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Aquatic litter, management and prevention – the role of measurement

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Abstract. Methodology of litter management has many forms and increasingly measurement is linked to management. By providing measured profiles of the quality of litter types, trends in the input of new items can be assessed and prevention programmes directed more effectively to sources. Developing methodologies and their application to management cover three main areas.
1. Rapid appraisal where a framework of litter categories and pollution grades is used to map litter distribution on a broad geographic scale.
2. The benefits of using the 'species-area' approach with transects to enable quantitative data to be collected in a cost efficient manner.
3. Linking litter to an input source, requires that the qualities of individual litter items be assessed. The species area approach is useful in this context since by the time that 300 - 400 litter items have been described the main composition of a sample can be characterized and input sources attributed.

Keywords: Litter category; Litter management; Pollution.

Introduction

Issues relating to litter in the aquatic environment are becoming much more widely understood and it is being increasingly recognized as a serious pollutant which costs a great deal to clean up. There is an increasing understanding of the links between the original sources of aquatic litter, the complex mixture which ends up in the aquatic environment, the risks this litter poses and the alternative management options (Fig. 1). For many years, litter management equated only to physical clean-up. However, the costs of litter clean-up have escalated rapidly prompting beach managers to take a fresh look at more effective ways of preventing litter. This situation is made all the worse by the fact that clean-up is only a temporary solution and depending on the site, beaches become littered very rapidly. '*Prevention at the source'* is the much trumpeted aim of many anti-litter programmes, however, for this to become a reality much stronger links need to be established between measurement and management. Whilst the saying '*You cannot manage what you cannot measure'* is routine currency in environmental management, there are still some major challenges facing those who seek to link litter measurement to effective prevention at source measures. This paper reviews progress with litter measurement on a number of fronts and highlights those areas where progress is needed if prevention at source is to operate effectively.

Most surveys are limited by time, in monitoring frequency or the total length for the survey. An important point all surveys must acknowledge is the skill level of the end-user, and their expected data collection proficiency. Often a survey aimed at public participation will be targeted as much towards providing an educational package for participants as to providing a means of collecting data. In doing so they serve two equally valid functions.

Review of methods

The Coastwatch UK Survey is an example of a public participation survey (Williams & Pond 1999), and forms part of the Coastwatch Europe organization. It is targeted towards volunteer groups and aims to gather basic information from large geographical areas. In almost all cases riverine litter assessments have evolved from their more established marine counterparts. In parallel with Coastwatch UK, a riverine survey form was launched in 1991, named Riverwatch. Its user-friendly format is similar to that of Coastwatch, along with a large geographical target area. Riverwatch, however, aims to monitor all aspects of river pollution, of which only a small part relates to litter. Both surveys fulfil educational roles in raising the environmental awareness of the large number of volunteers who participate each year. Results are collected on an annual basis and cover large areas which would be logistically impossible without public participation. Unfortunately,

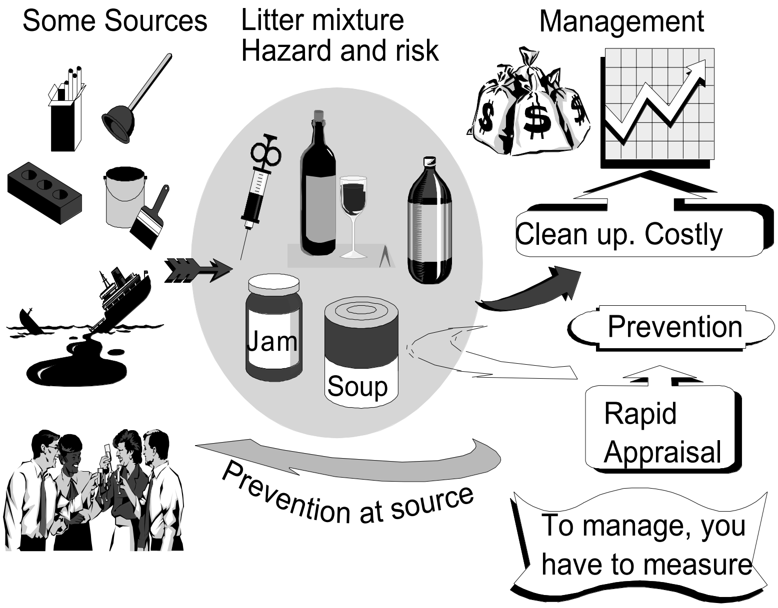

Fig. 1. Aquatic litter linkages.

a problem inherent with volunteer-based surveys is the questionable credibility of results. With no training, unskilled surveyors cannot guarantee any consistency in monitoring techniques. As such, results from this type of survey should be treated with caution.

