

Monitoring Bathing Waters - A Practical Guide to the Design and Implementation of Assessments and Monitoring Programmes

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Chapter 12*: AESTHETIC ASPECTS

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A clean beach is one of the most important characteristics of a waterside resort sought by visitors (Oldridge, 1992; Morgan *et al.*, 1993). Accumulations of coastal debris raise a number of concerns: risks to marine wildlife, potential human health hazards and threats to the economy of coastal communities especially in tourist areas. In extreme cases people may avoid visiting an area if it is littered with potentially hazardous and unaesthetic items such as sanitary and medical waste. Beach quality can be viewed from two perspectives:

- It is the responsibility of the receiving area to ensure clean beaches and water.
- It is the responsibility of the user to behave in an appropriate manner and to avoid spoiling the beach with litter.

Aesthetics does not deal with a health burden directly but affects well being and health gain. The effects of aesthetic issues on the amenity value of marine and riverine environments have been defined by the World Health Organization (WHO) as: loss of tourist days; resultant damage to leisure/tourism infrastructure; damage to commercial activities dependent on tourism; damage to fishery activities and fishery-dependent activities; and damage to the local, national and international image of a resort (Philipp, 1993). Such effects were experienced in New Jersey, USA in 1987 and Long Island, USA in 1988 where the reporting of medical waste, such as syringes, vials and plastic catheters, along the coastline resulted in an estimated loss of between 37 and 121 million user days at the beach and between US\$ 1.3×10^9 and US\$ 5.4×10^9 in tourism-related expenditure (Valle-Levinson and Swanson, 1991).

The robustness of scientific techniques used in litter analysis is of varying quality and methodologies involved for any beach aesthetic programme must be comparable, have a quantitative basis and, more importantly, be easily understood by the end user. The reduction of beach litter for visual, olfactory and health reasons should be a paramount aim for society. Ideally litter should be cut off at source, but in reality this has been found difficult. Fundamental to this aim are universal education programmes.

Box 12.1 Public perception of microbiological quality and aesthetic aspects

A study was carried out in 1987 in the UK to investigate the public perceptions of beach and sea pollution with particular reference to the perception of bathing water quality. Samples were taken from two holiday resorts. On the basis of pre-existing microbiological evidence, the two resorts were chosen so they would have contrasting levels of measured sea pollution.

Interviewers were instructed to select respondents of a wide variety of ages and apparent social classes, recruiting approximately equivalent numbers of men and women on or near the beach in each of the two resorts. The interview schedule was designed to elicit the public's perception of beach and sea pollution, their perception of the quality of bathing water and their reporting of any of a list of symptoms. Respondents were also asked about their, and their children's (if applicable), swimming and other water-related activities. Sampling took place over an eight-week sampling period during the summer months in 1987. All interviews took place on the beach or in the immediate surroundings.

- The microbiological results for Resort 1 indicated higher levels of microbiological contamination than at Resort 2.
- The sea at Resort 1 was more likely to be seen as discoloured, dirty, cloudy, having film, oil or slime than at Resort 2.
- The frequency of reported debris in both the sea and beach was significantly greater at Resort 1.
- There was a higher incidence of discarded food or drink containers reported on the beach than in the sea.

Swimmers and non-swimmers at Resort 1 showed a significantly different percentage of holidaymakers reporting symptoms of illness such as stomach upsets, nausea, diarrhoea or headaches compared with holidaymakers at Resort 2.

Source: University of Surrey, 1987

12.1 Beach litter visual triggers

The presence of clear water does not guarantee that the water is uncontaminated and free from pathogens but the presence of certain items on a beach may however, imply poor microbiological water quality (University of Surrey, 1987) (Box 12.1). Equally, beaches free from litter do not imply that the sanitary quality of the sand is good (Mendes *et al.*, 1997). The general public usually infer that a highly littered beach has poor water quality and it is logical to assume that people prefer to visit a clean beach rather than a dirty beach (Rees and Pond, 1995a). It has been reported by WHO, that *"Good health and well-being require a clean and harmonious environment in which physical, psychological, social and aesthetic factors are all given due importance"* (WHO, 1989 p. 5).

Marine litter is defined as *"solid materials of human origin that are discarded at sea or reach the sea through waterways or domestic or industrial outfall"* (NAS, 1975 p. 104). However, the question remains whether a single item of sanitary waste on a beach necessarily means that a beach is dirty or, alternatively, how many condoms, sanitary towels or metal cans it takes to make a beach aesthetically displeasing. Aesthetics is defined by Collins Concise Dictionary (1995 p. 19) as relating to *"(a) pure beauty rather than to other consideration, (b) relating to good taste"*. It relates to personal preferences, which in turn encompass things perceptible by the senses (sight, smell, taste, touch and hearing), gender, socio-economic status, psychological profile, climate, "sense of well being", age, culture, and whether the observer or user is local or a tourist (Dinius, 1981; Williams, 1986; Oldridge, 1992; Morgan *et al.*, 1993; Bonaiuto *et al.*, 1996). Certain aspects of aesthetic pollution have a greater impact on the public than others and it has been suggested that a weighting of importance should be placed on the determinands so that an overall aesthetic index could be established (NRA, 1996).

The perception of the beach user should be taken into account in award schemes (see Chapter 6) of which many exist (Williams and Morgan, 1995). Cognisance of such perception is sadly lacking in all current award schemes (see Chapter 6). Perception by the general public of the beach aesthetic appearance and water quality has become increasingly important (David, 1971; Williams, 1986; House, 1993; NRA, 1996; Williams and Nelson, 1997). The problems of beach litter are being tackled with respect to the physical (Williams and Simmons, 1997a,b) and psychological well-being of the consumer (Williams and Nelson, 1997). Emphasis is being applied increasingly to development of aesthetic health indicators which will aid in the implementation of planning measures to deal with beach health hazards (Philipp *et al.*, 1997). The presence of sewage-related debris (SRD) and medical items tend to evoke stronger feelings of unpleasantness with respect to beach aesthetics than items such as cans or plastic bottles but the tolerance level on a world-wide basis has yet to be quantified. The former items attract media attention because of the potential health risks associated with stepping on syringes, ingesting SRD or other contaminated material (Walker, 1991; Rees and Pond, 1995a). Herring and House (1990) concluded that sewage-derived debris had a greater social impact than any other aesthetic pollution environmental parameter. Williams and Nelson (1997) (Box 12.2) showed that the general public are more affected by mixtures of generic debris categories (e.g. cans, bottles and SRD such as condoms and sanitary towel backings), and it appears that females are more sensitive to beach debris (in particular SRD) than males (which could be due to a higher recognition of these particular items). It has been stated by the UK House of Commons Committee that *"while the risk of infection by serious disease is small, the visible presence of faecal and other offensive materials carried by the sewerage system can mean serious loss of amenity and is therefore an unacceptable form of pollution"* (HCEC, 1990 p. xvii).

