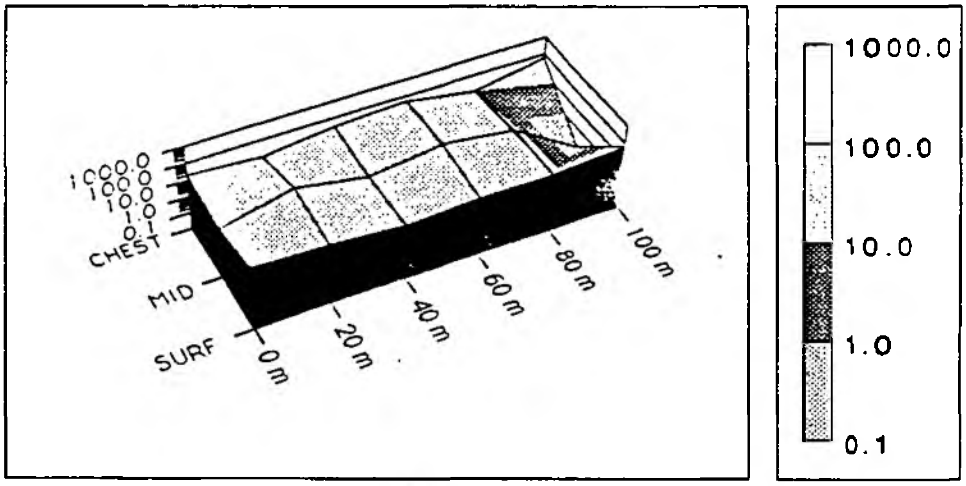


Figure 6.2 continued


(g) Total coliform (per 100 ml), 14.20


(h) Total coliform (per 100 ml), 14.40

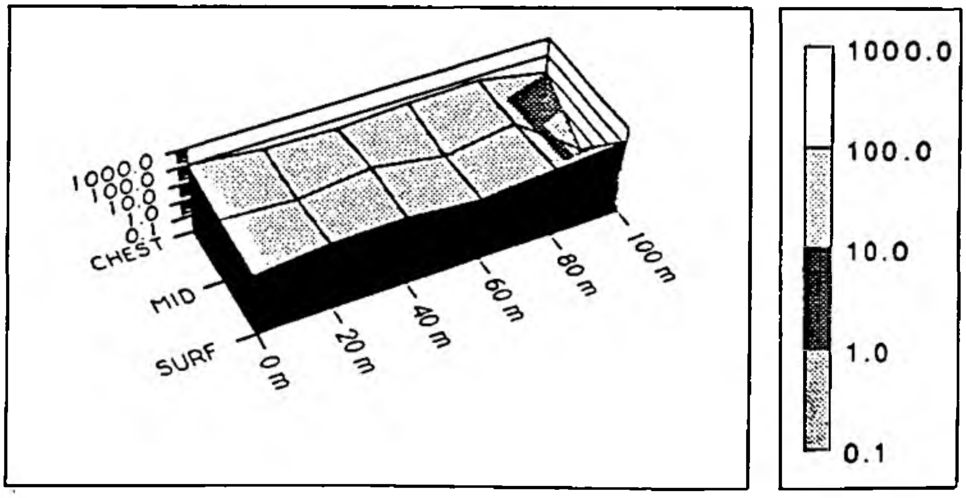
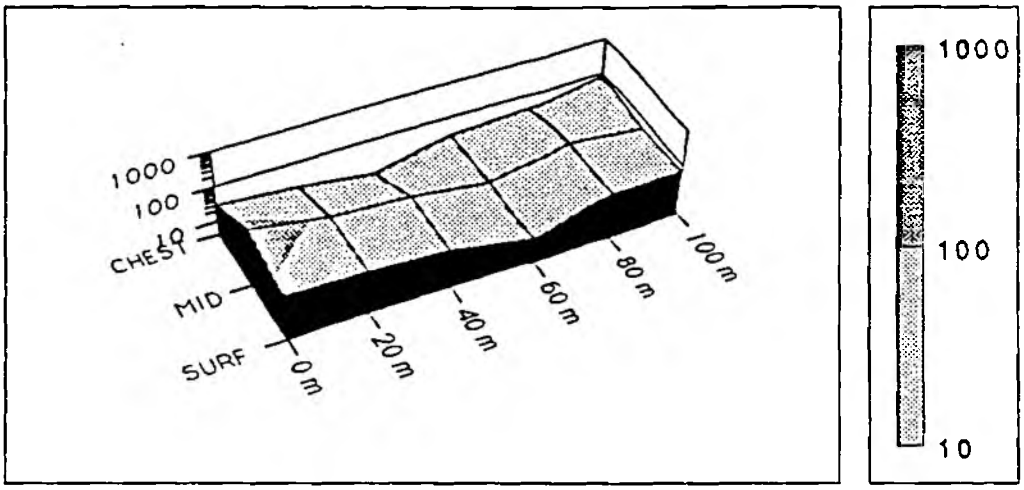
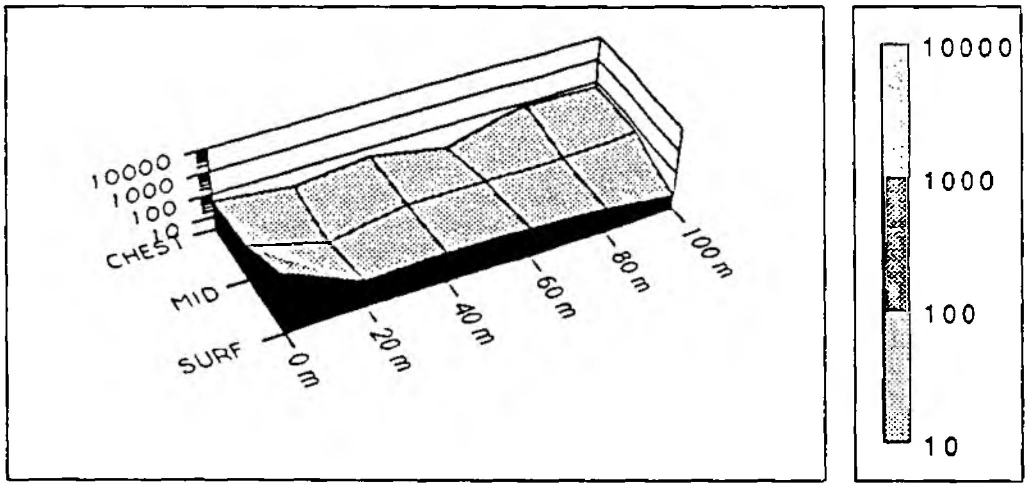

(i) Total coliform (per 100 ml), 15.00

Figure 6.3 Faecal coliform, Langland Bay 2/9/89, 12.00-15.00 BST

(a)Faecal coliform (per 100 ml), 12.00



(b) Faecal coliform (per 100 ml), 12.30



(c) Faecal coliform (per 100 ml), 13.00

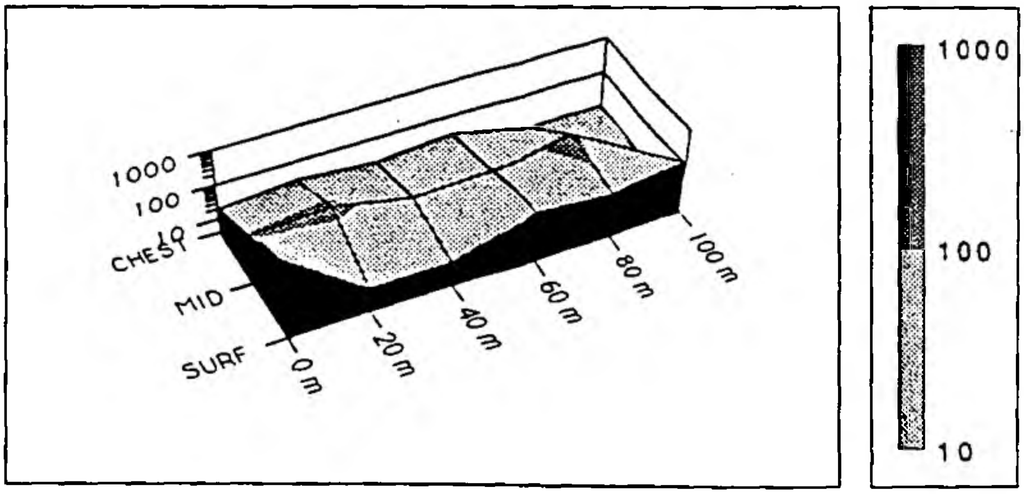
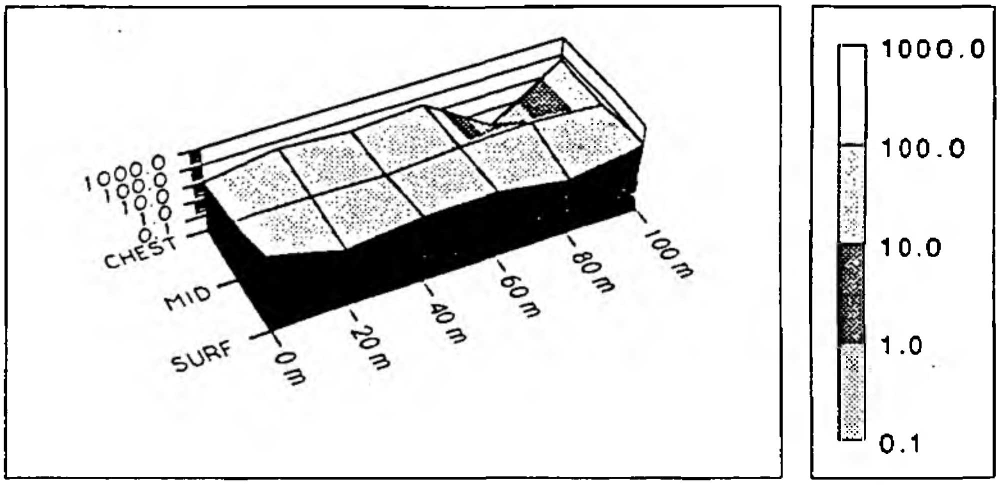
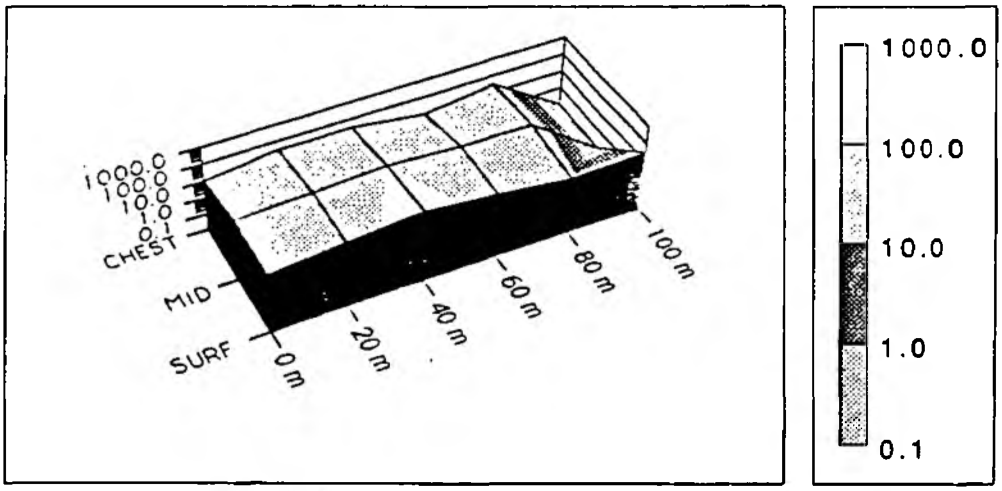


Figure 6.3 continued

(d) Faecal coliform (per 100 ml), 13.20



(e) Faecal coliform (per 100 ml), 13.40



(f) Faecal coliform (per 100 ml), 14.00

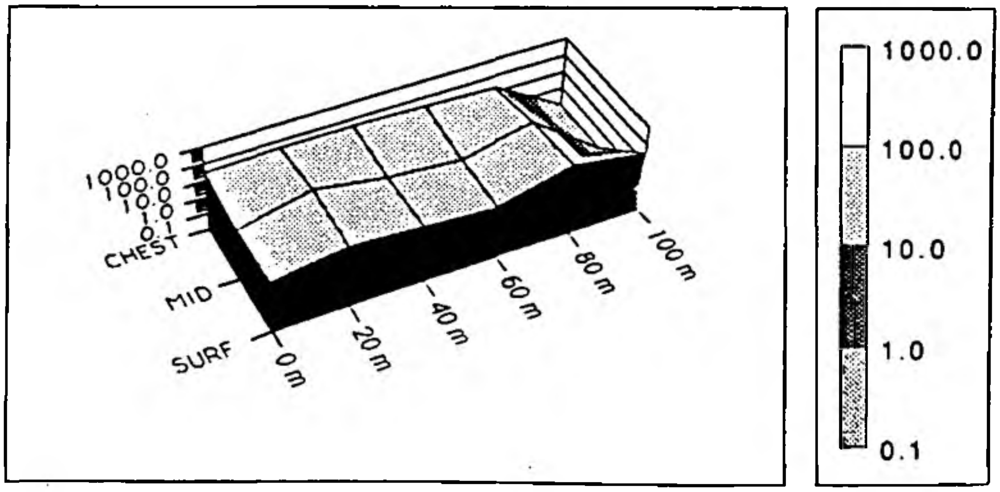
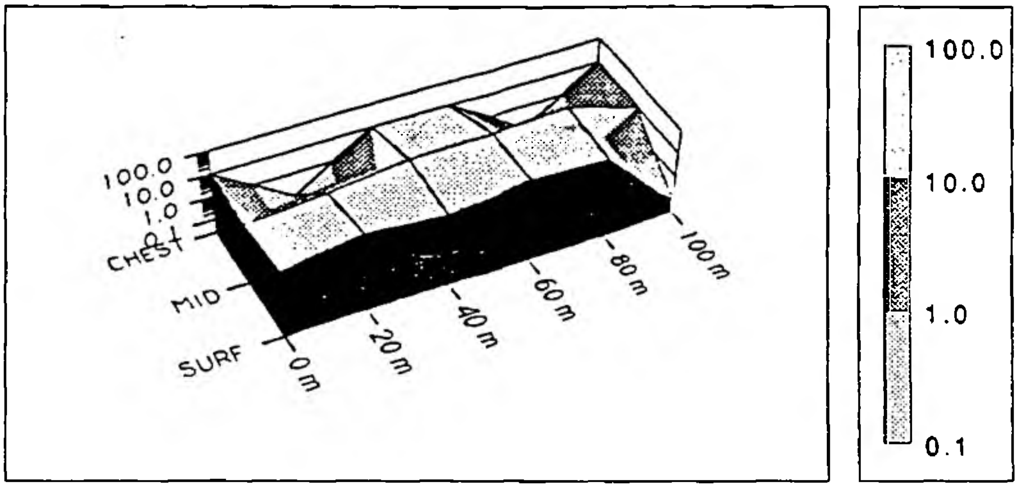
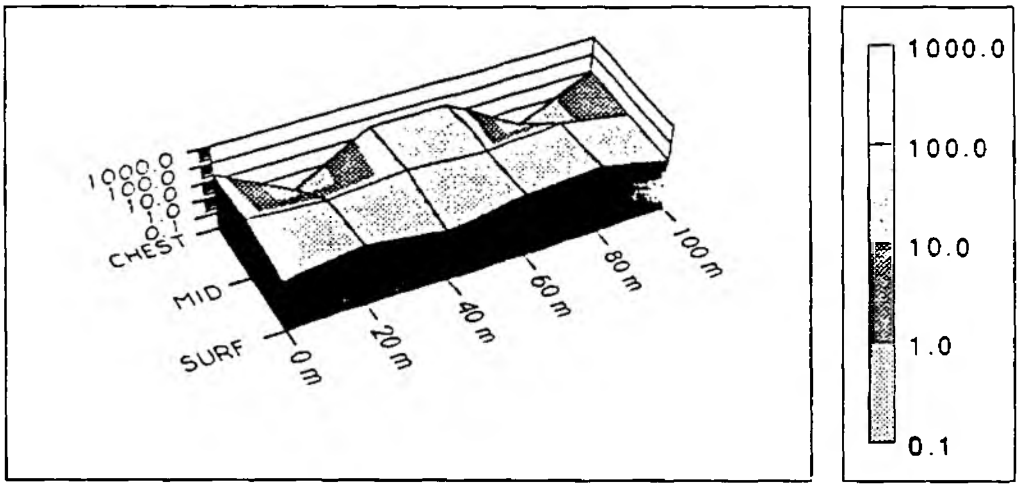


Figure 6.3 continued

(g) Faecal coliform (per 100 ml), 14.20



(h) Faecal coliform (per 100 ml), 14.40



(i) Faecal coliform (per 100 ml), 15.00

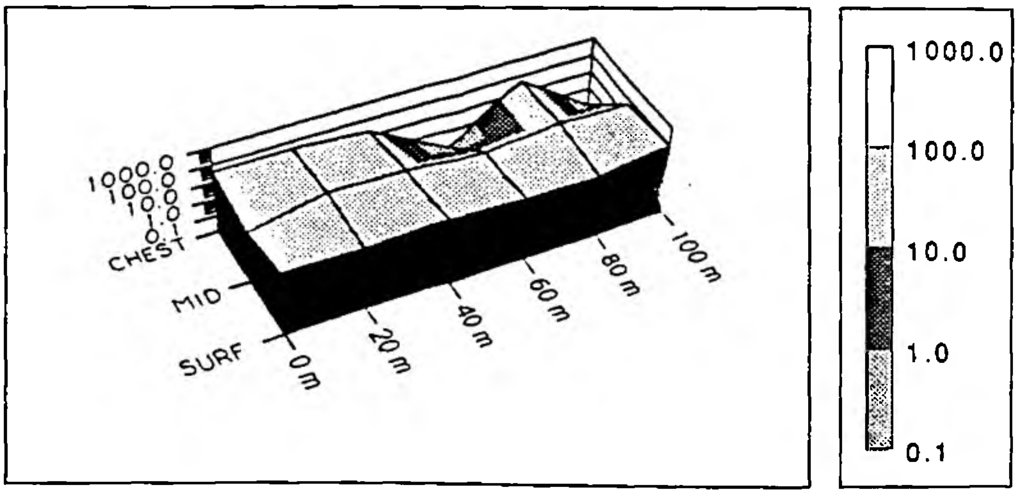
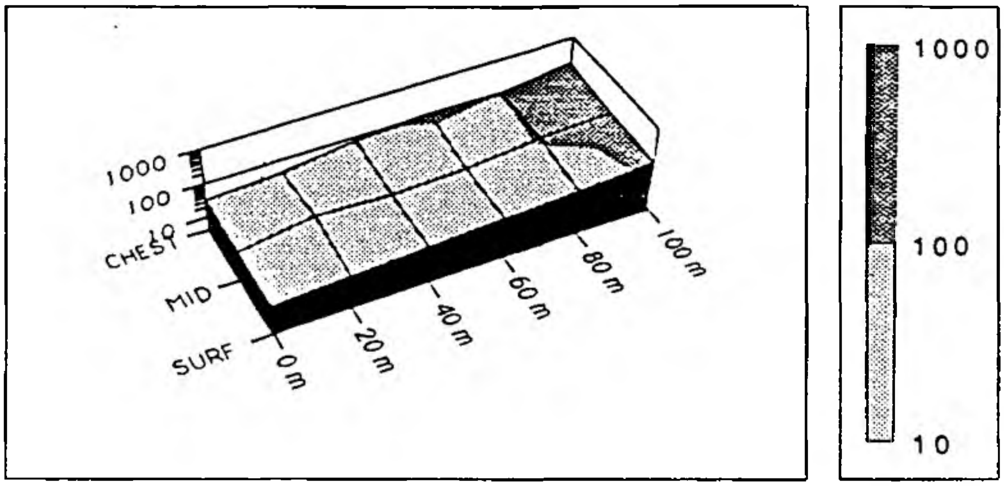
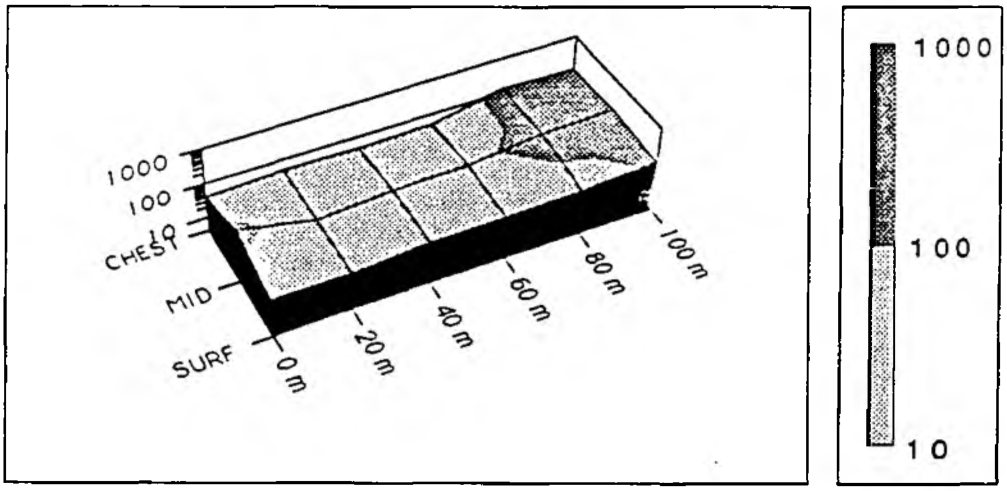


Figure 6.4 Faecal streptococci, Langland Bay 2/9/89 12.00-15.00 BST

(a) Faecal streptococci (per 100 ml), 12.00



(b) Faecal streptococci (per 100 ml), 12.30



(c) Faecal streptococci (per 100 ml), 13.00

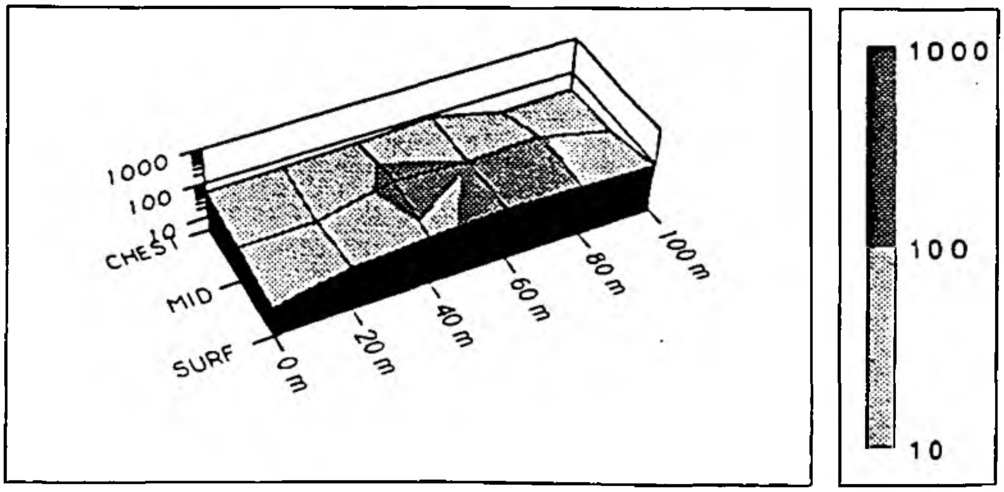
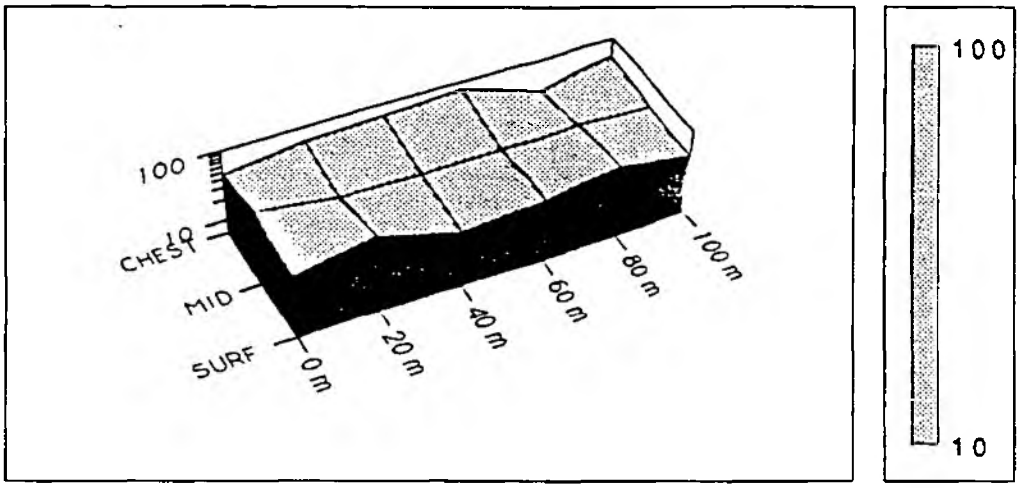
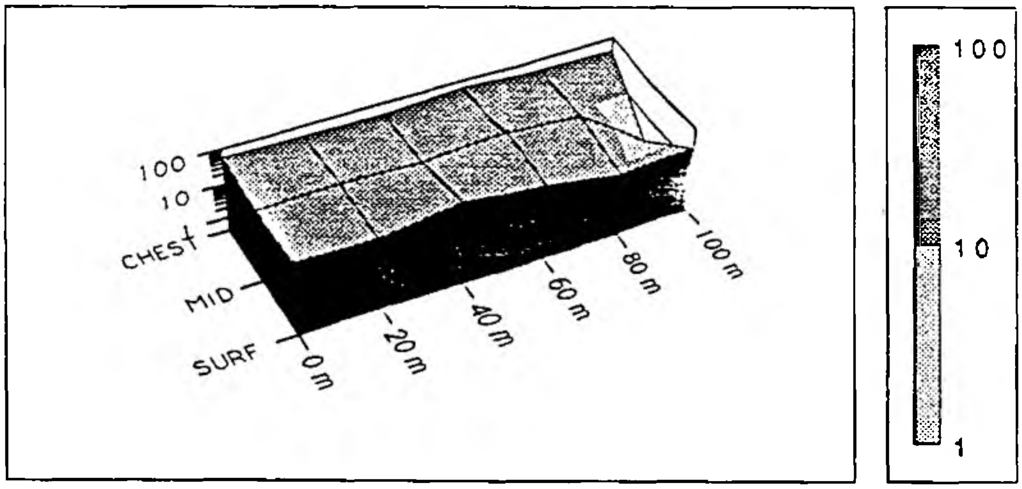


Figure 6.4 Continued

(d) Faecal streptococci (per 100 ml), 13.20



(e) Faecal streptococci (per 100 ml), 13.40



(f) Faecal streptococci (per 100 ml), 14.00

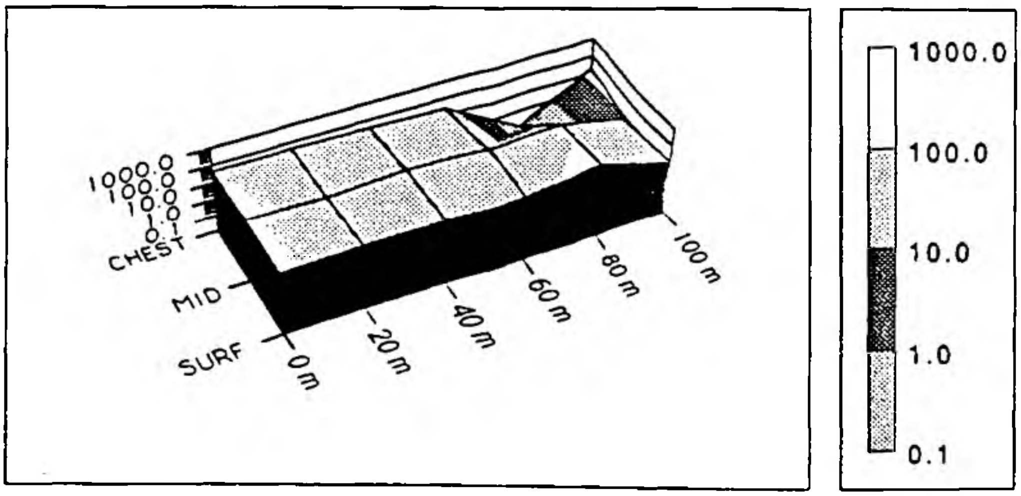
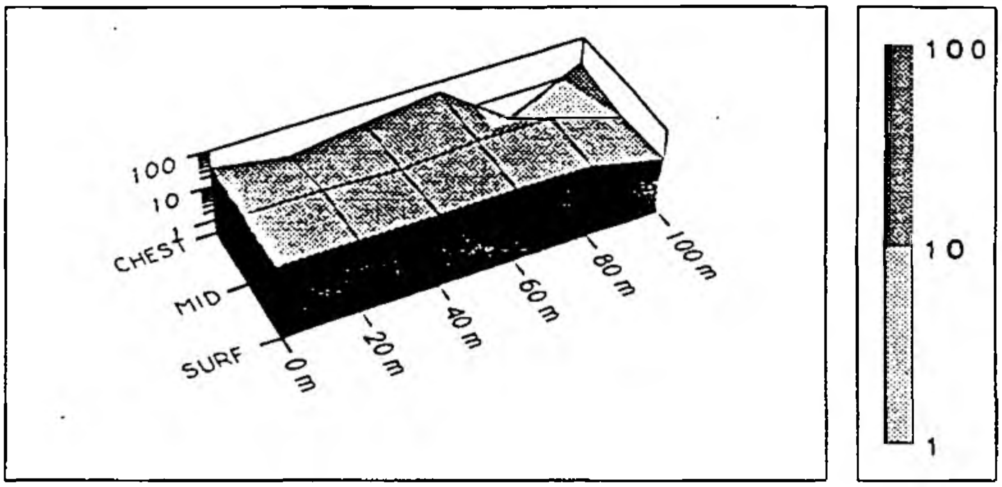
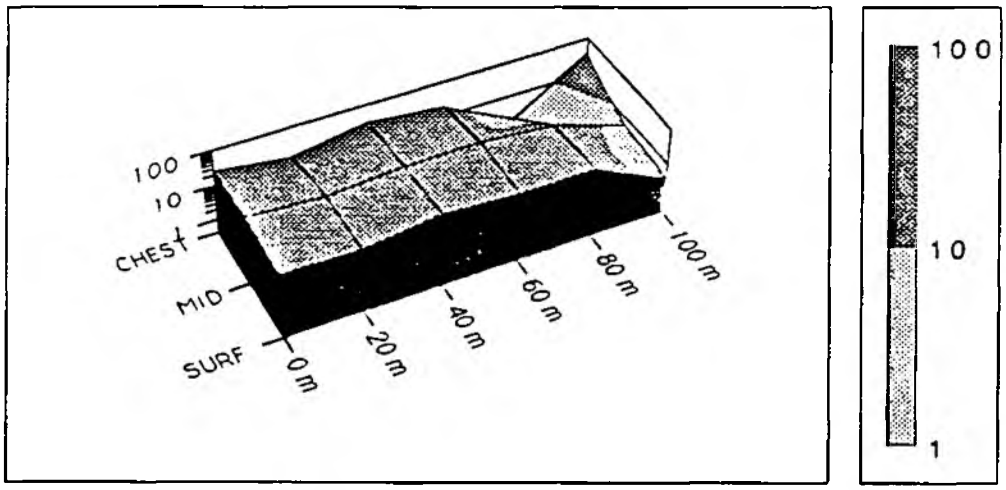