Surveys targeted for use within the scientific community tend to be more rigorous in the sampling methodologies used and, the type of data collected. One of the first marine surveys of this nature was developed by Garber (1960) who attempted to quantify the appearance of receiving waters as an operational efficiency indicator of offshore treatment plants. This approach was later adapted for use as a shoreline survey (Anon. 1992). Garber's (1960) logsheet, was split into two sections. Section A dealt with the presence and absence of certain visual characteristics which related to water quality: Section B dealt with material quantification at differing beach positions, and numbers and activities of beach/sea users. The survey format gave immediate assessment allowing rapid assimilation of valuable information on the recreational water quality of large areas. The main drawback of Garber's (1960) approach was its subjectiveness. For example, for water quality factors, only presence and absence were recorded in section A. This may be insufficient since, for example, the amount of material such as tar/floating matter may be important. However, even in section B, where material quantification was attempted, assessment was still subjective with the application of a scale ranging from absence of material to an amount which was sufficient to be objectionable. Another deficiency was that no guidelines or definitions were given relating to this scale.

Again, a riverine equivalent has been developed based on this marine survey. The National Rivers Authority (NRA), now part of the Environment Agency (which has a legal duty to protect and improve the environment throughout England and Wales), used facets of Garber's (1960) work for their Investigation of the River Taff Litter Problem (Davies 1989). The river, which is located in South Wales, UK, was primarily divided along its length into 2-km reaches. On a random ease of access basis, one 40-m site was selected within each reach, and a subjective qualitative assessment of litter, within the river channel and on both banks, was carried out using a scale adapted from Garber (1960). A 5-m belt transect was then established and litter quantified on a logarithmic scale. This study allowed for far more extensive site descriptions, and although still anecdotal in parts, the checklist did include litter categories more relevant to the riverine situation. Unfortunately litter types were not grouped, except for a division between sewage and other refuse. This method has since been applied to assess litter on two tributaries of the River Taff, namely the River Cynon and River Rhondda (Davies & Boden 1991).

Another bench mark in marine litter assessments was devised by Dixon & Dixon (1981) for the Tidy Britain Group's (TBG) Marine Litter Research Programme. The TBG is an independent charity charged with the improvement of local environments across the UK. The TBG has had the Marine Litter Research Programme in place since 1973, with the primary aim of generating accurate and representative data showing the types, quantities, sources and other attributes of marine litter in the coastal and oceanic waters of the UK (Dixon 1995).

This involved a more complex sampling regime, and required certain specialist knowledge for accurate item identification. The survey could be implemented in many ways; to gather nominal, ordinal or interval scale data, or to review the effectiveness of certain litter abatement legislation. Dixon & Dixon (1981) in their marine litter surveillance study, outlined the following method of beach litter assessment. Stratified random sampling was used to select beach survey sites. Within these survey sites, sampling areas were also selected via random number tables. Three, 5-m wide belt transects were used. They were orthogonal to the sea, encompassed all high water marks and wind-blown litter, and extended an additional 30 m down shore. Data on abundance, fabrication of materials, geographical origins, ages and original contents of containers were recorded within these transects. A checklist allowed data recording in predetermined categories, giving definitive results rather than anecdotal descriptions. This method has been widely accepted as a technique to study marine litter (Simmons & Williams 1993) and has been further adapted to investigate specific problem areas. Marine surveys have greatly influenced the formulation of methodologies of riverine litter management. Although obvious parallels do exist between approaches needed for both marine and riverine assessments, it is not sufficient to simply apply one to the other, due to physical differences within each environment. Therefore caution is urged when assessing these two different environments,

Survey forms (Anon. 1991a) developed by the NRA and the TBG for The Yorkshire Rivers Litter Monitoring Project, hardly differed from those used for the TBG's Marine Litter Research Programme (Dixon & Dixon 1981). Litter types were categorized primarily by composition i.e. metal, paper, plastic, with some additional arbitrary groupings. The benefits of this approach were negated by the 'details of visit' section which requested anecdotal recordings such as description of sites and possible sources of litter. Such recordings result in data analysis limitations. Little consideration within the research literature appears to have been given to the differences between marine and riverine litter. Emphasis has been placed on the recording of container details, as in the marine surveys e.g. age and place of manufacture. Containers, however, appeared to be a far less prominent feature of riverine systems. More evident were household wastes such as furniture and decorating material due to the high incidence of fly-tipping (Williams & Simmons 1997). Omission of such categories and the lack of site background information meant considerable improvements were necessary in order that the data would allow relevant hypotheses to be formulated and tested. Each site must be evaluated as site specific.

Links to measurement

A wide range of measurement methods have been applied to aquatic litter studies and a selection is described below**.** The general aims behind these projects often involve a number of social, educational and scientific ideas. Whilst all these approaches are valid, the problem of aquatic litter is not being resolved and measurement alone is not solving the problem. Measurement has to be seen as part of the overall management of the aquatic litter pollution issue.

Public awareness through public involvement: Projects such as Coastwatch Europe involve thousands of people in recording aspects of the marine environment, including litter.

Beach cleaning and public involvement: A number of public participation projects, including Beachwatch, have involved large numbers of volunteers collecting beach litter but then carefully recording the items collected. This can be linked to education about recycling schemes. The Beachwatch campaign was launched in the UK in 1993 by the Marine Conservation Society charity to raise awareness of the problem of marine and coastal litter, and to monitor levels and sources of litter on Britain's beaches (Pollard et al. 1999).