Box 12.2 Public perception analysis at Barry Island, South Wales, UK

Public perception to litter was investigated by questionnaire during August 1995 and 1996 at Barry Island beach, South Wales, UK. Results showed that beach users were acutely aware of land-based and marine coastal pollution. A high percentage of beach users (69 per cent) thought the water to be polluted and a large percentage reported a list of litter items as being present on the beach including food packaging (83 per cent) and excrement (27 per cent).

The most prominent items of debris noted on the beach at the end of the day were food packaging, plastic bottles, aluminium cans, excrement and hygiene items. A composition of general litter and sewage-related debris was found to be the more offensive than individual generic items. The most sensitive groups of people to beach litter were females, people in the age range 30-39, and local people when compared with visitors who travelled greater than 10 miles to their destination.

A high degree of concern about the water condition was expressed by the public and a large number, 69 per cent, decided not to enter the water because they believed it to be polluted. Chi-square analysis at the 0.05 level showed females, and also people in the age category 30-40 years old, to be more sensitive to perception of pollution. However, parents still chose to visit the beach for the sand and amenity value without allowing their children into the water. Water quality was the main reason for not swimming (55 per cent), followed by temperature (23 per cent). Floating objects were considered to be the most obtrusive forms of marine debris by 53 per cent of the respondents. Such objects included anything from food packaging and hygiene items to faecal matter. The colour of the water was reported to be unfavourable by 21 per cent of those surveyed, while 14 per cent of respondents commented that the water had a "foul smell" and oil was perceived to be a problem by 12 per cent.

Source: Williams and Nelson, 1997

Dinius (1981) found that water discoloration was a factor that led respondents to make a judgement about the level of pollution of an area. Any visually unpleasant pollutant has the potential to have a negative impact on tourism, whether or not it poses an actual health risk. The aesthetic quality of the Mediterranean has been affected where eutrophication and algal blooms have occurred. There is also evidence of nutrient enrichment in the Baltic Sea, Kattegat, Skagerrak, Dutch Wadden Sea, North Sea and Black Sea (Saliba, 1995). Izmir Bay, Turkey, has been suffering red algal tides and, in 1993, pollution-related illness caused an estimated 10,000 lost working days amongst local swimmers and fishermen using the Bay (Pearce, 1995). Eutrophication has been reported as a problem along virtually every country bordering the Mediterranean. One of the consistently worst affected areas is the northern Adriatic where algae affecting areas of sea water up to 50 km² have been reported (Pearce, 1995).

One model for aesthetic standards defines the aesthetic value of recreational waters as (MNWH, 1992):

- Absence of visible materials that may settle to form objectionable deposits; absence of floating debris, oil, scum and other matter.

- Absence of substances producing objectionable colour, odour, taste and turbidity.
- Absence of substances and conditions (or combinations) which produce undesirable aquatic life.

It is imperative that future beach management plans consider the beach users perception of the coastline. Although poor visual appearance of the beach does not necessarily infer danger to health, results of other surveys (see Box 12.1) strongly suggested a link between the presence of certain items of debris and higher bacterial counts in water.

There are a number of human health risks posed by marine debris. Injuries caused by marine debris include entanglement of scuba divers (Cottingham, 1989), cuts caused by broken glass and discarded ring tabs from cans, skin punctures from abandoned syringes and exposure to chemicals from leaking containers washed ashore (Dixon and Dixon, 1981). In addition, munitions and pyrotechnics such as smoke and flame markers have been recovered on beaches (Dixon, 1992). Fishermen and those involved in dredging operations are at particular risk from such items although there are numerous reports of injuries to holidaymakers who have inadvertently picked up such items (Dixon, 1992).

Horsnell (1977) has documented the actual safety hazards arising from individual or small numbers of individual chemical packages. Studies by Dixon (1992) have shown a 63 per cent reduction in dangerous or harmful substances in England and Wales between 1982 and 1992. The reduction was most marked for flammable liquids, oxidising substances and corrosives. Koops (1988) analysed chemical cargoes lost off the Dutch coast that included the gases ethylene oxide and chlorine and the corrosive, sulphur dichloride.

Less obvious health risks are posed by items of SRD and medical waste. Clinical waste represents the potential vectors of infectious diseases such as Hepatitis B and Human Immunodeficiency virus (Walker, 1991). In addition, other visible pollutants, such as discarded food, dead animals, oil, containers and tyres, commonly found along the coastline have been associated with microbiological hazards (Philipp, 1991). Where visible litter is present there are also likely to be high counts of *Escherichia coli* (Philipp, 1991) which are commonly associated with human faecal material. Long-term monitoring of marine debris can therefore become an important part of the process to identify suitable indicators (Pond, 1996).

12.2 Litter survey techniques

There are a number of uses for data gathered by beach survey, including the application of the data to assess the effectiveness of remedial measures; appraisal prior to management programmes; tourism guides (e.g. MCS, 1996); as part of an integrated coastal zone management programme; identification of health hazards and/or particular threats; identification of trends; raising public awareness through public involvement; investigations for identifying the source of the litter, ageing litter and identifying the dynamics of litter in the environment. In all cases the data collected must be of quality suitable for the purpose and, where comparisons are to be made, the data must be standardised. The use of photography as the basis for routine comparisons, training and

communication may be important, particularly because the perception of litter is a visual and aesthetic process. Education has a major role to play in respect to the above, both at the formal and informal level.

Litter surveys are conducted to assess types, amounts, distribution and source of litter (Rees and Pond, 1995b) and in turn to assess the effectiveness of legislation. Human health, litter and tourism are intimately connected issues and surveys, such as enumerated below, are needed in order to monitor progress in cleaning up litter (or the lack of it) through time.

Monitoring parameters, sampling stations and sites and sampling frequencies, should all be considered when establishing beach quality monitoring programmes. The problems associated with microbiological sampling of seawater have been well documented (Fleisher, 1985, 1990; Jones *et al.*, 1990; EC, 1995; Rees, 1997) and a number of these factors will apply to aesthetic quality sampling, namely variation between analysts, methods, culture mediums, choice of sampling location, number of transects from which samples are taken, number of sampling points on any stretch of beach, time of sampling (spring to neap tides), frequency of sampling, as well as wind, tide, currents and sunlight. All of these can contribute to inconsistency in results (see Chapters 2 and 9) which raises the question of whether it is possible to take a representative sample. Some of the factors above could certainly apply to beach quality monitoring and it is uncertain whether existing award schemes (see Chapter 6) show realistic representations on which to base any quality assessments.