Figure 6.4 Continued

(g) Faecal streptococci (per 100 ml), 14.20



(h) Faecal streptococci (per 100 ml), 14.40



(i) Faecal streptococci (per 100 ml), 15.00

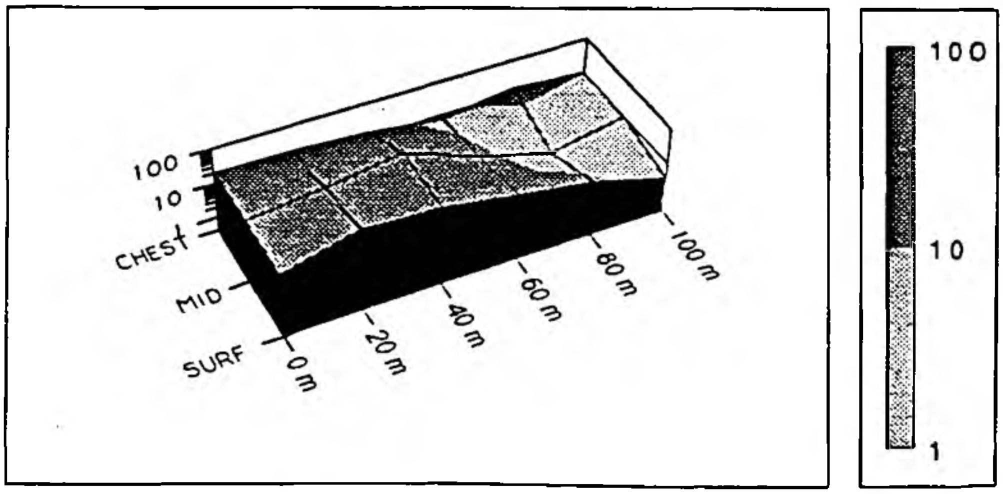
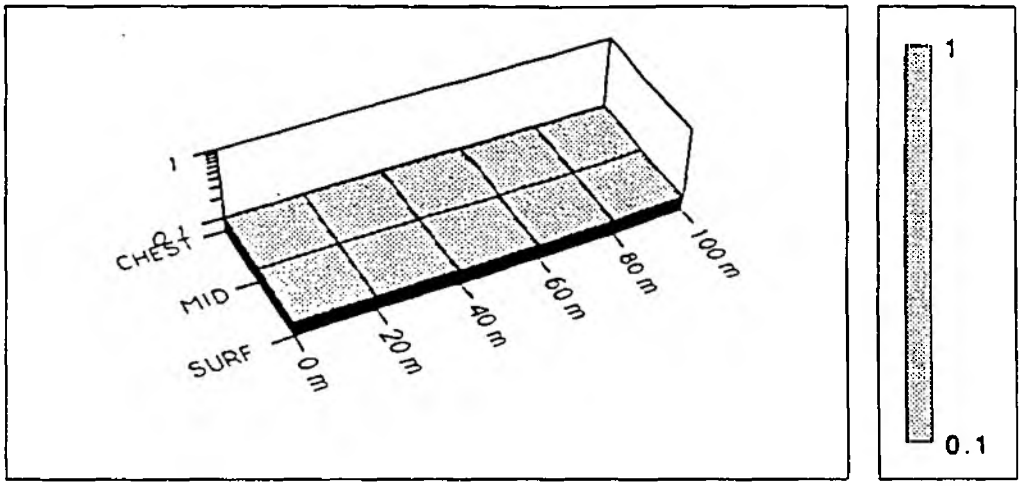
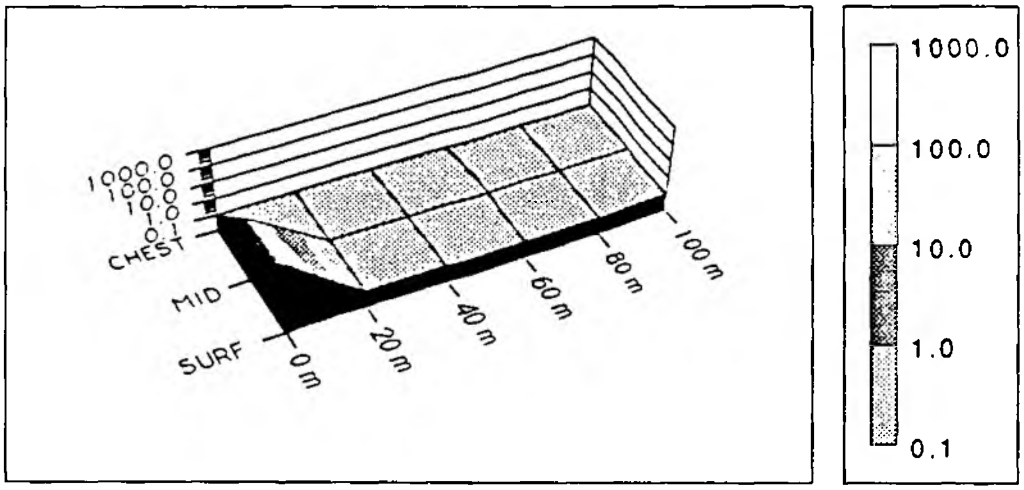


figure 6.5 Pseudomonas aeruginosa, Langland Bay 2/9/89, 12.00-15.00 BST

(a) Pseudomonas aeruginosa (per 100 ml), 12.00



(b) Pseudomonas aeruginosa (per 100 ml), 12.30



(c) Pseudomonas aeruginosa (per 100 ml), 13.00

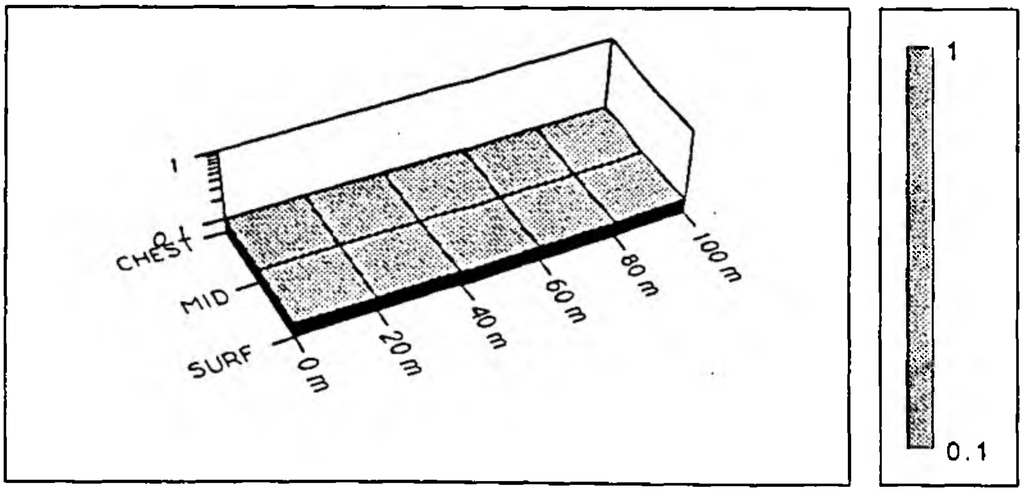
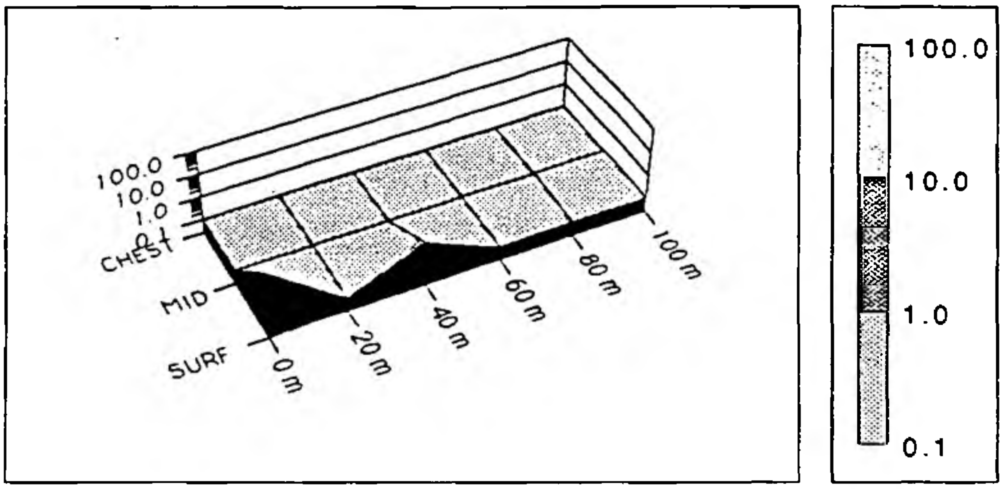
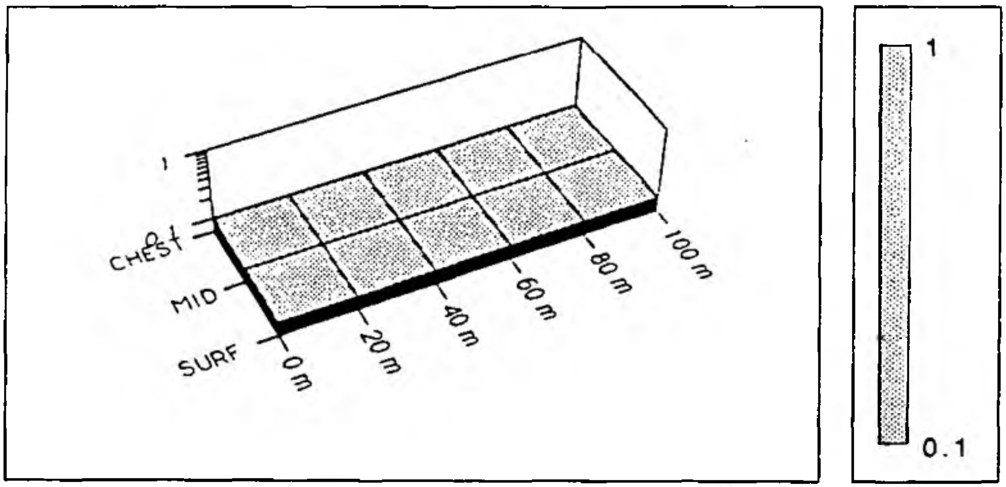


Figure 6.5 continued

(d) Pseudomonas aeruginosa (per 100 ml), 13.20



(e) Pseudomonas aeruginosa (per 100 ml), 13.40



(f) Pseudomonas aeruginosa (per 100 ml), 14.00

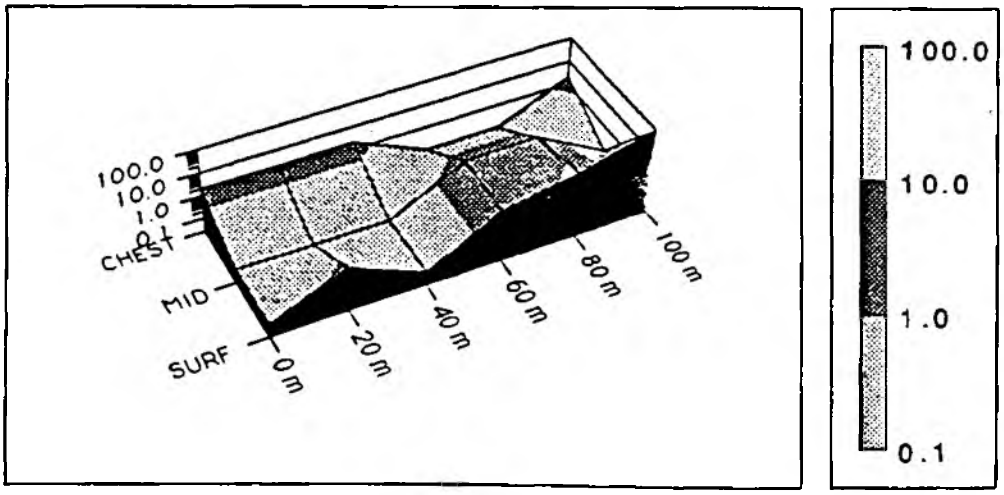
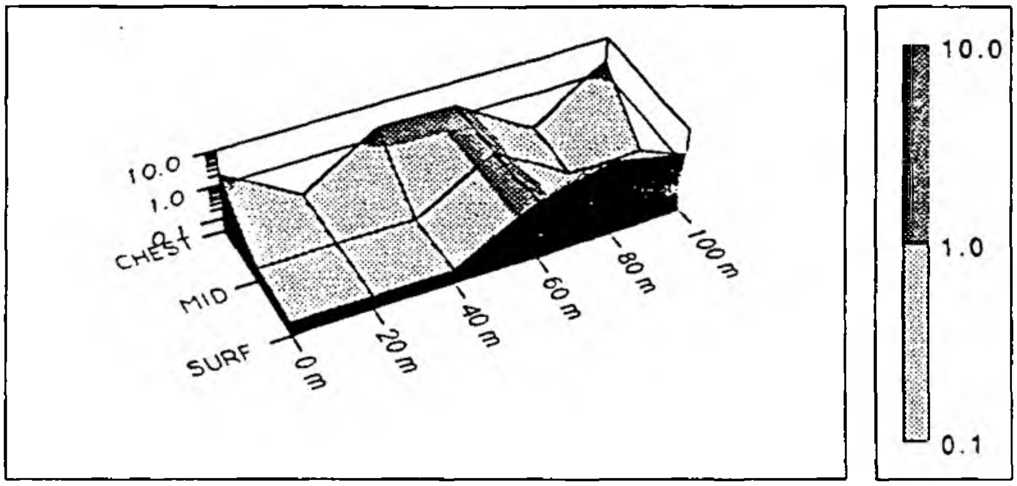
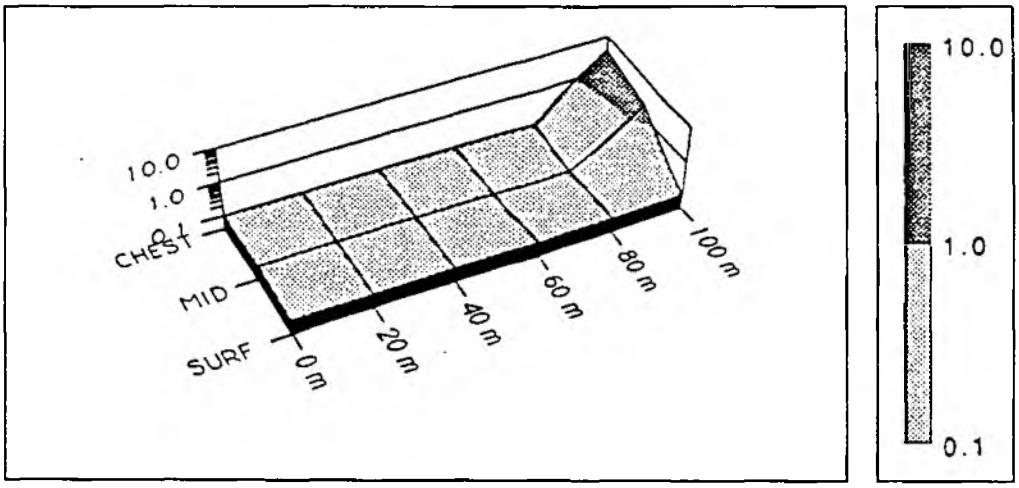


Figure 6.5 continued

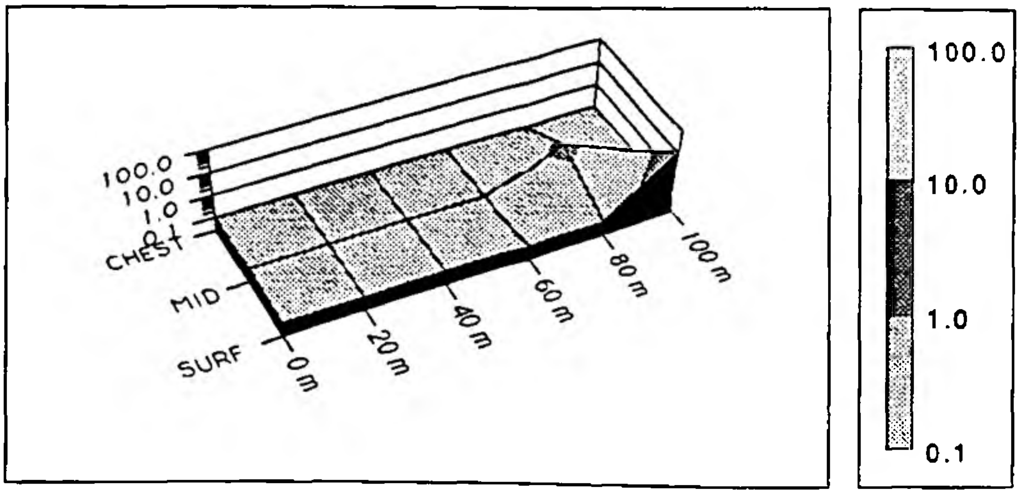
(g) Pseudomonas aeruginosa (per 100 ml), 14.20



(h) Pseudomonas aeruginosa (per 100 ml), 14.40



(i) Pseudomonas aeruginosa (per 100 ml), 15.00



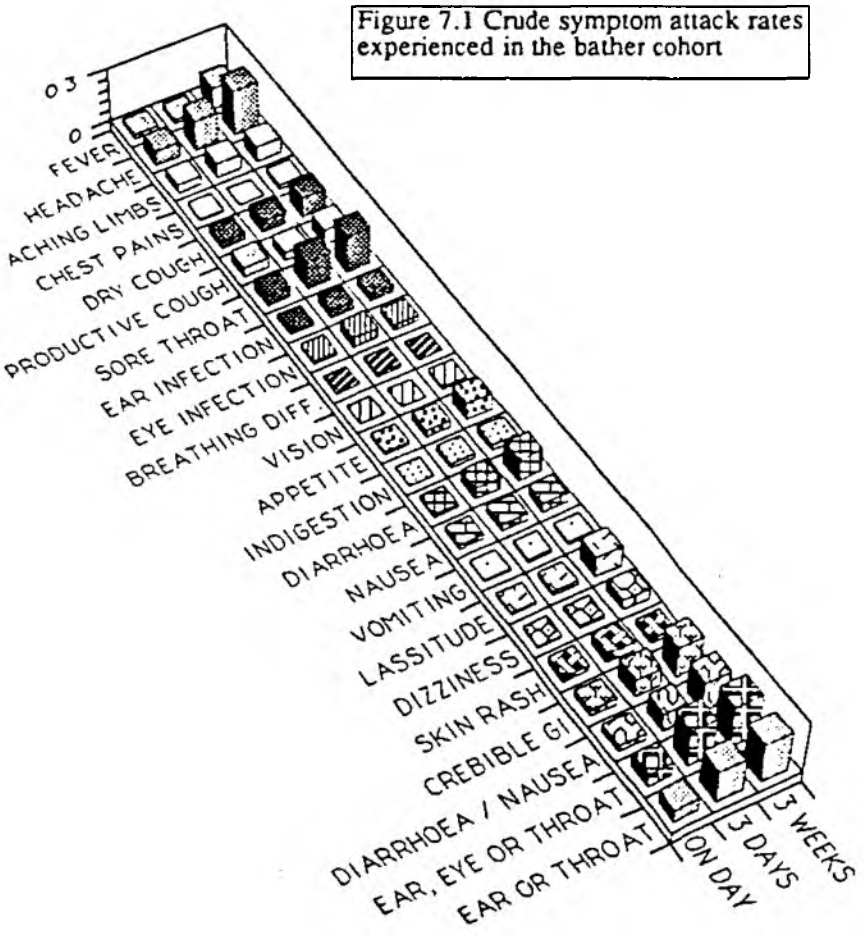


Figure 7.1 Crude symptom attack rates experienced in the bather cohort

Figure 7.2 Crude symptom attack rates experienced in the non-bather cohort

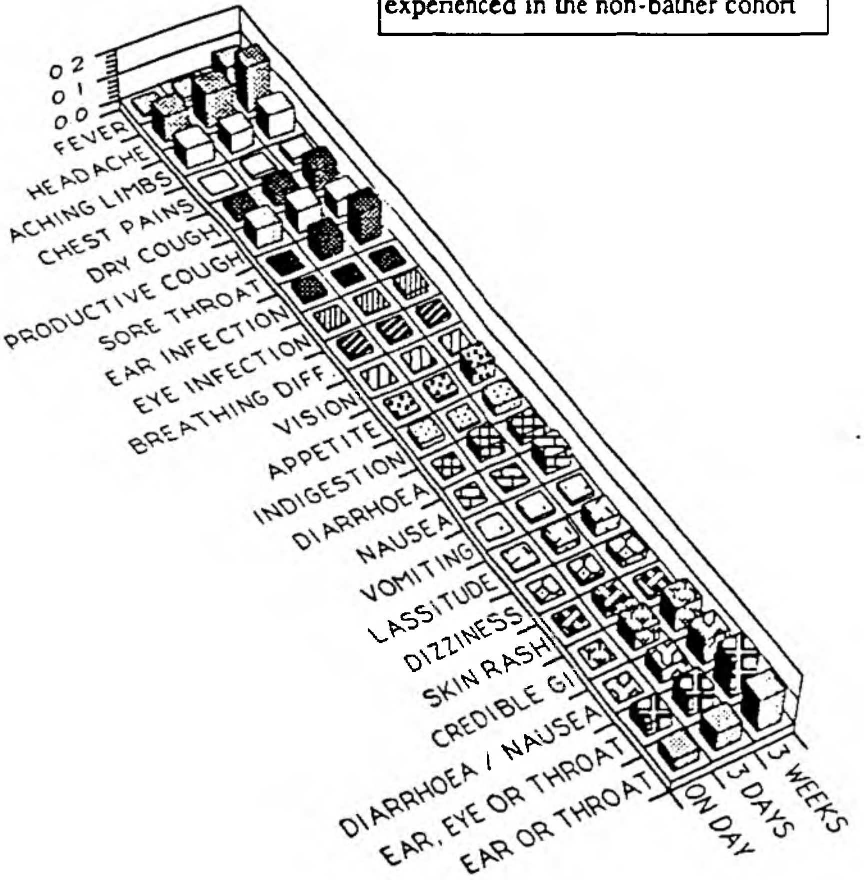
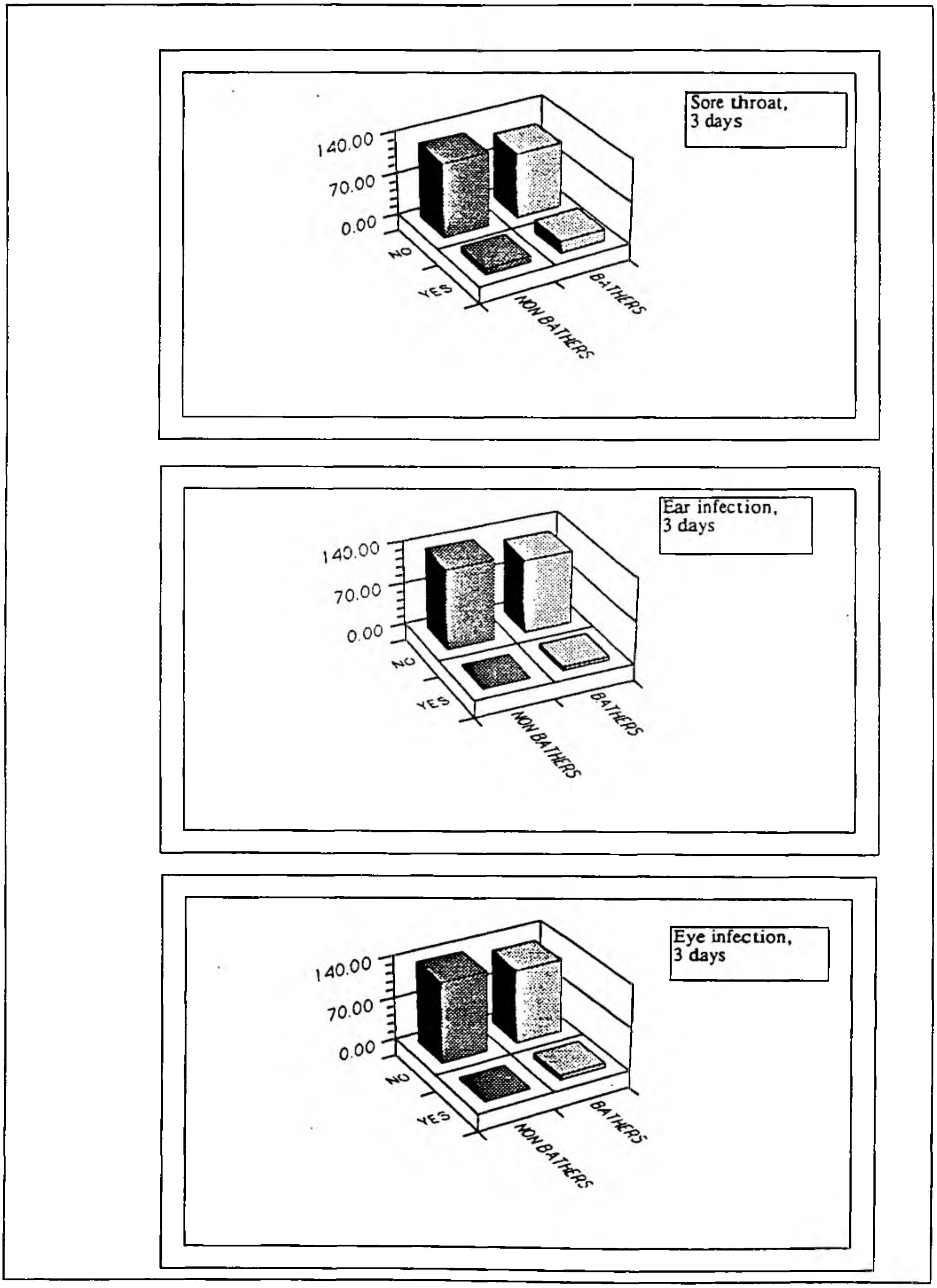


Figure 7.3 Rates of symptom reporting for all significant differences between bather and non-bather cohorts

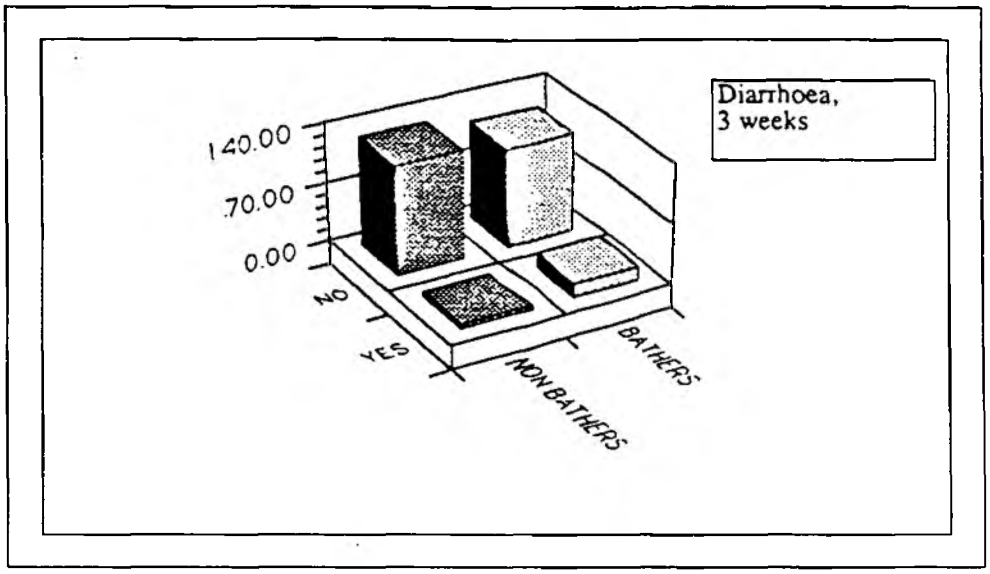


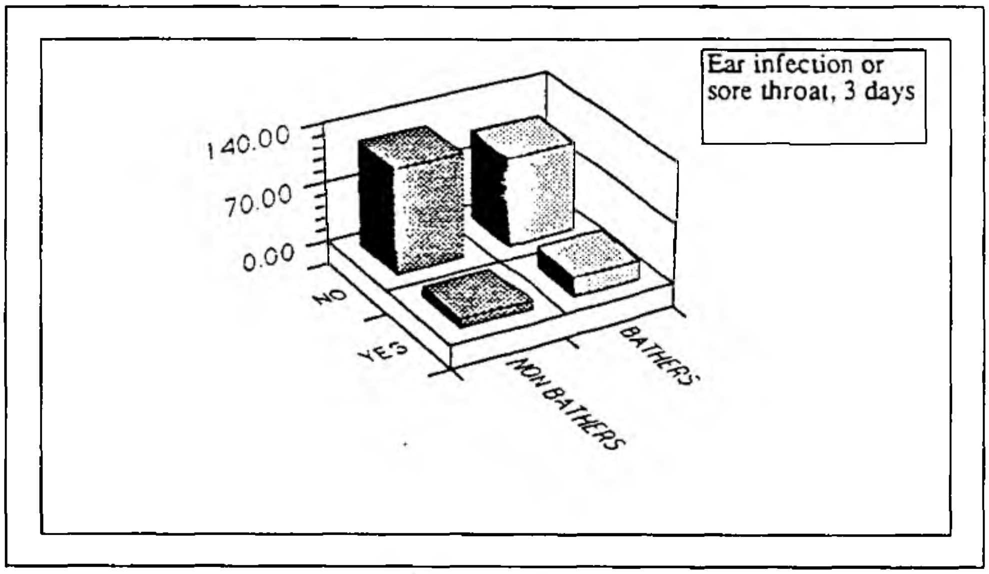
Sore throat, 3 days

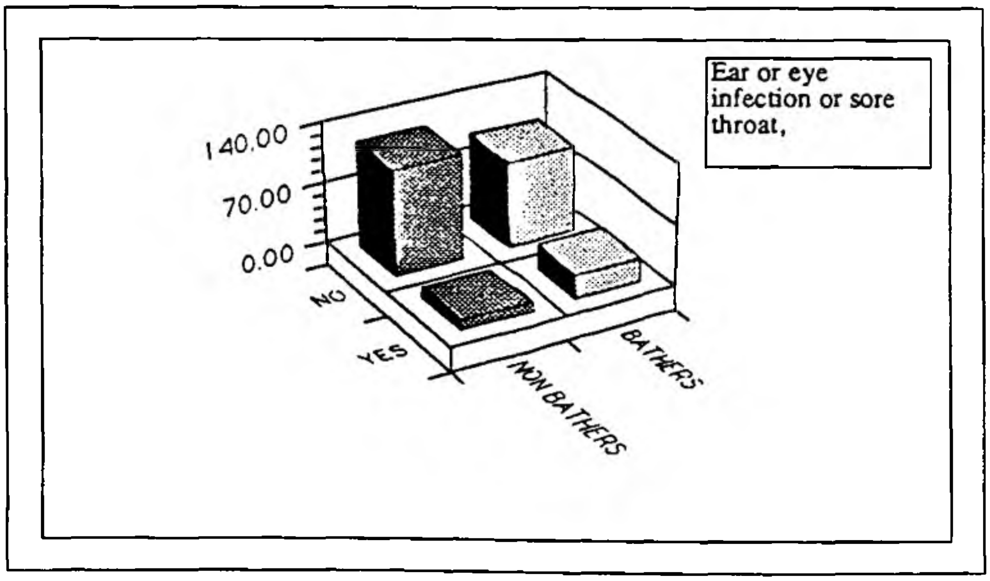
Ear infection, 3 days

Eye infection, 3 days

Figure 7.3 continued







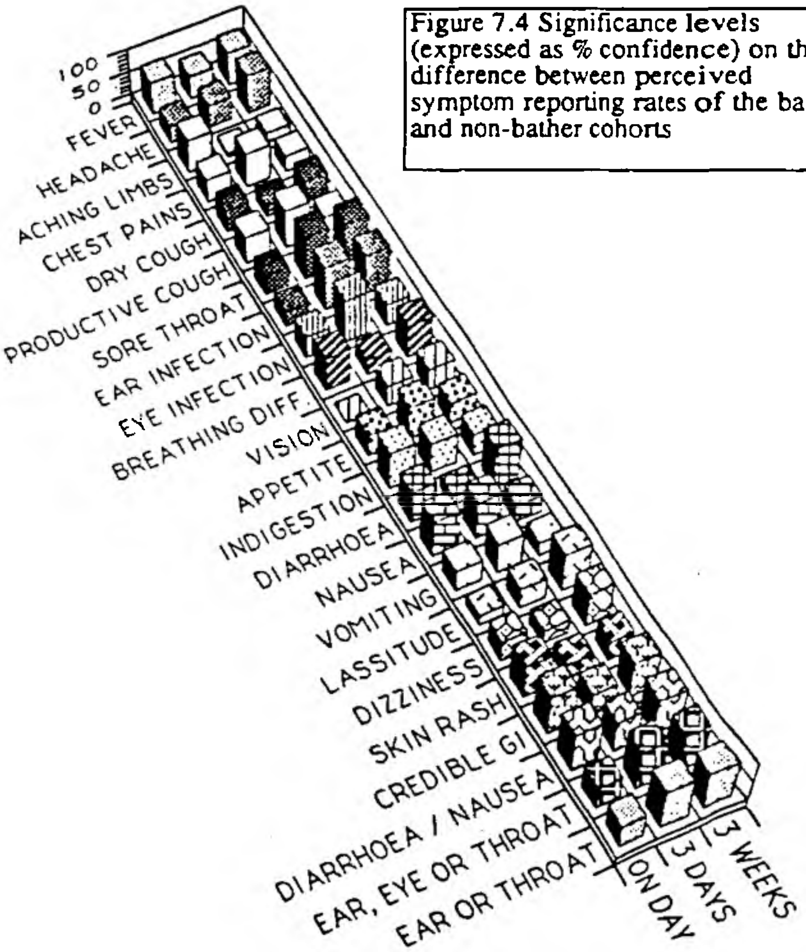
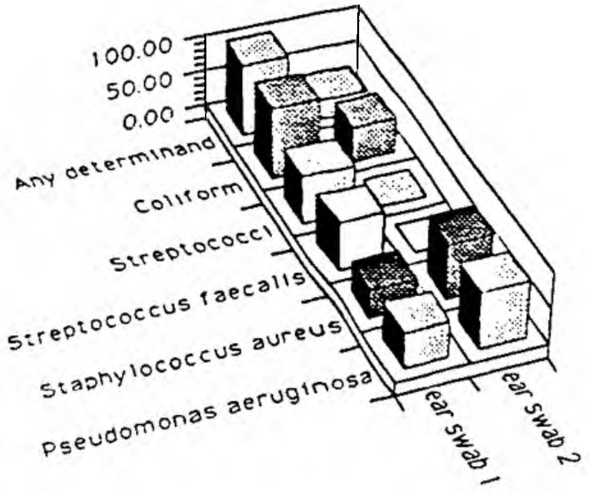


Figure 7.4 Significance levels (expressed as % confidence) on the difference between perceived symptom reporting rates of the bather and non-bather cohorts

Figure 8.1 Percentage confidence values from chi-square analysis of swab results

(a) Ear swabs



(b) Throat swabs

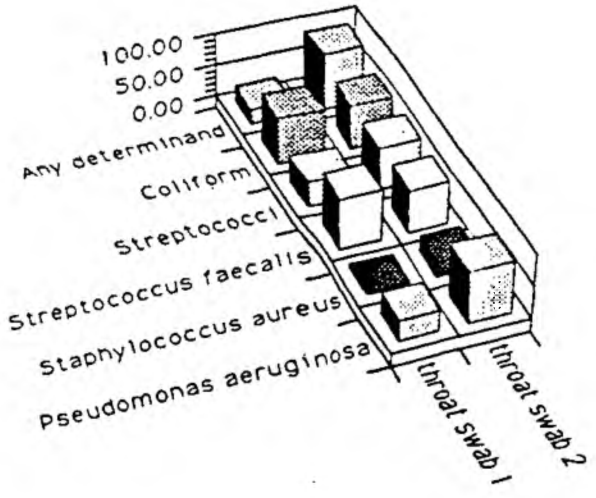
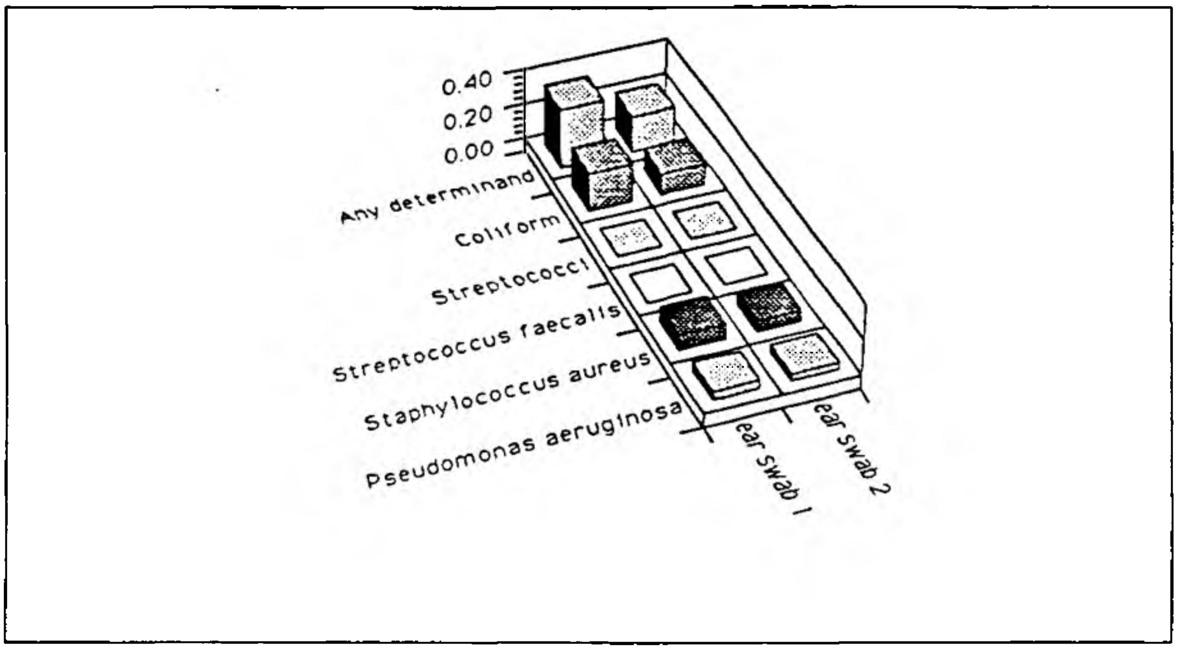


