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# Temporal Trends in Litter Dynamics at a Pebble Pocket Beach

**A.T. Williams and D.T. Tudor**

Faculty of Applied Sciences
Bath Spa University College
Newton Park, Bath, UK, BA2 9BN

**ABSTRACT**

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A pocket beach in South Wales (Tresilian), UK, was studied over a five year period (1994–1998) to assess amounts, types and accumulation of litter. At low spring tide, the beach was sub-divided into 5m transects and all litter recorded prior to removal. At the subsequent low spring tide, roughly 15 days after the initial survey, the beach was revisited and the litter recording repeated. The study established that at least 19% of the total amount of pre clean up beach litter, returned within two weeks; in one year this figure was as high as 46%. Trends in the amounts and composition of the litter were also apparent. The litter standing stock fell by almost 50% between 1995 and 1998, with plastics being the dominant litter material. Plastic containers increased in proportion over the survey period, making up some 30% of the litter in 1998 compared with 12% in 1996. Litter was distributed across the beach at varying levels, with the largest accumulations occurring at the eastern end of the beach, this was especially so in 1997. The litter distribution across this pocket beach brings into question the validity of using selected small transects to give a true assessment of the amounts of litter present.

**ADDITIONAL INDEX WORDS:** *South Wales, pollution, coastal management, beach clean-ups.*

## INTRODUCTION

Whilst there is clearly a need to be able to monitor litter pollution in the aquatic environment there has been no *widely accepted* standardised 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 organisations who use different methods and they seem unlikely to change these drastically (EARLL and JOWETT, 1998).

Pathways taken by beach litter are analogous to those taken by sediments, *i.e.* there must be a source, pathway and sink. The source of litter can be attributed to three main areas of concern, all obviously connected with anthropogenic activity: marine, riverine and the beach itself. A decade ago, most 'experts' would have argued for a marine source for litter; today it is estimated that some 80% of the litter found on beaches is land based (FARIS and HART, 1995). Debris can be blown, washed or discharged into water from land. Absence of sewage treatment installations, combined sewer outfalls, storm water discharges, run-off from landfills sited nearby rivers and in coastal areas, absence of waste services or landfills in rural areas, recreational beach users, and fly tipping all contribute to debris ending up on beaches or in the oceans (NOLLKAEMPER, 1994). Due to the characteristics of their sources and routes of travel, the majority of contaminants entering the marine environment from land based sources are delivered to the near-shore resulting in many being trapped and cycled (WINDOM, 1992).

The aim of this study was to establish a long-term view of litter amounts, types, and accumulation patterns, as well as determining the rate of litter re-colonisation of a pocket beach over a two week period. Litter pick ups can have a public service and educational value, but it was hypothesised that in the main litter clearance is futile and it is a necessity to manage litter at its source. A further goal was to ascertain the effectiveness of sampling the beach as a whole, as opposed to a small selection of narrow transects (5m) on a 100m long pocket beach.

## PHYSICAL BACKGROUND

Tresilian beach is located on the Severn Estuary and is one of several pocket beaches in the Glamorgan Heritage Coast, South Wales, UK. It is a pebble beach some 100m in length and the estuary has the second highest tidal range (16.4m) in the world, so the tidal flat exposed between high and low tides can extend to > 500m. The encircling rocks are Lias limestone and shales, and erosion of these cliffs—at some 6–10cm /annum, gives rise to the pebble beaches that abound in this region (WILLIAMS and DAVIES, 1989; BELOV *et al.*,

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1999). The pebble beach itself is 40m in width and at the landward edge rises >8m in height above the shore platform, enclosing a pebble volume of some 16,000m$^3$. Pebbles within this embayment tend to be trapped as longshore drift for the Glamorgan Heritage Coast (GHC) coastal cell in this area is eastwards, but as Tresilian is a pocket beach, pebble migration around the cliff extremity is minimal; two-dimensional cross beach movement being more common than lateral. The shore platform substrate, pebble beach and difficulty of access, leads to only small numbers of visitors to Tresilian beach, tending to exclude this group as a major litter source. The only other possible litter sources are sea vessel debris and the riverine system. The amount of shipping in the Severn estuary is small, the bulk of the litter found in this area being thought to have a mainly riverine origin (WILLIAMS and SIMMONS, 1997).

## METHODOLOGY

Currently, no standard methodology exists with respect to the measurement of beach litter. The literature is replete with measurements/analyses, amongst others: of transects orthogonal to a beach (SIMMONS and WILLIAMS, 1993); black bin-bag collections (GHC, DUNN, *personal communication*); weights of litter (YRLMP, 1991); strand line counts of containers (DIXON and COOKE, 1977); counts of macro litter in a transect (WILLOUGHBY *et al.*, 1997); of all litter on the beach between vegetation and low water mark (HAYNES, 1997); floatable litter vs. non floatable (FROST and CULLEN, 1997).