12.2.1 Survey objectives

Of particular importance is the identification of realistic objectives that must be clearly stated and understood before the survey begins. The objectives of any litter study will define the timing of the sampling period. However, all surveys should encompass varying seasons in order to obtain a representative sample. Baseline studies (to identify the types of material found) are generally carried out over large geographical areas using a low sampling frequency. Assessment studies (to identify density of debris and changes over time) are usually carried out over more intense sampling periods and in smaller geographical areas. Temporal changes, physical characteristics of a beach, tidal patterns and use of the beach can have dramatic influences on the composition of debris found at any one time. It is therefore important that the programme design suits the study aims. Resources may also be a factor determining survey timings. Where sampling is carried out for health reasons it may be desirable to survey throughout the year but the availability of resources may restrict sampling to the bathing season.

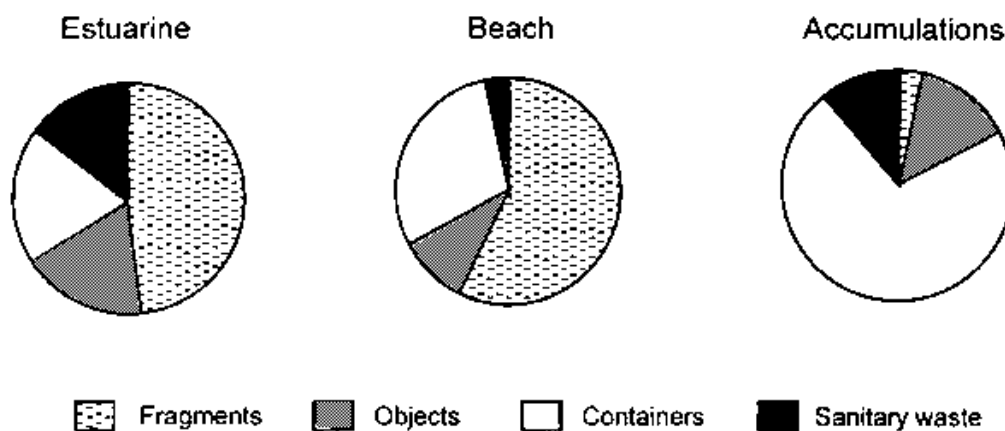
12.2.2 Methods

Surveys can be focused on the beaches, seas or rivers where beach debris is used as an indicator of oceanic, riverine, estuarine or lake conditions. One of the earliest litter surveys to be undertaken was by Garber (1960) and this approach has been used by others (NRA, 1992). The main disadvantage of the method used by Garber (1960) was its subjectiveness. For example, only presence or absence of certain visual characteristics relating to water quality was recorded in section A of the official form whereas in section B scales ranged from "absence" to an amount that was sufficient to be objectionable. No definitions of these categories were given.

Surveys can be on a small scale, such as that by Gilligan *et al.* (1992) in Chatham County, Georgia, USA where four types of site were selected to obtain samples representative of tidal influence; or they can be large scale such as those carried out by the Coastwatch Europe network (Dubsky, 1995) and the Tidy Britain Group (TBG) in the UK (Dixon and Hawksley, 1980).

A number of guides and reviews exist to help survey design (Gilbert, 1987; Ribic *et al.*, 1992; Rees and Pond, 1995b; Earll, 1996). To date, it has been inappropriate to apply a standardised methodology to assess riverine and marine debris, due to the different objectives of the surveys and the diverse nature of coastlines world-wide (Faris and Hart, 1995; Verlander and Mocogni, 1996). Faris and Hart (1995) concluded that monitoring studies can be carried out in a variety of ways provided standardised sampling protocols are established at the beginning and basic requirements are followed. Study objectives will determine the ultimate project design. Studies may be simple enumeration studies, assessing types and litter quantities, or they can be more detailed indicating age and origin of items. They can cover large geographical areas or they can relate to detailed information about specific regions or places (Williams and Simmons, 1997a). The time element, personnel needs and the costs are restricting factors. Details, such as site description, map reference, category definition, wave, wind, current patterns, site topography, physical characteristics of the beach, measurement units, survey frequency and date of survey, all need to be identified and recorded.

Figure 12.1 Plastic litter found at Merthyr Mawr beach, South Wales, UK (After Williams and Simmons, 1997a)



It is important to recognise that undertaking a beach survey can be hazardous. In addition to detailed instructions on how to complete the survey, special attention should be paid to safety aspects. Surveyors should wear appropriate footwear as well as gloves if it is necessary to handle the litter.

Litter can be categorised according to size (Ribic, 1990), composition (Dixon and Dixon, 1983) or weight (YRLMP, 1991). Three main methods of assessing type, amount and distribution of marine debris have been documented:

- Record solid waste generated by ships or pleasure crafts (Dixon and Dixon, 1981).

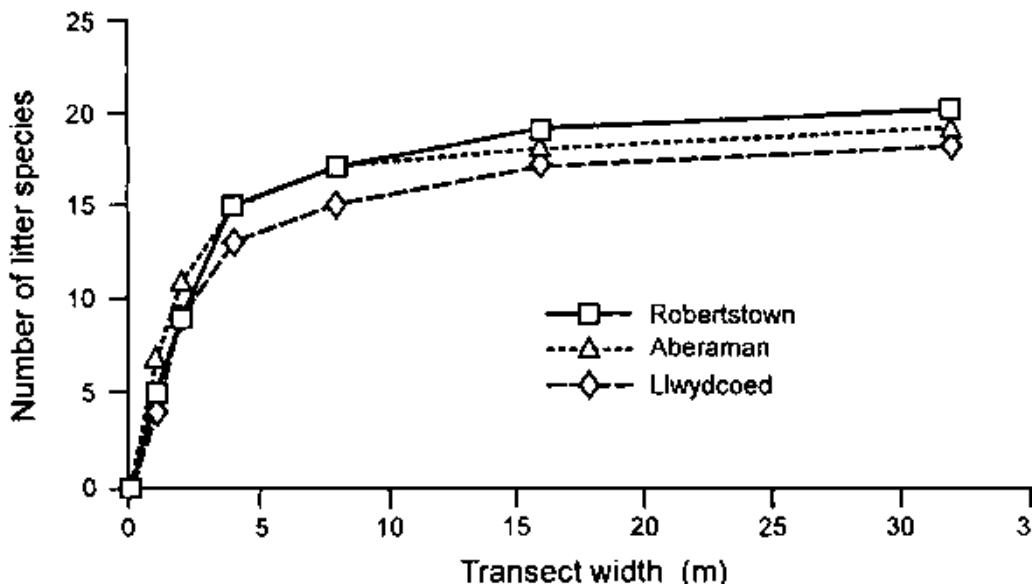
- Collect or observe litter floating in coastal waters (Cuomo *et al.*, 1988).
- Estimate litter during beach surveys (Rees and Pond, 1995b, 1996; Williams and Simmons, 1997a) (Figures 12.1 and 12.2).