Figure 8.2 Crude attack rates, swab results from the bather cohort

(a) Ear swabs



(b) Throat swabs

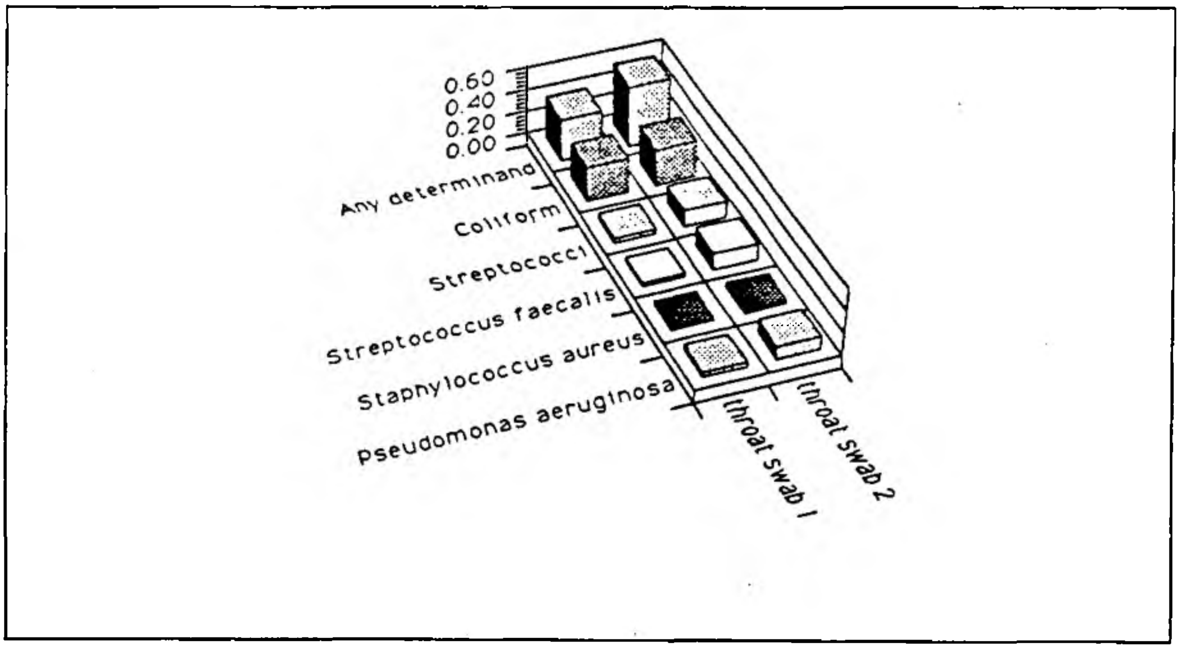
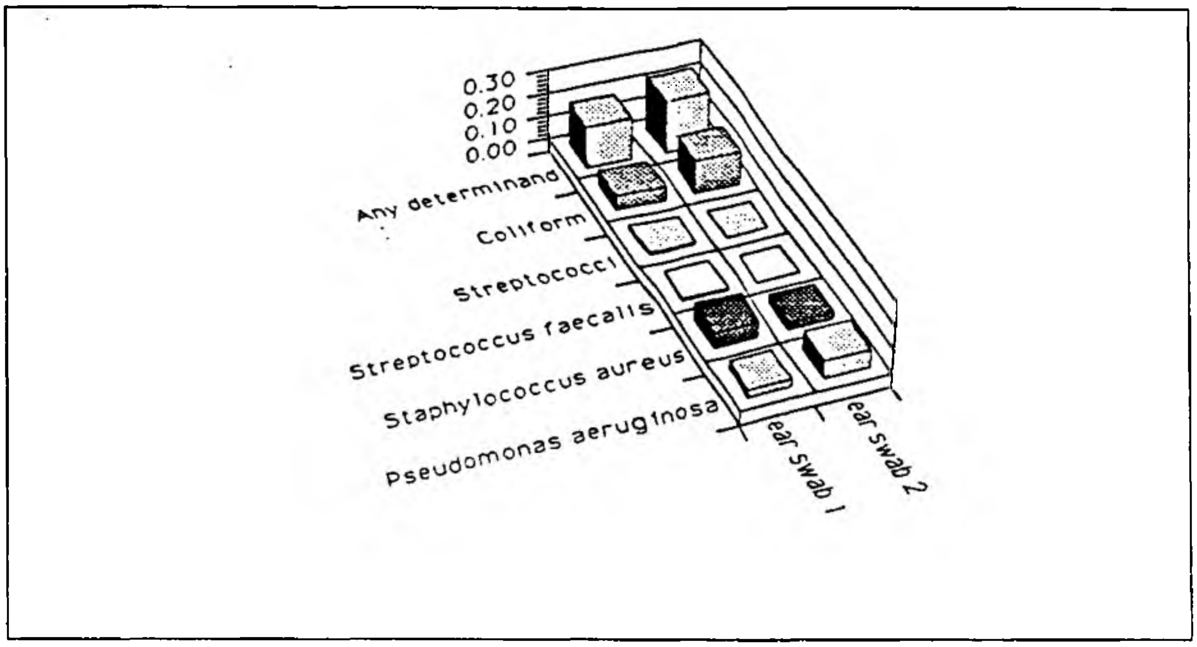


Figure 8.3 Crude attack rates, swab results from the non-bather cohort

(a) Ear swabs



(b) Throat swabs

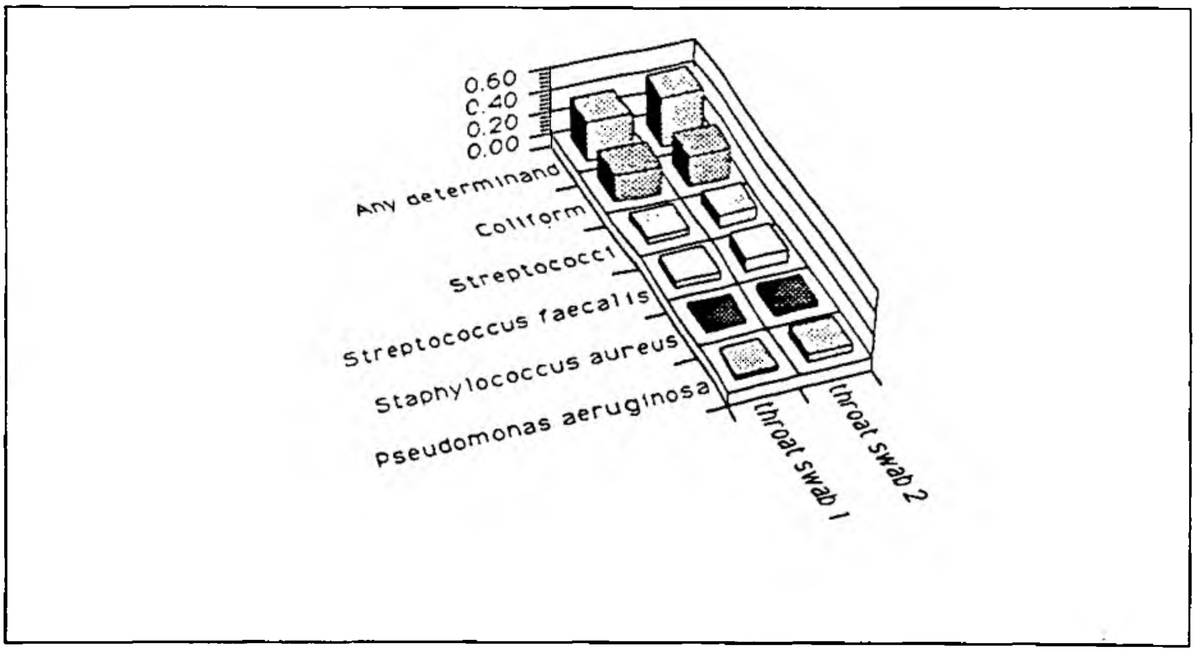
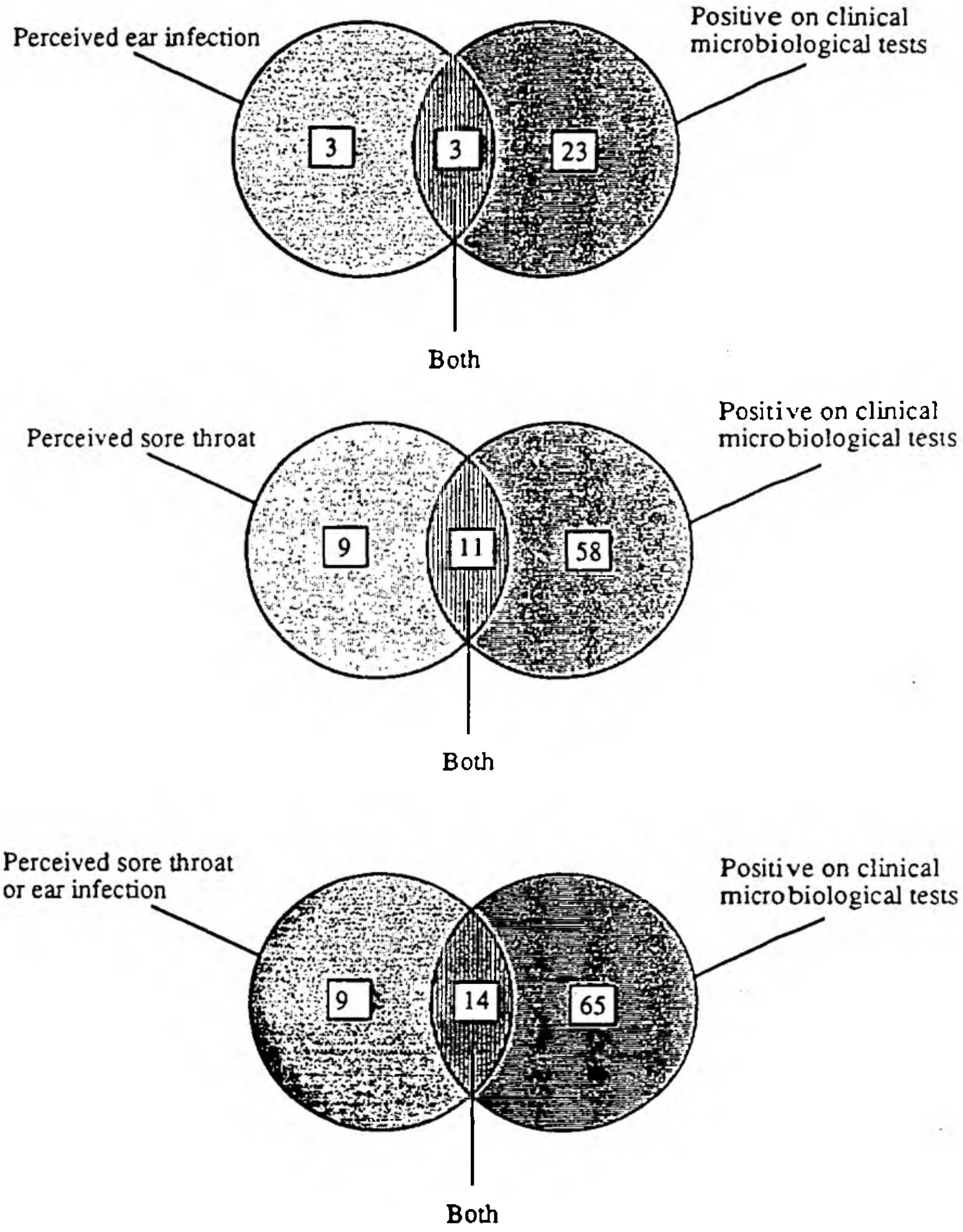
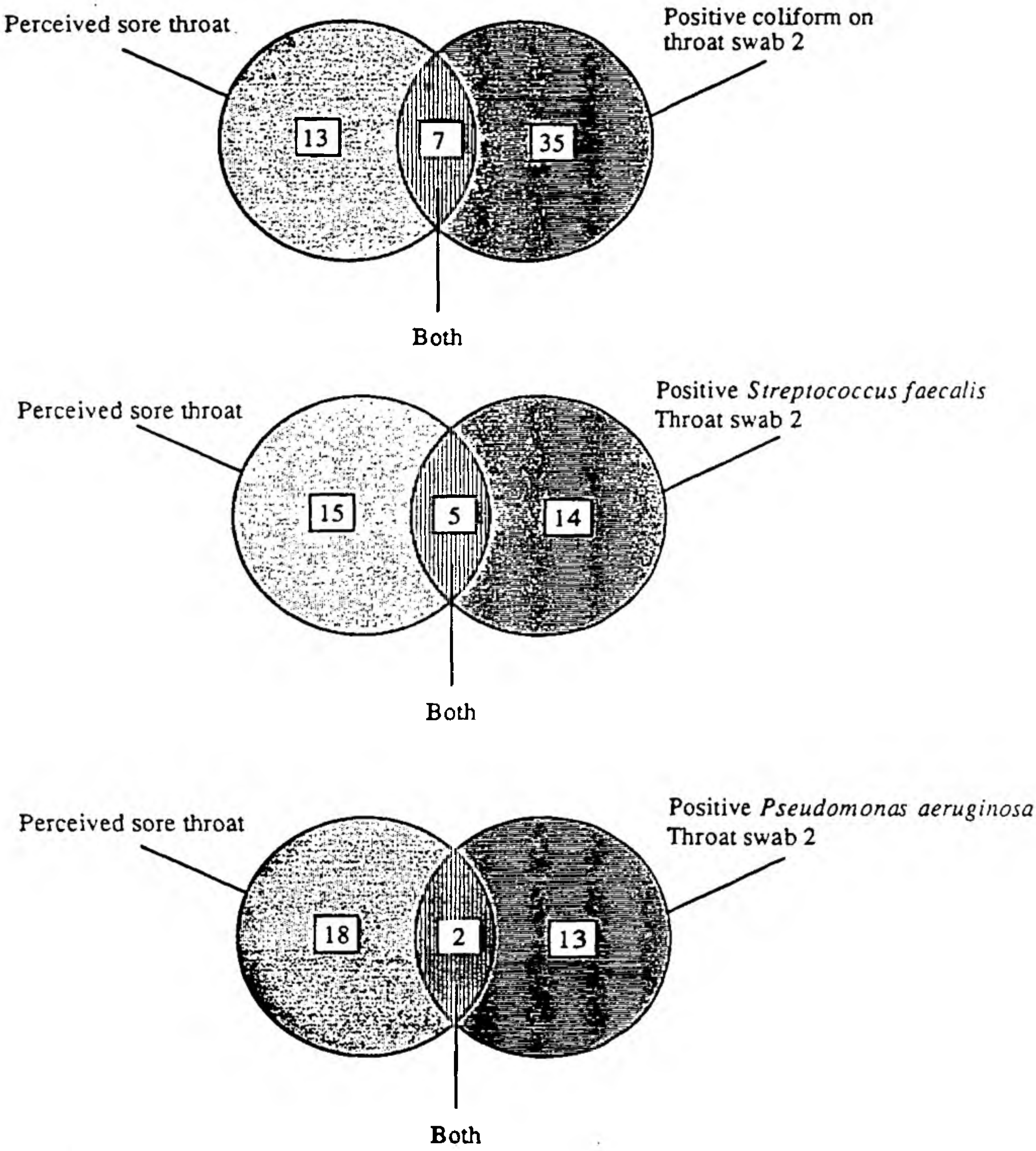


FIGURE 8.4 Schematic venn diagrams - Bathers showing numbers of perceived symptoms and positive swab results for a sore throat or ear infection three days after exposure



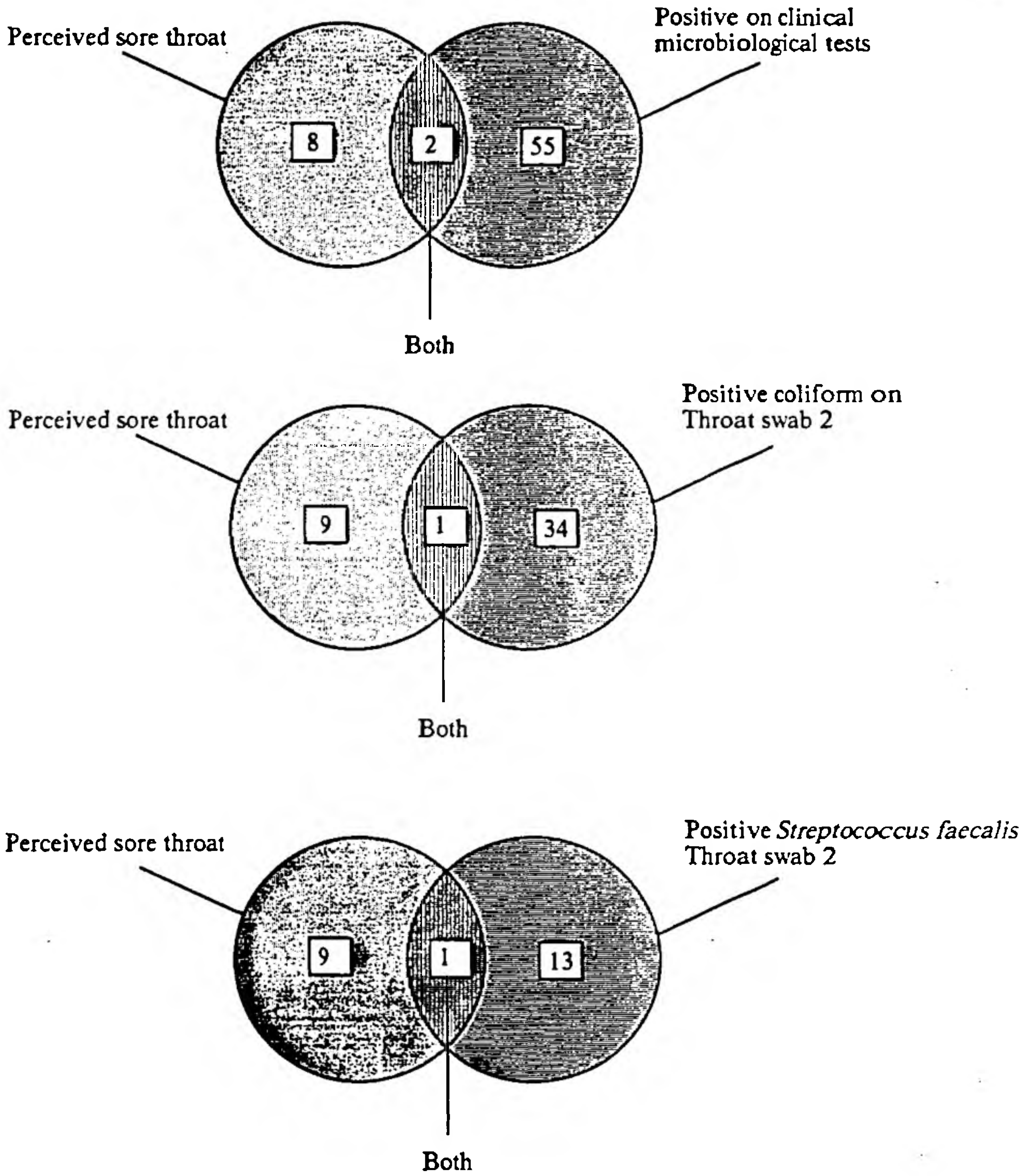
Note : Total in each circle is the sum of the two figures appearing within the circle

FIGURE 8.5 Schematic venn diagrams - Bathers showing numbers of perceived symptoms for a sore throat and positive swab results for coliform, *Streptococcus faecalis* or *Pseudomonas aeruginosa*



Note : Total in each circle is the sum of the two figures appearing within the circle

FIGURE 8.6 Schematic venn diagrams - Non-bathers showing numbers of positive perceived symptoms and positive swab results for a sore throat three days after exposure.



Notes : Total in each circle is the sum of the two figures appearing within the circle
No non-bathers with perceived sore throats had positive *Pseudomonas aeruginosa* or *Staphylococcus aureus* on the second throat swab

TABLES

Table 3.1 Summary results of the Cabelli style prospective epidemiological studies.

AUTHOR	*DATE*	*NATION*	*FRESH/SEA*	*INDICATOR*	*R^2*	*SYMPTOMS*
Stevenson	1953	USA	both	total coliform	NR	ENT/GI/R
Cabelli	1982	USA	both	enterococci	.56	GI
Seyfried	1985	Canada	fresh	total staphylococci	.19	R/GI
				faecal coliform	.08	
				faecal streptococci	.03	
Lightfoot	1989	Canada	fresh	age	NR	R/GI
				contact person		
				interviewer		
Cheung	1988	Hong Kong	sea	*E. coli*	.53	S/GI
				staphylococci		
El Sharkawi	1983	Egypt	sea	enterococci	.79	GI
				E. coli	.77	
Fattal	1986	Israel	sea	enterococci	NR	GI
				E. coli	NR	GI
Mujeriego	1982	Spain	sea	faecal streptococci	NR	S/E/ENT/GI
Foulon	1983	France	sea	faecal streptococci	NR	E/S/GI
				total coliforms		
				faecal coliforms		

List of Symptoms

NR = not reported
E = eye infections
S = skin complaints
GI = gastrointestinal symptoms
ENT = ear nose and throat infections
R = respiratory illness
Sources All named authors and Shuval

R^2 = Coefficient of determination

Table 4.1 Volunteer numbers taking part at each phase of the controlled cohort pilot study and full return details of questionnaires and clinical samples. Initially 465 volunteers were recruited.

	Questionnaire Return	Ear Swab	Throat Swab	Faecal Sample
First Interview	276	262+	262¶	269*
At the Beach	266	-	-	-
Second Interview	262	255+	255¶	261
Postal Questionnaire	259	-	-	248*

+ 246 pairs

¶ 244 pairs

* figure includes 1 empty sample container

Table 6.1 Summary statistics, Langland Bay summer 1989

Variable	Mean	Standard Deviation	Min	Max	N
Total coliform	1396.000	1828.000	100.00	7200.00	19
Faecal streptococci	119.600	125.800	2.00	500.00	19
Faecal coliform	451.000	494.000	10.00	2200.00	19
Log$_{10}$ Total coliform	2.849	0.545	2.00	3.86	19
Log$_{10}$ Faecal streptococci	1.763	0.632	0.30	2.70	19
Log$_{10}$ Faecal coliform	2.417	0.528	1.00	3.34	19

Table 6.2 Compliance with EC bathing waters directives, Langland Bay 1989 bathing season

	Imperative	Guide	N
	No. samples not exceeding: 2000 / 100 ml (95% to comply)	No. samples not exceeding: 100 / 100 ml (80% to comply)	
Faecal coliform	18 (94.7%)*	6 (31.6%)	19
	No. samples not exceeding: 10,000 / 100 ml (95% to comply)	No. samples not exceeding: 500 / 100 ml (80% to comply)	
Total coliform	19 (100%)	7 (36.8%)	19
		No. samples not exceeding: 100 / 100 ml (90% to comply)	
Faecal streptococci		9 (47.4%)	19

*1 sample > 2000 / 100 ml is acceptable when N > 12 < 39

Table 6.3 Summary statistics, all data, Langland Bay 2/9/89

Variable	Mean	Standard Deviation	Min	Max	N
Total coliform	86.911	175.269	0.00	1434.00	180
Faecal streptococci	48.033	35.219	0.00	196.00	180
Pseudomonas aeruginosa	2.483	17.010	0.00	201.00	180
Faecal coliform	53.189	116.683	0.00	1310.00	180
Log_{10} Total coliform	1.567	0.759	-1.00	3.16	180
Log_{10} Faecal streptococci	1.501	0.530	-1.00	2.29	180
Log_{10} *Pseudomonas aeruginosa*	-0.758	0.629	-1.00	2.30	180
Log_{10} Faecal coliform	1.295	0.850	-1.00	3.12	180

Note: all Log_{10} values are log_{10} (concentration (per 100 ml) + 0.1)

Summary statistics for water quality parameters experienced by bathers at Langland Bay, 2/9/89.

Variable	Mean	S.D.	Min	Max	N
Total coliform, surf zone	1.85	0.17	1.60	2.23	120
Faecal Streptococci, surf zone	1.80	0.20	1.15	2.29	120
***Pseudomonas aeruginosa*, surf zone**	-0.91	0.36	-1.00	1.15	120
Faecal coliform, surf zone	1.65	0.26	1.30	2.20	120
Total coliform, 30 cm zone	1.87	0.23	1.30	2.32	120
Faecal Streptococci, 30 cm zone	1.80	0.22	0.61	2.14	120
***Pseudomonas aeruginosa*, 30 cm zone**	-0.97	0.22	-1.00	0.61	120
Faecal coliform, 30 cm zone	1.78	0.28	1.00	2.14	120
Total coliform, chest depth	1.43	0.80	-1.00	2.11	120
Faecal Streptococci, chest depth	1.66	0.38	-1.00	2.11	120
***Pseudomonas aeruginosa*, chest depth**	-0.93	0.29	-1.00	0.32	120
Faecal coliform, chest depth	1.11	0.82	-1.00	1.90	120

Table 6.4 Summary statistics for samples from three depth locations, Langland Bay 2/9/89

a. Surf zone

Variable	Mean	Standard Deviation	Min	Max	N
Total coliform	153.500	286.439	20.00	1434.00	54
Faecal streptococci	55.370	33.217	4.00	196.00	54
Pseudomonas aeruginosa	6.611	29.878	0.00	201.00	54
Faecal coliform	97.056	201.859	0.00	1310.00	54
Log$_{10}$ Total coliform	1.918	0.395	1.30	3.16	54
Log$_{10}$ Faecal streptococci	1.657	0.314	0.61	2.29	54
Log$_{10}$ *Pseudomonas aeruginosa*	-0.602	0.849	-1.00	2.30	54
Log$_{10}$ Faecal coliform	1.648	0.572	-1.00	3.12	54

b. 30cm depth zone

Variable	Mean	Standard Deviation	Min	Max	N
Total coliform	71.111	55.004	0.00	297.00	54
Faecal streptococci	56.037	34.803	2.00	156.00	54
Pseudomonas aeruginosa	1.296	7.635	0.00	56.00	54
Faecal coliform	52.889	37.043	0.00	188.00	54
Log$_{10}$ Total coliform	1.637	0.697	-1.00	2.47	54
Log$_{10}$ Faecal streptococci	1.637	0.375	0.32	2.19	54
Log$_{10}$ *Pseudomonas aeruginosa*	-0.816	0.552	-1.00	1.75	54
Log$_{10}$ Faecal coliform	1.574	0.488	-1.00	2.27	54

c. Chest depth

Variable	Mean	Standard Deviation	Min	Max	N
Total coliform	59.722	106.610	0.00	791.00	54
Faecal streptococci	46.185	34.379	0.00	180.00	54
Pseudomonas aeruginosa	0.370	0.875	0.00	4.00	54
Faecal coliform	24.389	19.104	0.00	80.00	54
Log$_{10}$ Total coliform	1.519	0.533	-1.00	2.90	54
Log$_{10}$ Faecal streptococci	1.502	0.511	-1.00	2.26	54
Log$_{10}$ *Pseudomonas aeruginosa*	-0.774	0.511	-1.00	0.61	54
Log$_{10}$ Faecal coliform	0.994	0.932	-1.00	1.90	54

Note: all Log$_{10}$ values are log$_{10}$ (concentration (per 100 ml) + 0.1)

Table 6.5 Summary statistics for the boat samples, Langland Bay 2/9/89

Variable	Mean	Standard Deviation	Min	Max	N
Total coliform	16.111	16.139	0.00	40.00	18
Faecal streptococci	7.556	6.271	0.00	22.00	18
Pseudomonas aeruginosa	0.000	0.000	0.00	0.00	18
Faecal coliform	8.889	9.003	0.00	30.00	18
Log_{10} Total coliform	0.451	1.203	-1.00	1.60	18
Log_{10} Faecal streptococci	0.622	0.668	-1.00	1.34	18
Log_{10} *Pseudomonas aeruginosa*	-1.000	0.000	-1.00	-1.00	18
Log_{10} Faecal coliform	0.301	1.077	-1.00	1.48	18

Note: all Log_{10} values are $\log_{10}$ (concentration (per 100 ml) + 0.1)

Table 6.6 Compliance with EC bathing waters directives, Langland Bay 2/9/89

	Imperative	Guide	N
	No. samples not exceeding: 2000 / 100 ml (95% to comply)	No. samples not exceeding: 100 / 100 ml (80% to comply)	
Faecal coliform	54 (100%)	50 (92.6%)	54
	No. samples not exceeding: 10,000 / 100 ml (95% to comply)	No. samples not exceeding: 500 / 100 ml (80% to comply)	
Total coliform	54 (100%)	54 (100%)	54
	-	No. samples not exceeding: 100 / 100 ml (90% to comply)	
Faecal streptococci	-	47 (87.0%)	54

Table 6.7 Virus concentrations, Langland Bay 2/9/89

Enteroviruses (pfu / 10 l)	**Rotaviruses (pfu / 10 l)**	**Tme (BST)**	**Shore Location**
0	0	12.15	20 m
0	0	12.15	40 m
0	0	12.15	60 m
0	0	12.50	40 m
0	0	12.50	60 m
0	0	12.50	80 m
0	0	13.25	20 m
2	4	13.25	40 m
0	0	13.25	60 m
0	0	14.00	0 m
0	0	14.00	80 m
0	4	14.00	100 m
0	8	14.15	20 m
0	0	14.15	80 m
0	0	14.15	100 m

Table 7.1 Significance values (p) for χ^2 analysis of significance between bather and non-bather perceived symptom attack rates.

Symptom	On the day	3 days after	3 weeks after
Fever	0.32 +	0.49 +	0.30
Headache	0.62	0.50	0.16
Aching limbs	0.28	0.93	0.80
Chest pains	0.51 +	0.26 +	0.65 +
Dry cough	0.51 +	0.73	0.54
Productive cough	0.42	0.16	0.65
Sore throat	0.57	0.04 *	0.11
Ear infection	0.68 +	0.03 (+)*	0.11
Eye infection	0.51 +	0.02 (+)*	0.51 +
Breathing difficulty	0.24 +	0.67 +	0.25 +
Blurred vision	-	0.51 +	0.50 +
Loss of appetite	0.51 +	0.23 +	0.51
Indigestion	0.12 +	0.30 +	0.49 +
Diarrhoea	0.25 +	0.74	0.01 *
Nausea	0.13 +	0.10 +	0.58
Vomiting	0.51 +	0.68 +	0.68 +
Lassitude	0.75 +	0.52 +	0.08
Dizziness	0.51 +	0.67 +	0.20 +
Skin rash	0.19 +	0.72	0.51 +
Credible gastro-intestinal (GI)	0.03(+)*	0.46	0.11
Diarrhoea or Nausea	0.03(+)*	0.23	0.11
Ear or Eye or Throat	0.47	0.00 *	0.07
Ear or throat	0.45	0.01 *	0.06

+ Fishers exact test (used when expected cell count < 5)

- untestable, 2 cells contained no positive responses

* significant at $\alpha < 0.05$

Table 7.2 Perceived symptom attack rates, all subjects

Symptom	On the day	3 days after	3 weeks after
Fever	0.0153	0.0191	0.0947
Headache	0.0923	0.1500	0.2083
Aching limbs	0.0613	0.0766	0.0868
Chest pains	0.0038	0.0076	0.0226
Dry cough	0.0345	0.0575	0.0947
Productive cough	0.0651	0.0687	0.0758
Sore throat	0.0462	0.1149	0.1667
Ear infection	0.0153	0.0192	0.0226
Eye infection	0.0115	0.0344	0.0264
Breathing difficulty	0.0077	0.0153	0.0075
Blurred vision	0.0000	0.0038	0.0114
Loss of appetite	0.0038	0.0267	0.0792
Indigestion	0.0115	0.0153	0.0345
Diarrhoea	0.0077	0.0573	0.0792
Nausea	0.0116	0.0229	0.0620
Vomiting	0.0038	0.0153	0.0151
Lassitude	0.0038	0.0267	0.0840
Dizziness	0.0038	0.0153	0.0453
Skin rash	0.0192	0.0230	0.0075
Crebible G I	0.0192	0.0878	0.1357
Diarrhoea or nausea	0.0192	0.0802	0.1357
Ear or eye or throat	0.0654	0.1462	0.1938
Ear or throat	0.0575	0.1269	0.1783

Table 7.2 (cont.) bather cohort only

Symptom	On the day	3 days after	3 weeks after
Fever	0.0227	0.0233	0.1145
Headache	0.0833	0.1654	0.2500
Aching limbs	0.0454	0.0781	0.0833
Chest pains	0.0076	0.0000	0.0227
Dry cough	0.0379	0.0625	0.1069
Productive cough	0.0530	0.0465	0.0840
Sore throat	0.0534	0.1563	0.2045
Ear infection	0.0152	0.0391	0.0379
Eye infection	0.0153	0.0620	0.0303
Breathing difficulty	0.0000	0.0156	0.0000
Blurred vision	0.0000	0.0000	0.0153
Loss of appetite	0.0152	0.0388	0.0909
Indigestion	0.0000	0.0233	0.0313
Diarrhoea	0.0152	0.0620	0.1212
Nausea	0.0229	0.0388	0.0560
Vomiting	0.0075	0.0155	0.0152
Lassitude	0.0075	0.0233	0.1145
Dizziness	0.0075	0.0156	0.0606
Skin rash	0.0303	0.0547	0.0227
Credible G I	0.0379	0.1008	0.1692
Diarrhoea or nausea	0.0379	0.1008	0.1692
Ear or eye or throat	0.0763	0.2126	0.2385
Ear or throat	0.0682	0.1811	0.2231

Table 7.2 (cont.) non-bather cohort only

Symptom	On the day	3 days after	3 weeks after
Fever	0.0075	0.0150	0.0752
Headache	0.1015	0.1353	0.1742
Aching limbs	0.0775	0.0752	0.0902
Chest pains	0.0000	0.0150	0.0227
Dry cough	0.0310	0.0526	0.0827
Productive cough	0.0775	0.0902	0.0677
Sore throat	0.0038	0.0752	0.1278
Ear infection	0.0155	0.0000	0.0075
Eye infection	0.0075	0.0075	0.0226
Breathing difficulty	0.0155	0.0150	0.0150
Blurred vision	0.0000	0.0075	0.0075
Loss of appetite	0.0075	0.0150	0.0677
Indigestion	0.0233	0.0075	0.0376
Diarrhoea	0.0000	0.0526	0.0376
Nausea	0.0000	0.0075	0.0677
Vomiting	0.0000	0.0150	0.0150
Lassitude	0.0078	0.0300	0.0534
Dizziness	0.0000	0.0150	0.0300
Skin rash	0.0078	0.0451	0.0150
Credible G I	0.0000	0.0752	0.1016
Diarrhoea or nausea	0.0000	0.0602	0.1016
Ear or eye or throat	0.0543	0.0827	0.1484
Ear or throat	0.0465	0.0752	0.1328