In this paper, Tresilian beach was divided into 5m wide down beach transects and *all* litter found in each transect was recorded. Several five metre transects are fairly commonly utilised in such work (DIXON and DIXON, 1981). The number of litter items were counted and attributed to the following litter categories—plastic; polystyrene; metal; glass; plastic containers; polystyrene containers; metal containers; paper containers; shoes; tyres and rubber; clothing; string, rope and nets. The transects were labelled A, B, C etc. with transect A being located at the eastern edge of the beach. Therefore *all* beach litter was recorded. The survey covered a period of 5 years, 1994–1998, and after each initial survey, taken at low spring tide in May, *all litter was taken from the beach*. A second survey was initiated at the next low spring tide, roughly 15 days later, and the litter recording in each of the transects was repeated.

These surveys were termed, *'pre clean up'* (PCU) and *'after clean up'* (ACU). The amounts of litter found were graphed and subject to standard statistical analysis. All statistical analysis utilised the non-parametric Wilcoxon Signed Rank Test as recorded values for litter comparison failed normality testing for 85% of the time.

## RESULTS AND DISCUSSION

### Beach Transects

DIXON and DIXON (1981), have argued that three random number generated transects of 5 metre width taken orthogonal to a beach, can adequately represent the litter content of that beach, and this seems to have been accepted unquestioningly by many researchers. The 5m width was apparently chosen arbitrarily without any justification or discussion regarding implications with respect to sample representativeness. Also why three transects? 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". SIMMONS (1993), showed by minimal area curve analysis, also known as species area curves derived from the BRAUN-BLANQUET school of phytosociology (1932), that the curve associated with litter items *does* start to tail off around this transect width. The principle is that narrow belt transects are more easily studied, because they enable work to be completed more quickly, 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. Further work by WILLIAMS *et al.* (1999), found that a 5 metre transect would cover some 66% of litter categories present on the beach studied. It should be noted though that this figure is dependent on the litter categories used, as well as the beach being investigated.

However, the works cited above (DIXON and DIXON, 1981; SIMMONS, 1993) were carried out at linear beaches and riverine areas respectively, *i.e.* areas having a basic unidirectional flow pattern and they were not pocket beaches. Inspection of Figures 1 and 2 for 1998, shows that the selection of three 5m transects on Tresilian beach would produce vastly differing results. Figure 3, shows that the litter was concentrated against the eastern edge of the beach in 1997 and the pattern is completely different from the 1998 litter distribution. On pocket beaches it is suggested that *all* litter should be sampled.

### Litter Amounts

#### Time trends

Figure 4 shows the total amounts of litter collected at Tresilian beach over a 5 year period both pre clean up (PCU) and subsequently (approximately 15 days) after a total beach clean up (ACU). Figure 5 shows the total amounts collected PCU along each 5m transect over the same period. Values seen for 1996 (Figure 4) are instructive in that the beach had been cleaned on a 'Public Beach Clean Exercise', about a month previous to the survey carried out for this paper.

Tables 1a and b, give the results of analysing eleven categories of litter. The aim was to ascertain if there were any statistical changes in the amounts of litter year on year, *i.e.* each survey was compared with the previous years results. Glass has not been included in statistical analyses as it occurred in very small amounts (0 or 1) in all years except in the PCU, 1996. An inexorable rise in the use of plastics by society has been mirrored in the amounts of plastic litter found on a beach, but the plus side has been the decline in glass (whole or fragmented) on beaches.

For the PCU period 1995/6, statistical differences can be attributed to the unusually low figures of litter abundance in 1996 due to the beach clean up as previously mentioned (Table 1a). The PCU 1997/8 figures reflect in the main, differences between polystyrene and plastic containers. Plastic