All surveys should be repeated to show temporal changes in amount and type of litter and, hopefully, to determine its source, accumulation rate, standing stock, etc.

Individual items of beach marine debris are usually counted and classified or recorded as presence or absence (Pollard, 1996; Rees and Pond, 1996). The sampling size unit is a function of the survey aims. Examples include:

- The whole beach can be surveyed from splash zone to waters edge (Dubsky, 1995).
- Transects may be used of varying width. The optimum transect width is one which provides a reliable sample.
- Transect line quadrats or randomly dispersed quadrats (Dixon and Hawksley, 1980).
- Strand line counts (Williams and Simmons, 1997a).
- Postal surveys (Dixon, 1992).
- The offshore water column can be sampled (Williams *et al.*, 1993).

Figure 12.2 A minimal area curve for beach sites on the River Cynon, South Wales, UK (After Earll *et al.*, 1997)



The advantages and disadvantages of various methods of litter surveys are shown in Table 12.1. Survey design and methodological development are considered to be of

paramount importance and many statisticians and environmental scientists have provided guidelines to aid formulation of sound survey designs (Gilbert, 1987; Ribic *et al.*, 1992). Common to each approach is an emphasis on formulation of realistic objectives that must be stated and clearly understood before work can progress. No precedent exists regarding the optimum type of data, i.e. qualitative or quantitative. Two approaches to aesthetic surveys are described below: transect surveys and questionnaire surveys.

Transect surveys

Gilbert (1987, p. 7) stated, "*the target population is the set of N population units about which inferences will be made. The sampled population is the set of population units directly available for measurement*". The target population must be limited to litter at sites deemed accessible for sampling purposes, e.g. litter on riverbank sites where both banks can be sampled up to the bank-full position (highest possible water level), beach strandlines, etc. Due to logistical problems of assessing all litter at a site, representative sampling units are needed to provide an accurate portrayal of the whole site. For rivers and beaches, a series of continuous quadrats can be laid starting at the water's edge and finishing at the natural limit of the bank or beach (sites chosen with predominantly natural characteristics). Within each quadrat, litter abundance can be measured in the form of density counts, i.e. the number of individuals of particular litter types within a quadrat. Not every litter type exists on any one particular river or beach.

Table 12.1 The principle advantages and disadvantages of various methods of litter survey

| Method | Advantages | Disadvantages |
|--|--|--|
| Five strand lines, excluding the vegetation line | Covers a large area of beach where items may accumulate in algae or as mats of debris left as the tide recedes | Can give biased results as the areas between the strand lines are not surveyed and the method only counts the most recent tidal borne debris (1) Only covers surface litter; some litter may be buried (2) It may be difficult to identify strand lines; these vary daily and seasonally (3) Not suitable for beaches with large boulders (4) |
| Five strand lines, plus the vegetation line | Area covered includes a good cross section; both accumulated and fresh litter is surveyed | As above (1-3) |
| Top, bottom and vegetation lines | Easy to use; quicker than the above methods | As for the first method (1-3) |
| Five metre wide strip transect | Covers a large area of beach where items may accumulate in algae or as mats of debris left as the tide recedes | As for the first method (1-3) |
| One metre wide strip transect | Covers a large area of beach where items may accumulate in algae or as mats of debris left as the tide recedes | As for the first method (1-3) |

| | | |
|---------------------------|--|---|
| Random 2x2 quadrats | Fast method of sampling; sampling is not influenced by location of litter and is therefore statistically valid | Results may be variable and depend on the amount of litter present |
| Random dispersed quadrats | Fast; economic | Possibility of missing litter clumping |
| Whole beach | Covers all sections of the beach; avoids bias | Time consuming; care needs to be taken not to miss items Best suited to pocket beaches |
| Postal surveys | Can cover a large geographical area | May be relatively high percentage of non-response |

A useful tool adapted to determine whether transect sampling is an appropriate method for river and beach litter assessments (species) and, if found suitable, to assess the optimum transect width size, is classic minimal area analyses (also known as species area curves) derived from the Braun-Blanquet school of phytosociology (Braun-Blanquet 1921, 1932; Cain, 1932, 1935; Gilbertson *et al.*, 1985).

Narrow belt transects are more easily studied and enable work to be achieved quicker, but wider transects probably yield more reliable data (Burnham *et al.*, 1980). Therefore, the optimum transect width is one which provides a reliable representation of the litter present, for the minimum amount of work. For example, for investigating riverine litter (Figure 12.2), starting from the site's centre point, a tape is placed up the river bank perpendicular to the river flow. A second tape is then placed parallel to the first, at the smallest possible distance apart (in this case approximately 10 cm). The number of litter types is counted and recorded. The exact initial distance decided upon is unimportant, provided it is small enough to contain only one or two items, because recordings are made in relation to a doubling of transect width and not as a function of the exact width measurement. The transect width is doubled and the number of litter types present counted. The doubling and counting procedure is repeated until the number of litter types at each doubling of the transect width has shown no further increase. The resultant data curve starts to level off at the point that resembles the minimal width necessary to obtain representative samples.

Figure 12.2 shows how three different sites produced similar curves, with the curve gradient indicating the number of litter types found, and the curve beginning to level off after 5 m transect widths. On an objective basis it is very difficult to determine the exact optimum transect width. At a 5 m transect width some 13-15 litter types were identified; but at 15 m width 15-17 types were identified. Detailed field work showed that 20 litter types were present at these sites, i.e. 5 m transect widths covered some 65-75 per cent of the litter present whereas 15 m widths covered some 75-85 per cent. The 5 m transect width has been used in many litter surveys (Dixon and Dixon, 1981; Davies, 1989) but there is no clear scientific justification for this. On applying a pre-specified relative error (Gilbert, 1987), results indicated that any between-site comparisons should only be carried out using litter types known to have a more uniform within-site distribution. Commonly occurring litter types, such as plastic sheeting and sewage-derived articles, could be represented realistically using only three transects. Other litter types needed 64 transects, e.g. packing crates. It is meaningless to compare sites of

different litter types, because the within-site variation can be greater than the differences between two sites.

Questionnaire surveys

An alternative approach to transect sampling is to survey the entire beach area. This approach has been followed by the Coastwatch Europe network and has been described in detail by Pond (1996) and Rees and Pond (1995b; 1996). Essentially, the study area is divided into manageable units of 0.5 km in length. The method uses standard questionnaires, translated as necessary (see Rees and Pond, 1996). All surveyor groups are provided with detailed instructions on how to complete the survey, including which items of litter should be included in each category, detailed safety notes and the contact telephone number of a national and local co-ordinator. The survey is conducted over a common time period so that the results can be compared between participating countries and between sites within countries. A six-figure map reference of each unit of coastline is recorded and stored on a database in order to ensure that the same units are surveyed in subsequent surveys.