Table 7.3 Symptom attack rates reported in some recent investigations

	Bather	Non-bather
Lightfoot 1989 Tab 4-8		
GI	0.0217	0.0043
EYE	0.0101	0.0022
EAR	0.0098	0.0014
Cheung - Holmes 1989 P 379 Tab 1		
HCGI	0.0025	0.0005
EYE	0.0055	0.0014
New Jersey (ocean rates) 1989 Tab 10-4		
HCGI	0.0208	0.0086
THROAT	0.0445	0.0219
EAR	0.0197	0.0098

Table 7.4 Bacterial water quality and perceived symptom analysis, T-tests between water quality parameters experienced by bathers not reporting ear, or eye or throat symptoms at three days or diarrhoea at three weeks (group 1) and those bathers reporting this set of symptoms (group 2)

Variable	Mean	S.D.	N
Total coliform, surf zone			
group 1	1.87	0.17	86
group 2	1.78	0.16	34
	D.F.	**Calculated t**	**Critical t** $\alpha=0.05$
	63	2.57	1.99
	Mean	**S.D.**	**N**
Faecal streptococci, surf zone			
group 1	1.81	0.21	86
group 2	1.77	0.19	34
	D.F.	**Calculated t**	**Critical t** $\alpha=0.05$
	64	0.92	1.99
	Mean	**S.D.**	**N**
***Pseudomonas aeruginosa*, surf zone**			
group 1	-0.89	0.40	86
group 2	-0.96	0.23	34
	D.F.	**Calculated t**	**Critical t** $\alpha=0.05$
	103	1.17	1.98
	Mean	**S.D.**	**N**
Faecal coliform, surf zone			
group 1	1.64	0.25	86
group 2	1.69	0.27	34
	D.F.	**Calculated t**	**Critical t** $\alpha=0.05$
	57	-0.87	2.00

all values expressed as $\log_{10}$ (concentration (per 100 ml) + 0.1)

Table 7.4 continued

Variable			
	Mean	**S.D.**	**N**
Total coliform, 30 cm zone			
group 1	1.87	0.22	86
group 2	1.88	0.25	34
	D.F.	**Calculated t**	**Critical t** $\alpha=0.05$
	53	-0.30	2.00
	Mean	**S.D.**	**N**
Faecal streptococci, 30 cm zone			
group 1	1.81	0.22	86
group 2	1.76	0.20	34
	D.F.	**Calculated t**	**Critical t** $\alpha=0.05$
	66	1.33	1.99
	Mean	**S.D.**	**N**
***Pseudomonas aeruginosa*, 30 cm zone**			
group 1	-0.95	0.26	86
group 2	-1.00	0.00	34
	D.F.	**Calculated t**	**Critical t** $\alpha=0.05$
	85	1.74	1.99
	Mean	**S.D.**	**N**
Faecal coliform, 30 cm zone			
group 1	1.78	0.27	86
group 2	1.78	0.29	34
	D.F.	**Calculated t**	**Critical t** $\alpha=0.05$
	57	0.00	2.00

Group 1 = bathers not reporting ear, eye or throat symptoms at three days, or diarrhoea at three weeks

Group 2 = bathers reporting ear, eye or throat symptoms at three days, or diarrhoea at three weeks

all values expressed as $\log_{10}$ (concentration (per 100 ml) + 0.1)

Table 7.4 continued

Variable			
	Mean	S.D.	N
Total coliform, chest zone			
group 1	1.47	0.79	86
group 2	1.33	0.83	34
	D.F.	Calculated t	Critical t α=0.05
	58	0.77	2.00
	Mean	S.D.	N
Faecal streptococci, chest zone			
group 1	1.65	0.41	86
group 2	1.69	0.27	34
	D.F.	Calculated t	Critical t α=0.05
	91	-0.77	1.99
	Mean	S.D.	N
Pseudomonas aeruginosa, chest zone			
group 1	-0.94	0.28	86
group 2	-0.92	0.31	34
	D.F.	Calculated t	Critical t α=0.05
	54	-0.26	2.00
	Mean	S.D.	N
Faecal coliform, chest zone			
group 1	1.06	0.84	86
group 2	1.23	0.74	34
	D.F.	Calculated t	Critical t α=0.05
	68	-1.04	1.99

Group 1 = bathers not reporting ear, eye or throat symptoms at three days, or diarrhoea at three weeks

Group 2 = bathers reporting ear, eye or throat symptoms at three days, or diarrhoea at three weeks

all values expressed as $\log_{10}$(concentration (per 100 ml) + 0.1)

Table 8.1 Significance values (p) for χ^2 analysis of significance between bather and non-bather clinical symptom attack rates

	Ear swab 1	**Ear swab 2**	**Throat swab 1**	**Throat swab 2**
Any determinand	0.0040*	0.7201	0.7721	0.1176
Coliform	0.0004*	0.5072	0.2792	0.3193
Streptococci	0.3221+	-	0.6124	0.3386
Streptococcus faecalis	0.3221+	-	0.2248+	0.3386
Staphylococcus aureus	0.6022	0.2207+	0.9525+	0.7680
Pseudomonas aeruginosa	0.4942+	0.1992	0.6796+	0.1912

+ Fishers exact test (used when expected cell count<5)

- Untestable, 2 cells contained no positive occurences

* Significant at $\alpha < 0.01$

Table 8.2 Crude clinical attack rates

(a) all subjects

	Ear swab 1	Ear swab 2	Throat swab 1	Throat swab 2
Any determinand	0.2569	0.2157	0.3680	0.4941
Coliform	0.1383	0.1333	0.2800	0.3020
Streptococci	0.0039	0.0000	0.0480	0.1294
Streptococcus faecalis	0.0039	0.0000	0.0400	0.1294
Staphylococcus aureus	0.0791	0.0471	0.0240	0.0431
Pseudomonas aeruginosa	0.0395	0.0588	0.0360	0.0941

(b) bather cohort only

	Ear swab 1	Ear swab 2	Throat swab 1	Throat swab 2
Any determinand	0.3360	0.2060	0.3770	0.5433
Coliform	0.2160	0.1190	0.3115	0.3307
Streptococci	0.0000	0.0000	0.0410	0.1496
Streptococcus faecalis	0.0000	0.0000	0.0246	0.1496
Staphylococcus aureus	0.0880	0.0635	0.0246	0.0394
Pseudomonas aeruginosa	0.0480	0.0397	0.0410	0.1181

(c) non-bather cohort only

	Ear swab 1	Ear swab 2	Throat swab 1	Throat swab 2
Any determinand	0.1797	0.2248	0.3594	0.4453
Coliform	0.0625	0.1473	0.2500	0.2734
Streptococci	0.0078	0.0000	0.0547	0.1094
Streptococcus faecalis	0.0078	0.0000	0.0547	0.1094
Staphylococcus aureus	0.0703	0.0310	0.0234	0.0469
Pseudomonas aeruginosa	0.0313	0.0775	0.0313	0.0703

Table 8.3 Faecal sample results, number of positive occurences

	Salmonella sp.	*Campylobacter sp.*	*Cryptosporidia sp.*
Sample 1	1	1	0
Sample 2	1+	0	0

	cyst / ova / parasite	enteroviruses	N
Sample 1	3 *Giardia lamblia*	-	266
Sample 2	3 *Giardia lamblia*+	-	260
Sample 3	1 *Giardia lamblia**	5¶	255

+ Same host(s)

* One carrier did not present a third sample, one was negative on sample 3

¶ 2 bathers, 3 non-bathers

Table 8.4 Bacterial water quality and clinical result analysis, T-tests between water quality parameters experienced by bathers with negative swab results (group 1) and those bathers with positive results (group 2)

(a) Any determinand on the second ear or throat swab

Variable	No. of cases	Mean	Standard deviation	t value	Degrees of freedom	2 tail probability
Total coliform, surf zone						
group 1	43	1.8507	0.187	0.03	79.57	0.979
group 2	71	1.8498	0.164			
Faecal streptococci, surf zone						
group 1	43	1.8002	0.184	-0.01	100.26	0.988
group 2	71	1.8007	0.218			
***Pseudomonas aeruginosa*, surf zone**						
group 1	43	-0.9078	0.341	0.27	92.93	0.788
group 2	71	-0.9260	0.362			
Faecal coliform, surf zone						
group 1	43	1.6551	0.262	0.09	88.37	0.927
group 2	71	1.6504	0.260			
Total coliform, 30 cm						
group 1	43	1.8764	0.226	-0.13	84.91	0.894
group 2	71	1.8804	0.214			
Faecal streptococci, 30 cm						
group 1	43	1.8044	0.185	0.00	101.66	0.997
group 2	71	1.8046	0.224			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	43	-0.9693	0.202	-0.25	102.02	0.803
group 2	71	-0.9587	0.246			
Faecal coliform, 30 cm						
group 1	43	1.8137	0.294	0.89	80.91	0.378
group 2	71	1.7654	0.262			
Total coliform, chest depth						
group 1	43	1.5073	0.665	0.88	107.44	0.383
group 2	71	1.3781	0.899			
Faecal streptococci, chest depth						
group 1	43	1.7131	0.239	0.90	110.93	0.371
group 2	71	1.6559	0.440			
***Pseudomonas aeruginosa*, chest depth**						
group 1	43	-0.9078	0.341	0.95	63.51	0.348
group 2	71	-0.9628	0.220			
Faecal coliform, chest depth						
group 1	43	1.1384	0.749	-0.27	90.62	0.785
group 2	71	1.1784	0.769			

all values expressed as $\log_{10}$ (concentration (per 100 ml) + 0.1)

(b) Any determinand on the second ear swab

Variable	No. of cases	Mean	Standard deviation	t value	Degrees of freedom	2 tail probability
Total coliform, surf zone						
group 1	90	1.8554	0.171	0.46	35.76	0.650
group 2	24	1.8372	0.174			
Faecal streptococci, surf zone						
group 1	90	1.8025	0.198	-0.09	33.14	0.931
group 2	24	1.8069	0.224			
***Pseudomonas aeruginosa*, surf zone**						
group 1	90	-0.9067	0.354	0.04	31.43	0.969
group 2	24	-0.9104	0.439			
Faecal coliform, surf zone						
group 1	90	1.6614	0.262	0.56	38.36	0.581
group 2	24	1.6297	0.244			
Total coliform, 30 cm						
group 1	90	1.8623	0.213	-1.11	34.75	0.273
group 2	24	1.9193	0.225			
Faecal streptococci, 30 cm						
group 1	90	1.7924	0.215	-1.14	40.75	0.259
group 2	24	1.8432	0.187			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	90	-0.9706	0.196	-0.54	27.49	0.595
group 2	24	-0.9328	0.329			
Faecal coliform, 30 cm						
group 1	90	1.7941	0.257	0.81	31.08	0.425
group 2	24	1.7362	0.325			
Total coliform, chest depth						
group 1	90	1.3873	0.860	-0.98	47.73	0.331
group 2	24	1.5433	0.639			
Faecal streptococci, chest depth						
group 1	90	1.7016	0.286	0.95	25.78	0.350
group 2	24	1.5803	0.607			
***Pseudomonas aeruginosa*, chest depth**						
group 1	90	-0.9265	0.305	0.29	40.08	0.775
group 2	24	-0.9449	0.270			
Faecal coliform, chest depth						
group 1	90	1.1371	0.765	-0.75	36.94	0.457
group 2	24	1.2667	0.746			

Group 1 = bathers with negative swab result

Group 2 = bathers with positive swab result

all values expressed as $\log_{10}$(concentration (per 100 ml) + 0.1)

(c) Any determinand on the second throat swab

Variable	No. of cases	Mean	Standard deviation	t value	Degrees of freedom	2 tail probability
Total coliform, surf zone						
group 1	52	1.8472	0.182	-0.17	104.05	0.868
group 2	62	1.8526	0.165			
Faecal streptococci, surf zone						
group 1	52	1.8029	0.198	0.11	110.82	0.911
group 2	62	1.7986	0.213			
***Pseudomonas aeruginosa*, surf zone**						
group 1	52	-0.8824	0.423	0.98	85.62	0.328
group 2	62	-0.9499	0.280			
Faecal coliform, surf zone						
group 1	52	1.6556	0.255	0.13	109.94	0.900
group 2	62	1.6494	0.266			
Total coliform, 30 cm						
group 1	52	1.9010	0.229	1.02	104.29	0.312
group 2	62	1.8591	0.208			
Faecal streptococci, 30 cm						
group 1	52	1.8108	0.185	0.30	111.83	0.765
group 2	62	1.7992	0.229			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	52	-0.9436	0.286	0.78	79.15	0.438
group 2	62	-0.9787	0.168			
Faecal coliform, 30 cm						
group 1	52	1.7979	0.291	0.50	103.56	0.615
group 2	62	1.7716	0.261			
Total coliform, chest depth						
group 1	52	1.5272	0.623	1.24	106.29	0.216
group 2	62	1.3427	0.949			
Faecal streptococci, chest depth						
group 1	52	1.6540	0.446	-0.59	88.48	0.558
group 2	62	1.6971	0.310			
***Pseudomonas aeruginosa*, chest depth**						
group 1	52	-0.9237	0.311	0.64	93.67	0.524
group 2	62	-0.9573	0.236			
Faecal coliform, chest depth						
group 1	52	1.1548	0.764	-0.11	108.44	0.913
group 2	62	1.1705	0.761			

Group 1 = bathers with negative swab result

Group 2 = bathers with positive swab result

all values expressed as $\log_{10}$ (concentration (per 100 ml) + 0.1)

(d) Coliform on second ear swab

Variable	No. of cases	Mean	Standard deviation	t value	Degrees of freedom	2 tail probability
Total coliform, surf zone						
group 1	101	1.8591	0.170	1.32	15.37	0.206
group 2	13	1.7936	0.168			
Faecal streptococci, surf zone						
group 1	101	1.8082	0.206	0.82	16.91	0.425
group 2	13	1.7661	0.170			
***Pseudomonas aeruginosa*, surf zone**						
group 1	101	-0.8956	0.393	2.67	100.00	0.009
group 2	13	-1.0000	0.000			
Faecal coliform, surf zone						
group 1	101	1.6668	0.259	1.52	16.14	0.147
group 2	13	1.5613	0.232			
Total coliform, 30 cm						
group 1	101	1.8643	0.211	-1.24	14.39	0.236
group 2	13	1.9520	0.244			
Faecal streptococci, 30 cm						
group 1	101	1.7979	0.213	-0.82	16.44	0.424
group 2	13	1.8432	0.184			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	101	-0.9578	0.243	1.74	100.00	0.085
group 2	13	-1.0000	0.000			
Faecal coliform, 30 cm						
group 1	101	1.7860	0.269	0.40	14.48	0.694
group 2	13	1.7502	0.307			
Total coliform, chest depth						
group 1	101	1.3945	0.859	-1.80	39.25	0.079
group 2	13	1.6192	0.326			
Faecal streptococci, chest depth						
group 1	101	1.6692	0.390	-0.75	20.02	0.464
group 2	13	1.7296	0.256			
***Pseudomonas aeruginosa*, chest depth**						
group 1	101	-0.9345	0.288	-0.34	13.97	0.737
group 2	13	-0.8983	0.367			
Faecal coliform, chest depth						
group 1	101	1.1388	0.761	-1.02	15.43	0.323
group 2	13	1.3631	0.743			

Group 1 = bathers with negative swab result

Group 2 = bathers with positive swab result

all values expressed as $\log_{10}$ (concentration (per 100 ml) + 0.1)

(e) Coliform on second throat swab

Variable	No. of cases	Mean	Standard deviation	t value	Degrees of freedom	2 tail probability
Total coliform, surf zone						
group 1	74	1.8561	0.179	0.52	88.20	0.601
group 2	40	1.8390	0.160			
Faecal streptococci, surf zone						
group 1	74	1.7996	0.200	-0.06	74.33	0.951
group 2	40	1.8022	0.218			
***Pseudomonas aeruginosa*, surf zone**						
group 1	74	-0.9174	0.358	0.07	82.27	0.943
group 2	40	-0.9223	0.347			
Faecal coliform, surf zone						
group 1	74	1.6377	0.255	-0.80	76.18	0.428
group 2	40	1.6791	0.270			
Total coliform, 30 cm						
group 1	74	1.8790	0.226	0.05	87.34	0.958
group 2	40	1.8768	0.204			
Faecal streptococci, 30 cm						
group 1	74	1.8139	0.198	0.63	70.27	0.534
group 2	40	1.7870	0.231			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	74	-0.9603	0.241	0.15	90.21	0.879
group 2	40	-0.9669	0.209			
Faecal coliform, 30 cm						
group 1	74	1.7809	0.294	-0.15	95.86	0.881
group 2	40	1.7885	0.236			
Total coliform, chest depth						
group 1	74	1.5080	0.689	1.30	59.14	0.200
group 2	40	1.2768	1.008			
Faecal streptococci, chest depth						
group 1	74	1.6595	0.412	-0.75	101.43	0.452
group 2	40	1.7107	0.304			
***Pseudomonas aeruginosa*, chest depth**						
group 1	74	-0.9285	0.301	0.80	104.97	0.427
group 2	40	-0.9669	0.209			
Faecal coliform, chest depth						
group 1	74	1.0981	0.834	-1.39	104.46	0.169
group 2	40	1.2839	0.585			

Group 1 = bathers with negative swab result

Group 2 = bathers with positive swab result

all values expressed as $\log_{10}$ (concentration (per 100 ml) + 0.1)

(f) *Streptococcus faecalis* on second throat swab

Variable	No. of cases	Mean	Standard deviation	t value	Degrees of freedom	2 tail probability
Total coliform, surf zone						
group 1	99	1.8477	0.172	-0.37	18.29	0.714
group 2	15	1.8658	0.176			
Faecal streptococci, surf zone						
group 1	99	1.8065	0.206	0.81	18.67	0.426
group 2	15	1.7608	0.202			
***Pseudomonas aeruginosa*, surf zone**						
group 1	99	-0.9249	0.336	-0.35	16.33	0.727
group 2	15	-0.8810	0.461			
Faecal coliform, surf zone						
group 1	99	1.6581	0.263	0.65	19.23	0.522
group 2	15	1.6134	0.245			
Total coliform, 30 cm						
group 1	99	1.8938	0.213	1.88	17.84	0.076
group 2	15	1.7753	0.230			
Faecal streptococci, 30 cm						
group 1	99	1.8050	0.202	0.05	16.69	0.960
group 2	15	1.8014	0.259			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	99	-0.9570	0.246	1.74	98.00	0.085
group 2	15	-1.0000	0.000			
Faecal coliform, 30 cm						
group 1	99	1.7931	0.270	0.88	17.63	0.391
group 2	15	1.7210	0.300			
Total coliform, chest depth						
group 1	99	1.4232	0.834	-0.13	19.98	0.894
group 2	15	1.4510	0.730			
Faecal streptococci, chest depth						
group 1	99	1.6949	0.358	1.03	16.44	0.320
group 2	15	1.5624	0.480			
***Pseudomonas aeruginosa*, chest depth**						
group 1	99	-0.9599	0.228	-1.11	15.03	0.283
group 2	15	-0.8237	0.465			
Faecal coliform, chest depth						
group 1	99	1.2228	0.670	1.49	15.49	0.156
group 2	15	0.7706	1.145			

Group 1 = bathers with negative swab result

Group 2 = bathers with positive swab result

all values expressed as $\log_{10}$(concentration (per 100 ml) + 0.1)

(g) *Staphylococcus aureus* on second ear swab

Variable	No. of cases	Mean	Standard deviation	t value	Degrees of freedom	2 tail probability
Total coliform, surf zone						
group 1	106	1.8534	0.171	0.40	8.05	0.698
group 2	8	1.8276	0.175			
Faecal streptococci, surf zone						
group 1	106	1.8041	0.190	0.08	7.32	0.936
group 2	8	1.7938	0.347			
***Pseudomonas aeruginosa*, surf zone**						
group 1	106	-0.9208	0.328	-0.70	7.20	0.506
group 2	8	-0.7313	0.760			
Faecal coliform, surf zone						
group 1	106	1.6530	0.257	-0.24	7.91	0.813
group 2	8	1.9260	0.157			
Total coliform, 30 cm						
group 1	106	1.8704	0.219	-0.93	9.19	0.374
group 2	8	1.9260	0.157			
Faecal streptococci, 30 cm						
group 1	106	1.8058	0.208	0.44	7.77	0.671
group 2	8	1.7663	0.247			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	106	-0.9751	0.181	-0.87	7.11	0.411
group 2	8	-0.7984	0.247			
Faecal coliform, 30 cm						
group 1	106	1.7907	0.271	1.20	7.99	0.263
group 2	8	1.6655	0.284			
Total coliform, chest depth						
group 1	106	1.4370	0.807	0.67	7.71	0.525
group 2	8	1.1965	0.996			
Faecal streptococci, chest depth						
group 1	106	1.7055	0.274	1.19	7.08	0.271
group 2	8	1.2869	0.988			
***Pseudomonas aeruginosa*, chest depth**						
group 1	106	-0.9252	0.307	2.51	105.00	0.014
group 2	8	-1.0000	0.000			
Faecal coliform, chest depth						
group 1	106	1.1885	0.722	0.82	7.41	0.438
group 2	8	0.8457	1.167			

Group 1 = bathers with negative swab result

Group 2 = bathers with positive swab result

all values expressed as $\log_{10}$ (concentration (per 100 ml) + 0.1)

(h) *Staphylococcus aureus* on second throat swab

Variable	No. of cases	Mean	Standard deviation	t value	Separate variance estimate Degrees of freedom	2 tail probability
Total coliform, surf zone						
group 1	109	1.8487	0.172	-0.37	4.30	0.727
group 2	5	1.8812	0.192			
Faecal streptococci, surf zone						
group 1	109	1.8013	0.205	0.17	4.28	0.876
group 2	5	1.7836	0.235			
***Pseudomonas aeruginosa*, surf zone**						
group 1	109	-0.9154	0.360	2.45	108.00	0.016
group 2	5	-1.0000	0.000			
Faecal coliform, surf zone						
group 1	109	1.6580	0.260	1.19	4.44	0.294
group 2	5	1.5261	0.242			
Total coliform, 30 cm						
group 1	109	1.8788	0.218	0.13	4.30	0.903
group 2	5	1.8646	0.242			
Faecal streptococci, 30 cm						
group 1	109	1.7996	0.210	-1.34	4.52	0.243
group 2	5	1.9101	0.178			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	109	-0.9609	0.234	1.74	108.00	0.085
group 2	5	-1.0000	0.000			
Faecal coliform, 30 cm						
group 1	109	1.7811	0.275	-0.43	4.36	0.686
group 2	5	1.8368	0.282			
Total coliform, chest depth						
group 1	109	1.4098	0.833	-4.47	76.29	0.000
group 2	5	1.7998	0.079			
Faecal streptococci, chest depth						
group 1	109	1.6742	0.382	-0.65	4.98	0.543
group 2	5	1.7482	0.240			
***Pseudomonas aeruginosa*, chest depth**						
group 1	109	-0.9393	0.278	2.28	108.00	0.025
group 2	5	-1.0000	0.000			
Faecal coliform, chest depth						
group 1	109	1.1537	0.771	-1.19	5.67	0.282
group 2	5	1.3728	0.377			

Group 1 = bathers with negative swab result

Group 2 = bathers with positive swab result

all values expressed as $\log_{10}$ (concentration (per 100 ml) + 0.1)

(i) *Pseudomonas aeruginosa* on second ear swab

Variable	No. of cases	Mean	Standard deviation	t value	Degrees of freedom	2 tail probability
Total Coliform, surf zone						
group 1	109	1.8470	0.170	-1.26	4.33	0.270
group 2	5	1.9518	0.182			
Faecal streptococci, surf zone						
group 1	109	1.8004	0.205	-1.02	4.80	0.356
group 2	5	1.8682	0.142			
***Pseudomonas aeruginosa*, surf zone**						
group 1	109	-0.9033	0.379	2.66	108.00	0.009
group 2	5	-1.0000	0.000			
Faecal coliform, surf zone						
group 1	109	1.6529	0.262	-0.55	5.06	0.603
group 2	5	1.6946	0.159			
Total coliform, 30 cm						
group 1	109	1.8766	0.215	0.49	4.31	0.647
group 2	5	1.8235	0.237			
Faecal streptococci, 30 cm						
group 1	109	1.7965	0.210	-1.90	4.57	0.121
group 2	5	1.9466	0.170			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	109	-0.9609	0.234	1.74	108.00	0.085
group 2	5	-1.0000	0.000			
Faecal coliform, 30 cm						
group 1	109	1.7857	0.263	0.40	4.11	0.706
group 2	5	1.6995	0.473			
Total coliform, chest depth						
group 1	109	1.4016	0.832	-4.47	39.16	0.000
group 2	5	1.8243	0.114			
Faecal streptococci, chest depth						
group 1	109	1.6758	0.382	-0.05	4.75	0.962
group 2	5	1.6821	0.272			
***Pseudomonas aeruginosa*, chest depth**						
group 1	109	-0.9272	0.303	2.51	108.00	0.014
group 2	5	-1.0000	0.000			
Faecal coliform, chest depth						
group 1	109	1.1553	0.772	-1.10	5.57	0.318
group 2	5	1.3626	0.389			

Group 1 = bathers with negative swab result

Group 2 = bathers with positive swab result

all values expressed as $\log_{10}$(concentration (per 100 ml) + 0.1)

(j) *Pseudomonas aeruginosa* on second throat swab

Variable	No. of cases	Mean	Standard deviation	t value	Degrees of freedom	2 tail probability
Total coliform, surf zone						
group 1	101	1.8499	0.173	-0.03	15.29	0.974
group 2	13	1.8516	0.172			
Faecal streptococci, surf zone						
group 1	101	1.7904	0.211	-2.11	21.19	0.047
group 2	13	1.8788	0.130			
***Pseudomonas aeruginosa*, surf zone**						
group 1	101	-0.9087	0.374	2.46	100.00	0.016
group 2	13	-1.0000	0.000			
Faecal coliform, surf zone						
group 1	101	1.6544	0.257	0.23	14.59	0.823
group 2	13	1.6354	0.287			
Total coliform, 30 cm						
group 1	101	1.8778	0.221	-0.06	15.91	0.955
group 2	13	1.8813	0.202			
Faecal streptococci, 30 cm						
group 1	101	1.7981	0.216	-1.27	20.44	0.217
group 2	13	1.8543	0.139			
***Pseudomonas aeruginosa*, 30 cm**						
group 1	101	-0.9578	0.243	1.74	100.00	0.085
group 2	13	-1.0000	0.000			
Faecal coliform, chest depth						
group 1	101	1.7845	0.266	0.08	13.88	0.940
group 2	13	1.7768	0.346			
Total coliform, chest depth						
group 1	101	1.4386	0.786	0.33	13.71	0.743
group 2	13	1.3358	1.073			
Faecal streptococci, chest depth						
group 1	101	1.6742	0.390	-0.35	19.63	0.729
group 2	13	1.7031	0.262			
***Pseudomonas aeruginosa*, chest depth**						
group 1	101	-0.9476	0.259	-0.47	13.59	0.646
group 2	13	-0.8983	0.367			
Faecal coliform, chest depth						
group 1	101	1.1524	0.767	-0.45	15.74	0.659
group 2	13	1.2481	0.718			

Group 1 = bathers with negative swab result

Group 2 = bathers with positive swab result

all values expressed as $\log_{10}$(concentration (per 100 ml) + 0.1)

TABLE 8.5 Significance values (p) for $\chi 2$ analysis of significance between bather and non-bather clinical result attack rates for the groups with perceived sore throat or ear infection symptoms at three days.

Subjects reporting a sore throat :	**Subjects reporting a sore throat or ear infection:**

	Throat swab 2	**Either swab 2**
Any determinand	0.0743	0.2338
Coliform	0.1540	0.1870
Streptococcus faecalis	0.3264	0.3729
Staphylococcus aureus	-	-
Pseudomonas aeruginosa	0.4368	0.6895

All values: significance for Fisher's exact test

- Untestable, two or more cells had counts of zero

PLATES

WESTERN MAIL

The National Newspaper of Wales

VOLUNTEERS NEEDED TO GO PADDLING

POLLUTION EXPERT Huw Morgan who is calling for volunteers to take a plunge in the sea

Take the plunge — and help pollution research

a

Evening Post

'Come on in – the water's lovely'

b

Plate 4.1 Local press coverage from the Western Mail (a) and the Swansea Evening Post (b).

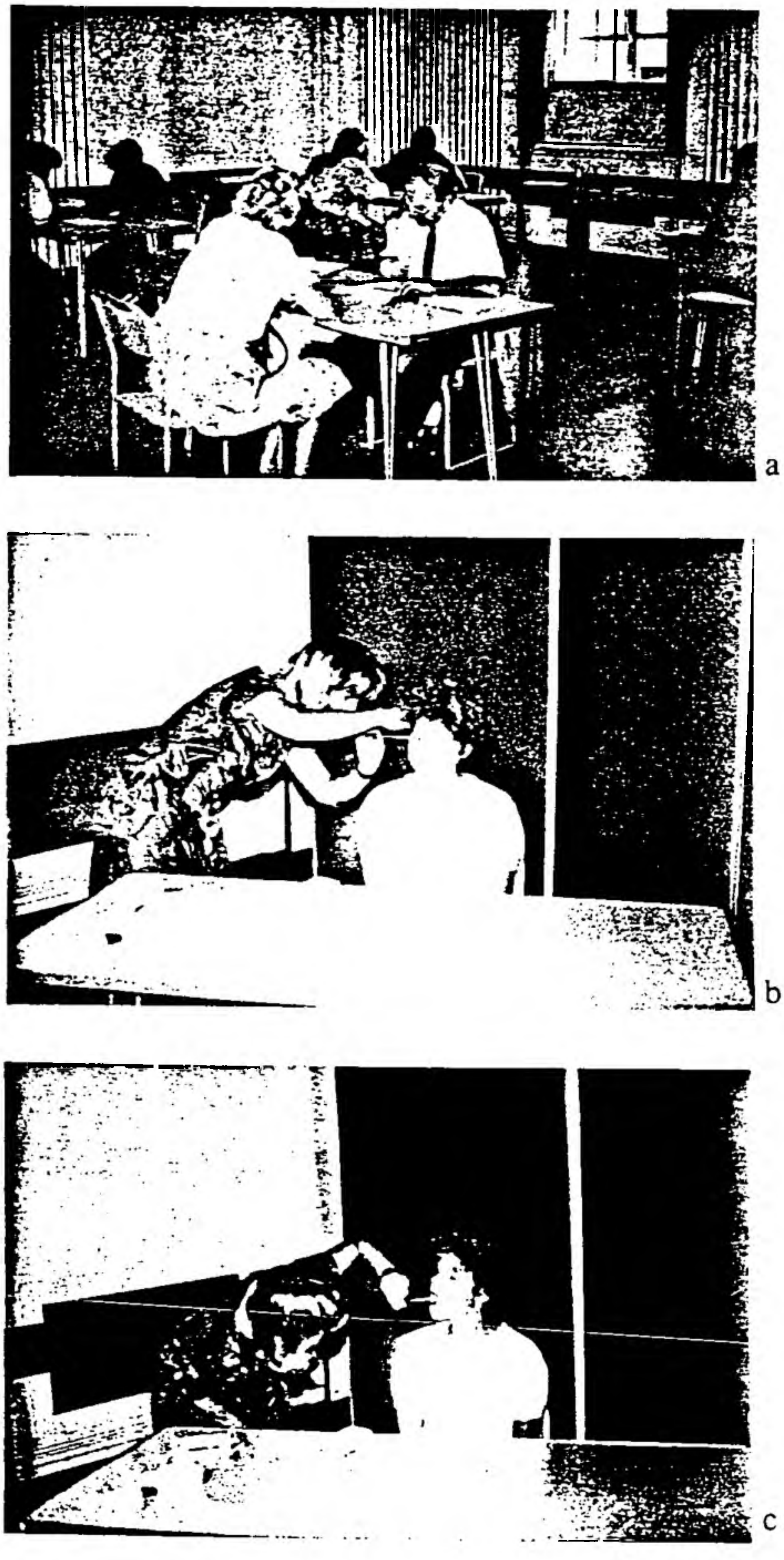


Plate 4.2 Medical interviews (a) , ear swabs (b) and throat swabs (c).

Plate 4.3 Langland Bay (a), reception at the beach (b), non-bather organisation (c) and bather organisation (d).

APPENDICES

APPENDIX I

Submission to the Committee on Ethical Issues in Medicine of the Royal College of Physicians

Mr. F. Jones (Project Director, Altwell Ltd.)

Dr. D. Kay (University of Wales)

Dr. R. Stanwell-Smith (Bristol and Weston
Health Authority)

Dr. I Barrow (Environmental Health Consultant)

Draft submission to the Committee on Ethical Issues in Medicine of the Royal College of Physicians

from the University of Wales/Altwell Research Group

PROJECT TITLE: The possible health effects of bathing in coastal waters
which meet EEC Directive Bathing Water Standards.

FUNDING AGENCY: The Department of the Environment.

1 BACKGROUND

The competent UK agencies, responsible for the marine disposal of sewage wastes, are the Regional Water Authorities and the Department of the Environment. Pressure is increasing for these agencies to reduce coastal pollution [1]. Both the European Commission and environmental groups inside the United Kingdom are giving attention to this issue[6,7,18-26,37,38]. Considerable expenditures, of over £1000m, may be required in this area in the period to 1995 [16]. The present standards, laid down in the EC Bathing Waters Directive, are not based on UK epidemiological research [12]. The UK competent authorities, therefore, have no firm information on which to judge the public health significance of the EEC Bathing Waters Directive standards.

Previous UK work in this area is sparse [30,31]. In 1959 the PHLS/MRC retrospective epidemiological investigation established that there is very little probability of contracting serious illnesses from bathing in sewage polluted waters. In the USA, Canada, Egypt, France and Hong Kong prospective epidemiological investigations have been completed which suggest that it may be possible to contract minor gastrointestinal, ENT and skin infections from bathing in sewage polluted waters [2-5,8-10,13,14,15,27-29,33-36]. To date, these investigations have not produced consistent results either in terms of the dose response relationships established or the most appropriate pollution indicators of health risk in the bathing zone [23]. It would not be valid therefore simply to transfer the results of these studies to the unique UK coastal environment [17,39].

The protocol adopted in these prospective studies was developed by Prof. Victor J. Cabelli of the USEPA. This protocol has four elements, namely;

(i) bather and non-bather cohorts are recruited from people who are at the beach under their own volition. Only those with wet hair are defined as bathers as they are likely to have immersed their nasal and oral orifices in the water.

(ii) The selection of '*weekend only*' bathers reduces the confounding effects of multiple exposure on different beaches.

(iii) Demographic information on both groups is collected by questionnaire survey at the beach.

A subsequent telephone interview defines the symptomology of both groups.

(iv) Intensive water sampling defines the concentrations of a range of relevant indicators on the day of exposure.

The Cabelli protocol is backed by the WHO and it has not encountered problems of medical ethics in other countries.