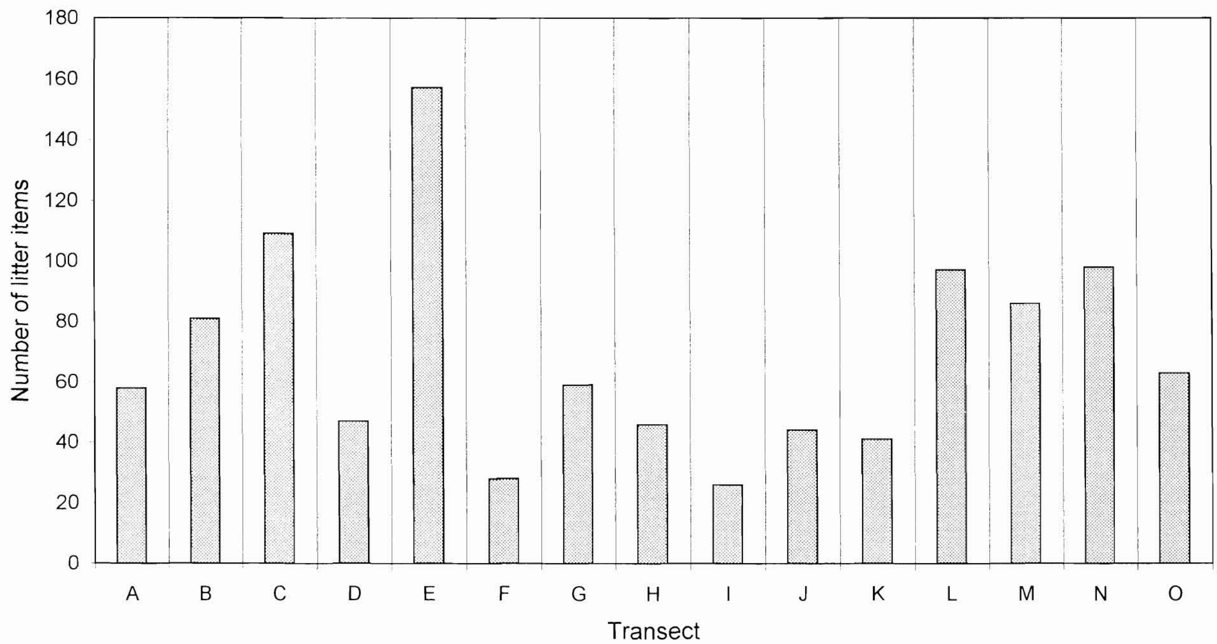


Figure 1. Pre Clean Up Tresilian Bay 1998

containers constituted a larger proportion of the litter found on the beach (32% in the PCU survey) compared to previous surveys, with polystyrene numbers being far lower in 1998 than 1997 (9% and 30% respectively). Other litter categories constituted similar litter proportions. In statistical analyses of the other two surveys, no difference was found (Table 1a).

For the ACU surveys (Table 1b), statistical differences were found between the 1994/5 surveys. The amount of litter showed a marked increase between the surveys in these years. This anomaly could be due to the weather patterns experienced for some time pre measurement as in 1995 the surveys coincided with a period of very inclement weather.