The survey is conducted as soon as possible after high tide. Surveyors are asked to walk along the intertidal area and to return along the splash zone recording the presence or absence of 17 "general" litter categories, such as sewage-related debris, cans, plastic bottles, etc. and nine "major items of debris", such as household refuse. Quantities of some items of litter are also requested. Surveyors are also asked to record potential threats to the area, to investigate the aesthetic quality of inflows (streams and rivers) and to record other information regarding management aspects of the coastal unit. Once the questionnaire has been completed surveyors return it to a national co-ordinating office for data analysis and report writing.

This approach has a number of advantages: the method is simple to use and can be undertaken by relatively inexperienced surveyors under instruction (see section 12.2.4) and the questionnaire can be adapted to focus on particular areas of interest, for example the Coastwatch Europe network has developed a section of the questionnaire to focus on medical and sanitary waste. It can also be adapted to collect qualitative data. Large areas of coastline can be covered, thus making the sample more representative. The method is also economical and does not require any special equipment or knowledge and can be undertaken in all weather conditions. The main disadvantage is that the method is time-consuming.

12.2.3 Qualitative versus quantitative data analysis

Qualitative data

The problems associated with the techniques used to assess litter and the resulting statistical analyses are comparable with those experienced by ecologists (Ludwig and Goodall, 1978; Ludwig and Reynolds, 1988). Qualitative data can give quick assessments (Hubalek, 1982). Many different pattern types can exist within communities, including spatial dispersion of litter types (species) "within" a site, and relationships "between" sites.

Ludwig and Reynolds (1988) recommended the variance ratio (VR) test of Schluter (1984) to measure association for more than a single pair of litter types. The Null Hypothesis (H_0) is that no association exists between litter types and the expected VR is 1. If an association occurs, then it is either positive ($VR < 1$), i.e. the pair of litter types occurred together more often than expected if independent; or negative ($VR > 1$), i.e. the pair of litter types occurred together less often than expected if independent. Litter types may show no association if independent, or when positive and negative associations between litter types cancel out each other.

The chi-square test can detect pair-wise associations of litter types, with H_0 indicating that the litter types were independent. In riverine litter examples quoted by Simmons and Williams (1997) a $\chi^2_t > 3.84$ at the 95 per cent level rejected H_0 , and 31 litter pairs were significantly associated. In the context of ecological monitoring, three qualitative (present/absent) binary techniques are common i.e. Ochai, Jaccard and Dice. Jaccard's technique is particularly robust and when using this technique Simmons and Williams (1997) showed that within-site litter transects were generally no more strongly associated than those between-sites. From these qualitative results it appears that within-site litter variations can be as great as between-site variations. If this is the case the representativeness of transects for each site may be questioned because the results from one transect could be dramatically different from another transect, even at the same site. In the Simmons and Williams (1997) study, no strong associations were apparent between sites; the highest index value reached 0.7 with the majority of indices < 0.5 . It appears that either significant differences in litter patterns did not exist between sites, or that the sample size was too small to show differences, or that the statistical test was not able to detect the differences.

Several major limitations negate the benefits of collecting by qualitative data alone. A lack of data versatility is a major problem, with few statistical analyses being appropriate. Even the statistical packages available (Ludwig and Reynolds, 1988) require very time-consuming data manipulation to carry out relatively simple calculations. If data are being compiled for several river catchments or marine sites, it is felt that data manipulation problems alone make qualitative analysis an unfavourable proposition.

Quantitative data

Quantitative data makes it amenable to a broader spectrum of analysis methods giving greater versatility. Three basic patterns may be recognised in litter communities, random, clumped and uniform, and the mean, variance and pattern of individuals within a quadrat are quite different between these patterns. Once a pattern has been identified, a test must be proposed concerning the community structure. Initially, it is important to determine if sampling units are discrete (natural) or continuous (arbitrary) because this influences the type of spatial pattern analysis. Based on the continuous nature of sampling units, the quadrat variance method of Ludwig and Goodall (1978) can be undertaken enabling spatial patterns to be observed by sampling a series of continuous quadrats. Data may be collected at all litter sites by a series of 1 m² quadrats extending up a river bank or along a beach transect. Quadrat-variance methods are based on examining the changes in the mean and variance of the number of individuals per sampling unit, for a range of sampling units.

Table 12.2 Significantly correlated litter pairs

| Correlated litter pairs | Level of significance ¹ |
|---|------------------------------------|
| Sanitary towel: parity liner | 0.000 |
| Panty liner: tampon | 0.019 |
| Sanitary towel: tampon | 0.007 |
| Plastic sheeting < 30 cm: plastic sheeting 30-60 cm | 0.006 |
| Plastic sheeting < 30 cm: plastic sheeting > 60 cm | 0.030 |
| Plastic sheeting 30-60 cm: plastic sheeting > 60 cm | 0.000 |

¹ Equivalent to the probability of the correlation arising purely by chance

Source: Simmons and Williams, 1997

Two types of quadrat variance methods can be used: paired-quadrat variance (PQV) and two-term local quadrat variance (TTLQV). The former uses (PQV) changes in quadrat spacing to provide spatial pattern information, whilst the latter (TTLQV) uses changes in quadrat size, through the blocking or combining of adjacent quadrats, to determine pattern intensity and range of densities present. Quantitative analyses can be done using the SPSSx® statistical software package (Norusis, 1983). If results from individual quadrats are combined to produce data representing a 1 m wide belt transect, the data could still be used to indicate whether certain statistical tests would be of future use. Data limitations can be due to small sampling areas and the use of only one transect to represent a site.

The normality of litter data sets should be tested using the Kolmogorov-Smirnov one sample non-parametric test (Miller and Miller, 1988), followed by finding the covariation between litter types, e.g. using the Spearman rank correlation. For example, Simmons and Williams (1997) found correlations between sanitary towels, panty liners and tampon applicators (Table 12.2). Plastic sheeting appeared to be correlated with other plastic sheeting of differing sizes, but not with sewage-derived litter (as indicated in the qualitative litter association analyses described above). This result may highlight one of the problems of using qualitative data in this sort of survey. Associations between plastic sheeting and sewage debris may have been calculated because of their common occurrence at sites. Associations shown by qualitative data may have led to the hypothesis that plastics were introduced to the system from the same sources as the sewage-derived litter, hence their association. However, it appears that although both items are present at the same site, their abundance is not correlated significantly. Major limitations of this type of analysis appear to arise from the number of zeros recorded in the data set; consequently large data sets are needed. A second problem is the realistic interpretation of results. When an expanse of coefficients has been calculated, multivariate methods of pattern recognition, such as cluster and principal component analysis, can and should be used (Derde and Massart, 1983).