The Cabelli protocol provides a measure of disease **perception** and not **incidence**. Full medical confirmation of the perceived symptomatology has never been achieved although it was attempted in the Canadian implementation of the Cabelli protocol [34,35]. The Cabelli protocol is therefore lacking in concrete public health information and it would certainly be criticised in retrospect on these grounds if completed in isolation. It is possible that the widely different dose response relationships and heterogeneous patterns of relevant indicators, identified by the subsequent replications of the Cabelli protocol, can be attributed to varying perceptions of the bathing related symptoms. Given the possible expenditure implications of this research, it would be unwise therefore for the UK competent authorities to rely on the results of a Cabelli style study alone.

For this reason the DoE advisory group are of the opinion that, in addition to a Cabelli style investigation, a study which involves taking a group of healthy volunteers to the same beach and monitoring them medically both before and after bathing would be essential to give a clear picture of disease incidence.

2 RESEARCH PROTOCOL FOR THE HEALTHY VOLUNTEER STUDY

This study will involve a group of uncoerced adult volunteers. They will be taken to a popular recreational beach which currently passes the EC Bathing Water Directive and which would also be used by the group undertaking the Cabelli style protocol as outlined above.

2.1 Cohort Recruitment

Four hundred adult volunteers (over 18 years) will be used for the initial pilot study. The group will be split into bathing and non-bathing cohorts in equal numbers. Subjects will not receive remuneration for exposure to risk. They will however receive £10 each for general inconvenience, subsequent faecal sample provision and any out-of-pocket expenses.

The cohort will be recruited on a regional basis primarily determined by the study site location. No pressure to participate will be placed on any particular group and all potential participants will be given an equal opportunity to join the experimental groups. A subject information sheet will be posted with the notice. This document will set out; (i) the potential risks involved in the research project; (ii) the provision of insurance cover which will be provided by the supervisors.

Full records will be kept of the recruited subjects who will each receive a full statement of the nature, objectives and duration of the study including their commitments both on the day of exposure and during subsequent follow-up investigations. When the subjects have been given sufficient time to consider this information they would each be asked to sign a consent form.

Compensation insurance cover as recommended by the Royal College of Physicians [32] will be arranged to cover all participants in this study.

The total time spent on the project will behalf a day for the initial exposure and less than a full day on follow-up examinations.

2.2 The beach

One beach will be selected. The chosen beach will PASS on current EC Directive '*Imperative*' coliform standards. It will be a beach which is currently considered '*clean*' by the competent UK authorities. Furthermore, it will be a popular bathing beach which is used by large numbers of bathers. The risk to the participant volunteers would therefore be no more that that experienced by millions of holidaymakers in Europe, the USA and Great Britain ever year. They would in effect be taking part in an accepted leisure time activity at a bathing location with a relatively '*good*' history of water quality.

2.3 Environmental quality

Baseline water quality data would be available from the DoE/WA monitoring programmes for about four years. Prior to bather exposure, temporal and spatial samples will be collected to determine the pattern of bacterial and viral contamination. WA liaison will determine the nature and management of relevant sewage flows. On the day of exposure, approximately 200 samples will be collected for bacteriological analyses. These will include tests for total coliform organisms, *Escherichia coli*, Faecal Streptococci, and *Staphylococcus aureus*. A subset of the samples will be analysed for *Pseudomanas aeruginosa, Shigella spp., Salmonella spp.* and Enteroviruses.

Patterns of correlation between past meteorological parameters and water quality will be investigated for the study beach. Detailed data describing climatic conditions throughout the test day will be collected.

2.4 Perceived symptoms

Perceived symptomatology will be determined by three questionnaire-based interviews of each subject. These will take place on the day before exposure, 72 hours after exposure and 3 weeks after exposure to provide better '*coverage*' of infectious incubation periods. Provision has been made for an input to the questionnaire design from social survey psychologists. The usual '*dummy*' questions will be used.

2.5 Analytical confirmation

The three stage questionnaire process will be paralled by the collection of faecal, nasal, and oral samples from each subject. Samples will be analysed by PHLS and a total of 3 faecal samples and 4 swab samples will be required. An outline of the required analyses and timings is presented in Table 1.

2.6 Medical supervision and confirmation

Dr R. Stanwell-Smith, a medical epidemiologist, will supervise medical aspects of the controlled cohort investigation. Additional medical assistance from four GP's and nursing staff has been arranged. Each subject will be given two medical examinations to parallel the questionnaire and sampling regime outlined above. Other supervisory personnel involved in this element of the project are; Mr. F. Jones (Project Director) and Dr. D. Kay (University of Wales).

2.7 Exposure of the subjects

Bathing and non-bathing cohorts will be transported to the beach on one day during the 1989 bathing season. All food intake for both groups during the test day will be recorded for each of the subjects. The bathing cohort will be allowed free access to the water and instructed to immerse their heads in the water on at least three occasions during normal swimming activities. Approximately 20 trained and supervised field staff will be available to provide safety cover and monitor the activities of both cohorts.

2.8 Financial rewards

This element of the pilot study, involving the controlled cohort epidemiological investigation, is being partly supported through staff time and the provision of clerical and financial management resources by St David's University College and Altwell Hygiene and Environmental Consultants Ltd. Neither organisation, or indeed the project supervisors, will receive any financial benefit.

3 SUMMARY

If the Royal College of Physicians Committee are able to authorise the full implementation of both elements outlined above, this project will provide a firm basis for policy decisions of national significance. In addition, the combination of this healthy volunteer study with the (Cabelli) type study which measures perceived symptoms will, for the first time, incorporate clinical confirmation of the perceived symptoms observed in previous studies. This will significantly enhance the national and international significance of this work and establish a clear lead for the UK in the field of bathing water epidemiology.

Table 1. Analyses of Faecal and Swab Samples

ANALYSES	INFECTIONS
A. FAECAL (both groups)	Principally gastroenteritis
(i) before exposure	-bacterial , viral and parasitic
enrichment *Salmonella/Shigella* plates; *Campylobacter*, rotavarius enterovirus	
(ii) 72 hours after exposure	
enrichment *Salmonella/Shigella* plates; *Campylobacter*, rotavarius enterovirus	
(iii) Three weeks after exposure	
ova, cysts and parasites	
B. SWABS (both groups)	Throat and ear infections
(i) Throat swabs	*Staphylococcus aureus* Haemolytic streptococci
Taken before and 72 hours after exposure	(Staphylococcal and Streptococcal infection)
-bacterial pathogens	
(ii) Ear swabs	*Staphylococcus aureus* *Pseudomonas aeruginosa*
Taken before and 72 hours after exposure	(Staphylococcal infection and *Otitis externa*)
-bacterial pathogens	

REFERENCES

1. **Brown, J.M., Campbell, E.A. Rickards, A.D. and Wheeler, D. (1987)** *The public health implications of sewage pollution of bathing water.* Published by the University of Surrey, Robens Institute.

2. **Cabelli, V.J., Levin, M.A., Dufour, A.P. and McCabe, L.J. (1975)** *The development of criteria for recreational waters.* In Gameson, A.L.H. (Ed.) *Discharge of sewage from sea outfalls.* Pergamon. 63-74

3. **Cabelli, V.J., Dufour, A.P., McCabe, L.J. and Levin, M.A. (1982)** Swimming associated gastroenteritis and water quality. *American Journal of Epidemiology 115(4),* 606-616.

4. **Cabelli, V.J., Dufour, A.P., McCabe, L.J. and Levin, M.A. (1983)** A marine recreational water quality criterion consistent with indicator concepts and risk analysis. *Journal of the Water Pollution Control Federation 55,* 1306-1314.

5 **Cheung, W.H.S., Kleevens, J.W.L., Chang, K.C.K. and Hung, R.P.S. (1988)** Health effects of beach water pollution in Hong Kong. *Proceedings of the Institution of Water and Environmental Management. Proceedings of the Annual Conference* 376-383

6. **Colwell, R.R. (1987)** *Microbiological effects of ocean pollution* . Paper 23 International Conference on Environmental Protection of the North Sea. 19p.

7. **Denness, B. (1987)** *Sewage disposal to the sea.* Sons of Neptune Ltd. Scarborough. 68p.

8. **Dufour, A.P. (1982)** *Fresh recreational water quality and swimming associated illness.* Second National Symposium on Municipal Wastewater Disinfection, Orlando Florida. January 26-28, 21p.

9. **Dufour, A.P. (1983)** Microbiological recreational water quality objectives. Paper presented at the First National Conference on Recreational Water Quality and Human Health. *Canadian Public Health Association. Oct. 27-28,* Toronto, Ontario.

10. **Dufour, A.P. (1984)** Bacterial indicators of recreational water quality. *Canadian Journal of Public Health 75,* 49-56.

11. **Dufour, A.P. (1988)** Personal communication. Dec. 1988

12. **EEC (1976)** Council Directive of 8 December 1975 concerning the quality of bathing water (76/160/EEC). *Official Journal L/31,* 1-7.

13. **El Sharkawi, F. and Hassan, M.N.E.R. (1982)** The relation between the state of pollution in Alexandria swimming beaches an the occurence of typhoid among bathers. *Bull High Inst. pub. Hlth Alexandria 12,* 337-351.

14. **Fattal, B., Peleg-Olevsky, T. Agurshy and Shuval, H.I. (1986)** The association between sea-water pollution as measured by bacterial indicators and morbidity of bathers at Mediterranean beaches in Israel. *Chemosphere*

15. **Foulon, G., Maurin, J., Quoi, N.N. and Martin-Bouyer, G. (1983)** Etude de la morbidite humaine en relation avec la pollution bacteriologique des eaux de baignade en mer. *Revue francaise des SCIENCES DE L'EAU 2(2)*, 127-143.

16. **Garrett, P. (1987)** Bathing water - time for change. *Water Bulletin 284*, 6-7.

17. **Health and Welfare Canada (1980)** *A study of disease incidence and recreational water quality in the great lakes phase I.* Report 81-EHD-67. 161p.

18. **H.M.S.O. (1985a)** *House of Commons Committee on Welsh Affairs Coastal sewage pollution in Wales* . Minutes of Evidence 5.12.84. H.M.S.O. London. 117p.

19. **H.M.S.O. (1985b)** *House of Commons Committee on Welsh Affairs Coastal sewage pollution in Wales.* Minutes of Evidence 16.1.85. H.M.S.O. London. 118-167p.

20. **H.M.S.O. (1985c)** *House of Commons Committee on Welsh Affairs Coastal sewage pollution in Wales.* Report and Proceedings Vol I and II. 12.12.85. H.M.S.O. London. 27p.

21. **Institute for European Environmental Policy (1986)** *Implementing the EC-Directive 76/160 concerning the quality of bathing water.* Conclusions of the Montpellier Seminar 12-15 October 1986. I.E.E.P. London WC1H 0DD. 14p.

22. **Jones, F. and Godfree, A.F. (1988)** Recreational and amenity aspects of surface waters: the public health implications. *Paper presented at the 1988 Confluence Conference,* in press.

23. **Jones, F. and Kay, D. (1989)** Bathing waters and health studies *Water Services 93(1117)* 87-89.

24. **Kay, D. and McDonald, A.T. (1986a)** Bathing water quality: the significance of epidemiological research in the British context. *European Water and Sewage 90(1085)*, 321-328.

25. **Kay, D and McDonald, A.T. (1986b)** Coastal Bathing Water Quality. *Journal of Shoreline Management 2*, 259-283.

26. **Kay, D. (1988)** Coastal bathing water quality: the application of water quality standards to Welsh beaches. *Applied Geography 8* 117-134.

27. **Kiel, D. (1988)** Personal communication. Dec 1988.

28. **New Jersey Department of Health (1988)** *A study of the relationship between illness in swimmers and ocean beach water quality.* New Jersey Health Dept. March 1988. 167p.

29. **Mujeriego, R., Bravo, J.M. and Feliu, M.T. (1982)** *Recreation in coastal waters public health implications.* Vier Journee Etud. Pollutions, Cannes, CIESM. pp. 585-594.

30. **M.R.C. (1959)** MEDICAL RESEARCH COUNCIL *Sewage contamination of bathing beaches in England and Wales.* Medical Research Council Memorandum No. 37, 32p.

31. **P.H.L.S. (1959)** PUBLIC HEALTH LABORATORY SERVICE. Sewage contamination of coastal bathing waters in England and Wales: a bacteriological and epidemiological study. *Journal of Hygiene, Cambs. 57(4),* 435-472.

32. **Royal College of Physicians (1986)** Research on healthy volunteers. *Journal of the Royal College of Physicians 29(4),* 17p.

33. **Seyfried, P.L., Tobin, R., Brown, N.E. and Ness, P.F. (1985a)** A prospective study of swimming related illness. I Swimming associated health risk. *American Journal of Public Health 75(9)* 1068-1070.

34. **Seyfried, P.L., Tobin, R., Brown, N.E. and Ness, P.F. (1985b)** A prospective study of swimming related illness. II Morbidity and the microbiological quality of water. *American Journal of Public Health 75(9)* 1071-1075.

35. **Shuval, H.I. (1986)** *Thalassogenic diseases.* Unep Regional Seas Reports and Studies No. 79.

36. **Stevenson, A.H. (1953)** Studies of bathing water quality and health. *American Journal of Public Health 43,* 529-538.

37. **Tyler, J. (1985)** Occurrence in water of viruses of public health significance. *Journal of Applied Bacteriology Vol 59. Symposium Supplement,* 37S-46S.

38. **White, W.R. and Godfree, A.F. (1985)** Pollution of freshwaters and estuaries. *Journal of Applied Bacteriology Symposium Supplement 14,* S67-S79.

39. **W.H.O. (1986)** *Correlation between coastal water quality and health effects.* World Health Organisation Copenhagen. 44p.

SUBJECT INFORMATION SHEET

Study on the Possible Health Effects of Bathing in waters which meet EEC Directive standards

FUNDING AGENCY	Department of the Environment
MANAGEMENT AGENCY	Water Research Centre
RESEARCH SUPERVISORS	Mr F. Jones (Altwell Ltd), Dr D. Kay (University of Wales), Dr R. Stanwell-Smith (Bristol and Weston Health Authority,) Dr I Barrow (Environmental Health Consultant).

1. NATURE OF THE STUDY

1.1 Background

A degree of sewage contamination can be detected at most UK bathing beaches. There is no reliable information, for UK bathing waters, with which to define the minor risks to health caused by bathing in this coastal environment. Britian and our European partners accept the European Bathing Waters Directive standards as one measure of '*acceptable*' bathing water quality. However, we do not know if these standards are either too lax or too stringent to ensure that minor diseases will not be contracted by the bathers. It is the objective of this study to answer some of these questions.

1.2 Research Method

This project will involve 400 healthy volunteers. All will be adults over 18 years of age. They will be taken to a beach which has been given a PASS grade on the European bathing water standards. In UK terms this would place the beach in the top 67% of our identified *Eurobeaches*. The chosen beach will be at a popular resort town and the group of bathers would be taking part in a common leisure time activity practiced by millions of other UK and European citizens (i.e. coastal bathing). The beach would have relatively '*good*' water quality. The group of 400 volunteers would be split into two equal groups at the beach. One group will take part in normal beach activities other than water contact pursuits, whilst the other will go into the water. This latter group will each be asked to immerse their heads in the water at least three times during the test as they might during normal recreational activity.

Every volunteer would have three questionnaire-based assessment to ascertain their state of '*perceived*' health, first on the day before exposure, the second 72 hour later and the third after three weeks. Paralleling this schedule will be the collection of ear andthroat swabs together with faecal samples by qualified personnel for analysis by the Public Health Laboratory Service.

2. Health risks

The Department of Health have indicated that there is only a small risk of illness even if waters are seriously and visibly contaminated. The fact that the study is to be conducted on a beach which meets the standards of the EEC Bathing Waters Directive can give confidence that there is no risk of serious illness. However, previous work in this area, conducted outside the UK, has suggested that there might be a slight risk of contracting minor illnesses such as stomach infections. We cannot guarantee that there is zero risk of volunteers contracting such infections. However, this risk is no greater than that experienced by many millions of coastal bathers each year who use waters which currently meet EEC standards.

3. Insurance cover

All participants in the study will be covered for accidental injury. Exact details of this insurance cover are available for inspection on request from any of the four supervisors listed above. In broad terms this policy follows the guidelines recommended by the Royal College of Physicians Research on Healthy Volunteers (1986).

4. Expenses

All participants will receive £10 for out of pocket expenses and the inconvenience experienced on the day of exposure and during the associated medical examinations. This token payment is not intended to cover '*risk*'.

5. Consent

(i) I have read and understood sections 1 through 4 of this subject information sheet.

(ii) I give my consent for the medical examinations and sample collections outlined and I am willing to be involved in this experiment.

(iii) I understand that insurance cover has been arranged by the project supervisors. I understand that I can pull out of this study at any time but I undertake to inform the supervisors immediately I take such a decision.

(iv) I am willing to provide information on my medical history to the researchers on the understanding that any such information will be treated in strictest confidence.

Signed ....

Name (PLEASE PRINT) ....

Date ....

APPENDIX II

Subject Information Sheet and Recruitment Guidelines as used for the Pilot Study

SUBJECT INFORMATION SHEET

Study on the Possible Health Effects of Bathing in waters which meet EEC Directive standards

FUNDING AGENCY	Department of the Environment
MANAGEMENT AGENCY	Water Research Centre
RESEARCH SUPERVISORS	Mr F. Jones (Altwell Ltd), Dr D. Kay (University of Wales), Dr R. Stanwell-Smith (Bristol and Weston Health Authority), Dr I Barrow (Environmental Health Consultant).

1. NATURE OF THE STUDY

1.1 Background

A degree of sewage contamination can be detected at most UK bathing beaches. There is no reliable information, for UK bathing waters, with which to define the minor risks to health caused by bathing in this coastal environment. Britian and our European partners accept the European Bathing Waters Directive standards as one measure of '*acceptable*' bathing water quality. However, we do not know if these standards are either too lax or too stringent to ensure that minor diseases will not be contracted by the bathers. It is the objective of this study to answer some of these questions.

1.2 Research Method

This project will involve 400 healthy volunteers. All will be adults over 18 years of age. They will be taken to a beach which has been given a PASS grade on the European bathing water standards. In UK terms this would place the beach in the top 67% of our identified *Eurobeaches*. The chosen beach will be Langland bay and the group of bathers would be taking part in a common leisure time activity practiced by millions of other UK and European citizens (i.e. coastal bathing). The beach has relatively '*good*' water quality and has passed the EEC bathing water directive at the Imperative level in recent years. The group of 400 volunteers would be split into two equal groups at the beach. One group will take part in normal beach activities other than water contact pursuits, whilst the other will go into the water. This latter group will each be asked to immerse their heads in the water at least three times during the test, as they might during normal recreational activity.

Every volunteer would have three questionnaire-based assessments to ascertain their state of '*perceived*' health, first on the day before exposure, the second 72 hours later and the third after three weeks. Paralleling this schedule will be the collection of ear and throat swabs together with faecal samples by qualified personnel for analysis by the Public Health Laboratory Service.

2. Health risks

The Department of Health have indicated that there is only a small risk of illness even if waters are seriously and visibly contaminated. The fact that the study is to be conducted on a beach which meets the standards of the EEC Bathing Waters Directive can give confidence that there is no risk of serious illness. However, previous work in this area, conducted outside the UK, has suggested that there might be a slight risk of contracting minor illnesses such as stomach infections. We cannot guarantee that there is zero risk of volunteers contracting such infections. However, this risk is no greater than that experienced by many millions of coastal bathers each year who use waters which currently meet EEC standards.

3. Insurance cover

All participants in the study will be covered for accidental injury . Exact details of this insurance cover are available for inspection on request from any of the four supervisors listed above. In broad terms, this policy follows the guidelines recommended by the Royal College of Physicians Research on Healthy Volunteers (1986).

4. Expenses

All participants will receive £10 for out of pocket expenses and the inconvenience experienced on the day of exposure and during the associated medical examinations. This token payment is not intended to cover '*risk*'.

5. Consent

(i) I have read and understood sections 1 through 4 of this subject information sheet.

(ii) I give my consent for the medical examinations and sample collections outlined and I am willing to be involved in this experiment.

(iii) I understand that insurance cover has been arranged by the project supervisors. I understand that I can pull out of this study at any time but I undertake to inform the supervisors immediately I take such a decision.

(iv) I am willing to provide information on my medical history to the researchers on the understanding that any such information will be treated in strictest confidence.

Signed

____

Name (Please print)

____

Date

_|_|_

Daytime Phone No. ____________

Department ________

Home Address ________

____

____

____

Phone No. ________

GP's Name ________

Surgery Address ______

____

____

____

Bathing Water Study

Cohort Recruitment Guidelines

The methods of cohort recruitment are of central importance in maintaining the ethical acceptability of this study and the following guidelines will be circulated to all involved in cohort recruitment.

General Principles

1. The cohort must be volunteers. There must be no element of coercion

2. Inappropriate pressure should not be placed on any group or individual to take part. Such pressure could take the form of;

(i) immoderate financial inducement,
(ii) immediate superiors acting as recruiters.

3. All participants must be made aware of the potential risks and level of protection they will receive.

Those involved in cohort recruitment can maintain these principles by the following actions :

1. Circulating all potential cohort members in a particular organisationproviding an equal chance for all to participate

2.Ensuring that potential cohort members have read the subject information sheet which explains the risk aspects and that the study has been approved by the Ethics Committee of the Royal College of Physicians.

3. Informing volunteers that insurance cover has been arranged with Royal Insurance to cover all participants, and that they are welcome to inspect the policy should they so wish. Also the supervisors are covered by indemnity cover (which applies to legal liability) to £5 million.

APPENDIX III

Supervisor Instructions used for the Pilot Study

INSTRUCTIONS FOR THE CAR PARK SUPERVISORS ON 02/09/89. CONTROLLED COHORT PILOT STUDY.

Be at Langland bay by 10.30 am for the site meeting of supervisors. Two people have been assigned to the car park area from 12.00 pm., to meet the participants. Pick up the following items, by 11.50 am at the latest:

1. 450 lists of bathers printed on BLUE paper. (225 each).

2. 450 lists of non bathers printed on RED paper. (225 each).

3. 450 maps of the beach.

One supervisor will meet participants as they alight from the bus at the car park. The other should position him/herself at the top of the entrance steps to the beach from the car park (see attatched map). You must ensure that each participant receives copies of both the red and blue lists, and a map. You will ask participants to identify themselves on the lists, and direct them to the appropriate marshalling point. (BLUE= BATHER, RED=NON BATHER). You are also expected to offer general guidance to participants throughout the afternoon, so make sure you can direct people to facilities such as toilets etc.

At the end of the study period, around 4.00 pm, please help with litter collection and/or equipment dismantling.

INSTRUCTIONS FOR BATHING WATER SAMPLERS ON 02/09/89. CONTROLLED COHORT PILOT STUDY.

Be at Langland bay by 10.30 am for the site meeting of supervisors. After the site meeting make your way to the bathing area by 11.50 am at the latest. This is marked on the attatched map, and by BLUE tape fencing and markers on the beach. The seaward side of the bathing area is marked at 20 m intervals by flags. You are responsible for taking the bacterological samples at one of these points. You will take sets of three samples at your location, from the sea, at the following depths :

1. Surf

2. 30 cm

3. Chest depth

You will take seven sets of three samples in all, at the following approximate times (BST) :

12.00 noon, 13.00 pm, 13.20 pm, 13.40 pm, 14.00 pm,
14.20 pm, and 15.00 pm.

As overall group supervisor Richie Westlake will indicate the times of each sample. The group should aim to take synchronous samples.

Five minutes before each sample time collect three pre-marked bottles from RW and take up your station to commence sampling. On RW's signal take your bottles and sample surf, then 30cm depth then the chest depth sample. A blue shoulder bag will be provided for bottle storage.

When you have collected all your samples return the to RW who will check each label and place them immediately into the cold box.

INSTRUCTIONS FOR THE NON BATHER SUPERVISORS ON 02/09/89. CONTROLLED COHORT PILOT STUDY.

Be at Langland bay by 10.30 am for the site meeting of supervisors. Pick up the following items :

1. A RED tee shirt, with a number from 1-5.

2. 1 clipboard, numbered as per your tee shirt (1-5), with 50 copies of the yellow exposure day form attatched and a list of allocated participants.

4. 6 biros.

You should then proceed to the marshalling point, marked by the RED/WHITE tape fencing and RED marker signs, and arrive by no later than 12.15 pm. You will have a group of 40 non bathers who will identify you by the number on your tee shirt.As the participants arrive, you will hand out the YELLOW FORMS and assist with their completion. You will stress to your group that they must not go into the water for the duration rest of the day, and ideally not for the next week at least. The volunteers will be allowed to leave the site once they have completed the YELLOW FORM and had their lunch. When you have received all your completed questionnaires and ticked them off on your list, return them to Penny Davies, your supervisor in charge.

If any participants do not confine themselves to the constraints of the experiment, their movements should be reported to Penny Davies.

At the end of the study, please help with litter clearance and equipment dismantling as necessary.

INSTRUCTIONS FOR THE BATHER SUPERVISORS ON 02/09/89. CONTROLLED COHORT PILOT STUDY.

Be at Langland bay by 10.30 am for the site meeting of supervisors. Pick up the following items :

1. A BLUE tee shirt, with a number from 1-20.

2. 1 set of 10 COLOURED arm bands, numbered 1-10.

3. 1 clipboard, numbered as per your tee shirt (1-20), with the following attatched :

12 copies of the yellow exposure day form
1 set of bather cohort coding sheets.

4. 6 biros.

You should then proceed to the marshalling point, marked by the BLUE tape fencing and BLUE marker signs, and arrive by no later than 12.15 pm. Familiarise yourself with the coding form. You will have a group of ten bathers on your coding forms, who will identify you by your numbered shirt, as they arrive. They will not arrive all at once, so give the participants the YELLOW FORM to fill in as they arrive. Assist the group with the questionnaire, as necessary. You will tell each of the group members that they must fully immerse themselves, including their head, at least 3 times, during bathing. NB keep your group within +/- 10m of a single location marker in the range 20m-80m.

Once the forms are filled in, and returned to you and arm bands have been fitted, bathing can commence. The bathing period will last 5-15 minutes, maximum. Note the time at which the bathing started on the coding form. From then on, note the general location and activities of each bather on the coding form for sussesive 5 minute blocks, by ticking the location/activity boxes. Each bather must immerse themselves fully, including the head, at least 3 times. They will be allowed out after they have done this, but may wish to stay in the sea for longer.

If any participants did not fill in the YELLOW FORM prior to bathing, make sure they do so once they are out of the water. Participants may now leave the bathing area and/or the site from then on. After ticking your list, completed forms should be given to the supervisor in charge,CP. If they have not done so already, participants may pick up their packed lunch from the allocated beach hut, but remind them to take their blue/red list with them.

At the end of the study, please help with litter clearance and equipment dismantling as necessary.

APPENDIX IV

Supervisor Name ____________________ * Locations : 1= Surf Zone, 2= >50 cm, 3= >1 m

**Activities : 1=paddle/wade, 2=swim, 3=full immersion

Supervisor No. ____

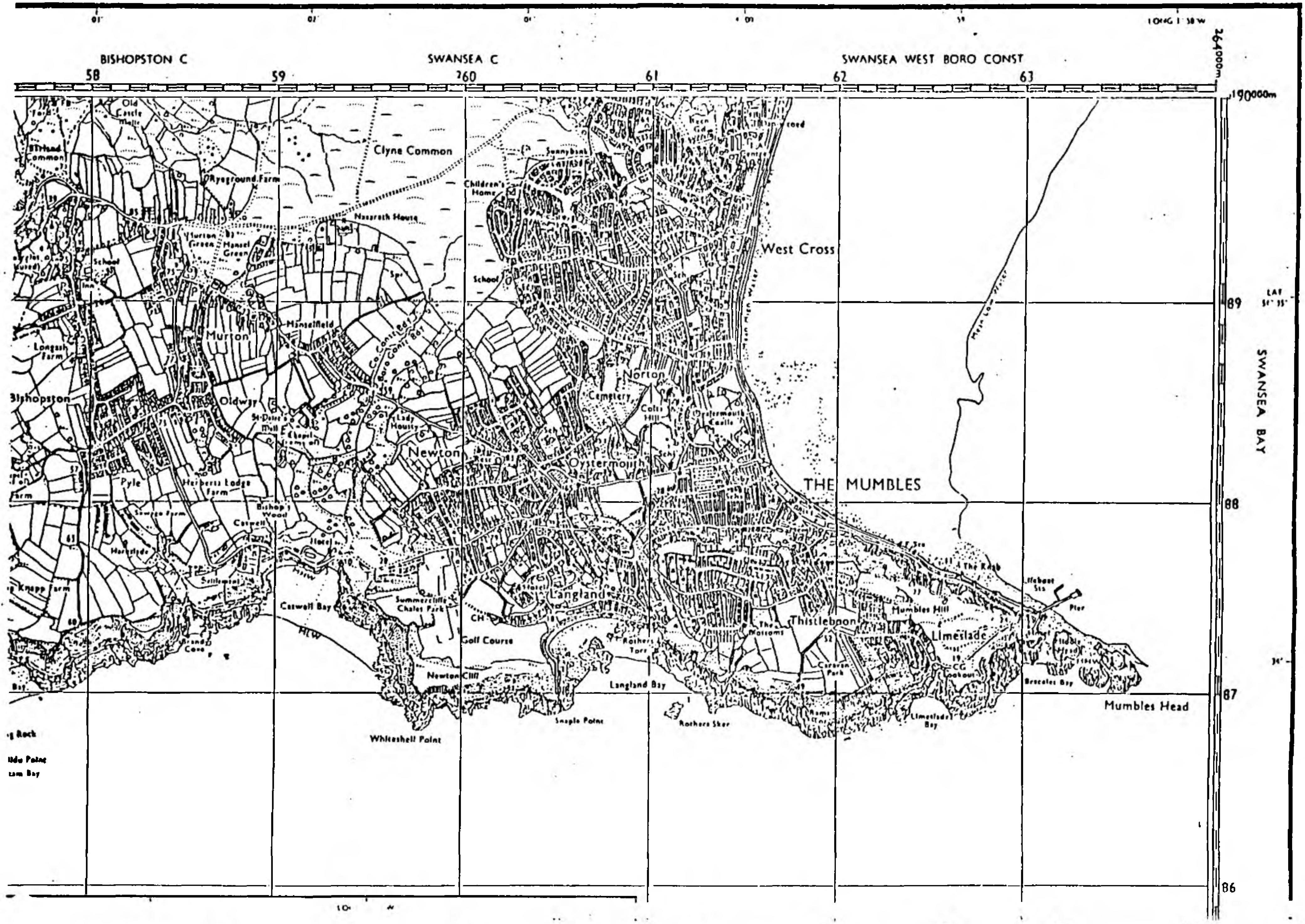
		* Location →		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
		** Activity →		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Name	No.	Study Number	Time →	0-10 mins			10-20 mins			20-30 mins			30-40 mins			40-50 mins			50-60 mins			60-70 mins			70-80 mins			80-90 mins		
Start time	1		Loc.																											
			Act.																											
Start time	2		Loc.																											
			Act.																											
Start time	3		Loc.																											
			Act.																											
Start time	4		Loc.																											
			Act.																											
Start time	5		Loc.																											
			Act.																											
Start time	6		Loc.																											
			Act.																											
Start time	7		Loc.																											
			Act.																											
Start time	8		Loc.																											
			Act.																											
Start time	9		Loc.																											
			Act.																											
Start time	10		Loc.																											
			Act.																											

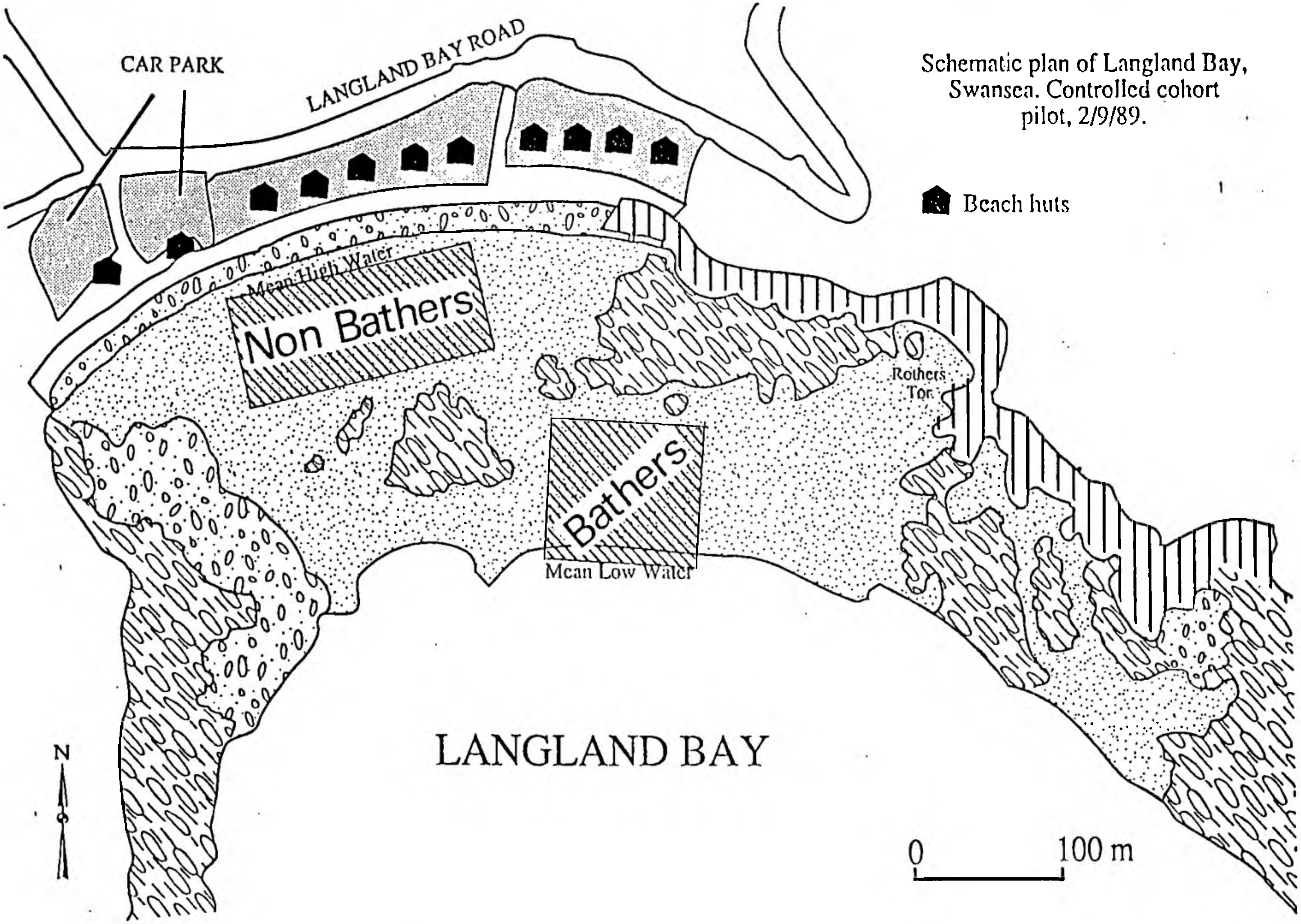
Location on shore (i.e. Between which sampling points) ____________________

APPENDIX V

Site Location Map for the Pilot Study: Langland Bay, Swansea

SHEET SS 48/58/68





Schematic plan of Langland Bay, Swansea. Controlled cohort pilot, 2/9/89.