Beach cleaning – with secondary recording: In Sweden, a major programme of litter clearance in the coastal zone has removed tonnes of debris using previously unemployed people on work programmes. During this process, statistics about the types of litter have also been collected to assist with sourcing and lobbying activities (Olin et al. 1995).

Education – in a formal sense: Teaching and education in a formal sense in schools, requires a good deal of thought to make project material relevant to the needs of children and the curriculum at different stages of development and of practical use for teachers. Studies of aquatic litter are increasingly being used in colleges of further education and universities.

Public perception – aesthetics: A number of major studies have recently been completed on the aesthetic aspects of litter pollution (Williams & Nelson 1997). The difference between say one condom and a naturally weathered log is enormous in terms of the response evoked from the public and methods used by social scientists become highly relevant in this context.

Quantitative measurements of litter on beaches: These are undertaken by a variety of organizations e.g. Coastwatch, to measure quite specific items for different purposes, e.g. the number of cotton buds per $0.25m^2$ as an indication of sewage-related debris (SRD).

Age of litter: One of the major concerns about litter, especially plastics, glass and aluminium, is that it is persistent and accumulates in the environment. A variety of studies have set out to collect data on specific products to see how long they survive in the environment (e.g. Pruter 1987).

Sources of litter: Preventing pollution at source requires that the source is known. This can be attempted with differing levels of subtlety. In many cases the sources are obvious and local (Willoughby et al. 1997). However, in coastal situations, the sources can also be international either in terms of shipping or land based litter from other continents e.g. American litter on west coast European shores (Olin et al. 1995).

Rapid appraisal prior to management programmes: The need to assess levels of litter so that the logistics of physical removal can be estimated, has led to the development of rapid appraisal methods using photographic comparisons. This approach has been widely used in recent river based programmes e.g. the river Taff in South Wales.

Specific surveys in relation to particular threats: Sewage-related debris, monofilament netting, the small plastic pellets at the sea surface, pyrotechnics washed up on beaches, drugs and needles on beaches have all been the subject of specific studies to quantify the nature of the problem and risk (Dixon & Dixon 1981; Gregory 1977; Williams & Simmons 1996).

Dynamics of litter in the environment: We still do not understand enough about the movements, degradation rates, final sinks of litter in the aquatic environment and this is a fertile area for study (Bowman et al. 1998; Williams & Simmons 1997).

Social studies of littering: Studies on *people* of why littering takes place in particular situations e.g. fly-tipping, or failure to use port reception facilities, are likely to be very important in future as greater emphasis is placed on management aimed at preventing litter.

This paper presents results from UK initiatives which are seeking to make links between measurement and management more effective. These approaches highlight those areas where progress will be needed if the links between measurement, management and prevention are to be made more effectively. Three areas of development are described:

1. Rapid appraisal methods to standardize categories and grades of litter pollution.
2. Species area curves which enable researchers to determine how large sampling areas should be.
3. Initiatives on sourcing.

Developing a standardized approach for comparing beach litter pollution

In the last few years it has become widely recognized that the problem of litter in rivers, estuaries and at the coast, far from being under control, is actually getting worse. In particular, the increase in sewage-related debris has caused much concern. There is a strong desire to be able to measure litter pollution in the aquatic environment so as to be able to effectively manage and prevent it. A workshop in 1995 set out general principles for developing a wide range of litter studies (Earll et al. 1996). Whilst there is clearly a need to be able to monitor litter pollution in the aquatic environment there has been no widely accepted standardized approach to enable this to be done. This is probably because:

- ‘beaches’ and their hinterland are extremely variable in size, structure and dynamic processes.
- the location of litter on beaches is extremely variable and depends on many physical processes.
- the types, quantities and sources of the litter make its composition very variable.

This has led to a wide variety of methods being used to describe and measure litter which are not directly comparable because situations or objectives differ. There are a wide variety of individuals and organizations who use different methods and they seem unlikely to change these drastically. Is it possible to devise a standardized framework which enable site data to be compared from the different projects? In November 1996, the UK National Aquatic Litter Group held a workshop recognizing these problems to see if they could be resolved. A series of discussion drafts were prepared both before and after the workshop and the concept is now being integrated with the UK Environment Agency approach to general quality assessment (GQA). The broad aim of this workshop, was to develop a standardized approach which included both general litter and sewage-related debris and which would enable both sites to be assessed and national trends to be detected.

Standardized grades and categories

In resolving this situation, the workshop drew heavily upon two models: firstly the Environment Agency pollution incident categories and secondly, the ABCD grading used in the Code of Practice on Litter and Refuse developed for the 1990 Environment Protection Act (Anon. 1991b) and the Thames Clean Project (Lloyd 1996). The solution developed by the workshop process puts forward the concept of *standardized grades and categories* for describing beach litter. This has the main virtue that different methods and different types of litter can be assessed and compared. This operates in the same way that the pollution incident categories work (Anon. 1995). This is essentially a crude tool but it does enable comparisons to be made and priorities developed.