Cluster analysis may be used to place similar objects or variables into groups or "clusters", in order to produce a hierarchical tree-like structure known as a dendrogram. Dendograms demonstrate graphically, in two dimensions, similarities between variables by the varying distances from the x-axis at which the groups are formed. The closer a group is formed to the x-axis, the stronger the similarities between its constituent parts

(Simmons and Williams, 1997). The cluster analysis approach appears to be a very useful tool for indicating patterns within a data set and reduction of the numbers of zeros recorded is the main key.

Principal Component Analysis (PCA) is an alternative method of pattern recognition that aims to identify principal components that explain correlations among a set of variables (litter types, see Table 12.3). The method condenses information on litter types from many dimensions (N sites) to two or three dimensions that may be more easily interpreted. In addition, it calculates "loadings" to indicate the significance of each of the variables in determining the data structure. The higher the loading, the greater the importance the variable has in determining that component. In Figure 12.3, the first three factors accounted for 20, 16, and 11 per cent of the data variation respectively (Simmons and Williams, 1997).

12.2.4 Volunteers versus "professionals"

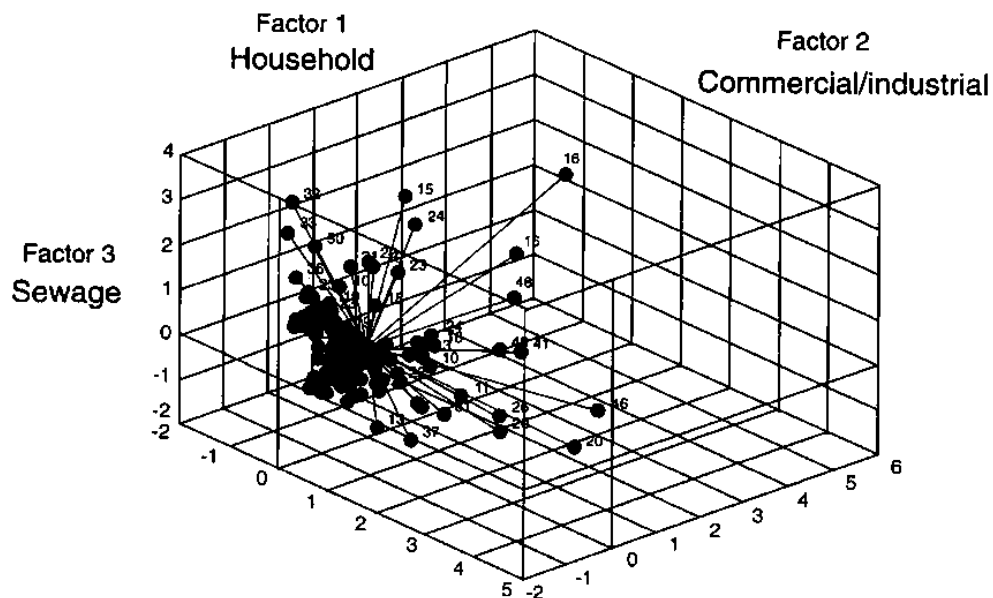
There has been considerable debate about who should conduct litter surveys (Dixon, 1992; Amos *et al.*, 1995; Pollard, 1996; Rees and Pond, 1996). The use of volunteers was discussed at length at the Third International Conference of Marine Debris in 1995 (Paris and Hart, 1995). No conclusions were made, but the Conference recommended that where volunteers are used, clear instructions must be given and good quality assurance procedures must be established. There are both advantages and disadvantages in this approach. The use of volunteers to conduct litter surveys means that a large sample size can be achieved at low cost. However, concerns exist that reporting rates between groups may not be consistent. Trials have shown that volunteers frequently identify litter items incorrectly (Dixon, 1992). This has been investigated recently through the Coastwatch UK programme and it was found that these concerns were largely unfounded (Pond, 1996).

Table 12.3 A litter identification key

| Source | Category | Type of litter |
|-------------------|------------------|---|
| Sewage derived | Feminine hygiene | Sanitary towels Panty liners Tampon/applicator |
| | General | Toilet paper Cotton buds Other/unidentified |
| Housing materials | Combustible | Fencing Hardboard/wood Other/unidentified |
| | Non-combustible | Brick/rubble Floor coverings Other/unidentified |
| Household (large) | Brown goods | Furniture Mattress/foam |
| | White goods | Other/unidentified |
| Household (small) | Metal | Cans/tins |

| | | |
|-----------------------|----------------|---|
| Commercial/industrial | Metal | Container drums Sheeting Other/unidentified |
| | Plastic | Polystyrene Sheeting < 30 cm Sheeting 30-60 cm Sheeting > 60 cm Plastic bags Sweet papers Bottles |
| | Glass | Bottles Other/unidentified |
| Transport-associated | Motor vehicles | Cars/parts Motorbikes/parts Other/unidentified |
| | General | Signs/cones |
| General | Packaging | Cardboard |
| | Miscellaneous | Cloth/shoes Rope/fishing line Other/unidentified |

Figure 12.3 Principal Component Analysis of litter sites along the River Cynon in summer and winter. Numbers represent litter types described in Table 12.3



12.2.5 Beach quality questionnaires

Beach quality questionnaires should be objective. Several rating systems are based on a limited number of parameters (Table 12.4) and it should be an axiom that ratings must cover physical, human and biological parameters. Nevertheless, many existing systems

have been found wanting in this respect. Virtually all the following do not take into consideration the beach user's perception of his or her environment.

The majority of beach quality schemes look at one or only a few of the parameters associated with beach ratings (Table 12.4). Beach aesthetics cannot be rated effectively on one facet alone, e.g. biological parameters. Table 12.4 shows a summary of the scope of a variety of beach awards and rating systems currently in place. Chapter 6 deals with beach award schemes in greater detail.