APPENDIX VI

Questionnaire Set used for the Pilot Study

Pre-exposure, exposure day, 3 day and 3 week post exposure questionnaires

STRICTLY CONFIDENTIAL

HEALTH SURVEY OF SEA WATER BATHING :PILOT 1989

Pre-exposure interview:

Interviewer name: ____________________

SECTION ONE-PERSONAL DETAILS

1. Subject name: ____________________

2. Age/D.O.B.: ____________ yrs

3. Sex : MALE 1 / FEMALE 2

4. Home address: ____________________

____________ Postcode ____________

Telephone no. (home): ____________________

5. Work/study address ____________________

____

6. Contact details for follow-up (address etc. over next three months).

____

____

7. Occupation :

Student ☐ 1 H/Wife ☐ 2 Empl ☐ 3 Self-Emp ☐ 4

Unempl ☐ 5 Retired ☐ 6 Other* ☐ 7

*Details/Specify: ____________________

If unemployed, please state for how long:

____________ Years ____________ Months

Coding only

Volunteer no. ☐☐☐☐ 1 Form 1 2

Study no ☐☐☐☐☐ 3

date ☐☐ ☐☐ 8 9 4

Interviewer ☐☐ 5 Bather / non bather ☐ 6

dob ☐☐ ☐☐ ☐☐ 7

sex ☐ 8

post code ☐☐☐☐☐☐☐☐ 9

work/college ☐ 10

job - head ☐ 11

U/E Head- Months ☐☐ 12

STRICTLY CONFIDENTIAL

PERSONAL DETAILS - CONTINUED

Coding only

8. Please give the job occupation of the head of household: (If unemployed, retired, or job has changed in last three months, please state most recent occupation).
(What is the official title of the job?)

____

9. In the current or most recent job, please describe the actual work done:
(Prompt for seniority, level of responsibility, etc Code as No. 1-6 in box 13)

____

S.C. Head ☐ 13

10. Please describe the place of work/school /etc.
(Prompt - type of environment or most recent job/school).

Home ☐ 1 Office ☐ 2 W/Shop ☐ 3 Factory ☐ 4 School ☐ 5

Nursery ☐ 6 Shop ☐ 7 Outdoors ☐ 8 *Other ☐ 10

Workplace ☐☐ 14

*Specify: ______________________________

11. General Practitioner: ______________________________
(Name/Address/Tel No.)

______________________________ Tel: ______________________________

12. Health Authority:

____

H.A. ☐☐ 15

13. Local Authority:

____

L.A. ☐☐ 16

14. Please list all the members of your household (i.e. all those who live in your home) with their sex and ages :
(A household means sharing facilities and at least one meal per day)

Name (Surname not essential)	Sex	Age	Name (Surname not essential)	Sex	Age

Total in household ☐☐ 17

Total children upto 5 in household ☐☐ 18

SECTION TWO - GENERAL HEALTH

15. Do you have any longstanding illness, disability or infirmity? (Anything that has troubled you over a period of time or is likely to affect you over a period in the future).

Yes ☐ 1 No ☐ 0

if no, turn to page 5

If yes, please indicate the nature of the problem by ticking all the boxes that apply from this list on this and the following page. Use the space at the bottom of page 4 to describe any circumstances not covered by the available boxes.

ARTHRITIS: specify joints ____________________ ☐

BACK PAIN (include aches/lumbago/disc problems) ☐

raised BLOOD PRESSURE ☐

CANCER: specify type ____________________ ☐

CHEST PROBLEMS (include asthma/bronchitis) ☐

DEPRESSION ☐

DIABETES ☐

DIGESTION PROBLEMS (e.g. dispesia (ulcer)) : specify ☐

____

BOWEL PROBLEMS (e.g. constipation, colitis, irritable bowel syndrome) : specify ☐

____

HEARING LOSS/EAR PROBLEMS : specify ☐

HEART DISEASE (include angina) ☐

HEPATITIS ☐

Problems due to INFECTION ☐

specify infection and problem: ____________________

____

Coding only

Long. ill ☐ 19

Arthritis ☐ 20

Back Pain ☐ 21

Blood Pressure ☐ 22

Cancer ☐ 23 Cancer type ☐☐ 24

Chest ☐ 25

Depression ☐ 26

Diabetes ☐ 27

Digestion problems ☐ 28 Problem type ☐☐ 29

Bowel problems ☐ 30 Problem type ☐☐ 31

Hearing/ear problems ☐ 32 Problem Type ☐☐ 33

Heart ☐ 34

Hepatitis ☐ 35 Type ☐ 36

Infection ☐ 37 Infection Type ☐☐ 38

Infection problem ☐☐ 39

STRICTLY CONFIDENTIAL

GENERAL HEALTH - CONTINUED

Problems resulting from INJURY OR ACCIDENT: ☐
specify : the problem ____________________

the cause: road traffic accident ☐

accident at work ☐

accident at home ☐

other * ☐

*specify: ____________________

KIDNEY or BLADDER problem: ☐

specify: ____________________

MIGRAINE/persistent HEADACHES ☐

NEUROLOGICAL Condition: specify ☐
(e.g.strokes / epilepsy / paralysis) ____________________

SKIN Problems: specify ____________________ ☐
(e.g. eczema)

STRESS / ANXIETY ☐

POOR VISION/ EYES: ☐

specify: ____________________

OTHER PROBLEMS: Please give a brief description ☐

____

____

____

16. Do you see a doctor regularly for any of these problems?

Yes ☐1 No ☐0 Not sure ☐9

If yes, give details ____________________

____

Coding only

Injury/Accident ☐ 40

Traffic accident ☐ 41

Work accident ☐ 42

Home accident ☐ 43

Other accident ☐ 44

Kidney/ Bladder ☐ 45 Problem type ☐ 46

Migraine/ Headaches ☐ 47

Neurological ☐ 48 Problem type ☐ 49

Skin ☐ 50 Problem type ☐ 51

Stress / Anxiety ☐ 52

Eyes ☐ 53 Problem type ☐ 54

Other ☐ 55 Problem type ☐ 56

Doctor seen ☐ 57

STRICTLY CONFIDENTIAL

GENERAL HEALTH - CONTINUED

17. How many times a year do you have diarrhoea?

(3 or more loose bowel movements in a 24 hour period)

Often 1-2 a month	Sometimes 3-11 a year	Hardly ever <2 a year	Never	Not Sure
☐ 3	☐ 2	☐ 1	☐ 0	☐ 9

18. How many times a year do you have toothache?

Often 1-2 a month	Sometimes 3-11 a year	Hardly ever <2 a year	Never	Not Sure
☐ 3	☐ 2	☐ 1	☐ 0	☐ 9

19. Have you in the past 6 months had an illness which caused you to stay home from work or go to hospital?

Yes	No	Not Sure
☐ 1	☐ 0	☐ 9

If no go to Question 20 Page 6

If yes please complete the following section (for up to 3 illnesses).

Diagnosis	Hospital admission		Days sick / off work	
	Yes	No	Weeks	Days
1	☐ 1	☐ 0		

Month illness started	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
	☐	☐	☐	☐	☐	☐	☐	☐
	1	2	3	4	5	6	7	8

2	☐ 1	☐ 0	

Month illness started	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
	☐	☐	☐	☐	☐	☐	☐	☐
	1	2	3	4	5	6	7	8

3	☐ 1	☐ 0	

Month illness started	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
	☐	☐	☐	☐	☐	☐	☐	☐
	1	2	3	4	5	6	7	8

Other	☐ 1	☐ 0	

Month illness started	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
	☐	☐	☐	☐	☐	☐	☐	☐
	1	2	3	4	5	6	7	8

Coding only

Diarrhoea ☐ 58

Toothache ☐ 59

Ill in last 6 months ☐ 60

Illness 1 ☐ 61

Illness 1 type ☐ 62

Illness 1 Hosp. adm. ☐ 63

Illness 1 time off (MWD) ☐ 64

Illness 1 start (M) ☐ 65

Illness 2 ☐ 66

Illness 2 type ☐ 67

Illness 2 Hosp. adm. ☐ 68

Illness 2 time off (MWD) ☐ 69

Illness 2 start (M) ☐ 70

Illness 3 ☐ 71

Illness 3 type ☐ 72

Illness 3 Hosp. adm. ☐ 73

Illness 3 time off (MWD) ☐ 74

Illness 3 start (M) ☐ 75

Other Illness ☐ 76

Other Illness type ☐ 77

Other Illness Hosp. adm. ☐ 78

Other Illness time off (MWD) ☐ 79

Other start (M) ☐ 80

GENERAL HEALTH - CONTINUED

Coding only

20. In the last 6 months, please answer whether you have had any of the following symptoms.

(Answer Yes, No or Not sure for every symptom)

		Yes	No	Not sure	
1.	Fever/hot &cold shivers	☐ 1	☐ 0	☐ 9	Fever ☐ 81
2.	Headache	☐ 1	☐ 0	☐ 9	Headache ☐ 82
3.	Aching arms, legs, joints	☐ 1	☐ 0	☐ 9	Aching limbs ☐ 83
4.	Chest pains / aches	☐ 1	☐ 0	☐ 9	Chest pains ☐ 84
5.	Dry cough	☐ 1	☐ 0	☐ 9	Dry cough ☐ 85
6.	Productive cough *(Phlegm, Sputum)*	☐ 1	☐ 0	☐ 9	Productive cough ☐ 86
7.	Sore throat	☐ 1	☐ 0	☐ 9	Sore throat ☐ 87
8.	Ear infection	☐ 1	☐ 0	☐ 9	Ear infection ☐ 88
9.	Eye infection/ sore red eyes	☐ 1	☐ 0	☐ 9	Eye infection ☐ 89
10.	Shortness of breath/ difficulty with breathing	☐ 1	☐ 0	☐ 9	Breathing ☐ 90
11.	Blurred vision/ difficulty with eyesight	☐ 1	☐ 0	☐ 9	Vision ☐ 91
12.	Loss of appetite	☐ 1	☐ 0	☐ 9	Appetite ☐ 92
13.	Indigestion	☐ 1	☐ 0	☐ 9	Indigestion ☐ 93
14.	Loose bowel motions/ diarrhoea *(3 or more loose bowel movements in a 24 hour period)*	☐ 1	☐ 0	☐ 9	Diarrhoea ☐ 94
15.	Nausea	☐ 1	☐ 0	☐ 9	Vomiting ☐ 95
16.	Vomiting	☐ 1	☐ 0	☐ 9	Nausea ☐ 96
17.	Excessive or unusual tiredness/lassitude	☐ 1	☐ 0	☐ 9	Lassitude ☐ 97
18.	Dizziness/giddiness	☐ 1	☐ 0	☐ 9	Dizziness ☐ 98
19.	Skin rash	☐ 1	☐ 0	☐ 9	Skin rash ☐ 99

20. Other: please describe ____________________

____

Other ☐ 100 Type ☐ 101

STRICTLY CONFIDENTIAL

GENERAL HEALTH - CONTINUED

Coding only

21. Are you taking any drugs or medicines PRESCRIBED BY YOUR DOCTOR ?

Yes	No	Not sure
☐ 1	☐ 0	☐ 9

If yes please list: ______________________________

____

____

____

Prescr. drugs ☐ 102

Drug type ☐|☐ 103

22. Recent illness

(e.g. colds, stomach upsets, short term illness)

In the last four weeks have you had any illness?

Yes	No	Not Sure
☐ 1	☐ 0	☐ 9

Recent illness ☐ 104

If yes has this already been recorded on this questionnaire?

Yes	No
☐ 1	☐ 0

Reported? ☐ 105

For new illness, not previously mentioned, please give diagnosis, date of onset and symptoms as per the list on page 6:

Diagnosis: ______________________________

Diagnosis ☐ 106

Ring all days on which you were ill :

(When did the illness start, whem did it finish and how long did it last? Bank Holidays shown)

August 1989

M	T	W	T	F	S	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Date of on set ☐|☐ 0|8 8|9 107

Duration - days ☐|☐ 108

Fever 1	Headache 2	Aching limbs 3	Chest Pains 4	Dry cough 5	Productive cough 6	Sore throat 7	Ear infection 8	Eye infection 9	Short of breath 10

Symptoms ☐|☐ ☐|☐ ☐|☐ 109

Blurred vision 11	Loss of appetite 12	Indigestion 13	Diarrhoea 14	Vomiting 15	Nausea 16	Lassitude 17	Dizziness 18	Skin rash 19	Other* 20

Symptoms continued ☐|☐ ☐|☐ ☐|☐ 110

*Other, Please specify ______________________________

____

Other type ☐|☐ 111

GENERAL HEALTH - CONTINUED

23. How many cigarettes do you smoke per day?

(Include cigars and 'roll your own' cigarettes. Each one counts as one cigarette.)

None	<5	5-10	11-20	>20	Pipe or any other kind of Smoker	Not sure
☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☐ 7	☐ 9

24. If you are an ex smoker how long is it since you gave up?

Non smokers tick appropriate box

☐☐ Years ☐☐ Months ☐☐ Days ☐ 0 Non smoker

25. Vaccination

Have you, or has anyone in your family / household had an oral polio vaccine booster in the last 6 months?

(Prompt: recent polio vaccination may be detected from stool samples. N.B. a polio booster is <u>not</u> required for UK bathing waters! Only code vaccinations in members of immediate family who live in the same home.)

Yes / me	Yes / Family	No	Not Sure
☐ 1	☐ 2	☐ 0	☐ 9

If yes, please give month of vaccination:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8

Smoking ☐ 112

Gave up ☐☐☐ 113
Y M D

Non smoker ☐ 114

Vaccination ☐ 115

Month of Vaccination ☐ 116

26. Have you taken any tablets or medicines in the last four weeks?
(Include regular/ chronic prescriptions as well as drugs bought from the chemists/ supplied by the clinic)

Yes	No	Not Sure
☐ 1	☐ 0	☐ 9

Drugs ☐ 117

Tick which:

Name of Tablet/Medicine

1. Antibiotics ☐ 1 ____________________
2. Vitamins ☐ 1 ____________________
3. Inhalers/ Steroids ☐ 1 ____________________
4. Analgesics ☐ 1 ____________________
   (e.g. Aspirin/Panadol/ Calpol)
5. Cough medicine ☐ 1 ____________________
   (e.g. Actifed)
6. Mild Sedatives ☐ 1 ____________________
   (e.g. Phenergan)
7. O/C Pill ☐ 1 ____________________
8. Laxatives ☐ 1 ____________________
9. Stomach remedies ☐ 1 ____________________
   (e.g. Milk of magnesia, antacids etc.)
10. Other ☐ 1 ____________________

Antibiotics ☐ 118

Vitamins ☐ 119

Inhalers/ steroids ☐ 120

Analgesics ☐ 121

Cough medicine ☐ 122

Mild sedatives ☐ 123

O/C pill ☐ 124

Laxatives ☐ 125

Stomach remedies ☐ 126

Other ☐ 127

Other type ☐☐ 128

STRICTLY CONFIDENTIAL

SECTION THREE - VISITS AT HOME AND ABROAD

26. In the past 6 months have you spent any nights away from home, e.g. for a holiday or to visit relatives?

Yes ☐1 No ☐0 Not Sure ☐9

If yes was this in the U.K. or abroad?

U.K. ☐1 Abroad ☐2 Both ☐3

Please give the date(s) and place(s) visited below:

Place(s)	Date(s)	Duration of stay

27. Were you born overseas?

Yes ☐1 No ☐0 Not Sure ☐9

If yes please state country of birth:

____

28. Have you spent any time overseas at any time in your life?

(Excluding holidays)

Yes ☐1 No ☐0 Not Sure ☐9

If no go to section 4, page 12.

If yes how many years?

Up to 1 ☐1 1-3 ☐2 >3 ☐3 Not Sure ☐9

Please list the country / countries :

____

____

____

____

Coding only

Visits away from home ☐ 129

Visits U.K. / abroad ☐ 130

No. visits U.K. ☐ 131

No. visits Abroad ☐ 132

	UK/ Abroad	Location	Weeks	Days	
1					133
2					134
3					135
4					136
5					137

Born overseas ☐ 138

Country of origin ☐ 139

Trips overseas ☐ 140

Time overseas ☐ 141

Country visited 1 ☐ 142

Country visited 2 ☐ 143

Country visited 3 ☐ 144

Country visited 4 ☐ 145

29. Have you had any of the following vaccines in relation to foreign travel? *(Year of last course is sufficient accuracy)*

	Yes	No	Not Sure	Date of last booster or course
1. Typhoid	☐ 1	☐ 0	☐ 9	________
2. Paratyphoid	☐ 1	☐ 0	☐ 9	________
3. Cholera	☐ 1	☐ 0	☐ 9	________
4. Yellow fever	☐ 1	☐ 0	☐ 9	________
5. Immunoglobin / gamma globulin	☐ 1	☐ 0	☐ 9	________
(5. For hepatitis A)				
6. Tetanus	☐ 1	☐ 0	☐ 9	________
7. Polio (oral) *("sugar lump")*	☐ 1	☐ 0	☐ 9	________
8. Polio (injected)	☐ 1	☐ 0	☐ 9	________
9. Other vaccines	☐ 1	☐ 0	☐ 9	________

If yes please list with dates :

Vaccine	Date
________	________
________	________
________	________

Booster date M Y
code missing as 9

Typhoid	☐☐☐	146
Paratyphoid	☐☐☐	147
Cholera	☐☐☐	148
Yellow fever	☐☐☐	149
Hepatitis A	☐☐☐	150
Tetanus	☐☐☐	151
polio oral	☐☐☐	152
Polio inject	☐☐☐	153
Other 1	☐☐☐	154
Other 2	☐☐☐	155
Other 3	☐☐☐	156

STRICTLY CONFIDENTIAL

SECTION FOUR - GENERAL LEISURE ACTIVITIES

Coding only

30. How often do you take part in the following activities?

(Average no. of times in the spring and autumn months.)

	Every day	>7 Times	4-7 Times	1-3 Times	Not at all	Not Sure	No. of times in last month
Pub / Drinking club	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐
Party	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐
Leisure centre	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐
Public swimming pool	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐
Other swimming pool	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐
Church / religious meeting	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐

Pub	☐ 157	Frequency	☐ 158
Party	☐ 159	Frequency	☐ 160
Leisure Centre	☐ 161	Frequency	☐ 162
Public pool	☐ 163	Frequency	☐ 164
Other pool	☐ 165	Frequency	☐ 166
Church	☐ 167	Frequency	☐ 168

30. How often do you take part in the following water related sports / activities?

(Please give average/typical exposure in times per month during the summer period with reasonable weather, and in fresh/sea water).

	Every day	>7 Times	4-7 Times	1-3 Times	Not at all	Not Sure	Sea water	Fresh water	No. of times in last month
Dinghy sailing	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐
Canoeing	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐
Windsurfing / Sailboarding	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐
Speed / motor boating	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐
Other sailing / boating	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐
Subaqua / snorkeling	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐
Water skiing	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐
Surfing	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐
Other*	☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐

Specify:* ____________________

Code positive response for sea / fresh water as 1 and negative response as 0.

		Sea	Fresh			
Dinghy	☐ 169	☐	☐ 170	Frequ	☐ 171
Canoe	☐ 172	☐	☐ 173	Frequ	☐ 174
w.surf	☐ 175	☐	☐ 176	Frequ	☐ 177
speed boat	☐ 178	☐	☐ 179	Frequ	☐ 180
other sail.	☐ 181	☐	☐ 182	Frequ	☐ 183
sub aqua	☐ 184	☐	☐ 185	Frequ	☐ 186
water ski.	☐ 187	☐	☐ 188	Frequ	☐ 189
surf	☐ 190	☐	☐ 191	Frequ	☐ 192
other	☐ 193	☐	☐ 194	Frequ	☐ 195

STRICTLY CONFIDENTIAL

GENERAL LEISURE ACTIVITIES - CONTINUED

32. How often do you take part in sea or fresh water bathing?

(Please give average/typical exposure in times per month during the summer period with reasonable weather, and in fresh/sea water)..

Every day	>7 Times	4-7 Times	1-3 Times	Not at all	Not Sure	Sea water	Fresh water	No. of times in last month
☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐

Please specify locations frequented in the past three weeks:

	Place(s)	UK 1	Abroad 2	Date(s)
1				
2				
3				
4				

33. How often do you visit a beach without going into the water?

Every day	>7 Times	4-7 Times	1-3 Times	Not at all	Not Sure	Sea water	Fresh water	No. of times in last month
☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐

34. In the last month have you been to a theme / leisure park and used any water rides?

(e.g. log rides, water shutes).

Yes	No	Not Sure
☐ 1	☐ 0	☐ 9

If yes was the site at home or abroad?

U.K.	Abroad
☐ 1	☐ 2

Please give the name of the site:

35. Are you able to swim competently ?

(Can you swim approximately 2 lengths in a swimming pool?)

Yes	No
☐ 1	☐ 0

Coding only

Code positive response for sea / fresh water as 1 and negative response as 0.

bathing ☐ 196 Sea Fresh ☐☐ 197 Freqs ☐ 198

	UK?	Location	Weeks	Days	
1	☐	☐	☐	☐	199
2	☐	☐	☐	☐	200
3	☐	☐	☐	☐	201
4	☐	☐	☐	☐	202

beach without bathing ☐ 203 Sea Fresh ☐☐ 204 Freqs ☐ 205

water rides ☐ 206

UK? ☐ 207

Park Location ☐ 208

Swimmer? ☐ 209

36. Additional comments. Use the space below to add any other information that you feel will help this study

(Information about general health, travel / work abroad, and leisure activities relating to recreational use of water)

Other comments 1 ☐ 210

Other comments 1 ☐ 211

Other comments 1 ☐ 212

STRICTLY CONFIDENTIAL

HEALTH SURVEY OF SEA WATER BATHING :PILOT 1989

Exposure day interview

Interviewer name: ______________________

SECTION ONE-FOOD INTAKE

1. Subject name: ______________________

2. Have you eaten any of the following foods during the past three days?

(tick boxes for days on which the particular food was consumed. Boxes in the shaded area refer to the exposure day itself i.e. 2/9/89 only.)

	Wed. 30/8/89	Thurs. 31/8/89	Fri. 1/9/89	Sat. 2/9/89	Prepared or brought from home	Purchased at resort	No	Not Sure
Ice cream	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Bought sandwiches	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Chicken	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Eggs	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Mayonnaise *(Fresh)*	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Hot dogs	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Hamburgers	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Salad	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Raw milk *(i.e. green top)*	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Cold meat / Pate	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9
Sea food* *(e.g. shellfish, cockles etc.)*	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 2	☐ 0	☐ 9

*Specify: ______________________

____

____

Coding only

Volunteer no. ☐☐☐☐ 213

Form ☐2 214

Study no ☐☐☐☐☐ 215

date 0 2 0 9 8 9 216

Interviewer ☐☐ 217

Bather / non bather ☐ 218

Code No as 0 in all boxes,
code not sure as 9 in all boxes,
code other negative responses as 0.

	30/8	31/8	1/9	2/9			
Ice cream	☐	☐	☐	☐	219	Source ☐	220
Bought sandwiches	☐	☐	☐	☐	221	Source ☐	222
Chicken	☐	☐	☐	☐	223	Source ☐	224
Eggs	☐	☐	☐	☐	225	Source ☐	226
Mayonnaise	☐	☐	☐	☐	227	Source ☐	228
Hot dogs	☐	☐	☐	☐	229	Source ☐	230
Hamburgers	☐	☐	☐	☐	231	Source ☐	232
Salad	☐	☐	☐	☐	233	Source ☐	234
Raw milk	☐	☐	☐	☐	235	Source ☐	236
Cold meat / pate	☐	☐	☐	☐	237	Source ☐	238
Sea food	☐	☐	☐	☐	239	Source ☐	240

Sea food type ☐☐ 241

STRICTLY CONFIDENTIAL

SECTION TWO-HEALTH

Coding only

3. In the last 3 days, including today, please tick whether you have had any of the following symptoms.

(Answer Yes, No or Not sure for all, or None on next page)

	Yes	No	Not sure
1. Fever/hot &cold shivers	☐ 1	☐ 0	☐ 9
2. Headache	☐ 1	☐ 0	☐ 9
3. Aching arms, legs, joints	☐ 1	☐ 0	☐ 9
4. Chest pains / aches	☐ 1	☐ 0	☐ 9
5. Dry cough	☐ 1	☐ 0	☐ 9
6. Productive cough *(Phlegm, Sputum)*	☐ 1	☐ 0	☐ 9
7. Sore throat	☐ 1	☐ 0	☐ 9
8. Ear infection	☐ 1	☐ 0	☐ 9
9. Eye infection/ sore red eyes	☐ 1	☐ 0	☐ 9
10. Shortness of breath/ difficulty with breathing	☐ 1	☐ 0	☐ 9
11. Blurred vision/ difficulty with eyesight	☐ 1	☐ 0	☐ 9
12. Loss of appetite	☐ 1	☐ 0	☐ 9
13. Indigestion	☐ 1	☐ 0	☐ 9
14. Loose bowel motions/ diarrhoea *(3 or more loose bowel movements in a 24 hour period)*	☐ 1	☐ 0	☐ 9

List continued on following page

Code response to no symptoms (see page 3) as 0 in all boxes

Fever ☐ 242
Headache ☐ 243
Aching limbs ☐ 244
Chest pains ☐ 245
Dry cough ☐ 246
Productive cough ☐ 247
Sore throat ☐ 248
Ear Infection ☐ 249
Eye Infection ☐ 250
Breathing ☐ 251
Vision ☐ 252
Appetite ☐ 253
Indigestion ☐ 254
Diarrhoea ☐ 255

3. Symptoms continued

	Yes	No	Not sure
15. Nausea	☐1	☐0	☐9
16. Vomiting	☐1	☐0	☐9
17. Excessive or unusual tiredness/lassitude	☐1	☐0	☐9
18. Dizziness/giddiness	☐1	☐0	☐9
19. Skin rash	☐1	☐0	☐9

20. Other: please describe ____________________

____

No symptoms recorded in the last 3 days ☐

4. Ring all days on the calendar on which the symptoms occured :

(When did the illness start, whem did it finish and how long did it last?)

August / September 1989

M	T	W	T	F	S	S
21	22	23	24	25	26	27
28	29	30	31	01	02	

5. Have you seen your doctor about these symptoms?

Yes ☐1 No ☐0

If yes has an illness been diagnosed?

Diagnosis ____________________

6. Apart from this study, have you been swimming, taken part in any water sports / water leisure activities, or visited a beach since you completed your interview with the GREEN FORM?

Yes ☐1 No ☐0 Not sure ☐9

If yes please give details : ____________________

____

____

7. Do you have any other information you would like to add?

____

____

____

Coding only

Code response to no symptoms as 0 in all boxes

Vomiting ☐ 256

Nausea ☐ 257

Lassitude ☐ 258

Dizziness ☐ 259

Skin rash ☐ 260

Other ☐ 261

Type ☐☐ 262

Date of on set ☐☐ ☐☐ 8 9 263

Duration - days ☐☐ 264

Doctor seen ☐ 265

Diagnosis ☐ 266

Water activities ☐ 267

Activity type ☐☐ 268

Further Information ☐ 269

STRICTLY CONFIDENTIAL

HEALTH SURVEY OF SEA WATER BATHING :PILOT 1989

Post exposure interview

Interviewer name: ____________________

SECTION ONE-FOOD INTAKE

1. Subject name: ____________________

2. Have you eaten any of the following foods during the past three days? *(tick boxes for days on which the particular food was consumed.)*

	Sun. 3/9/89	Mon. 4/9/89	Tues. 5/9/89	No	Not Sure
Ice cream	☐1	☐1	☐1	☐0	☐9
Bought sandwiches	☐1	☐1	☐1	☐0	☐9
Chicken	☐1	☐1	☐1	☐0	☐9
Eggs	☐1	☐1	☐1	☐0	☐9
Mayonnaise *(fresh)*	☐1	☐1	☐1	☐0	☐9
Hot dogs	☐1	☐1	☐1	☐0	☐9
Hamburgers	☐1	☐1	☐1	☐0	☐9
Salad	☐1	☐1	☐1	☐0	☐9
Raw milk *(i.e. green top)*	☐1	☐1	☐1	☐0	☐9
Cold meat / pate	☐1	☐1	☐1	☐0	☐9
Sea food* *(e.g. shellfish, cockles etc.)*	☐1	☐1	☐1	☐0	☐9

*Specify: ____________________

____

Coding only

Volunteer no. ☐☐☐☐ 301

Form 3 302

Study no ☐☐☐☐☐ 303

date ☐☐ 0 9 8 9 304

Interviewer ☐☐ 305

Bather / non bather ☐ 306

Code No as 0 in all boxes,
code not sure as 9 in all boxes,
code other negative responses as 0.

	3/9	4/9	5/9	
Ice cream	☐	☐	☐	307
Bought Sandwiches	☐	☐	☐	308
Chicken	☐	☐	☐	309
Eggs	☐	☐	☐	310
Mayonnaise	☐	☐	☐	311
Hot dogs	☐	☐	☐	312
Hamburgers	☐	☐	☐	313
Salad	☐	☐	☐	314
Raw milk	☐	☐	☐	315
Cold meat / pate	☐	☐	☐	316
Sea food	☐	☐	☐	317

Sea food type ☐☐ 318

STRICTLY CONFIDENTIAL

SECTION TWO-HEALTH

3. In the last 3 days, including today, please tick whether you have had any of the following symptoms.

(Answer Yes, No or Not sure for all, or None on next page)

	Yes	No	Not sure
1. Fever/hot &cold shivers	☐ 1	☐ 0	☐ 9
2. Headache	☐ 1	☐ 0	☐ 9
3. Aching arms, legs, joints	☐ 1	☐ 0	☐ 9
4. Chest pains / aches	☐ 1	☐ 0	☐ 9
5. Dry cough	☐ 1	☐ 0	☐ 9
6. Productive cough *(Phlegm, Sputum)*	☐ 1	☐ 0	☐ 9
7. Sore throat	☐ 1	☐ 0	☐ 9
8. Ear infection	☐ 1	☐ 0	☐ 9
9. Eye infection/ sore red eyes	☐ 1	☐ 0	☐ 9
10. Shortness of breath/ difficulty with breathing	☐ 1	☐ 0	☐ 9
11. Blurred vision/ difficulty with eyesight	☐ 1	☐ 0	☐ 9
12. Loss of appetite	☐ 1	☐ 0	☐ 9
13. Indigestion	☐ 1	☐ 0	☐ 9
14. Loose bowel motions/ diarrhoea	☐ 1	☐ 0	☐ 9

(3 or more loose bowel movements in a 24 hour period)

List continued on following page

Coding only

Code response to no symptoms (see page 3) as 0 in all boxes

Fever	☐	319
Headache	☐	320
Aching limbs	☐	321
Chest pains	☐	322
Dry cough	☐	323
Productive cough	☐	324
Sore throat	☐	325
Ear Infection	☐	326
Eye Infection	☐	327
Breathing	☐	328
Vision	☐	329
Appetite	☐	330
Indigestion	☐	331
Diarrhoea	☐	332

STRICTLY CONFIDENTIAL

3. Symptoms continued

	Yes	No	Not sure
15. Nausea	☐ 1	☐ 0	☐ 9
16. Vomiting	☐ 1	☐ 0	☐ 9
17. Excessive or unusual tiredness/lassitude	☐ 1	☐ 0	☐ 9
18. Dizziness/giddiness	☐ 1	☐ 0	☐ 9
19. Skin rash	☐ 1	☐ 0	☐ 9

20. Other: please describe ____________________

____

No symptoms recorded in the last 3 days ☐

4. Ring all days on the calendar on which the symptoms occured :

(When did the illness start, when did it finish and how long did it last?)

September 1989

M	T	W	T	F	S	S
					02	03
04	05	06	07	08	09	10

5. Have you seen your doctor about these symptoms?

Yes ☐ 1 No ☐ 0

If yes has an illness been diagnosed?

Diagnosis ____________________

6. Apart from this study, have you been swimming, taken part in any water sports / water leisure activities, or visited a beach since Saturday 2nd September?

Yes ☐ 1 No ☐ 0 Not sure ☐ 9

If yes please give details : ____________________

____

____

Coding only

Code response to no symptoms as 0 in all boxes

Vomiting ☐ 333

Nausea ☐ 334

Lassitude ☐ 335

Dizziness ☐ 336

Skin rash ☐ 337

Other ☐ 338 Type ☐☐ 339

Date of on set ☐☐ ☐☐ 8 9 340

Duration - days ☐☐ 341

Doctor seen ☐ 342

Diagnosis ☐ 343

Water activities ☐ 344

Activity type ☐☐ 345

Coding only

7. Have you drunk any alcohol in the last week?

Yes	No	Not sure
☐ 1	☐ 0	☐ 9

alcohol ☐ 346

If no, skip to question 9 at the end of this page.

8. Please say how much you drank on the following days :

		No. of pints of beer, lager etc.	No. of glasses of spirits (gin, whisky, etc.)	No. of glasses of wine or sherry
Friday 1st	Sept.	________	________	________
Saturday 2nd	Sept.	________	________	________
Sunday 3rd	Sept.	________	________	________
Monday 4th	Sept.	________	________	________
Tuesday 5th	Sept.	________	________	________
Wednesday 6th	Sept.	________	________	________

	Beer	Spirits	Wine	
Sept 1	☐	☐	☐	347
Sept 2	☐	☐	☐	348
Sept 3	☐	☐	☐	349
SEpt 4	☐	☐	☐	350
Sept 5	☐	☐	☐	351
Sept 6	☐	☐	☐	352

9. Do you have any other information you would like to add?

____

____

____

Further Information ☐ 353

STRICTLY CONFIDENTIAL

Coding only

HEALTH SURVEY OF SEA WATER BATHING :PILOT 1989

Post exposure postal questionnaire

Volunteer no. ☐☐☐☐ 401

Form 4 402

Study no ☐☐☐☐☐ 403

date ☐☐/☐☐/8 9 404

Bather / non bather ☐ 405

Please read through this form and then answer the questions carefully. Please answer every question, circling items, ticking boxes e. g. :

September 1989

M	T	W	T	F	S	S
				1	[✓ 2]	3
4	[✓ 5]	[✓ 6]	[✓ 7]	[✓ 8]	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

YES ☑ 1 NO ☐ 0

or providing written answers, as necessary.

Please do not attempt to fill in the section designated for coding at the right hand side of the form.

The completed form should be returned in the envelope provided as soon as possible.