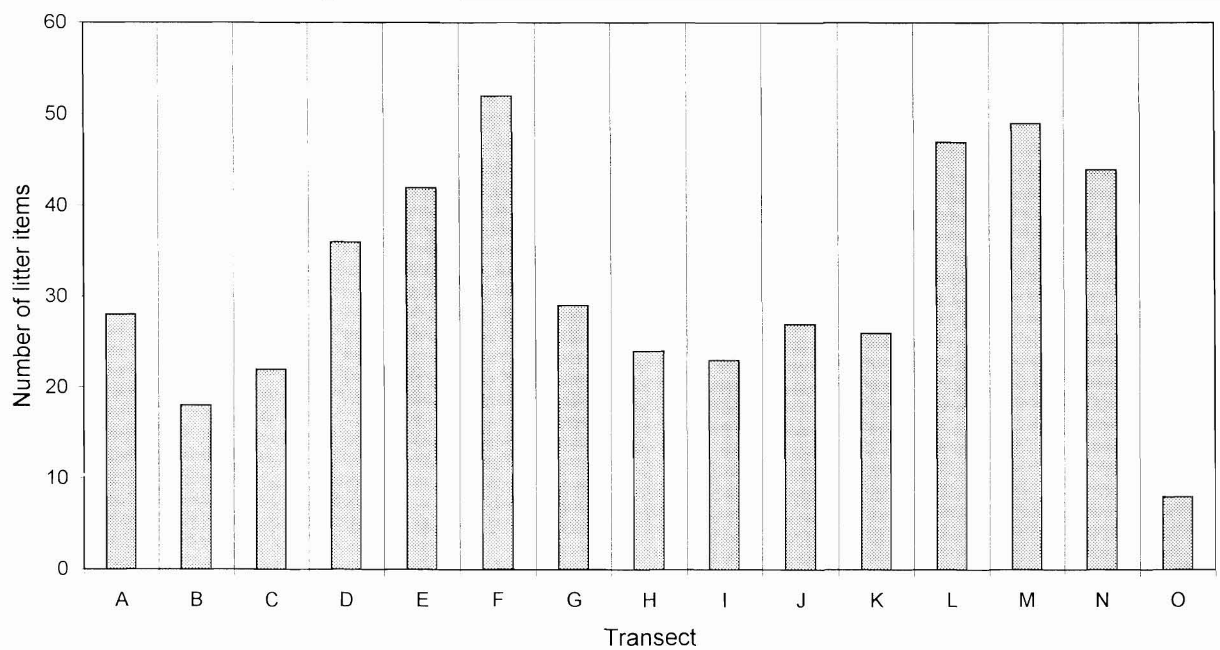


Figure 2. After Clean Up Tresilian Bay 1998

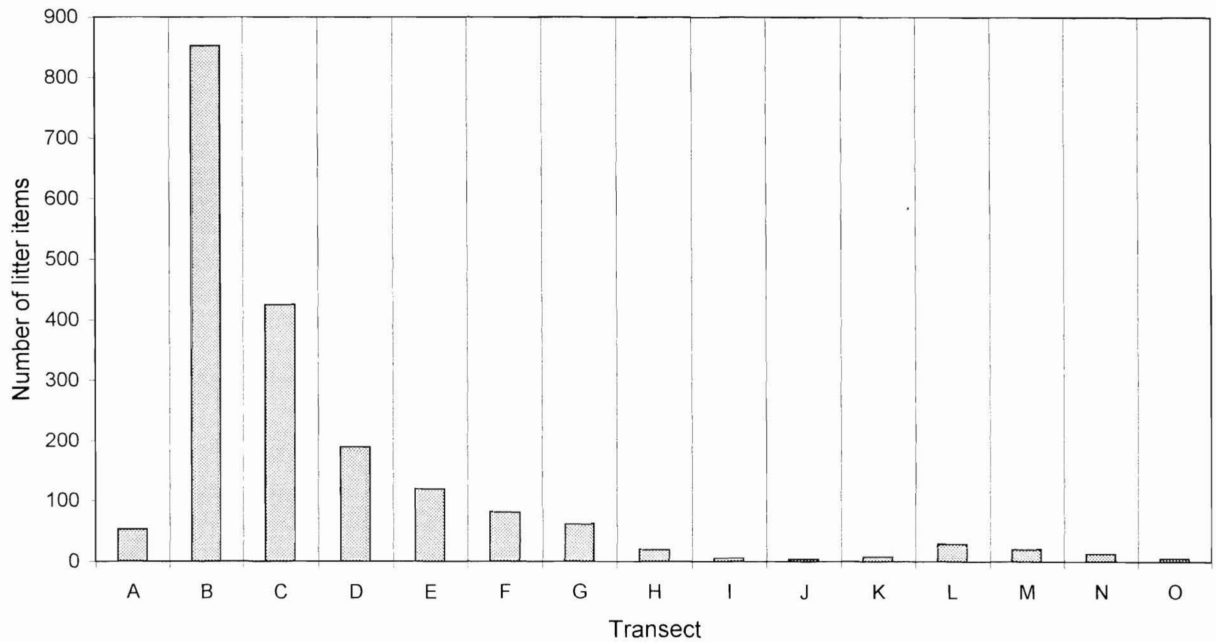


Figure 3. Pre Clean Up Tresilian Bay 1997

Litter in the area studied is known to be essentially *riverine* in origin (WILLIAMS and SIMMONS, 1997), therefore the material found on this beach could have originated from the river Ogmore some 10 km to the west, which would have been in a swollen state and had the ability to transport litter very rapidly to the sea (TUDOR, 1997).

## Pre Clean up and After Clean up Litter

Table 2a shows the litter categories utilised in this study and litter amounts obtained in the, *'pre clean up'* (PCU) and *'after clean up'* (ACU), for 1997. Table 2b shows the actual counts per 5m transect for the same time period. It can be seen that plastic and polystyrene categories represent the largest amounts of materials found on the beach (Figures 6, 7). Plastics probably will be the biggest problem of the 21st Century with respect to beach litter as, 'Plastic pollution has risen dramatically with an increase in production of plastic resin during the past few decades' (ROBARDS *et al.*, 1997, p.71). Numerous studies throughout the world have recorded plastic as the dominant material (CORBIN and SINGH, 1993; GARRITY and LEVINGS, 1993; JONES, 1995; BOWMAN *et al*, 1998).

Some 24% of the *total number of items* in the plastic and polystyrene category found on the beach pre clean up were returned over the next two weeks (Table 2a). It should be noted that these litter items are not the same objects returning, but are new ones arriving on the beach. This is indicative of the accumulation rate of litter at Tresilian beach. It would appear that the beach is merely a temporary site for litter before it is removed again by the sea. With regard to the following discussion, the transect positions (refer to methodology) are consistent with the layout shown in Figure 1.

a) 1994 Survey Results. The greatest abundance of PCU litter items was in transect E, with other large amounts in transects F and M. A very similar pattern was seen in the ACU survey, with E again showing the greatest abundance, and large amounts in D and M (Figure 8). The total amount of litter fell by some 81% from the first to second survey (Figure 4). This was the biggest fall recorded, which was not surprising as the beach had not been cleaned for several years. The category with the largest number of litter items was plastic followed by polystyrene and plastic containers in the PCU survey. Polystyrene was the most abundant item in the ACU survey, followed very closely by plastic. Although the enumeration of polystyrene can be misleading, it is still very important that its impact is not ignored as such small litter items are especially hazardous to bird life (MOSER and LEE, 1992).

b) 1995 Survey Results. In the PCU survey, transect F had the highest number of litter items, with D ranking second. The ACU survey had E as the highest ranked transect with F close behind, transect L also had high numbers. The total number of litter items fell by 71% between the surveys The most abundant litter category was polystyrene (31% of the total), followed by plastic and there were also high numbers (23%) of plastic containers. The same pattern was seen in the ACU survey. Both surveys produced the largest amounts of litter respectively over the five year study period (Figure 4).

c) 1996 Survey Results. This year was an unusual one regarding results obtained. The total amount of litter for the PCU survey was far lower than any other year, and yet the ACU survey had the second highest amount of litter compared to other ACU surveys (Figure 4). It was actually higher than the initial survey carried out in 1996. There was a 1%