Standardized grades

The grades outlined below are taken from the Thames Clean approach (Lloyd 1996).

Grade A: Absent: no evidence of litter anywhere.

Grade B: Trace: predominantly free from litter apart from a few small items.

Grade C: Unacceptable: some at intervals; widespread distribution of litter with minor accumulations.

Grade D: Objectionable amount: area heavily littered, with much accumulation.

Number of grades

The four-grade system, whether it be for litter or pollution incidents, is a crude tool designed to encourage significant progress. There is little purpose to be served by increasing the grades to five – because it would give the approach a spurious precision which it did not warrant. In practice, the Environment Agency, UK, and others have found that when problem sites or situations have be identified using this approach, a variety of more sophisticated techniques can then be brought to bear to collect appropriate information.

For the purposes of this paper the ABCD grading system will be used with the caveats that:

- at this point it has no implications for beach management in the sense implied by the DoE Code of Practice on Litter and Refuse (Anon. 1991b).
- it is probably not the most useful system for communicating study results.

Standardized litter pollution categories

The basic idea is that different categories can be used to assess the litter grades (A-D) of the beach. In relation to pollution incidents, for example, a fish kill or a breach of consent conditions, both can lead to a 'grade' 1 incident even though they would require *different* methods to detect. In this scheme different methods which generate information about different types of litter can be used to asses the litter grade of the beach. The litter pollution categories chosen were 'weighted' towards the areas of greatest public concern particularly with relation to perception (Williams & Nelson 1997) to include:

- sewage-related debris;
- accumulations of litter;
- the quantity of general and gross litter;
- harmful litter e.g. medical waste;
- oil;
- faeces.

Sampling unit

The standard sampling unit consists of a 100-m wide transect of the beach and extends from the landward edge of the usable beach, through and along the highest strandline and then down to the current strandline. There is a maximum 50 m distance down the beach from the highest strandline. The beach is classified according to the highest grade (A,B,C,D) recorded.

Functions of the standardized grades and categories

One of the main problems at present is that because all the major methods use different measures, it is very difficult to compare the results of the major surveys annually to assess the litter black spots or whether there are major trends in litter pollution. In other cases people 'know' a good deal about the distribution of litter on a stretch of coast – where it accumulates routinely, processes and inputs – this knowledge needs to be 'captured' and published. This is so-called phase one survey information – in essence the broad picture – which is needed before detailed studies are conducted.

The purpose of the standardized approach serves at least five functions:

1. Assessing the beach litter problem – developing priorities: It is envisaged that initially mapping will enable beaches to be identified routinely, and this will enable beaches which have consistently poor litter records to be identified.
2. Harmonizing methods: There seems little doubt that by clarifying the categories of litter which are being recorded and specifying the sampling details this will begin to enable a wide range of projects to harmonise their methods. It will also provide clear guidelines for new projects which arise.
3. Communication to the public: This grading approach could be used to communicate the litter pollution features of a beach to the public through the media; work is currently underway to see what the best system might be – ABCD – is not necessarily thought to be the most helpful in communication terms. The way that the individual litter categories contribute to

an overall beach grade is also being explored since there is a range of options available.

4. Beach management: In the UK the Environment Protection Act uses a ABCD grading system on land to relate the degree of littering directly to management (clean-up) operations. Further work is being undertaken to see how the grading approach can be adapted to management covering a wide range of resort and wilderness beaches. It is likely that the litter grading will be part of a more comprehensive beach management package.
5. Monitoring: The use of the litter categories for specific beaches could be easily incorporated into a beach litter monitoring project. Repeated assessments for these categories will provide a clearer picture of the dynamics of littering.

It seems likely that this approach will point to where litter black spots are and the need to focus efforts at those sites. The scheme is being actively developed during 1997 and 1998 with a view to adoption by the Environment Agency in 1999. It provides the survey stage assessment of where, how much and the implications of the problem. To link litter to sourcing requires that a more detailed approach be taken which links litter items directly with sources. Function is subservient to material (genus) but knowing that it is for example plastic is not enough. In reality, even a small number of items will provide a range of categories, all of which can contain useful information.

Species area curves

Surveys

Surveys in associated litter research areas have been designed to fulfil a variety of objectives. These range from simple enumeration studies, giving quantitative and compositional results (Corbin & Singh 1993), to detailed monitoring of indicator items, providing insight into origins and ages of for example waste (Dixon 1995). Studies are often designed to gain basic data covering large geographical origins, or to collect detailed information on specific regions. A theoretical vacuum exists in geographical fieldwork as to what sample size (*N*) the number of samples to be taken from a population which are representative of that population, should be taken for field transects. In a recent research project (Simmons 1993), no definitive methodology could be found to act as a guideline for current/ future work in riverine and marine litter assessment. Therefore survey design and methodological development are considered to be of paramount importance.

These are helpful in the design of methodologies for litter research, successful environmental sampling studies require detailed planning of the major tasks involved. In response to this, many statisticians and environmental scientists have provided guidelines to aid formulation of sound survey designs (Cochran 1977; 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. Due to the diversity of previous work in this general area, no precedent exists regarding the optimum type of data, i.e. qualitative or quantitative.