---

1. Name: ____________________

2. Date of Birth ☐☐/☐☐/☐☐

dob ☐☐/☐☐/☐☐ 406

3. Sex : MALE ☐ 1 FEMALE ☐ 2

sex ☐ 407

4. Home address: ____________________

____________________ Postcode ____________________

post code ☐☐☐☐☐☐☐☐ 408

Telephone no. (home): ____________________

5. Work/study address ____________________

____

6. Contact details for follow-up (address etc. over next three months).

____

____

7. In the last three weeks have you had any illness or unusual symptoms?

YES	NO
☐1	☐0

8. If YES how many illnesses have you had in the last three weeks?
(Please tick the box below the appropriate number)

One illness	Two illnesses	Three illnesses	More than three illnesses	Not sure
☐1	☐2	☐3	☐4	☐9

If the answer to question 7, above, was YES please complete the following sections for up to three separate illnesses. If you have had no symptoms of illness since the bathing day PLEASE SKIP TO QUESTION 29, PAGE 9.

If you have had more than THREE illnesses please answer the questions for the three most serious or longest duration illnesses. Fill in the additional information section at the end of this questionnaire, giving details of other illness.

9. Please ring the dates on the calendar when your FIRST illness started and how long it lasted. (i.e. ring all the dates on the calendar on which you were ill).

September 1989

M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

October 1989

M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

The bathing day is marked on the calendar

Coding only

Recent illness ☐ 409

Number of illnesses ☐ 410

Code as 0 if no dates are ringed, and as 1 if a dates are ringed.

Recent illness 1 ☐ 411

Date of onset illness 1 ☐☐☐☐ 8 9 412

Duration of illness 1 ☐☐ 413

STRICTLY CONFIDENTIAL | **Coding only**

10. FIRST ILLNESS.

Examine the following list of symptoms and please answer for each one. (i.e. please answer 'YES', 'NO' or 'NOT SURE' for every symptom).

	YES	NO	NOT SURE	
1. Fever/hot &cold shivers	☐ 1	☐ 0	☐ 9	Fever ☐ 414
2. Headache	☐ 1	☐ 0	☐ 9	Headache ☐ 415
3. Aching arms, legs, joints	☐ 1	☐ 0	☐ 9	Aching limbs ☐ 416
4. Chest pains / aches	☐ 1	☐ 0	☐ 9	Chest pains ☐ 417
5. Dry cough	☐ 1	☐ 0	☐ 9	Dry cough ☐ 418
6. Productive cough *(Phlegm, Sputum)*	☐ 1	☐ 0	☐ 9	Productive cough ☐ 419
7. Sore throat	☐ 1	☐ 0	☐ 9	Sore throat ☐ 420
8. Ear infection	☐ 1	☐ 0	☐ 9	Ear Infection ☐ 421
9. Eye infection/ sore red eyes	☐ 1	☐ 0	☐ 9	Eye Infection ☐ 422
10. Shortness of breath/ difficulty with breathing	☐ 1	☐ 0	☐ 9	Breathing ☐ 423
11. Blurred vision/ difficulty with eyesight	☐ 1	☐ 0	☐ 9	Vision ☐ 424
12. Loss of appetite	☐ 1	☐ 0	☐ 9	Appetite ☐ 425
13. Indigestion	☐ 1	☐ 0	☐ 9	Indigestion ☐ 426
14. Loose bowel motions/ diarrhoea	☐ 1	☐ 0	☐ 9	Diarrhoea ☐ 427
(3 or more loose bowel movements in a 24 hour period)				
15. Nausea	☐ 1	☐ 0	☐ 9	Vomiting ☐ 428
16. Vomiting	☐ 1	☐ 0	☐ 9	Nausea ☐ 429
17. Excessive or unusual tiredness/lassitude	☐ 1	☐ 0	☐ 9	Lassitude ☐ 430
18. Dizziness/giddiness	☐ 1	☐ 0	☐ 9	Dizziness ☐ 431
19. Skin rash	☐ 1	☐ 0	☐ 9	Skin rash ☐ 432

20. Other: please describe ____________________

____

Other ☐ 433 Type ☐ 434

STRICTLY CONFIDENTIAL

Coding only

11. Was this illness diagnosed by your G.P.?

YES	NO
☐ 1	☐ 0

If YES, what was the diagnosis? ____________________

____

Diagnosis illness 1 ☐ 435

12. Did you take any drugs or medicines for your illness, **PRESCRIBED BY YOUR DOCTOR ?**

YES	NO
☐ 1	☐ 0

If YES please list: ____________________

____

____

____

Prescr. drugs illness 1 ☐ 436

Drug type illness 1 ☐☐ 437

13. Did you receive hospital treatment for your illness?

YES	NO
☐ 1	☐ 0

If YES which hospital did you attend? ____________________

____

Hospital treatment illness 1 ☐ 438

14. How many days did you have away from work because of this illness?

MORE THAN 14 DAYS	7-14 DAYS	2-7 DAYS	ONE DAY ONLY	NONE	NOT SURE
☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9

Working days lost illness 1 ☐ 439

15. How many days normal activity did you lose as a result of this illness, even if you were not off work? (i.e. How many days were you not able to do normal leisure activities, housework etc.).

MORE THAN 14 DAYS	7-14 DAYS	2-7 DAYS	ONE DAY ONLY	NONE	NOT SURE
☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9

Other days lost illness 1 ☐ 440

IF YOU HAD A SECOND ILLNESS PLEASE COMPLETE THE FOLLOWING SECTION:

If you have had no further symptoms of illness since the bathing day PLEASE SKIP TO QUESTION 29, PAGE 9.

16. Please ring the dates on the calendar when your **SECOND** illness started and how long it lasted. (i.e. ring all the dates on the calendar on which you were ill).

September 1989

M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

October 1989

M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

The bathing day is marked on the calendar

Code as 0 if no dates are ringed, and as 1 if a dates are ringed.

Recent illness 2 ☐ 441

Date of onset illness 1 ☐☐☐☐8 9 442

Duration of illness 1 ☐☐ 443

17. Examine the following series of boxes and tick any symptoms which occured during your **SECOND** illness. :

Fever 1	Headache 2	Aching limbs 3	Chest Pains 4	Dry cough 5	Productive cough 6	Sore throat 7	Ear infection 8	Eye infection 9	Short of breath 10

Blurred vision 11	Loss of appetite 12	Indigestion 13	Diarrhoea 14	Vomiting 15	Nausea 16	Lassitude 17	Dizziness 18	Skin rash 19	Other* 20

Symptoms illness 2 ☐☐☐☐☐☐ 444

Symptoms continued illness 2 ☐☐☐☐☐☐ 445

*Other, please specify any other symptoms not covered by the above boxes: ______________________

____

Other type illness 1 ☐☐ 446

18. Was this illness diagnosed by your G.P.?

YES ☐ 1 NO ☐ 0

If **YES**, what was the diagnosis? ______________________

____

Diagnosis illness 2 ☐ 447

19. Did you take any drugs or medicines for your illness, **PRESCRIBED BY YOUR DOCTOR ?**

YES	NO
☐ 1	☐ 0

If **YES** please list: ____

____

____

____

Prescr. drugs illness 2 ☐ 448

Drug type illness 2 ☐ 449

20. Did you receive hospital treatment for your illness?

YES	NO
☐ 1	☐ 0

If **YES** which hospital did you attend?____

____

Hospital treatment illness 2 ☐ 450

21. How many days did you have away from work because of this illness?

MORE THAN 14 DAYS	7-14 DAYS	2-7 DAYS	ONE DAY ONLY	NONE	NOT SURE
☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9

Working days lost illness 2 ☐ 451

22. How many days normal activity did you lose as aresult of this illness, even if you were not off work? (i.e. How many days were you not able to do normal leisure activities, housework etc.).

MORE THAN 14 DAYS	7-14 DAYS	2-7 DAYS	ONE DAY ONLY	NONE	NOT SURE
☐ 4	☐ 3	☐ 2	☐ 1	☐ 0	☐ 9

Other days lost illness 2 ☐ 452

IF YOU HAD A THIRD ILLNESS PLEASE COMPLETE THE FOLLOWING SECTION:
If you have had no further symptoms of illness since the bathing day **PLEASE SKIP TO QUESTION 29, PAGE 9.**

22. Please ring the dates on the calendar when your **THIRD** illness started and how long it lasted. (i.e. ring all the dates on the calendar on which you were ill).

September 1989

M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

October 1989

M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

The bathing day is marked on the calendar

Code as 0 if no dates are ringed, and as 1 if a dates are ringed.

Recent illness 3 ☐ 453

Date of onset illness 3 ☐☐☐☐☐8 9 454

Duration of illness 3 ☐☐ 455

23. Examine the following series of boxes and tick any symptoms which occured during your **THIRD** illness. :

Fever 1	Headache 2	Aching limbs 3	Chest Pains 4	Dry cough 5	Productive cough 6	Sore throat 7	Ear infection 8	Eye infection 9	Short of breath 10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Blurred vision 11	Loss of appetite 12	Indigestion 13	Diarrhoea 14	Vomiting 15	Nausea 16	Lassitude 17	Dizziness 18	Skin rash 19	Other* 20
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

*Other, please specify any other symptoms not covered by the above boxes: ____________________

____

Symptoms illness 3 ☐☐☐☐☐☐ 456

Symptoms continued illness 3 ☐☐☐☐☐☐ 457

Other type illness 3 ☐☐ 458

24. Was this illness diagnosed by your G.P.?

YES ☐ 1 NO ☐ 0

If YES, what was the diagnosis? ____________________

Diagnosis illness 3 ☐ 459

25. Did you take any drugs or medicines for your illness, **PRESCRIBED BY YOUR DOCTOR ?**

YES	NO
☐1	☐0

If **YES** please list: ____________________

Prescr. drugs illness 3 ☐ 460 Drug type illness 3 ☐☐ 461

26. Did you receive hospital treatment for your illness?

YES	NO
☐1	☐0

If **YES** which hospital did you attend? ____________________

____

Hospital treatment illness 3 ☐ 462

27. How many days did you have away from work because of this illness?

MORE THAN 14 DAYS	7-14 DAYS	2-7 DAYS	ONE DAY ONLY	NONE	NOT SURE
☐4	☐3	☐2	☐1	☐0	☐9

Working days lost illness 3 ☐ 463

28. How many days normal activity did you lose as aresult of this illness, even if you were not off work? (i.e. How many days were you not able to do normal leisure activities, housework etc.).

MORE THAN 14 DAYS	7-14 DAYS	2-7 DAYS	ONE DAY ONLY	NONE	NOT SURE
☐4	☐3	☐2	☐1	☐0	☐9

Other days lost illness 3 ☐ 464

Coding only

Everybody to fill in this section even if you have not been ill yourself

29. Has anyone else in your household been unwell in the last 3 weeks? (The household includes only the people you live with and with whom you share facilities).

YES ☐ 1   NO ☐ 0   NOT SURE ☐ 9

IF NO SKIP TO QUESTION 30, PAGE 10.

If YES , how many household members were ill? ______

Please ring the dates of this illness on the calendar :
(Please try to be as accurate as possible).

September 1989

M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

October 1989

M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

The bathing day is marked on the calendar

Please give details of this illness :
(i.e. who was ill, their ages, any symptoms, any diagnosis or treatment etc.).

____

____

____

____

____

____

____

____

____

____

____

Household illness ☐ 465

Number of members ill ☐ 466

Date of onset 1 ☐☐ ☐☐ 8 9 467

Duration of illness 1 ☐☐ 468

Date of onset 2 ☐☐ ☐☐ 8 9 469

Duration of illness 2 ☐☐ 470

Date of onset 3 ☐☐ ☐☐ 8 9 471

Duration of illness 3 ☐☐ 472

Date of onset 4 ☐☐ ☐☐ 8 9 473

Duration of illness 4 ☐☐ 474

Details of illness 1 ☐☐ 475

Details of illness 2 ☐☐ 476

Details of illness 3 ☐☐ 477

Details of illness 4 ☐☐ 478

30. Have you taken part in any water sports / swimming / visits tobeaches since the visit to Langland bay on 2ndSeptember? (Include any visits to beaches during which you did not go into the water).

YES	NO	NOT SURE
☐ 1	☐ 0	☐ 9

IF NO SKIP TO QUESTION 34, PAGE 12.

If YES please answer the following section, by ticking the appropriate box for each of the activities in the following list, i.e. please answer for all of the activities listed: (No. of times refers to the number of times you have carried out the activity since the visit to Langland bay).

	YES	NO	NOT SURE	NO. TIMES
Public swimming pool	☐ 1	☐ 0	☐ 9	☐☐
Other swimming pool	☐ 1	☐ 0	☐ 9	☐☐

Note : Sea and fresh water activities are not mutually exclusive; please tick both sea and fresh water boxes if you have taken part in the activity in both kinds of water since the visit to Langland bay. e.g. both boxes would be ticked if you had taken part in sea and fresh water canoeing.

	YES	NO	NOT SURE	SEA WATER	FRESH WATER	NO. TIMES
Dinghy sailing	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐☐
Canoeing	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐☐
Windsurfing / Sailboarding	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐☐
Speed / motor boating	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐☐
Other sailing / boating	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐☐
Subaqua / snorkeling	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐☐
Water skiing	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐☐
Surfing	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐☐
Other*	☐ 1	☐ 0	☐ 9	☐ 1	☐ 1	☐☐

Specify:* ____________________

Water activities ☐ 479

Public pool ☐ 480 Frequency ☐☐ 481

Other pool ☐ 482 Frequency ☐☐ 483

Code positive response for sea / fresh water as 1 and negative response as 0.

		Sea Fresh		
Dinghy	☐ 484	☐☐ 485	Frequ	☐☐ 486
Canoe	☐ 487	☐☐ 488	Frequ	☐☐ 489
w.surf	☐ 490	☐☐ 491	Frequ	☐☐ 492
speed boat	☐ 493	☐☐ 494	Frequ	☐☐ 495
other sail.	☐ 496	☐☐ 497	Frequ	☐☐ 498
sub aqua	☐ 499	☐☐ 500	Frequ	☐☐ 501
water ski.	☐ 502	☐☐ 503	Frequ	☐☐ 504
surf	☐ 505	☐☐ 506	Frequ	☐☐ 507
other	☐ 508	☐☐ 509	Frequ	☐☐ 510

31. Have you taken part in Sea or fresh water bathing since the day at Langland bay ?

YES	NO	NOT SURE	SEA WATER	FRESH WATER	NO. TIMES
☐ 1	☐ 0	☐ 9	☐	☐	☐☐

If YES please specify locations frequented, ticking whether in the United Kingdom or abroad and specifying dates if possible:

	Place(s)	UK 1	Abroad 2	Date(s)
1				
2				
3				
4				

32. Have you visited any beaches without going into the water since the day at Langland bay?

YES	NO	NOT SURE	SEA WATER	FRESH WATER	NO. TIMES
☐ 1	☐ 0	☐ 9	☐	☐	☐☐

If YES please specify locations frequented, ticking whether in the United Kingdom or abroad and specifying dates if possible:

	Place(s)	UK 1	Abroad 2	Date(s)
1				
2				
3				
4				

33. Since the day at Langland bay, have you been to a theme / leisure park and used any water rides? (e.g. log rides, water shutes).

YES	NO	NOT SURE
☐ 1	☐ 0	☐ 9

If YES was the site at home or abroad?

U.K.	ABROAD
☐ 1	☐ 2

Please give the name of the site:

____

Code positive response for sea / fresh water as 1 and negative response as 0.

bathing ☐ 511 Sea Fresh ☐☐ 512 Frequ ☐☐ 513

	UK?	Location	Weeks	Days	
1	☐	☐☐☐☐	☐☐	☐☐	514
2	☐	☐☐☐☐	☐☐	☐☐	515
3	☐	☐☐☐☐	☐☐	☐☐	516
4	☐	☐☐☐☐	☐☐	☐☐	517

beach no bathing ☐ 518 Sea Fresh ☐☐ 519 Frequ ☐☐ 520

	UK?	Location	Weeks	Days	
1	☐	☐☐☐☐	☐☐	☐☐	521
2	☐	☐☐☐☐	☐☐	☐☐	522
3	☐	☐☐☐☐	☐☐	☐☐	523
4	☐	☐☐☐☐	☐☐	☐☐	524

water rides ☐ 525

UK? ☐ 526

Park Location ☐☐ 527

34. How often, if ever, do you drink alcohol?

AT LEAST ONCE A WEEK	LESS THAN ONCE A WEEK	NEVER DRINK ALCOHOL	NOT SURE
☐ 2	☐ 1	☐ 0	☐ 9

IF YOU NEVER DRINK ALCOHOL, PLEASE SKIP TO QUESTION 37, PAGE 13.

Alcohol ☐ 528

35. Think back care fully over the last seven days and write in exactly what alcoholic drinks you consumed. For each day write in :

i) Number of pints of beer, shandy, cider, cider stout, etc.
ii) Number of single glasses of whisky, vodka, gin, rum, etc.
iii) Number of single glasses of martini, port, sherry, wine, etc.

Try to remember where you were and who you were with each day - it may help you to recall what you drank.

	NO. OF PINTS OF BEER, LAGER ETC.	NO. OF GLASSES OF SPIRITS (GIN, WHISKY, ETC.)	NO. OF GLASSES OF WINE OR SHERRY
MONDAY	______	______	______
TUESDAY	______	______	______
WEDNESDAY	______	______	______
THURSDAY	______	______	______
FRIDAY	______	______	______
SATURDAY	______	______	______
SUNDAY	______	______	______

	Beer	Spirits	Wine	
Monday	☐	☐	☐	529
Tuesday	☐	☐	☐	530
Wednesday	☐	☐	☐	531
Thursday	☐	☐	☐	532
Friday	☐	☐	☐	533
Saturday	☐	☐	☐	534
Sunday	☐	☐	☐	535

36. Would you say that last week was fairly typical of what you usually drink in a week? TICK ONE BOX ONLY

YES , THIS WAS A FAIRLY TYPICAL WEEK ☐ 1

NO, I NORMALLY DRINK MORE THAN THIS ☐ 2

NO , I NORMALLY DRINK LESS THAN THIS ☐ 3

Normal drinking ☐ 536

37. Comments. Please write any other information that will help our study, including details any other illness and symptoms.

____

____

____

____

____

Signature: ______________________________

Date of completion: ____/____/____

Thankyou for taking the time and trouble to fill in this form. Please return the completed form as soon as possible in the envelope provided.

Other comments 1 ☐ 537

Other comments 2 ☐ 538

Other comments 3 ☐ 539

Code in box 404 at the top of page 1

APPENDIX VII

APPENDIX VII

Environmental Bacteriology

Introduction

Water quality was assessed during the period of the study by examining samples taken at three depths and 10 sampling stations along the beach. Immediately after collection, samples were transported to a laboratory established in the Department of Biological Sciences, University College, Swansea. Samples were examined for total coliforms, faecal (thermotolerant) coliforms, faecal streptococci, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. During the sampling events meterological and environmental conditions were noted and recorded.

Materials and Methods

Sampling

Water samples were collected into each of two sterile polystyrene containers (Northern Media Ltd) to provide a combined volume of 300 ml. All sample containers were pre-labelled with a unique reference denoting the sample station, depth and run number. Immediately following collection, samples were placed into insulated containers containing freezer ice packs and transported to the laboratory at the University for analysis. Meterological and environmental conditions at the time of sampling were recorded on a *pro forma*. On receipt samples were checked for completeness and placed into a cold store (4°C) to await analysis. Laboratory examination was commenced on all samples within six hours of collection.Analysis All bacterial parameters examined for were performed using membrane filtration techniques (MF). Volumes of sample analysed were determined from data produced from routine monitoring for the immediately preceding weeks and the results of samples collected and analysed on the day prior to the study. Small volumes of sample (<50 ml) were added to approximately 50 ml of sterile distilled water prior to filtration. The MF apparatus consisted of polycarbonate filter funnels, the bases of which were held in a three place manifold (both Gelman Sciences Ltd). Filter funnels were sterilised by autoclaving for 15 minutes at 121°C before use and by immersion in a boiling waterbath for 10 minutes between samples. Membrane filters of 47mm diameter having a pore size of 0.45 µm were used throughout (GN6 Grade, Gelman Sciences Ltd). Depending upon the organisms sought, absorbent pads (Gelman Sciences Ltd) soaked in an excess of liquid broth or the appropriate agar medium was used in Petri dishes of 55mm diameter.

Total and faecal coliforms were enumerated using membrane lauryl sulphate broth (Oxoid MM615), incubating for 14 hours at 35°C and 44°C respectively following an initial incubation period of four hours at 30°C for both [1]. Faecal streptococci were enumerated using Slanetz & Bartley agar (Oxoid CM377) after incubation for 44 hours at 44°C, following an initial incubation period of four hours at 37°C [1]. *Ps. aeruginosa* were enumerated on a modification of King's A broth [1], solidified by the addition of agar (1.5% w/v) which was sterilised by autoclaving at 121°C for 15 minutes, allowed to cool to 50°C before the addition of filter sterilised ethanol. The complete medium was poured into 55mm Petri dishes and allowed to solidify. Membranes were incubated at 37°C for 48 hours and colonies producing a diffusible green pigment counted as *Ps. aeruginosa*, identification being assisted by viewing under long wave UV illumination. *St. aureus* were enumerated on Baird Parker agar (Oxoid CM275) following incubation at 37°C for 48 hours, after which time membranes were removed from the agar surface to enable any zones of clearing within the agar to be seen. Criteria for a positive finding were colonies producing a definite zone of clearing, 1.5-2.0mm in diameter and having a black, shiny convex appearance. Volumes of 0.1, 1.0 and 10 ml were examined for total coliforms with 1.0

and 10 ml aliquots being used for faecal coliforms. All other assays took place using 50 ml volumes of seawater. In the case of coliform counts all dilutions were counted and the final result expressed as the weighted average of all plates producing a value. On each run, quality control samples consisting of duplicated samples were collected and examined along with that batch. These results are shown in Appendix XI.

References

1 Anon(1983). Reports on Public Health and Medical Subjects No.71. *The Bacteriological Examination of Drinking Water Supplies* 1982. HMSO, London.

APPENDIX VIII

APPENDIX VIII

Isolation of Enteric Viruses from large volumes of water

Although enteric viruses are present initially in very high concentrations in sewage contaminated with stools from infected individuals, the subsequent dilution of sewage/sewage effluent in waters into which it is discharged, ensure that the final concentration of viruses in the aquatic environment is considerably less than the initial concentration in faeces. Thus, the isolation of enteric viruses from the aquatic environment involves the concentration of large volumes (10-20 litres) of water into small workable volumes (-10 ml) which can then be assayed for the presence of viruses using tissue culture or an appropriate assay for viral particles or antigens.

A variety of methods for the concentration of low numbers of viruses from large volumes of water have been described (Gerba et al, 1978; Ramia and Sattar, 1980). The method chosen for this study is the one used routinely by Welsh Water and is suitable for the isolation of both enteroviruses and rotavirus. It involves a two-stage concentration procedure, adsorption and elution of viruses on microporous filters, followed by organic flocculation.

In aqueous solution, viruses behave as amphoteric, hydrophilic colloids and the net charge is a function of pH, ionic composition and ionic strength of the solution (Morris and Waite, 1981). These properties are exploited in the concentration of viruses from large volumes of water. At low pH in the presence of cations, viruses adsorb by virtue of their surface charge to a variety of media, including cellulose nitrate and glass fibre. Elution from this initial adsorptive phase is achieved using an organic material at high pH, resulting in a primary eluate of more manageable volume. Further concentration of viruses is achieved by a secondary concentration step. This procedure, known as organic flocculation (Katznelson *et al*, 1976), utilises the property of organic materials to precipitate or flocculate when the pH of the solution is lowered near the isoelectric point of the material. Viruses are effectively adsorbed to this *de novo* precipitate, which form spontaneously upon lowering the pH of the solution. The precipitate and associated viruses are subsequently collected by low speed centrifugation. Viruses are then recovered for assay by dissolving the precipitate in a suitably small volume of moderately alkaline buffer.

Materials and Methods - Concentration of sample

1. Adsorption

10 litre samples of water were collected in sterile pots from fixed stations along the designated beach and transported to the Virology laboratory for processing within 24 hours of sampling.

The sample was acidified to pH 3.5 with concentrated HCl, and aluminium chloride, to a final concentration of 0.0005M was added to enhance virus adsorption (Goyal and Gerba, 1982). The sample was then filtered through a 257mm diameter glass fibre prefilter and a 295 mm diameter cellulose nitrate membrane (pore size (0.45 um) (Sartorius, UK Ltd) in series, at a pressure of 0.5 kg cm^{-2} compressed air. The prefilter prevented the pores of the membrane from becoming clogged with sand and fine silt commonly found in marine water samples. Adsorbed virus was then eluted from the membrane by passing 0.2% skimmed milk in 0.05M glycine (adjusted to pH 9.5 by addition ofIM NaOH) through the filter at a pressure of 0.5 kg cm^{-2} (Figure 1).

2. Flocculation

1M glycine (pH 2.0) was added dropwise to the filter eluate until a fine white precipitate began to form at around pH 4.5, the isoelectric point of casein, which generally coincided with the formation of a dense white precipitate. The eluate was transferred to a refrigerator at 4°C. After 1 hour, the precipitate took on a flaky appearance forming a "floc". This floc was centrifuged at 2800g for 20 minutes and the resultant pellet was resuspended in 10 ml 0.15M Na_2HPO_4 buffer. The pH of the concentrate was adjusted to 7.5 before dividing it into two equal aliquots and storage at -70°C until the samples were assayed for enteroviruses (aliquot 1) and rotavirus (aliquot 2).

3. Assay for enteroviruses

Buffalo Green Monkey kidney (BGM) cells (passage numbers 101-103) were used in the assay for enteroviruses. These cells are fibroblastic in morphology and have reported viral sensitivity to poliovirus types 1, 2 and 3, echovirus types 3, 6, 7, 9, 11, 12 and 27, coxsackie virus types A9 and B1, B2 and B3 and reovirus type 1. The BGM cell cultures were propagated serially in growth medium (HMEM) supplemented with 50% Leibovitz L15 medium and 10% Foetal Calf Serum (Flow Laboratories Ltd).

The samples were assayed for enteroviruses using the agar overlay method on confluent monolayers of BGM cells in 75 cm^3 plastic tissue culture flasks. The 5 ml concentrate derived after concentration of water samples (Figure 1) was divided into 3 approximately equal volumes and each aliquot was then added to one flask of confluent BGM cells previously washed twice with Earles Balanced Salt Solution (EBSS). Any viruses present in the concentrate were allowed to adsorb on to the cells for 1 hour at 37°C. The sample concentrate was then decanted off and 10-20 ml of agar overlay medium was added. When the agar was set, the flasks were inverted and incubated at 37°C in the dark for 3-6 days. The agar overlay medium contains the vital dye, neutral red, which specifically stains live cells. Virus-infected cells are apparent macroscopically as areas in the monolayer where the vital dye has not been taken up by the cells. These areas of dead cells (plaques), which usually correspond to the number of infectious units of virus in the sample, were noted, and after their confirmation as plaques (and not artifacts) using the inverted light microscope to detect cytopathic effect (CPE), were counted and for each sample expressed as plaque-forming units (pfu) per 5 litres. This figure was then multiplied by 2 to obtain the estimated level in the original 10 litre sample. Results were then expressed as plaque-forming units (pfu) per 10 litre sample. Poliovirus 2 was included as a control each time and batch of sample concentrates were assayed for the presence of enterovirus by the plaque assay.

4. Assay for rotavirus

Unlike the enteroviruses described above, human rotavirus cannot be cultivated directly in vitro by current organ or tissue culture techniques. However, if the virus is centrifuged at low speed on to a preformed monolayer of cells, the cells become more susceptible to infection and in the presence of trypsin and absence of serum, the virus undergoes an incomplete replicative cycle, producing viral antigens in the cell. Although the infection is abortive and yields little or no infectious virus (Thouless *et al*, 1977), the viral antigens that are produced can be detected using immunofluorescent antibodies.

The immunofluorescence technique is based on the antibody-antigen reaction in which the antibody-antigen complex is made visible by incorporating a fluorochrome in the antibody molecule. Fluorescence is then detected by dark-ground illumination using ultra-violet light or visible blue light. In this way, individual fluorescent foci (cells) are recorded and are quantified as infectious units.

Rhesus Monkey kidney (LLC-MK2) cells (passage number 240-245) were used for assay for rotavirus. These cells are susceptible to infection by both human and a variety of animal rotaviruses (McNulty *et al.*, 1977; Thouless *et al.*, 1977) and are used widely for immunofluorescence assays. The LLC-MK2 cultures are propagated serially in growth medium (HMEM) supplemented with 50% Leibovitz L15 medium and 10% foetal calf serum.

The sample concentrates were assayed for rotavirus as follows :

LLC-MK2 cells were removed from maintenance culture flasks by trypsinisation with 0.005% trypsin-EDTA solution. After addition of growth medium, the resultant cell suspension was centrifuged at 800g for 5 minutes. The supernatant was discarded and the cell pellet was resuspended in serum free medium (SFM) containing 0.5 $ugml^{-1}$ trypsin (without EDTA). Cells were seeded in 96-well microtitration plates at a rate of 5×10^4 cells/100 ul/ well (Figure 2). The plates were incubated for 1 hour at 37°C with high CO_2 concentration and then for a further 1.5 hours with low CO_2 concentration. 100 ul of the sample concentrate was then added to each well and the plates were centrifuged at 1400g for 60 minutes. The plates were then incubated at 37°C for 1 hour, when the sample was removed and replaced with 150 ul SFM (without trypsin). The plates were then incubated overnight at 37°C in 5% CO_2/air atmosphere.

After overnight incubation, the medium was removed and each well was washed once with phosphate buffered saline (PBS). The cells were then fixed in ice cold methanol at 4°C for 10 minutes, rehydrated with PBS and then incubated at room temperature for 10 minutes. The plates were then air-dried and 100 ul rabbit-anti-rotavirus antiserum (1:40 dilution in PBS) was added to each well and, after shaking for 5 minutes, the plates were incubated for 1 hour at 37°C. Each well was washed 3 times with PBS (with shaking) and 100 ul FITC conjugated goat-anti-rabbit antiserum (1:40 dilution in PBS) was added to each well. After shaking for 5 minutes, the plates were incubated for 1.5 hours at 37°C.

Each well was washed 3 times with PBS and 50 ul of 1% solution amido black was added to each well. After shaking for 10 minutes at room temperature each well was washed three times with PBS, and then the plates were air-dried. The number of fluorescing cells (fluorescing foci [ff]), which usually corresponds to the number of infectious rotavirus particles in the sample, were then counted using a Nikon "Diaphot" inverted microscope at an excitation wavelength of 495 mm. The results were then expressed as fluorescing foci per 10 litre sample. Human rotavirus extracted from stools from infected individuals, was used as a control and was included each time a batch of sample concentrates were assayed for rotavirus by the immunofluorescence test.

APPENDIX VIII REFERENCES

Gerba, C.P., Farrah, S.R., Goyal, S.M., Wallis, C., and Melnick, J.L. (1978) Concentration of enteroviruses from large volumes of tapwater, treated sewage and seawater. *Applied and Environmental Microbiology 35*, 540-548.

Goyal, S.M., and Gerba, C.P. (1982) *Concentration of viruses from water by membrane filters.* In : *Methods in Environmental Virology*, Gerba, C.P., and Goyal S.M., (eds) Marcel Dekker, New York pp 59-116.

Katzenelson, E. *Virologic and engineering problems in monitoring viruses in water.* (1976) In *Viruses in water,* Berg, G., Bodily, N.L., Lennette, E.H., Melnick, J.J. and Metcalf, T.G. (eds).

McNulty, M.S., Allan, G.M. and McFerran, J.B. (1977) Cell culture studies with cytopathic bovine rotavirus. *Arch. Virol. 54,* 201-209.

Morris, R. and Waite, W.M. (1981) Environmental virology and its problems. *J. of the Institution of Water Engineers and Scientists 35,* 232-245.

Ramia, S. and Sattar, S.A. Concentration of seeded simian rotavirus SA-11 from potable water by using talc-celite layers and hydroextraction. *Applied and Environmental Microbiology 39,* 493-499.

Thouless, M.E., Bryden, A.S., Flewett, T.H., Woode, G.N., Bridger, J.C., Snodgrass, D.R. and Herring, J.A. (1977) Serological relationship between rotaviruses from different species as studied by complement fixation and neutralisation. *Archives of Virology 53,* 287-294.

APPENDIX IX

APPENDIX IX ANALYSIS OF CLINICAL SAMPLES

Summary of Microbiological Investigations

Respiratory Specimens

specimen collections 1 pre-bathing
2 post-bathing (three days)

throat (T/S)	244 paired specimens 49 single specimens
aural (A/S)	246 paired specimens 44 single specimens

samples cultured on
- (1) 5% horse blood columbia agar, incubated anaerobically ($90\% H_2/10\% CO_2$) at 37°C.
- (2) MacConkey agar incubated at 37°C aerobically.

All specimens examined for
- (1) Gram positive organisms - B haemolytic streptococci, faecal streptococci, *Staphylococcus aureus*.
- (2) Gram negative organisms - *Enterobacteriacae*, *Salmonella* sp, *Shigella* sp, non-fermentative bacilli - especially *Pseudomonas* sp.

Significant isolates were identified by standard laboratory procedures.

Faeces

specimen collection 1 - pre-bathing
2 - post-bathing
3 - post-bathing

pre-bathing (1) (examined for *Salmonella*, *Shigella*, *Campylobacter*)
cultured <u>directly</u> on
- (1) Mannitol lysine crystal violet Brilliant green agar (MLCB)
- (2) Xylose lysine desoxycholate agar (XLD)
- (3) *Campylobacter* blood free medium (CCDA)

enrichment technique not used on pre-bathing specimens
faecal emulsions examined for *Cryptosporidia* by Methylene blue/safranin stain
faecal emulsion examined for ova, parasites and cysts by direct microscopy

post-bathing (2) (examined for *Salmonella*, *Shigella*, *Campylobacter*)
cultured directly on MLCB, XLD, CCDA
enrichment via Rappaport medium - subcultured to Brilliant green agar for Salmonella
these specimens not examined for *Cryptosporidia*, ova, parasites or cysts

post-bathing (3)
faecal emulsion examined for *Cryptosporidia*, ova, parasites and cysts only.

Virology Report

Number of faeces samples received

Prior to bathing	268 (+1 empty pot)
48h post-bathing	261
2 weeks post-bathing	247 (+1 empty pot)
Total	**776 (+2 empty pots)**

Methods

1. All post-bathing samples were examined for the presence of enterovirus by culture in monkey kidney and Hep 2 cell lines. Inoculated tubes incubated for 3 weeks before reporting as negative. Isolated enteroviruses identified by neutralisation with standard neutralising antisera. Pre-bathing faecal samples were cultured from those volunteers from whom an enterovirus was isolated from a post-bathing sample.