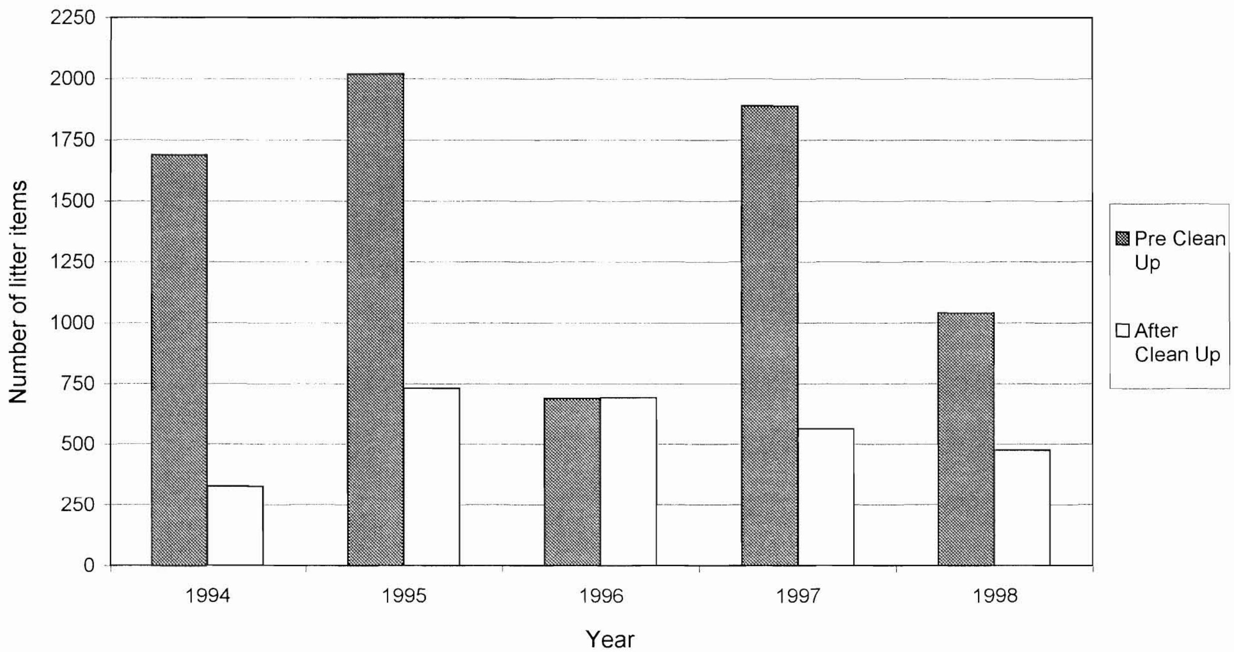


Figure 4. Total Litter Amounts Tresilian Bay 1994–1998

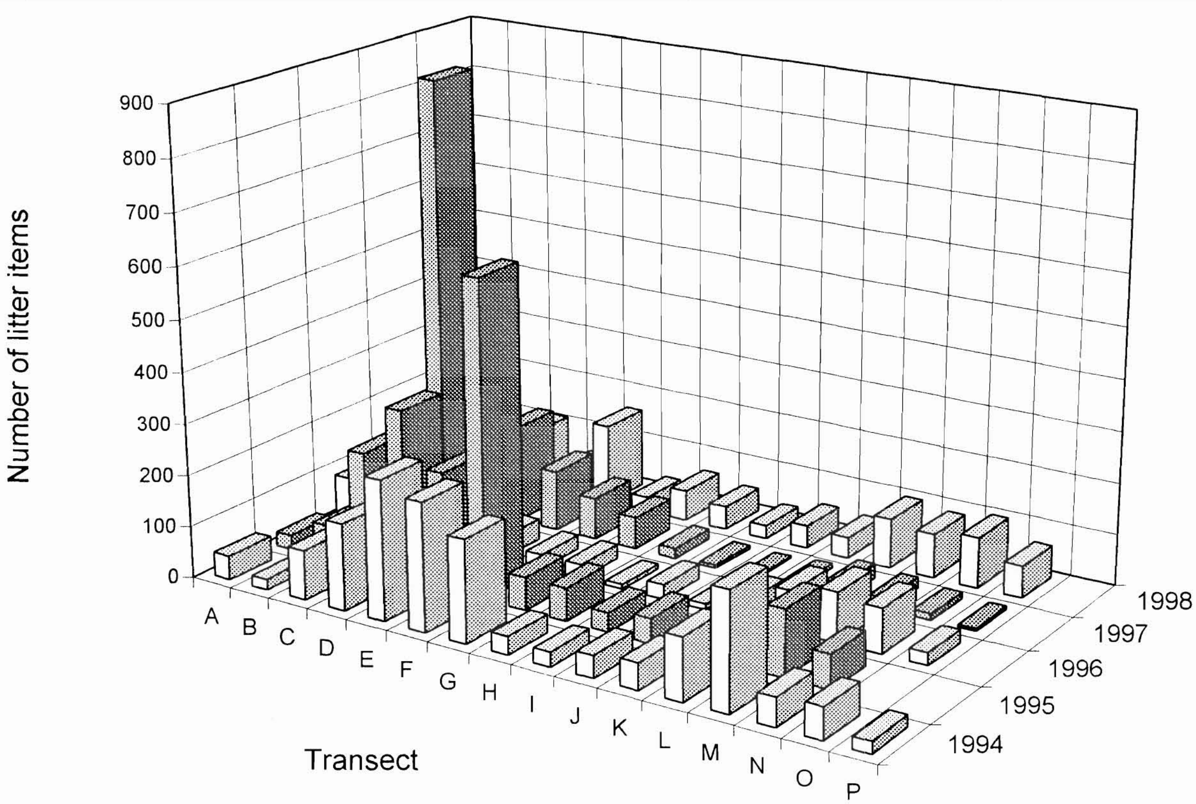


Figure 5. Total Pre Clean Up Transect Comparison Tresilian Bay 1994–1998

Table 1a. *Wilcoxon Signed Rank Tests. Pre Clean Up 1994–1998.*

| Pre Clean Up | Probability |
|---|---|
| 1994–1995 | 0.37 |
| 1995–1996 | 0.04* |
| 1996–1997 | 0.08 |
| 1997–1998 | 0.02* |

* significant at 0.05 level

increase in litter between survey periods, *i.e.* more litter had arrived at the beach than was taken away. The low levels of litter for the PCU survey are probably due to the public beach clean which occurred about a month previous to the survey carried out for this paper.

In the PCU survey, M was the transect with the greatest litter abundance, with transects A, L, N and D all having slightly less litter amounts. All five transects had similar amounts of litter, and a large accumulation of litter was found at the west end of the beach (transects L, M and N). This again bears out the point made earlier that random number transects on pocket beaches can give skewed results and all litter on such beaches should be recorded. In the ACU survey, transect F had the greatest litter abundance. In fact there was more litter in this transect than encountered in transect M in the PCU survey. In the PCU survey, plastic was the most abundant litter category (26%) followed by polystyrene and then plastic containers. In the ACU survey plastic was again the most abundant category, this time making up some 43% of the total amount of litter.

d) 1997 Survey Results. Transect B had the greatest abundance of litter, followed by transect C (C had half as much litter as B; Figure 3). Unlike most other years there was no peak at the western end of the beach. Transect B made up 45% of the total amount of litter on the beach, transect B and C combined made up 68% of the total. In the ACU survey, transects D and E had almost identical amounts of litter (68 and 67 respectively). There was a 70% drop in the total amount of litter between surveys (Figure 4). In the PCU survey, plastics and polystyrene were almost equal with plastic containers ranked third. These three items made up 82% of the total amount of litter. The ACU survey was similar, but this time the items made up 65% of the litter amount.