A pilot study

The River Cynon, a tributary of the river Taff, South Wales, UK, was chosen for a pilot study. The Cynon's close proximity to the river Taff and small size (22 km) enabled a detailed knowledge of the area and litter processes to be gained. This critical insight was channelled towards the development of a suitable sampling programme. Important in any environmental sampling program design is the definition of the target and sampled populations. Gilbert (1987: 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". As it is not logistically possible, and also dangerous, to reach every part of a river to assess the litter problem, the target population must be limited to litter at river sites deemed accessible for sampling purposes. The sampled population is limited by sampling design requirements. In this case it was decided that the sampled population should be litter on accessible sites with predominantly natural banks for a length of at least 50 m, where both banks could be sampled up to the bankfull position. In practice this meant a transect of ca. 30 m in length. A series of contiguous quadrats were laid along the upstream marker of a belt transect, starting at the water's edge and finishing at the natural limit of the bank (sites chosen with predominantly natural characteristics). Within each quadrat, abundance was measured in the form of density counts, i.e. the number of individuals of particular litter types within a quadrat.

Initially, all possible sites were noted from an accessibility and size viewpoint, and for the small scale pilot survey all potential sites (20) were assessed. Due to logistical problems of assessing all litter at a site, representative sampling units were needed to provide an accurate portrayal of the whole site. Dixon & Dixon's (1981) approach of assessing litter within randomly placed transects was adopted for this purpose. Transects used in marine litter surveys are commonly 5 m wide. This width was apparently arbitrarily chosen without any justification or discussion regarding implications with respect to

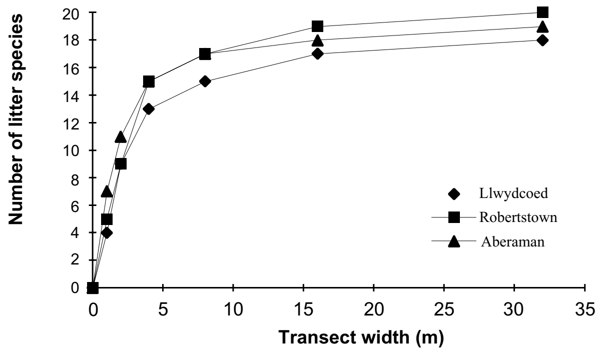

Fig. 2. Minimal area curve: River Cynon sites.

sample representativeness. Before applying this method to riverine assessments, literature confirmation was sought regarding the representativeness of transects as sampling units. The classic minimal area analyses from the Braun-Blanquet (1932) school of phytosociology followed by Gilbertson et al. (1985). This approach initially developed for determining optimum quadrat sizes for sampling plant species in ecological studies, was adapted to determine whether transect sampling was an appropriate method for river litter assessments (species), and if suitable, to assess the optimum transect width size. The principle is that narrow belt transects are more easily studied, and enable work to be achieved quicker, but wider transects probably yield more reliable data. Therefore, the optimum transect width is one which provides a reliable representation of the litter present, for the minimum amount of work. To determine this optimum width, data were obtained from all 20 survey sites of which three minimal area curves have been plotted and shown in Fig. 2. A similar pattern was encountered in all cases.

Starting from the site's centre point, a tape was placed up the river bank, perpendicular to the river flow. A second tape was then placed parallel to the first, at the smallest distance apart (in this case ca. 10 cm). The number of litter types were then counted and recorded. The exact initial distance decided upon was unimportant, as long as it was small enough to contain only one or two items, as recordings were made in relation to a doubling of transect width, and not as a function of the exact width measurement. The transect width was doubled and the number of litter types present again counted. The doubling and counting procedure was repeated until the number of litter types at each doubling of the transect width levelled off. The curve starts to level off at the point that resembles the minimal width necessary to obtain representative samples.

Fig. 2. shows that the three different sites produced similar curves, with the curve gradient indicating the number of litter types found, beginning to level off after five metres. It is very difficult to determine on an objective basis the exact position of the 'break point'. At 5 m transect width 13-15 litter types can be identified; at 15 m we have 15-17. Detailed field work showed that 20 litter types were present at these sites, i.e. 5-m transect widths covered 65% - 75%; 15-m widths 75% - 85% of the litter present. The 5-m width has been utilized in many litter surveys (Davies 1989; Dixon & Dixon 1981).