Table 12.4 An overview of the scope of selected beach awards and rating systems

| Component | European Blue Flag | Seaside Award (TBG) | Good Beach Guide (MCS) | NRA (sw region) | Chaverri, 1989 | Williams <i>et al.</i> , 1993 | Beach Quality Rating Scale |
|--|--------------------|---------------------|------------------------|-----------------|----------------|-------------------------------|----------------------------|
| Water quality | * | * | * | | * | * | * |
| Education and information | * | * | | | | | |
| Access | * | * | | | * | * | * |
| Lifeguards/first aid | * | * | | | | * | * |
| Litter | * | * | | | * | * | * |
| Sanitation | * | * | | | | | * |
| Sewage debris | * | * | * | * | * | * | * |
| Bathing water safety | | | | | * | * | * |
| Climate | | | | | * | * | * |
| Landscape quality | | | | | * | * | * |
| Beach material | | | | | * | * | * |
| Water temperature | | | | | * | * | * |
| Flora and fauna | | | | | * | * | * |
| Refreshments and facilities | Some | Some | | | | Some | * |
| Beach regulation (dogs, vehicles, etc.) | * | * | | | | * | * |
| Weighting of factors | | | | | | | * |
| Scoring based on preferences priorities of beach users | | | | | | | * |
| Quantification of most or all factors | | | * | * | | * | |
| Difference between resort/undeveloped beaches | | * | | | | | * |

TBG Tidy Britain Group
MCS Marine Conservation Society
NRA National Rivers Authority (south-west region)

12.3 Beach cleaning

Increasingly, environmental management systems are being used to assess the routine performance of management approaches to the environment. Sequences of planning, objective setting, implementation, audit and review are becoming commonplace. The audit process for such systems often requires field measurements to assess whether systems are working. Monitoring in terms of "cleanup" is often the response to litter. The cleaning of beaches provides a way of collecting data on the types and quantities of marine debris. However, the primary value of these methods is as public participation exercises and as a way of raising public awareness. The cleaning of beaches cannot solve the problem of marine debris permanently because they do not reduce the quantity of debris at source (Simmons and Williams, 1993). Physical "cleanups" are generally carried out by local authorities (Gilbert, 1996), local voluntary groups or volunteers co-ordinated by national voluntary bodies (Pollard and Parr, 1997). However, cleanups are really only useful at the local level, and they are expensive if undertaken by mechanical means or else they are labour intensive. Conversely, if volunteers are employed the costs are minimal. Site selection for beach cleaning programmes is biased towards areas with easy access, tourist locations and depositing beaches. Where volunteers are used, the collection of litter is the primary task and therefore the recording of the items is likely to be less of a priority (Rees and Pond, 1995a). Amos *et al.* (1995) have shown that volunteers participating in beach cleaning programmes undercounted individual items of debris by 50 per cent.

There are two methods of beach cleaning: mechanical and manual. Mechanical cleaning usually involves motorised equipment using a sieve effect that scoops up sand and retains the litter; therefore it is not selective. Litter retention is a function of the sieve. Most sieve machines are coarse grained allowing small items to pass through. The passage of such vehicles over the beach interferes with the beach ecology and the method is costly (Davidson *et al.*, 1991; Kirby, 1992; Acland, 1994; Llewellyn and Shackley, 1996). In addition this technique cannot be used on pebble beaches. Pressure to clean a beach is intense, especially where authorities wish to promote tourism. The advantages of such mechanical cleanups are that the result is achieved quickly, and large areas can be covered and they can provide an apparently pristine beach for visitors. Mechanical cleanups reduce the need for personal contact thus reducing health risks to individuals.

Manual beach cleaning programmes share many advantages and disadvantages with mechanical cleaning. They can help to raise community awareness of the litter problem and enable the sourcing of the litter (Earll, 1996) from a scientific perspective rather than scooping it up "en mass" for deposition in a landfill site. Manual beach cleanups organised as community events on small areas can ensure that the beach is cleaned of small items missed by mechanical methods (Pollard, 1996).

12.3.1 Economic aspects

Cleaning a country's coastline costs the responsible authorities large amounts of money each year. In the UK, Suffolk District Council estimated that GB£ 50,000 was spent each year on cleaning the grounds around the coast and picking up litter from the foreshore. Authorities in Kent estimated that between GB£ 32,000 and GB£ 48,000 was being spent annually per beach and the direct and indirect costs of dealing with litter on the Kent coast has been estimated at over GB£ 11 million (Gilbert, 1996), which places a strain on the Gross National Product (GNP) of the area. Woodspring District Council reported that GB£ 100,000 was spent on managing litter and sand on just two beaches in the district of Weston Super Mare (Acland, 1994). Nevertheless this expenditure is necessary for tourist beaches.

In 1993, it cost GB£ 937,000 to clean the Bohuslan coast of Sweden (Olin *et al.*, 1994) and more than US\$ 1 million was spent in 1988-89 cleaning up the coasts of Santa Monica and Long Beach in California (Kauffman and Brown, 1991). At Studland, Dorset, UK, one million visitors per year along a 6 km stretch of beach results in 12-13 tonnes of litter, collected each week during the summer months at a cost of GB£ 36,000 per annum. Additional costs are incurred when hazardous containers are found and have to be recovered from beaches (Dixon, 1992).

12.3.2 Measurable standards of cleanliness

The public perception of litter is intrinsically linked with standards of cleanliness. A number of issues become pertinent when setting standards or grades of cleanliness and these have been identified by Earll *et al.*, (1997).

- Will the public notice the standards set?
- If the public notice or recognise this material does it matter?
- At what level of littering do these issues become important to the public?
- Are the levels of litter indicative of other pollution, health and environmental hazards?

At present, it appears that very few standards of cleanliness exist regarding beach litter (see Chapter 6). It has been recognised that adequate information is required to support improvements in the cleaning of coastal waters and beaches (Anon, 1972). Coastal authorities, especially in Southern England, responded to the increasing amount of marine litter by extending the cleansing operation beyond the bathing season. The Royal Commission on Environmental Pollution (RCEP, 1984, 1985) noted the substantial costs incurred in beach cleaning operations. In the UK, the Environmental Protection Act (1990) sets standards of cleanliness under the Code of Practice issued under section 89(7) which are considered reasonable to meet. Local Authorities are encouraged to identify as "Category 5 Zone" areas, those beaches in their ownership or control that might reasonably be described as "amenity beaches". For such designated amenity beaches, the minimum standard is that they should be generally clear of all types of litter and refuse between May and September inclusive. This standard applies, not only to items discarded by beach users, but also to items or materials originating from disposal directly to the marine environment. The Code also notes that, in establishing a cleansing

standard for beaches, careful consideration should be given to the practical difficulties encountered in collecting and removing litter, and to the damage to sensitive habitats which may result from such operations (DoE, 1991).