e) 1998 Survey Results. In the PCU survey, transect E had the greatest amount of litter, followed by C, N and L (Figure 1). In the ACU survey, transect F had the highest amount followed by M (Figure 2). There was a 54% decrease in litter between surveys. The most abundant material in the PCU survey was plastic, with plastic containers a close second. Polystyrene made up a much smaller proportion of total litter

Table 1b. *Wilcoxon Signed Rank Tests. After Clean Up 1994–1998.*

| After Clean Up | Probability |
|---|---|
| 1994–1995 | 0.02* (t-test) |
| 1995–1996 | 0.83 |
| 1996–1997 | 0.15 |
| 1997–1998 | 0.70 |

* significant at 0.05 level

Table 2a. *Pre clean up (PCU) and after clean up (ACU) material rankings and litter totals for 1997.*

| Material Rank | PCU | Material Rank | ACU |
|---|---|---|---|
| Plastic | 577 | Plastic | 158 |
| Polystyrene | 573 | Polystyrene | 114 |
| Plastic Containers | 392 | Plastic Containers | 94 |
| Shoes | 72 | Metal Containers | 44 |
| Tyres and Rubber | 59 | Tyres and Rubber | 38 |
| Clothing | 51 | Shoes | 27 |
| String, Rope, Net | 48 | Metal | 27 |
| Polystyrene Containers | 46 | String, Rope, Net | 25 |
| Metal Containers | 36 | Clothing | 18 |
| Metal | 28 | Paper Containers | 11 |
| Paper Containers | 7 | Glass | 9 |
| Glass | 1 | Polystyrene Containers | 0 |
| Total | 1890 | | 565 |

amounts than in previous years (9%). Plastic and plastic containers made up 65% of the total amount of litter. In the ACU survey, plastic containers were the most abundant item for the first time in all 10 surveys (37%). These together with general plastics made up 62% of the total litter amount.

## Management

Litter is one of *the* main issues associated with coastal management. Results given above, have shown that beach clean operations are only a temporary management measure. All surveys were conducted approximately two weeks apart and initially involved the removal of all debris from the beach which resulted in less litter being found on the beach during the second survey. Nevertheless, the speed at which even the smaller amount of litter returned to the beach shows that the problem cannot be solved by simple beach clean ups and these are often a waste of time, money and effort. In a resort beach, management *has* to clean the beach; in rural beaches it is an option, but clean ups do not *solve* the problem. The problem clearly needs to be tackled at *source* and this is an area of research that has hardly been investigated. In this respect it should be reiterated that even in the lowest return period (1994), some 19% of the original litter amount had accumulated within a two week time span.