In Dixon & Dixon's (1981) beach assessments, three transects were assessed within each site. The representativeness of this approach was investigated, this time applying pre-specified relative error (Gilbert 1987). A definitive result could not be obtained from this approach as the method was devised for univariate analyses. However, a measure of the appropriateness of transects sampling for each of the litter types was still considered important. The within-site variation of data was measured at three sites (Aberaman, site 12; Robertstown, site 9; Llwydcoed, site 8). 10 5-m wide transects were positioned at each site, from which quantities of litter types were recorded. Calculations showed that for the same pre-specified relative error, differing litter types required vastly differing numbers of transects to be assessed to form a representative sample (Simmons & Williams 1997). Commonly occurring litter types such as plastic sheeting and sewage-derived articles could be realistically represented using only three transects. Conversely, items such as cans, floor covering and wire/cable required up to 17 transects to be sampled to produce results with the same margin of error. In the case of rare litter items, for example packaging crates, as many as 65 transects would be necessary. Results seemed to indicate that any between-site comparisons should only be carried out using those litter types known to have a more uniform within-site distribution. Site comparisons of other litter types would be meaningless as the within-site variation could be greater than that due to the differences between two sites. Gilbert (1987) stressed that these measurements of error should be considered within the realms of realistic sampling procedures. In light of the logistical difficulties of sampling large numbers of transects any site, it is proposed that the standard three transects should be assessed, but with realization of its limitations.

Three 5-m width transects can represent the main litter items at riverine and marine sites. A fixed point must be set at each site. If there is no obvious permanent landmark, an artificial marker may be positioned. From this point a random number table can be used to determine positions of three non-overlapping transects within site boundaries. A value obtained from a random number table can be paced downstream/down beach and tapes placed up both banks perpendicular to the river flow, or down beach. A distance of 5 m is measured and further tapes placed parallel to those already laid, clearly marking out the belt transect. Following this method, three transects can be positioned randomly from which qualitative and quantitative information can be found.

Sourcing

Sources of aquatic litter

There exists a multiplicity of sources/impacts. The mix of litter items found on river or sea shores is usually derived from a variety of sources (Fig. 1). Whilst pie charts which ascribe proportions to one source or another are very popular, in reality for any given site these proportions can change very significantly. In these circumstances one cannot generalise or make assumptions about sources – site specific measurements will almost always be required. The attribution of litter to broad sourcing categories would help direct prevention work and should be an essential part of monitoring work. There is a growing awareness of the impacts of main sources of pollution – which can be briefly summarized as:

1. Fishing: Fishing related debris, nets, ropes etc. The fishing industry is very susceptible to their own litter e.g. rope fouling propellers (Jones 1995). Netting, and ghost fishing have also been a considerable concern in relation to the impacts on wildlife (Pruter 1987).
2. Tourism: The huge scale of litter from tourist sources, forces most resorts to cleanse their beaches regularly (Olin et al. 1995).
3. Sewage related debris: With increased use and longevity of plastics in feminine hygiene products, cotton buds etc. (Williams & Simmons 1996), it has become very evident that sewerage systems are failing to prevent these items contaminating large areas of coast (Velander & Mocogni 1998). Health risks of bathing in sewage contaminated seas are increasingly well documented.
4. Domestic litter from waste dumps, burning or fly-tipping adjacent to the water: It is increasingly recognized that inputs of domestic and other types of waste on the coast or riverbank can become a significant part of litter in the aquatic environment, including rural areas where the seashore is often viewed as a convenient site for burning (Williams & Simmons 1997, 1999).

Developing links to sourcing

'Sourcing is the key to prevention of littering' is the mantra cited most often by those justifying a wide range of measurement methods. The fact is that there is little in the way of a current methodology which enables researchers to address many of the issues which are raised by this approach. Direct analogies exist with ecology. Much sourcing in the past has focused on the minutiae of identifying certain of the species – items of litter, whereas what is required is a combination of both a

Table 1. Litter pollution categories.

A. Sewage related debris - general

	A	B	C	D
Abundance	0	1 - 4	5 - 9	10

•The general component of sewage related debris includes: condoms, condom rings, sanitary towels, plastic backing strips from sanitary towels, tampon applicators, colostomy bags, toilet paper and fatty deposits.
•The key distinction is that the numbers of SRD (1 - 4) indicate individual use (by beach users) rather than a chronic or systematic discharge on a large scale (> 5 items).

B. Sewage related debris – Cotton bud sticks [CBS]

	A	B	C	D
Abundance	0-9	10-49	50-99	100

C. General litter

	A	B	C	D
General Litter	0-49	50-99	100-999	1000

•General litter includes all household items such as drink cans, food packaging, cigarette packets and any other item less than 50 cm in dimension. Items with a maximum diameter of less than 1 cm are not included.

D. Gross litter

	A	B	C	D
Abundance	0	1-5	6 - 9	10

•Gross litter comprises items that have at least one dimension greater than 50 cm. These include such items as shopping trolleys, pieces of furniture, large plastic or metal containers, road cones, bicycles, prams and large items of 'processed' wood e.g. pallets. Driftwood should not be included.

E. Harmful litter

	A	B	C	D
Abundance	0	1-5	6-24	25

•Harmful litter for the purposes of this table includes, sharp broken glass, medical waste (e.g. used syringes), sharps (metal wastes, barbed wire etc.), fresh disposable nappies, containers marked as containing toxic products and other dangerous products such as flares, ammunition and explosives.
•The key distinction is that the numbers 1-5 indicate individual use by beach users rather than a chronic or systematic discharge (>5 items) on a large scale.