2. All post-bathing samples were examined for the presence of rotavirus by an enzyme-linked immunosorbent assay for rotavirus antigen. Any faecal samples persistently reactive in this assay were examined by electron microscopy.

Results

1. Enteroviruses

   The following enteroviruses were isolated in cell culture:

Pre-bathing	48h	14 days
NVI*	NS+	coxsackievirus B4
NVI	NVI	coxsackievirus B4
NVI	NVI	enterovirus¶
NVI	NVI	echovirus 7
NVI	NVI	coxsackievirus B4

* No virus isolated
\+ No sample received
¶ As yet unidentified, investigation continuing

2. Although a small number of samples gave very low level reactivity by ELISA, rotavirus was not confirmed by electron microscopy. Hence no cases of rotavirus infection were identified.

APPENDIX X

Appendix X Comments from international experts.

This appendix gives a brief summary of the main points raised on the controlled cohort methodology by a small group of international experts who have kindly provided comments on a confidential document which sets out the protocol. This document comprised mainly Appendices I, II, IV, V and VI and it was posted in September 1989. The respondents to this letter and associated documentation are listed in the Acknowledgements section on Page 19.

The main points noted by this group are as follows;

(i) Sample size considerations.

The problem of a sufficiently large sample to avoid both Type I and Type II error was noted by most respondents. The central issue here is the attack rates which might be expected at a UK beach. Further information on this issue is presented in Tables 7.1 through 8.3 and Appendix XII. This remains, however, an important consideration in controlled cohort studies.

(ii) Cohort recruitment and characteristics

It was suggested that the higher attack, rates reported in previous perception studies, in the 0-5 age band makes study of younger cohort groups using the controlled cohort methodology desirable in future work. The ethical aspects of lowering the cohort age band should be investigated at the project design stage of future investigations.

Respondents also noted the differential immunity patterns produced by local as opposed to visitor cohorts and the effects of early season and late season timing of the cohort exposure day.

(iii) Environmental quality

The chosen indicators seem appropriate although total staphylococci may be more relevant than *Staphylococcus aureus*. The examination of bathing waters for viruses was also questioned as an inefficient and costly procedure and serological investigations were suggested as a more fruitful alternative for these expenditures.

(iv) Questionnaires

These were generally thought to be very comprehensive and well designed. However, it was suggested that they may be too long for beach interviews during Cabelli style investigations. The importance uniformity amongst interviewers was noted.

(v) Clinical tests

Analysis of blood samples for antibodies against Norwalk agents and rotaviruses was suggested.

(vi) Definition of swimmers

This was noted by some respondents who suggested that head immersion might not be the only definition of a swimmer and splashing in the surf zone may be an important activity.

APPENDIX XI

APPENDIX XI

Quality control analysis on environmental bacteriology

A set of 18 duplicate samples were taken during the afternoon of 2/9/89, to evaluate the precision of analytical techniques.Half of the sample set was taken from the surf zone and half from the 30 cm depth zone. The samples were analysed for Total coliform, Faecal streptococci, Pseudomonas aeruginosa, and Faecal coliform using British standard methods (Report 71): All values were recorded per 100 ml of water. Summary statistics for the samples and corresponding duplicates are given in table 1. The normalised $\log_{10}$ transformation statistics are also shown. A value of 0.1 was added for the transformation, to account for zero values in the data set.

Table 1. Summary statistics for samples and duplicate samples.

Variable	Mean	SD	Min.	Max.	N	Samples/ Duplicates
Total coliform	86.11	69.55	20	277	18	samples
Total coliform	139.06	340.69	0	1495	18	duplicates
Faecal streptococci	52.44	30.05	12	134	18	samples
Faecal streptococci	48.78	20.89	20	90	18	duplicates
Pseudomonas aeruginosa	5.11	21.69	0	92	18	samples
Pseudomonas aeruginosa	0.89	2.40	0	10	18	duplicates
Faecal coliform	55.78	40.91	10	188	18	samples
Faecal coliform	119.94	350.93	0	1520	18	duplicates
$\log_{10}$ Total coliform	1.82	0.32	1.3	2.44	18	samples
$\log_{10}$ Total coliform	1.63	0.82	-1.0	3.17	18	duplicates
$\log_{10}$ Faecal streptococci	1.65	0.26	1.1	2.13	18	samples
$\log_{10}$ Faecal streptococci	1.65	0.21	1.3	1.95	18	duplicates
$\log_{10}$ *P. aeruginosa*	-0.84	0.70	-1.0	1.96	18	samples
$\log_{10}$ *P. aeruginosa*	-0.67	0.65	-1.0	1.00	18	duplicates
$\log_{10}$ Faecal coliform	1.65	0.32	1.0	2.27	18	samples
$\log_{10}$ Faecal coliform	1.34	0.98	-1.0	3.18	18	duplicates

Significant differences between the samples and their duplicates were tested using a two tailed paired sample t-test on the $\log_{10}$ transformed data. Table 2 shows the degrees of freedom (DF), calculated and critical students-t values obtained for the comparisons.

Table 2. calculated and critical students-t values

Variable compared	DF	calculated t	critical t (α=0.01)	critical t (α=0.05)
$\log_{10}$ Total coliform	17	1.02	2.898	2.110
$\log_{10}$ Faecal streptococci	17	0.15	2.898	2.110
$\log_{10}$ *Pseudomonas aeruginosa*	17	-0.94	2.898	2.110
$\log_{10}$ Faecal coliform	17	1.27	2.898	2.110

The calculated values of students-t were always below the the critical values of students-t for all four variables compared, at both a-levels selected. This suggested that there were no significant differences between the mean of the sample set data and the mean of the corresponding duplicate samples i.e. :

$$\mu\text{samples} - \mu\text{duplicates} = 0$$

The sample sets were then split according to the zone from which they came. Summary statistics for the two groups are shown in table 3.

Table 3. Summary statistics for samples and duplicate samples for the two zones.

A. Surf zone

Variable	Mean	SD	Min.	Max.	N	Samples/ Duplicates
Total coliform	107.00	91.67	20	277	9	samples
Total coliform	225.11	478.65	5	1495	9	duplicates
Faecal streptococci	45.11	27.37	12	100	9	samples
Faecal streptococci	47.78	20.99	20	90	9	duplicates
Pseudomonas aeruginosa	10.22	30.67	0	92	9	samples
Pseudomonas aeruginosa	1.33	3.32	0	10	9	duplicates
Faecal coliform	58.57	49.98	30	188	9	samples
Faecal coliform	209.89	492.59	0	1520	9	duplicates
$\log_{10}$ Total coliform	1.89	0.38	1.3	2.44	9	samples
$\log_{10}$ Total coliform	1.82	0.68	0.7	3.17	9	duplicates
$\log_{10}$ Faecal streptococci	1.57	0.30	1.1	2.00	9	samples
$\log_{10}$ Faecal streptococci	1.63	0.23	1.3	1.95	9	duplicates
$\log_{10}$ *P. aeruginosa*	-0.67	0.99	-1.0	1.96	9	samples
$\log_{10}$ *P. aeruginosa*	-0.63	0.75	-1.0	1.00	9	duplicates
$\log_{10}$ Faecal coliform	1.76	0.27	1.5	2.27	9	samples
$\log_{10}$ Faecal coliform	1.53	1.10	-1.0	3.18	9	duplicates

B. 30 cm zone

Variable	Mean	SD	Min.	Max.	N	Samples/ Duplicates
Total coliform	65.22	29.83	20	100	9	samples
Total coliform	53.00	29.67	0	89	9	duplicates
Faecal streptococci	57.88	32.38	28	134	9	samples
Faecal streptococci	49.78	18.69	20	78	9	duplicates
Pseudomonas aeruginosa	0.00	0.00	0	0	9	samples
Pseudomonas aeruginosa	0.44	0.88	0	2	9	duplicates
Faecal coliform	43.00	26.27	10	90	9	samples
Faecal coliform	30.00	29.16	0	100	9	duplicates

Table 3. continued

B. 30 cm zone

$\log_{10}$ Total coliform	1.76	0.25	1.3	2.00	9	samples
$\log_{10}$ Total coliform	1.43	0.93	-1.0	1.95	9	duplicates
$\log_{10}$ Faecal streptococci	1.73	0.20	1.5	2.13	9	samples
$\log_{10}$ Faecal streptococci	1.66	0.19	1.3	1.89	9	duplicates
$\log_{10}$ *P. aeruginosa*	-1.00	0.00	-1.0	-1.00	9	samples
$\log_{10}$ *P. aeruginosa*	-0.71	0.58	-1.0	0.32	9	duplicates
$\log_{10}$ Faecal coliform	1.53	0.35	1.0	1.95	9	samples
$\log_{10}$ Faecal coliform	1.15	0.86	-1.0	2.00	9	duplicates

Table 4 presents the results of the corresponding paired t-tests for the two sampling depths.

Table 4. calculated and critical students-t values for the two sampling depths

A. Surf zone

Variable compared	DF	calculated t	critical t (α=0.01)	critical t (α=0.05)
$\log_{10}$ Total coliform	8	0.36	3.355	2.306
$\log_{10}$ Faecal streptococci	8	-0.97	3.355	2.306
$\log_{10}$ Pseudomonas aeruginosa	8	-0.13	3.355	2.306
$\log_{10}$ Faecal coliform	8	0.66	3.355	2.306

B. 30 cm zone

Variable compared	DF	calculated t	critical t	critical t
	(a=0.01)	(a=0.05)		
$\log_{10}$ Total coliform	8	0.94	3.355	2.306
$\log_{10}$ Faecal streptococci	8	1.15	3.355	2.306
$\log_{10}$ *Pseudomonas aeruginosa*	8	-1.15	3.355	2.306
$\log_{10}$ Faecal coliform	8	1.08	3.355	2.306

The results from table 4 show no significant difference between the means of the samples and duplicates for all four determinands, with calculated students-t values consistently well below corresponding critical values. This indicates that :

$$\mu\text{samples} - \mu\text{duplicates} = 0$$

holds true for both sampling zones at the chosen α-levels.

APPENDIX XII

Appendix XII.

COHORT SIZE CONSIDERATIONS IN FUTURE STUDIES

Given the clinical attack rates experienced in the Langland Bay study the following cohort sizes would be required to avoid both Type I and Type II error as explained by Lightfoot (1989) and New Jersey Health Department (1988). It **must** be stressed, however, that hese cohort sizes should be taken as **approximate** and the data given below represents the required cohort size for both bather and non-bather groups added together (i.e. the recruitment target should be over twice this figure when the expected 50% drop-out rate is taken into consideration).

Clinical symptom attack rates

Staphylococci ear	2000
Pseudomonas ear	1800
Streptococci throat	3000
Staphylococci throat	wrong direction ie non-bather more Staph

These cohort group sizes are feasible in a full scale study of say ten locations all passing the EC Directive standards. They would allow statements to be made concerning the statistical significance of any health risks caused by bathing in comparable coastal waters. It should be remembered, however, that these cohort size calculations are based on attack rates in both groups observed when enteric bacterial concentrations were relatively low when compared to other beaches which pass the Directive *Imperative* level. If higher pollution loadings were to produce greater absolute and differential attack rates then these cohort sizes would be reduced. It would seem reasonable, therefore, to treat these cohort sizes as upper estimates in future work.

Perceived symptom attack rates

The only statistically significant bather vv non-bather differential attack rates were for perceived throat, ear and eye symptoms after three days and for diarrhoea after three weeks. The bather plus non-bather sample sizes for these perceived attack rates are as follows;

Throat 3 days	636
Ear 3 days	252-1410
Eye 3 days	470
Diarrhoea 3 weeks	662

Tables 1 and 2 provide quick reference to the required sample sizes using the calculations of previous workers such as Lightfoot (1989) and New Jersey Department of Health (1988). It should be noted, however, that these tables calculate the number required in **each** cohort group and they should be doubled to obtain the required number in the experiment after appropriate drop-out rates have been allowed for.

APPENDIX XIII

Appendix XIII Demographic and social summary

(a) Gender

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Male	145	54.5	78	58.6	67	50.4
Female	121	45.5	55	41.4	66	49.6

(b) Age

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
18-24	69	25.9	39	29.3	30	22.6
25-34	61	22.9	29	21.8	32	24.1
35-44	72	27.1	32	24.1	40	30.1
45-54	35	13.2	19	14.3	16	12.0
55-64	16	6.0	5	3.8	11	8.3
65+	13	4.9	9	6.8	4	3.0

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
18-24	40	27.6	21	26.9	19	28.4
25-34	29	20.0	13	16.7	16	23.9
35-44	37	25.5	19	24.4	18	26.9
45-54	24	16.6	16	20.5	8	11.9
55-64	7	4.8	2	2.6	5	7.5
65+	8	5.5	7	9.0	1	1.5

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
18-24	29	24.0	18	32.7	11	16.7
25-34	32	26.4	16	29.1	16	24.2
35-44	35	28.9	13	23.6	22	33.3
45-54	11	9.1	3	5.5	8	12.1
55-64	9	7.4	3	5.5	6	9.1
65+	5	4.1	2	3.6	3	4.5

(c) Occupation

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Student	36	13.5	14	10.5	22	16.5
Housewife	28	10.5	12	9.0	16	12.0
Employed	152	57.1	80	60.2	72	54.1
Self employed	6	2.3	2	1.5	4	3.0
Unemployed	17	6.4	9	6.8	8	6.0
Retired	16	6.0	11	8.3	5	3.8
Other	11	4.2	5	3.8	6	4.6

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Student	18	12.4	5	6.4	13	19.4
Housewife	0	0.0	0	0.0	0	0.0
Employed	91	62.8	50	64.1	41	61.2
Self employed	5	3.4	2	2.6	3	4.5
Unemployed	14	9.7	8	10.3	6	9.0
Retired	12	8.3	10	12.8	2	3.0
Other	5	3.5	3	3.9	2	3.0

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Student	18	14.9	9	16.4	9	13.6
Housewife	28	23.1	12	21.8	16	24.2
Employed	61	50.4	30	54.5	31	47.0
Self employed	1	0.8	0	0.0	1	1.5
Unemployed	3	2.5	1	1.8	2	3.0
Retired	4	3.3	1	1.8	3	4.5
Other	6	5.0	2	3.6	4	6.1

(d) Place of work

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Home	23	8.6	9	6.8	14	10.5
Office	103	38.7	49	36.8	54	40.6
Workshop	19	7.1	9	6.8	10	7.5
Factory	18	6.8	7	5.3	11	8.3
School	12	4.5	3	2.3	9	6.8
Nursery	1	0.4	1	0.8	0	0.0
Shop	6	2.3	3	2.3	3	2.3
Outdoors	25	9.4	15	11.3	10	7.5
Other	47	17.8	29	21.9	18	13.6
Missing	12	4.6	8	6.0	4	3.1

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Home	7	4.8	2	2.6	5	7.5
Office	62	42.8	29	37.2	33	49.3
Workshop	12	8.3	6	7.7	6	9.0
Factory	6	4.1	4	5.1	2	3.0
School	6	4.1	1	1.3	5	7.5
Nursery	1	0.7	1	1.3	0	0.0
Shop	2	1.4	1	1.3	1	1.5
Outdoors	14	9.7	10	12.8	4	6.0
Other	28	19.4	19	24.4	9	13.4
Missing	7	4.8	5	6.4	2	3.0

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Home	16	13.2	7	12.7	9	13.6
Office	41	33.9	20	36.4	21	31.8
Workshop	7	5.8	3	5.5	4	6.1
Factory	12	9.9	3	5.5	9	13.6
School	6	5.0	2	3.6	4	6.1
Nursery	0	0.0	0	0.0	0	0.0
Shop	4	3.3	2	3.6	2	3.0
Outdoors	11	9.1	5	9.1	6	9.1
Other	19	15.7	10	18.2	9	13.6
Missing	5	4.1	3	5.4	2	3.0

(e) Health authority

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
W. Glam.	222	83.5	114	85.7	108	81.2
Mid. Glam.	5	1.9	3	2.3	2	1.5
Dyfed	8	3.0	0	0.0	8	6.0
Other Wales	2	0.8	1	0.8	1	0.8
English	25	9.4	13	9.8	12	9.0
Other	4	1.6	2	1.6	2	1.6

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
W. Glam.	127	87.6	70	89.7	57	85.1
Mid. Glam.	1	0.7	1	1.3	0	0.0
Dyfed	3	2.1	0	0.0	3	4.5
Other Wales	0	0.0	0	0.0	0	0.0
English	12	8.3	6	7.7	6	9.0
Other	2	1.4	1	1.3	1	1.5

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
W. Glam.	95	78.5	44	80.0	51	77.3
Mid. Glam.	4	3.3	2	3.6	2	3.0
Dyfed	5	4.1	0	0.0	5	7.6
Other Wales	2	1.7	1	1.8	1	1.5
English	13	10.7	7	12.7	6	9.1
Other	2	1.6	1	1.8	1	1.5

(f) Local authority

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Swansea	195	73.3	99	74.4	96	72.2
Lliw Valley	9	3.4	1	0.8	8	6.0
Neath	7	2.6	6	4.5	1	0.8
Llanelli	3	1.1	1	0.8	2	1.5
Port Talbot	2	0.8	2	1.5	0	0.0
Ogwr	6	2.3	2	1.5	4	3.0
Other Wales	12	4.5	5	3.8	7	5.3
English	26	9.8	13	9.8	13	9.8
Other	6	2.3	4	3.1	2	1.6

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Swansea	110	75.9	59	75.6	51	76.1
Lliw Valley	3	2.1	0	0.0	3	4.5
Neath	5	3.4	4	5.1	1	1.5
Llanelli	2	1.4	0	0.0	2	3.0
Port Talbot	2	1.4	2	2.6	0	0.0
Ogwr	2	1.4	1	1.3	1	1.5
Other Wales	6	4.1	4	5.1	2	3.0
English	13	9.0	6	7.7	7	10.4
Other	2	1.4	2	2.6	0	0.0

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Swansea	85	70.2	40	72.7	45	68.2
Lliw Valley	6	5.0	1	1.8	5	7.6
Neath	2	1.7	2	3.6	0	0.0
Llanelli	1	0.8	1	1.8	0	0.0
Port Talbot	0	0.0	0	0.0	0	0.0
Ogwr	4	3.3	1	1.8	3	4.5
Other Wales	6	5.0	1	1.8	5	7.6
English	13	10.7	7	2.7	6	9.1
Other	4	3.2	2	3.6	2	3.0

(g) Long term illness

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Yes	128	48.1	63	47.4	65	48.9
No	138	51.9	70	52.6	68	51.1

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Yes	69	47.6	34	43.6	35	52.2
No	76	52.4	44	56.4	32	47.8

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Yes	59	48.8	29	52.7	30	45.5
No	62	51.2	26	47.3	36	54.5

(b) Illness since March 1989

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Yes	66	24.8	41	30.8	25	18.8
No	199	74.8	91	68.4	108	81.2
Not sure	1	0.4	1	0.8	0	0.0

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Yes	37	25.5	23	29.5	14	20.9
No	107	73.8	54	69.2	53	79.1
Not sure	1	0.7	1	1.3	0	0.0

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Yes	29	24.0	18	32.7	11	16.7
No	92	76.0	37	67.3	55	83.3
Not sure	0	0.0	0	0.0	0	0.0

(i) Water related sport and activities (No. times / month in the summer)

	Dinghy Sailing		Canoe		Windsurf		Speed / motor boat	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	249	93.6	249	93.6	255	95.9	256	96.2
1-3	10	3.8	13	4.9	9	3.4	7	2.6
4-7	4	1.5	2	0.8	1	0.4	2	1.8
>7	2	0.8	2	0.8	1	0.4	1	0.4
Not sure	1	0.4	0	0.0	0	0.0	0	0.0

	Other Sailing		Sub Aqua		Water skiing		Surfing	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	250	94.0	248	93.2	261	98.1	236	88.7
1-3	10	3.8	13	4.9	3	1.1	18	6.8
4-7	4	1.5	4	1.5	2	0.8	4	1.5
>7	2	0.8	1	0.4	0	0.0	8	3.0
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other activity			Bathing		Beach only	
	freq.	%		freq.	%	freq.	%
Never	236	88.7	Never	61	22.9	77	28.9
1-3	20	7.5	1-3	98	36.8	85	32.0
4-7	2	0.8	4-7	47	17.7	54	20.3
>7	7	2.6	>7	46	17.3	37	13.9
Not sure	1	0.4	Every day	10	3.8	11	4.1
			Not sure	4	1.5	2	0.8

(i) Water related sport and activities continued (No. times / month in the summer)

Bathers

	Dinghy Sailing		Canoe		Windsurf		Speed / motor boat	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	126	94.7	123	92.5	130	97.7	127	95.5
1-3	4	3.0	6	4.5	2	1.5	4	3.0
4-7	2	1.5	2	1.5	0	0.0	2	1.5
>7	1	0.8	2	1.5	1	0.8	0	0.0
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other Sailing		Sub Aqua		Water skiing		Surfing	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	126	94.7	126	94.7	129	97.0	116	87.2
1-3	3	2.3	5	3.8	2	1.5	11	8.3
4-7	2	1.5	2	1.5	2	1.5	1	0.8
>7	2	1.5	0	0.0	0	0.0	5	3.8
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other activity			Bathing		Beach only	
	freq.	%		freq.	%	freq.	%
Never	116	87.2	Never	22	16.5	44	33.1
1-3	12	9.0	1-3	44	33.1	35	26.3
4-7	1	0.8	4-7	20	15.0	24	18.0
>7	4	3.0	>7	35	26.3	24	18.0
Not sure	0	0.0	Every day	9	6.8	5	3.8
			Not sure	3	2.3	1	0.8

(i) Water related sport and activities continued (No. times / month in the summer)

Non-bathers

	Dinghy Sailing		Canoe		Windsurf		Speed / motor boat	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	123	92.5	126	94.7	125	94.0	129	97.0
1-3	6	4.5	7	5.3	7	5.3	3	2.3
4-7	2	1.5	0	0.0	1	0.8	0	0.0
>7	1	0.8	0	0.0	0	0.0	1	0.8
Not sure	1	0.8	0	0.0	0	0.0	0	0.0

	Other Sailing		Sub Aqua		Water skiing		Surfing	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	124	93.2	122	91.7	132	99.2	120	90.2
1-3	7	5.3	8	6.0	1	0.8	7	5.3
4-7	2	1.5	2	1.5	0	0.0	3	2.3
>7	0	0.0	0	0.0	0	0.0	3	2.3
Not sure	0	0.0	1	0.8	0	0.0	0	0.0

	Other activity			Bathing		Beach only	
	freq.	%		freq.	%	freq.	%
Never	120	90.2	Never	39	29.3	33	24.8
1-3	8	6.0	1-3	54	40.6	50	37.6
4-7	1	0.8	4-7	27	20.3	30	22.6
>7	3	2.3	>7	11	8.3	13	9.8
Not sure	1	0.8	Every day	1	0.8	6	4.5
			Not sure	1	0.8	1	0.8

(i) Water related sport and activities continued (No. times / month in the summer)

Males

	Dinghy Sailing		Canoe		Windsurf		Speed / motor boat	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	136	93.8	133	91.7	136	93.8	137	94.5
1-3	4	2.8	9	6.2	8	5.5	6	4.1
4-7	3	2.1	2	1.4	0	0.0	1	0.7
>7	1	0.7	1	0.7	1	0.7	1	0.7
Not sure	1	0.7	0	0.0	0	0.0	0	0.0

	Other Sailing		Sub Aqua		Water skiing		Surfing	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	134	92.4	130	89.7	141	97.2	126	86.9
1-3	6	4.1	12	8.3	3	2.1	10	6.9
4-7	4	2.8	2	1.4	1	0.7	3	2.1
>7	1	0.7	1	0.7	0	0.0	6	4.1
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other activity			Bathing		Beach only	
	freq.	%		freq.	%	freq.	%
Never	122	84.1	Never	31	21.4	49	33.8
1-3	16	11.0	1-3	60	41.4	51	35.2
4-7	2	1.4	4-7	23	15.9	20	13.8
>7	5	3.4	>7	24	16.6	20	13.8
Not sure	0	0.0	Every day	5	3.4	3	2.1
			Not sure	2	1.4	2	1.4

(i) Water related sport and activities continued (No. times / month in the summer)

Females

	Dinghy Sailing		Canoe		Windsurf		Speed / motor boat	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	113	93.4	116	95.9	119	98.3	119	98.3
1-3	6	5.0	4	3.3	1	0.8	1	0.8
4-7	1	0.8	0	0.0	1	0.8	1	0.8
>7	1	0.8	1	0.8	0	0.0	0	0.0
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other Sailing		Sub Aqua		Water skiing		Surfing	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	116	95.9	118	97.5	120	99.2	110	90.9
1-3	4	3.3	1	0.8	0	0.0	8	6.6
4-7	0	0.0	2	1.7	1	0.8	1	0.8
>7	1	0.8	0	0.0	0	0.0	2	1.7
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other activity			Bathing		Beach only	
	freq.	%		freq.	%	freq.	%
Never	114	94.2	Never	30	24.8	28	23.1
1-3	4	3.3	1-3	38	31.4	34	28.1
4-7	0	0.0	4-7	24	19.8	34	28.1
>7	2	1.7	>7	22	18.2	17	14.0
Not sure	1	0.8	Every day	5	4.1	8	6.6
			Not sure	2	1.7	0	0.0

(i) Water related sport and activities continued (No. times / month in the summer)

Male bathers

	Dinghy Sailing		Canoe		Windsurf		Speed / motor boat	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	74	94.9	70	89.7	75	96.2	73	93.6
1-3	2	2.6	5	6.4	2	2.6	4	5.1
4-7	2	2.6	2	2.6	0	0.0	1	1.3
>7	0	0.0	1	1.3	1	1.3	0	0.0
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other Sailing		Sub Aqua		Water skiing		Surfing	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	72	92.3	72	92.3	75	96.2	69	88.5
1-3	3	3.8	5	6.4	2	2.6	5	6.4
4-7	2	2.6	1	1.3	1	1.3	1	1.3
>7	1	1.3	0	0.0	0	0.0	3	3.8
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other activity			Bathing		Beach only	
	freq.	%		freq.	%	freq.	%
Never	64	82.1	Never	14	17.9	30	38.5
1-3	10	12.8	1-3	27	34.6	20	25.6
4-7	1	1.3	4-7	10	12.8	10	12.8
>7	3	3.8	>7	20	25.6	15	19.2
Not sure	0	0.0	Every day	5	6.4	2	2.6
			Not sure	2	2.6	1	1.3

(i) Water related sport and activities continued (No. times / month in the summer)

Male non-bathers

	Dinghy Sailing		Canoe		Windsurf		Speed / motor boat	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	62	92.5	63	94.0	61	91.0	64	95.5
1-3	2	3.0	4	6.0	6	9.0	2	3.0
4-7	1	1.5	0	0.0	0	0.0	0	0.0
>7	1	1.5	0	0.0	0	0.0	1	1.5
Not sure	1	1.5	0	0.0	0	0.0	0	0.0

	Other Sailing		Sub Aqua		Water skiing		Surfing	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	62	92.5	58	86.6	66	98.5	57	85.1
1-3	3	4.5	7	10.4	1	1.5	5	7.5
4-7	2	3.0	1	1.5	0	0.0	2	3.0
>7	0	0.0	0	0.0	0	0.0	3	4.5
Not sure	0	0.0	1	1.5	0	0.0	0	0.0

	Other activity			Bathing		Beach only	
	freq.	%		freq.	%	freq.	%
Never	58	86.6	Never	17	25.4	19	28.4
1-3	6	9.0	1-3	33	49.3	31	46.3
4-7	1	1.5	4-7	13	19.4	10	14.9
>7	2	3.0	>7	4	6.0	5	7.5
Not sure	0	0.0	Every day	0	0.0	1	1.5
			Not sure	0	0.0	1	1.5

(i) Water related sport and activities continued (No. times / month in the summer)

Female bathers

	Dinghy Sailing		Canoe		Windsurf		Speed / motor boat	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	52	94.5	53	96.4	55	100.0	54	98.2
1-3	2	3.6	1	1.8	0	0.0	0	0.0
4-7	0	0.0	0	0.0	0	0.0	1	1.8
>7	1	1.8	1	1.8	0	0.0	0	0.0
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other Sailing		Sub Aqua		Water skiing		Surfing	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	54	98.2	54	98.2	54	98.2	47	85.5
1-3	0	0.0	0	0.0	0	0.0	6	10.9
4-7	0	0.0	1	1.8	1	1.8	0	0.0
>7	1	1.8	0	0.0	0	0.0	2	3.6
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other activity			Bathing		Beach only	
	freq.	%		freq.	%	freq.	%
Never	52	94.5	Never	8	14.5	14	25.5
1-3	2	3.6	1-3	17	30.9	15	27.3
4-7	0	0.0	4-7	10	18.2	14	25.5
>7	1	1.8	>7	15	27.3	9	16.4
Not sure	0	0.0	Every day	4	7.3	3	5.5
			Not sure	1	1.8	0	0.0

(i) Water related sport and activities continued (No. times / month in the summer)

Female non-bathers

	Dinghy Sailing		Canoe		Windsurf		Speed / motor boat	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	61	92.4	63	95.5	64	97	65	98.5
1-3	4	6.1	3	4.5	1	1.5	1	1.5
4-7	1	1.5	0	0.0	1	1.5	0	0.0
>7	0	0.0	0	0.0	0	0.0	0	0.0
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other Sailing		Sub Aqua		Water skiing		Surfing	
	freq.	%	freq.	%	freq.	%	freq.	%
Never	62	93.9	64	97.0	66	100.0	63	95.5
1-3	4	6.1	1	1.5	0	0.0	2	3.0
4-7	0	0.0	1	1.5	0	0.0	1	1.5
>7	0	0.0	0	0.0	0	0.0	0	0.0
Not sure	0	0.0	0	0.0	0	0.0	0	0.0

	Other activity			Bathing		Beach only	
	freq.	%		freq.	%	freq.	%
Never	62	93.9	Never	22	33.3	14	21.2
1-3	2	3.0	1-3	21	31.8	19	28.8
4-7	0	0.0	4-7	14	21.2	20	30.3
>7	1	1.5	>7	7	10.6	8	12.1
Not sure	1	1.5	Every day	1	1.5	5	7.6
			Not sure	1	1.5	0	0.0

(i) Drinking and alcohol consumption

Visits to the public house (No. times per month, in the summer)

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Never	56	21.1	27	20.3	29	21.8
1-3	91	34.2	46	34.6	45	33.8
4-7	53	19.9	25	18.8	28	21.1
>7	59	22.2	31	23.3	28	21.1
Every day	7	2.6	4	3.0	3	2.3

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Never	23	15.9	15	19.2	8	11.9
1-3	40	27.6	22	28.2	18	26.9
4-7	34	23.4	14	17.9	20	29.9
>7	43	29.7	24	30.8	19	28.4
Every day	5	3.4	3	3.8	2	3.0

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Never	33	27.3	12	21.8	21	31.8
1-3	51	42.1	24	43.6	27	40.9
4-7	19	15.7	11	20.0	8	12.1
>7	16	13.2	7	12.7	9	13.6
Every day	2	1.7	1	1.8	1	1.5

(i) Drinking and alcohol consumption continued

Regularity of alcohol consumption, per week

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Never	23	8.6	13	9.8	10	7.5
< Once	64	24.1	33	24.8	31	23.5
> Once	168	63.2	82	61.7	86	64.7
Not sure	11	4.1	5	3.8	6	4.5

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Never	11	7.6	7	9.0	4	6.0
< Once	21	14.5	15	19.2	6	9.0
> Once	105	72.4	52	66.7	53	79.1
Not sure	8	5.5	4	5.1	4	6.0

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
Never	12	9.9	6	10.9	6	9.1
< Once	43	35.5	18	32.7	25	37.9
> Once	63	52.1	30	54.5	33	50.0
Not sure	3	2.5	1	1.8	2	3.0

(i) Drinking and alcohol consumption continued

Alcohol consumption, units per day

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
< 2	174	68.5	80	62.5	94	74.6
2-4	54	21.3	30	23.4	24	19.0
4-6	12	4.7	8	6.3	4	3.2
> 6	14	5.5	10	7.8	4	3.2
Missing	12		5		7	

Males

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
< 2	78	57.4	40	54.1	38	61.3
2-4	35	25.7	17	23.0	18	29.0
4-6	10	7.4	7	9.5	3	4.8
> 6	13	9.6	10	13.5	3	4.8
Missing	9		4		5	

Females

	All		Bathers		Non-bathers	
	freq.	%	freq.	%	freq.	%
< 2	96	81.4	40	74.1	56	87.5
2-4	19	16.1	13	24.1	6	9.4
4-6	2	1.7	1	1.9	1	1.6
> 6	1	0.8	0	0.0	1	1.6
Missing	3		1		2	

(i) Drinking and alcohol consumption continued

Statistics for alcohol consumption, units per day, for groups reporting (group 2) and not reporting (group1) diarrhoea on the final questionnaire

	N	Mean	Standard Deviation	Significance (p) (Mann-Whitney test)
All				
group 1	232	1.6564	1.981	0.7479
group 2	21	1.7211	1.915	
Bathers				
group 1	111	1.8906	2.265	0.7681
group 2	16	1.9643	2.135	
Non-bathers				
group 1	121	1.4380	1.659	0.9351
group 2	5	0.9429	0.501	
Males				
group 1	123	2.2869	2.290	0.4621
group 2	12	2.0238	2.329	
Females				
group 1	109	0.9410	1.226	0.1368
group 2	9	1.3175	1.180	
Male bathers				
group 1	64	2.5781	2.629	0.6806
group 2	9	2.3810	2.600	
Female bathers				
group 1	47	0.9544	1.120	0.2338
group 2	7	1.4286	1.338	
Male non-bathers				
group 1	59	1.9709	1.824	0.4399
group 2	3	0.9524	0.705	
Female non-bathers				
group 1	62	0.9309	1.310	0.4728
group 2	2	0.9286	0.101	

APPENDIX XIV

APPENDIX XIV GENERAL ENVIRONMENTAL CONDITIONS AT LANGLAND BAY ON 2 SEPTEMBER 1989

Climatic and sea conditions

Time	Wind force	Wind direction	Sea state	Cloud cover	Sun	Colour	Mineral oils	Surface active substances	Phenols	Sewage	Rain
12.00	2	315	2	6	3	1	1	1	1	1	0
12.30	1	000	2	7	0	1	1	1	1	1	0
13.00	1	315	1	6	4	1	1	1	1	1	0
13.20	2	315	1	7	2	1	1	1	1	1	0
13.40	2	315	1	7	1	1	1	1	1	1	0
14.00	1	315	1	6	1	1	1	1	1	1	0
14.20	1	315	1	7	1	1	1	1	1	1	0
14.40	1	315	1	7	1	1	1	1	1	1	0
15.00	2	293	1	4	4	1	1	1	1	1	0

Turbidity of sea-water samples

Time	Locn.	NTU
12.40	40	16.0
12.45	0	54.0
12.45	20	27.0
12.45	60	8.7
12.45	80	23.0
12.45	100	32.0