Table 2b. *Transect litter counts 1997.*

| Transects | PCU | ACU |
|---|---|---|
| A | 53 | 27 |
| B | 852 | 33 |
| C | 425 | 35 |
| D | 190 | 68 |
| E | 119 | 67 |
| F | 82 | 42 |
| G | 62 | 25 |
| H | 20 | 43 |
| I | 6 | 18 |
| J | 4 | 20 |
| K | 9 | 37 |
| L | 29 | 28 |
| M | 21 | 53 |
| N | 13 | 37 |
| O | 5 | 32 |
| Total | 1890 | 565 |

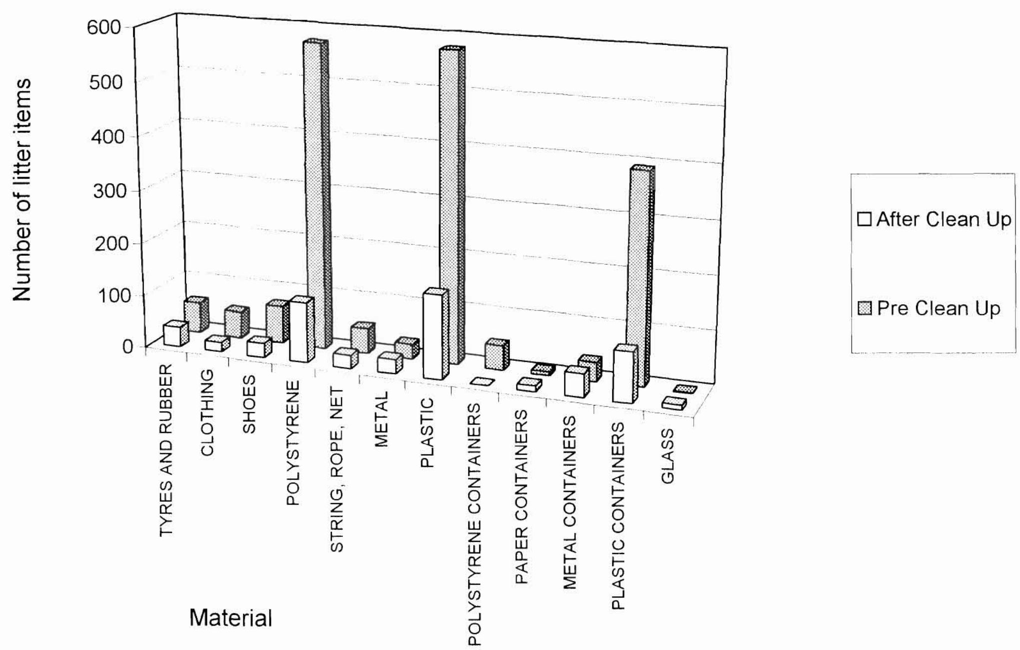


Figure 6. Material Comparison Tresilian Bay 1997

## CONCLUSIONS

Pocket beaches should be treated differently to linear beaches with respect to litter surveys. The latter can be subjected to differentiation of the beach by transects—usually assumed to be three in number—with some degree of success, although the number of transects should reflect the overall size of the beach. Pocket beaches though need to be considered as a whole and their relative small size allows for the beach to be surveyed in its entirety. The use of small size transects can lead to misrepresentation of the true picture of