F. Accumulations of litter

	A	B	C	D
Abundance	0	1-4	5-9	10

Accumulations of litter can occur behind the highest high water strandline either as a result of being blown by the wind or dumped by users of the beach, and in the high water strandline, often in seaweed.

G. Oil and other oil like substances

	A	B	CD
absent	trace	some	objectionable

•Oil should be assessed as to its general presence or absence and whether it is objectionable. This should cover all oil waste (mineral or vegetable), either from fresh oil spills or the presence of weathered oil deposits and tarry wastes. The assessment will necessarily be subjective.

H. Faeces (Non human)

A	B	C	D
0	1-5	6-24	25+

•The numbers of animal faeces (usually dogs) should be counted in each survey zone. Faeces from animals such as sheep, which tend to occur in groups, should be counted as one item per group.

good taxonomy and methodologies which look at the communities (mixtures) of litter which are found in reality.

Unless types of litter can be identified reasonably accurately then there is no chance of linking litter to sources. A significant portion of the litter in any sample will always be unidentifiable in any practical sense in relation to its source. As in ecology there need to be guides to the species of litter – but there appear to none. Such guides are required to enable:

- A consistent approach to be developed to identification and vocabulary.
- To capture the experience of identifying particular parts of the litter.
- Communication of this information to species to third parties.

Three approaches are being developed :

1. Species guide: Earll et al. (1999) using the framework provided by the Marine Conservation Society marine species guides, have developed A4 identification sheets which use standardized headings, to describe the litter and photographs to illustrate this. The basic idea is that the sheets can be used as a framework and built up as knowledge of particular areas litter is acquired. The information on these identification sheets can then be easily shared.
2. Aquatic litter information system: Exploratory work has begun developing this litter guide approach on a virtual web site and exploring how this would work in practice. The web provides a medium where the use of lots of images is becoming a relatively easy and cheap way to publish information of this nature.
3. Lists of litter items linked to specific sources: The idea is to list those items which are directly attributable to particular input sources in order assist this process by third parties. Some examples could include:

- Fishing: Ropes, netting, monofilament, fish tags, hooks, floats, etc.
- Sewage related debris: Cotton buds, condoms, feminine sanitary towels, tampon applicators, colostomy bags, toilet disinfectant holders, baby dummies etc.

The above lists can be expanded considerably with specific examples and varieties of rope, sanitary products etc. The interesting part of this is that with more knowledge, distinctive items like cyclume tubes and toilet disinfectant holders can also be associated to particular sources enabling attributions to be made more effectively. Much more research needs to be focused in this area.

Fieldwork checklists

A number of fieldwork checklists have been developed for projects like Beachwatch (Centre for Marine Conservation) and Coastwatch Europe to enable volunteers to score the litter they observe. These and other lists have two main weaknesses. Firstly they have focused on a classification based on materials – glass, plastic, paper, wood, and secondly of necessity, they are restricted in the number of categories they can provide to 50 or 60 boxes. In restricting the description of litter to 50 or 60 categories considerable information is lost. For example on a recent survey of two beach sites which recorded 600 items of litter, 150 distinct categories/ items of litter were described. In developing the link to sources, this potential information loss from using standard lists is important not least because it can conceal trends in new products reaching the litter. Modern computing means that project specific checklists can easily be constructed. All the pointers suggest that better quality (more detailed) descriptions of individual items will enable attribution to source to be completed more effectively.

In linking litter specimens to source it is the function of the item which relates most directly to the source not its material composition. Sweet wrappers in large amounts suggest a link to a source but simply enumerating that 10 pieces of paper occur is of little information value in relation to sourcing. Many litter items are plastic but seeing another pie diagram with the proportions of plastic to wood etc. really does almost nothing to link litter to sources.

How many specimens of litter do you need to characterise a sample?

Litter is a serious concern; how many litter items would you need to identify to characterise *the source* of the litter - 100, 200, 300? If this cannot be done then any pretence at linking litter measurement to prevention should be dropped. So having gone beyond the surveys that indicate that litter is a problem, more detailed assessments will be required to attribute it to particular sources. Figs. 3a and b show cumulative percentage scores for the major categories of litter at two sites, an estuary and at the strand line of a dune system all located at Merthyr Mawr, South Wales, UK.

Samples comprising 25 items of litter were collected by different field workers and described until 300 items had been collected from each site. In the laboratory a common checklist was constructed and litter items assigned to the checklist categories. Fig. 3 shows that the major types of litter including ca. 60% of the items found, can be characterized. From a practical analysis, the proportions of major litter types change very little (one or