Table 12.5 Relative contribution of different sources of the marine debris found in St Brides Bay, Wales, 1997

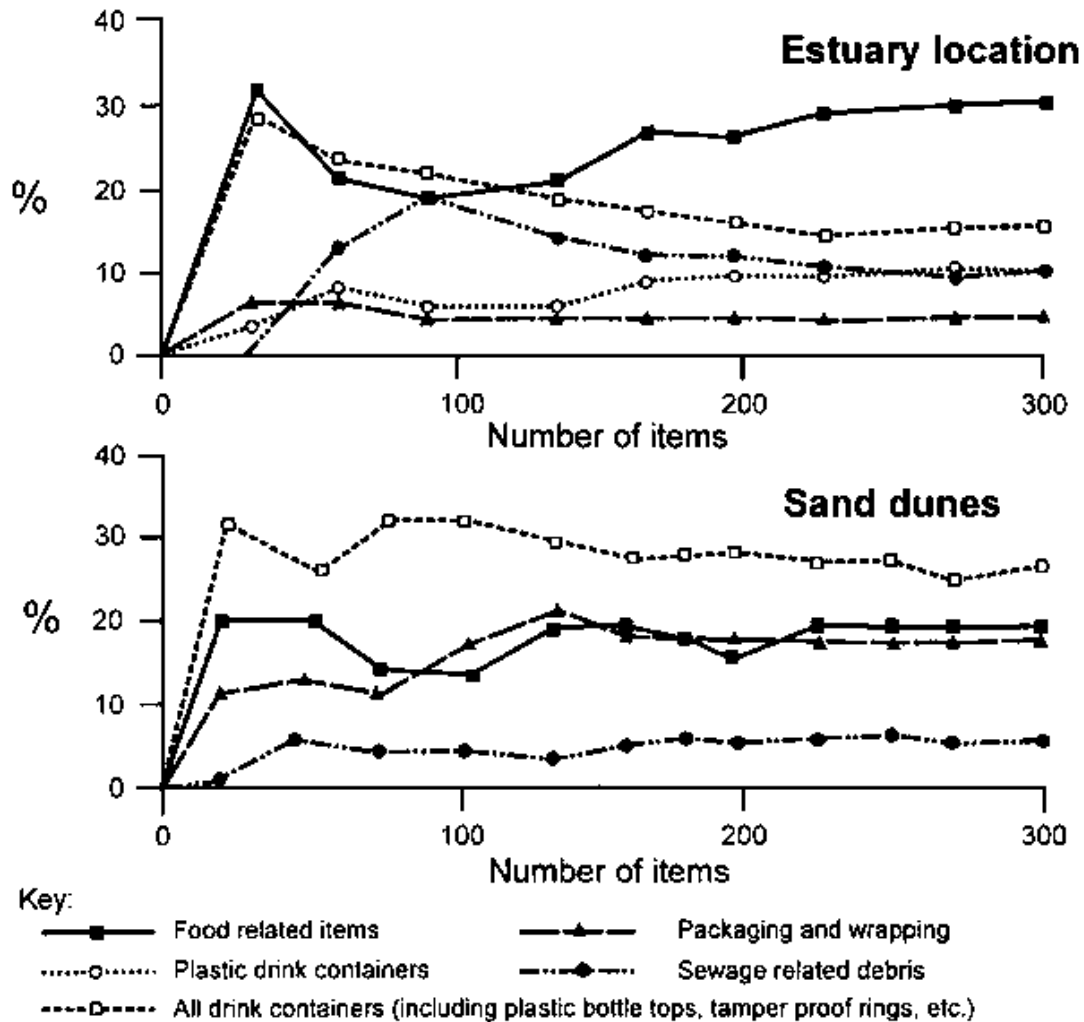
| Source | Summer (% of total) | Winter (% of total) | Average over the year (% of total) |
|-----------------------|------------------------|------------------------|---------------------------------------|
| Tourism | 15.7 | 1.8 | 8.8 |
| Shipping | 9.1 | 13.4 | 11.2 |
| Sewage-related debris | 2.9 | 3.4 | 3.2 |
| Fishing | 8.9 | 19.5 | 14.2 |
| Fly tipping | None found | None found | 0.0 |
| Medical items | None found | None found | 0.0 |
| Non-sourced | 63.0 | 61.7 | 62.6 |

12.4 Debris sourcing

An objective of collating and analysing litter is to identify the source because it is only when the source is known that really effective action can be undertaken to remedy the situation. It is essential to have robust quantitative information to enable litter types to be monitored in a systematic manner and to enable assessments and judgements to be made. Sources could be marine (ships), tourists on a beach, fly tipping or a river.

Dixon (1992) concluded that beach litter in the UK consisted mainly of waste generated by ships, sewage discharges and material discarded by the general public, and that discharges of rubbish from ships and other crafts constituted 70 per cent of litter. This is almost the opposite viewpoint to that expressed by Faris and Hart (1995) in the USA, Gabrielides *et al.* (1991) in the Mediterranean, Ross *et al.* (1991) in Canada and Pond and Rees (1994). Litter sourcing seems to be highly site specific and generalisations should be avoided. For example, work carried out at St Brides Bay, Wales in 1997 showed that fly tipping and medical waste were not sources from which litter originated (Table 12.5). Non-sourced litter accounted for 62 per cent of the litter generated. Frost and Cullen (1997) attempted to categorise debris on northern New South Wales beaches by dividing debris into that which has the potential to float and debris that sank. It was then assumed that floatable debris was marine-based and sinking debris was from land-based or *in situ* sources.

Figure 12.4 Cumulative percentage scores for litter: A. Estuary location; B. Sand dunes (After Earll *et al.*, 1997)



In Auckland City, attempts have been made to assess the scale of litter discharged from the City into the coastal marine area (Arnold, 1995). This involved monitoring material trapped by a 19 mm wire net placed on three storm-water catchments representative of each land use type. Comparison of the number of items associated with land-use types showed that industrial areas were the major source (9.69 items per hectare per day) followed by commercial (3.33 items per hectare per day) and residential areas (1.22 items per hectare per day).

An interesting approach for litter is to try to identify the people dropping the litter and to make inferences regarding their life style from the types of litter groups. This could help with direct prevention work. However, the number of items that should be collected in order to characterise life style groups still has to be resolved. One way would be to collect, for example, 200 items (in batches of 40-50 items) and to list them by function rather than by material and to carry out a similar analysis to that shown in Figure 12.2, but by plotting the number of categories against percentage occurrence and/or the

number of sampled items against the number of litter categories. The common items that should take priority would show up very clearly and a long "tail" would be shown in the plot (Figure 12.4) (Earll *et al.*, 1997). The above approach could be adopted easily and could be carried out on a routine basis and in a cost-effective way. Photography would be an invaluable aid in this approach.

12.5 Elements of good practice

The following are considered to be the main elements of good practice for monitoring aesthetic parameters.

- Monitoring for specific aesthetic pollution parameters should be undertaken where hazards to human health and well being are suspected.
- Selection of aesthetic pollution parameters for monitoring should take into account local conditions and should consider parameters such as surface accumulation of tar, scums, odours, plastic, macroscopic algae or macrophytes (stranded on the beach and/or accumulated in the water) or cyanobacterial and algal scums, dead animals, sewage-related debris and medical waste.
- Sampling of aesthetic pollution indicators should take into account the perception and requirements of the local and any visiting populations in relation to specific polluting items as well as in relation to the feasibility of their monitoring.

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