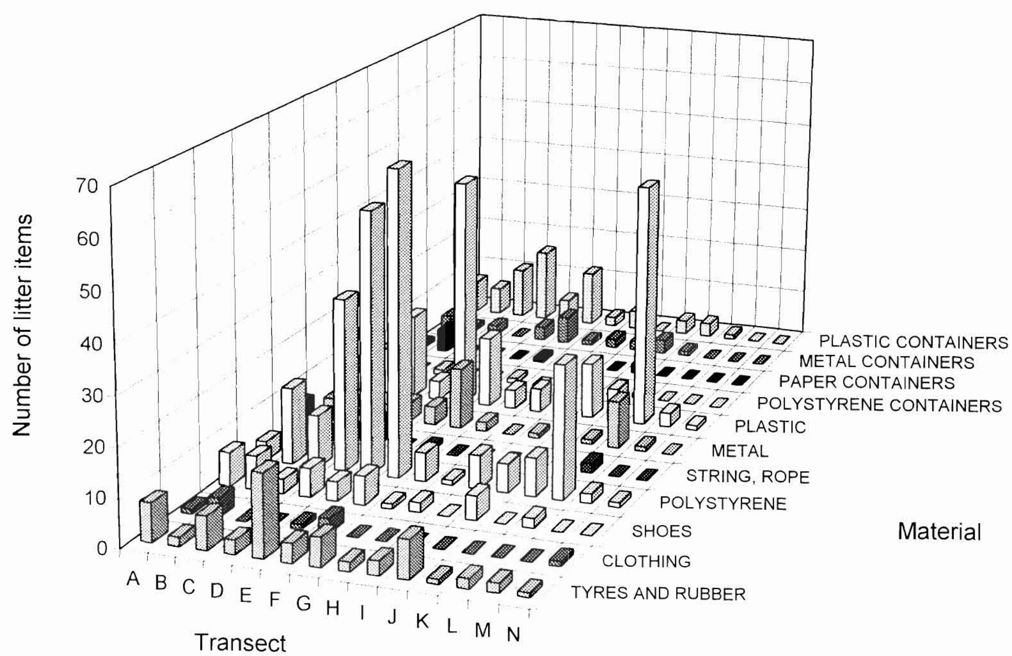


Figure 7. After Clean Up Tresilian Bay 1995

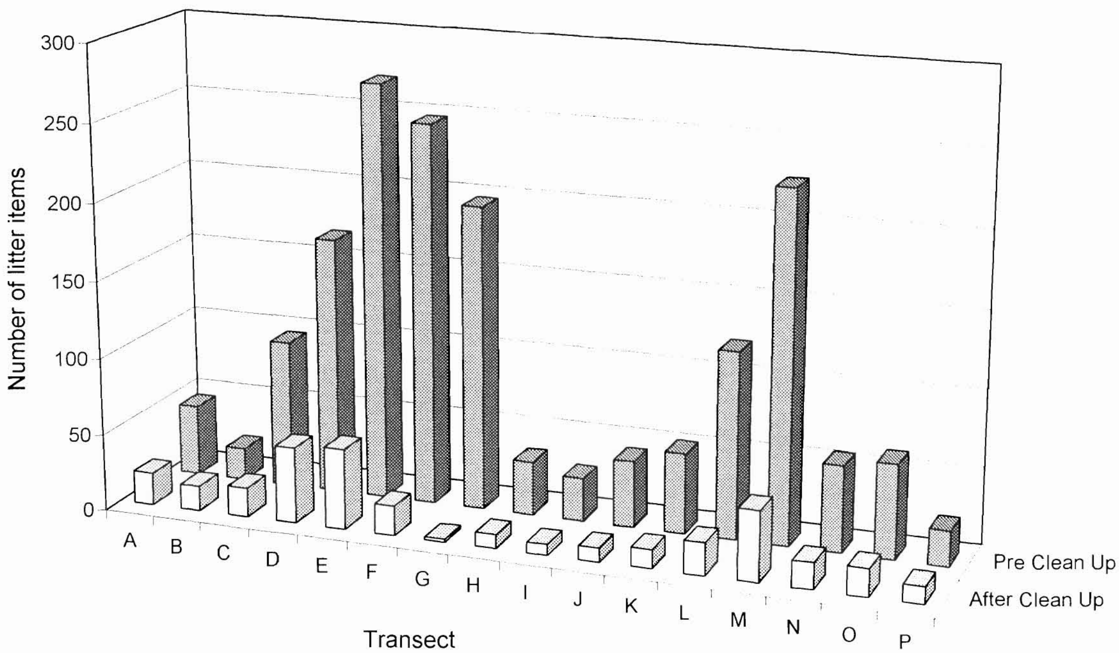


Figure 8. Transect Comparison Tresilian Bay 1994

the beach condition. The litter on the beach is acting much the same as the pebbles with regards to their distribution. The differing distribution patterns experienced across the beach over the five years is to be expected, but this confirms the notion that a whole beach survey is appropriate on beaches such as these.

As with many other studies around the world, plastics were the most numerous litter items. In addition, polystyrene made up a large proportion of the litter found, although problems do exist with counts of this material. Polystyrene readily breaks down into small pieces, often resulting in huge numbers of individual fragments which can imbalance the results of a litter study as well as proving hazardous to bird life. The small amount of glass found on the beach is indicative of the reduction in use of this material in preference to plastic, also pebble beaches break down glass which makes it difficult to find in the voids between the pebbles. Although total amounts of litter have decreased over the five years, longer term studies would need to be conducted to discover if this trend continues.

Pre clean up surveys of beaches reveal the beach standing stock, with after clean up surveys giving accumulation rates. In this paper, the time interval between surveys was *circa* two weeks, *i.e.* consecutive Spring Tidal cycles. The amount of litter standing stock over the five years of the present study, decreased from 1,689 in 1994 to 1,040 in 1998—a 38% decrease. Whether this is indicative of a reduction in the amount of waste reaching the sea from rivers and beaches and subsequently washing ashore can be confirmed in time, as only very long term monitoring can answer this question. The level of re-accumulation of the beach by litter from the PCU to ACU varied from year to year, being 19% in 1994 and 46% in 1998. The accumulation rate of the litter is very fast, the litter amount for the PCU survey at any one time is *at most* only five times that of the subsequent ACU survey. This indicates that the litter found was simply in transit, that is, it is on a pathway and has not yet arrived at a sink.

The use of beach clean ups is a short sighted, temporary cure and can only be justified in areas of high tourism income and with the current absence of an effective solution to this form of pollution. However, beach cleans can serve as instructive exercises where members of local communities are involved. Over a five year experimental period, removal of all beach litter and assessing litter inputs after a two week period showed the inadequacy of such clean ups as the litter problem is not solved by such means. Litter cut off at source is the only real answer.

## ACKNOWLEDGEMENTS

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