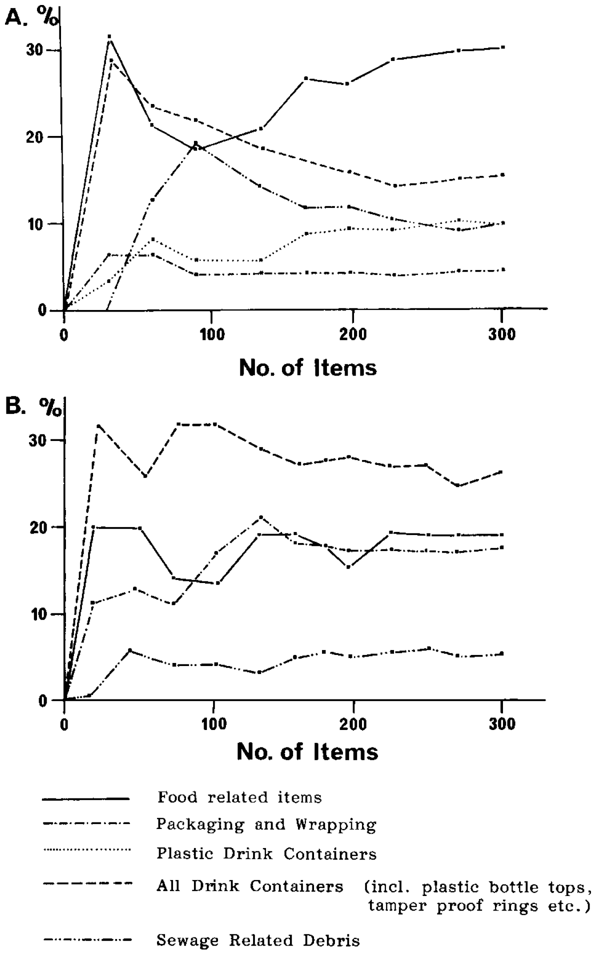

Fig. 3. Cumulative percentage scores for litter; **A.** Sand dunes; **B.** Estuary.

two percentage points) between 100 and 300 items. This is a significant finding because processing samples takes time and if good characterization can be obtained through the analysis of a smaller number of specimens then this will have important cost benefits. It illustrates also that decision making in relation to sampling can be based on this approach, for example there is little point collecting further plastic bottles if the information being gained has levelled off. At this point it may be more instructive to collect information on a particular type of litter which is not so common.

These particular samples illustrated the systematic pollution of these beaches by sewage related debris. Food related items were those associated with recreational tourism sweet wrappers, ice cream wrappers etc. A significant item was plastic bottles and their associated parts – tamper proof rings, bottle tops etc. The vast majority of these items contained soft drinks, lemonade etc. one would normally associate with the younger generation. In order to make sense of the array of plastic bottles a visit to the supermarket is essential because at this point it is possible to build the picture of the grouping actually doing the littering.

Conclusions

The three main approaches described illustrate developing thinking, set in the context of a growing desire to resolve a wide range of issues surrounding litter measurement so that valuable information can be provided in a cost effective manner to guide management approaches. Studies of risk (Risk = Hazard + Effect) to specific groups are increasingly well understood, for example, plastic pellets and petrel feeding, drift nets and seals, sewage related debris, water quality (Nelson & Williams 1997). While such knowledge is valuable, it also begs the question of how this knowledge is linked to management to prevent the problem. Increasingly, environmental management systems are being used to assess the routine performance of management approaches to the environment. Sequence of planning, objective setting, implementation, audit and review are becoming commonplace. The audit process for such systems will often require field measurements to assess whether systems are working. Monitoring in terms of clean up is often the response to litter. However, beach clean-ups are expensive – in 1993, it cost £937 000 to clean the Bohuslan coast of Sweden (Olin et al. 1995)– but have to be done on tourist beaches. However, clean ups *per se* are pointless if they do not address the issues of prevention at the source and it is the links to sources that represents the future challenge (Fig. 1).

Sourcing litter can be likened to species identification but needs to be more like community ecology. It is from litter group assessments that the social grouping which put litter into the environment can be attributed. The use of photography helps identification and description and communication. In addition, the power of photography to communicate in this area has been underused. Litter offends very directly and because of this photography can be used with great effect to communicate degrees of litter in a variety of settings, not least rapid appraisal methods. This can allow a wide range of workers to assess whether there exists a problem or not. If there is, the range of methods presented here will enable workers to assess in a cost effective manner how many samples are needed to obtain quantitative information. Litter guides on paper or the Internet will enable researchers to communicate more effectively. More importantly photos are powerful tools in communicating results to the public and decision makers.

Linking people doing measurements, with people who are managing the sources, will require effective

communication. If measurement methods are to be viewed as relevant to management and not undertaken in an academic vacuum, then they must be more directly linked to management outcomes. In the UK a series of meetings on aquatic litter has le
d to the development of a National Aquatic Litter Group which spans a very wide constituency including both those people doing the measuring to those with the power to prevent litter through investment in ports, local authorities and water companies. The power of net-working has also led to developments such as the standardized approach (ABCD) which has drawn a high level of support across a wide constituency.

The measurement of 'field' litter is but part of the process of establishing links to social groups. Once successful attribution to source has been made then management work will need to focus on prevention programmes. There will be a real need both to test the effectiveness of programmes by field measurements and on the targeted people. In developing approaches to combat aquatic litter, 'measurement' is, and will come, to play an important part. If a link to prevention at source is to be realized, considerable efforts will be required. Many items, especially plastics, have little functionality and yet appear prevalent. If these items could be designed out there would be less of a problem.

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