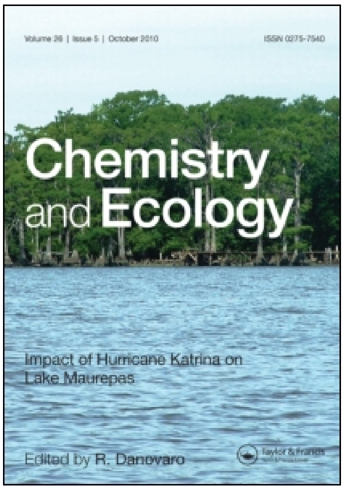

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The Occurrence of Litter of Natural and Anthropogenic Origin in Solway Firth and Other Coastal Sediments

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The litter content of littoral and sublittoral sediments from the Solway Firth, Firth of Clyde and the coast of Devon was measured by passing samples of sediment through 500 and 1000 μm sieves and hand picking of the residues. The litter present in samples from each station was shown to be very variable both in amount and in the quality of the component fractions. No clear relationship with silt content and type of shore emerged.

INTRODUCTION

It is generally recognised that particulate and subparticulate organic carbon derived from the macrophytes of rocky shores and salt marshes provide an important source of energy for the consumer processes of neritic communities (e.g. Newell, 1979). Further, the organic matter in recent subaqueous sediments may give rise to liquid hydrocarbons in addition to a wide range of other organic substances (Bordovsky, 1965). In the open sea the plankton is the main source of organic carbon, but this importance decreases in coastal waters, where benthic sources assume a greater significance and, according to Bordovsky (1965), the rivers may contribute 7.0×10^8 tons of organic matter annually. At the level where organic matter is generally considered as a food source for

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many marine animals, i.e. detritus, it has already been much reduced in size by physical and biological activity. In contrast, relatively little attention is paid to particles of a size exceeding 100 μm, i.e. litter rather than detritus (Perkins, 1974). Nevertheless, such materials also are an important food source for neritic microflora and animals (Perkins, 1974) and may adsorb substantial amounts of heavy metals (Bryan, 1969) and colloidal radioactive nuclides (Jones, 1960; Perkins and Williams, 1966).

Litter particles in a marine sediment may be derived from different origins, viz., plant, animal, man-made, marine, fluvial, terrestrial, which will influence the rate and mode of subsequent breakdown and these in turn will have some bearing upon the value of each with respect to the roles noted above. Organic matter present in Solway Firth soils comprises the following elements: (1) Plant and animal litter (2) Litter of synthetic origin (3) Coal and shale (together with associated Fe^{++} compounds) (4) Microbenthos and meiobenthos (5) Large molecules of organic matter adsorbed onto and associated with soil particles, and (6) from 1967 onwards, wood fibre and particles derived from Thames Board Ltd., Siddick works.

Perkins and Williams (1966) noted that in the presence of significant amounts of (3) determination of the total organic content of these soils (e.g. Wakeel and Riley, 1956) renders any meaning of the results obscure. Determinations of the amounts of finely divided coal and shale present were made by Perkins and Kendrick (1978) and although this problem might be overcome, in part, by use of the method of Buchanan and Longbottom (1970) it would still leave the contribution made by 1, 2, 4, 5 and 6 unresolved. For this reason, I developed the method of wood fibre measurement, later used by Reid and Perkins (1979, 1980): this method assumes that each fibre recovered from water and soil has the dimensions of a perfect cylinder and a specific gravity of 0.5 (see for example, Weast, 1972) consequently the concentration in the original sample may be derived by the enumeration and measurement of each in a sample of known volume. The studies of Reid and Perkins (1979, 1980) compared the number of litter particles of natural (i.e. plant and animal) and Thames Board derived origin. Their work did not however, estimate the quantities of naturally occurring litter present and consequently a consideration of the relative importance of the two sources was impossible. The present study seeks to elucidate this problem further both with respect to the different sources of naturally occurring litter and that of anthropogenic origin including sewage and synthetic

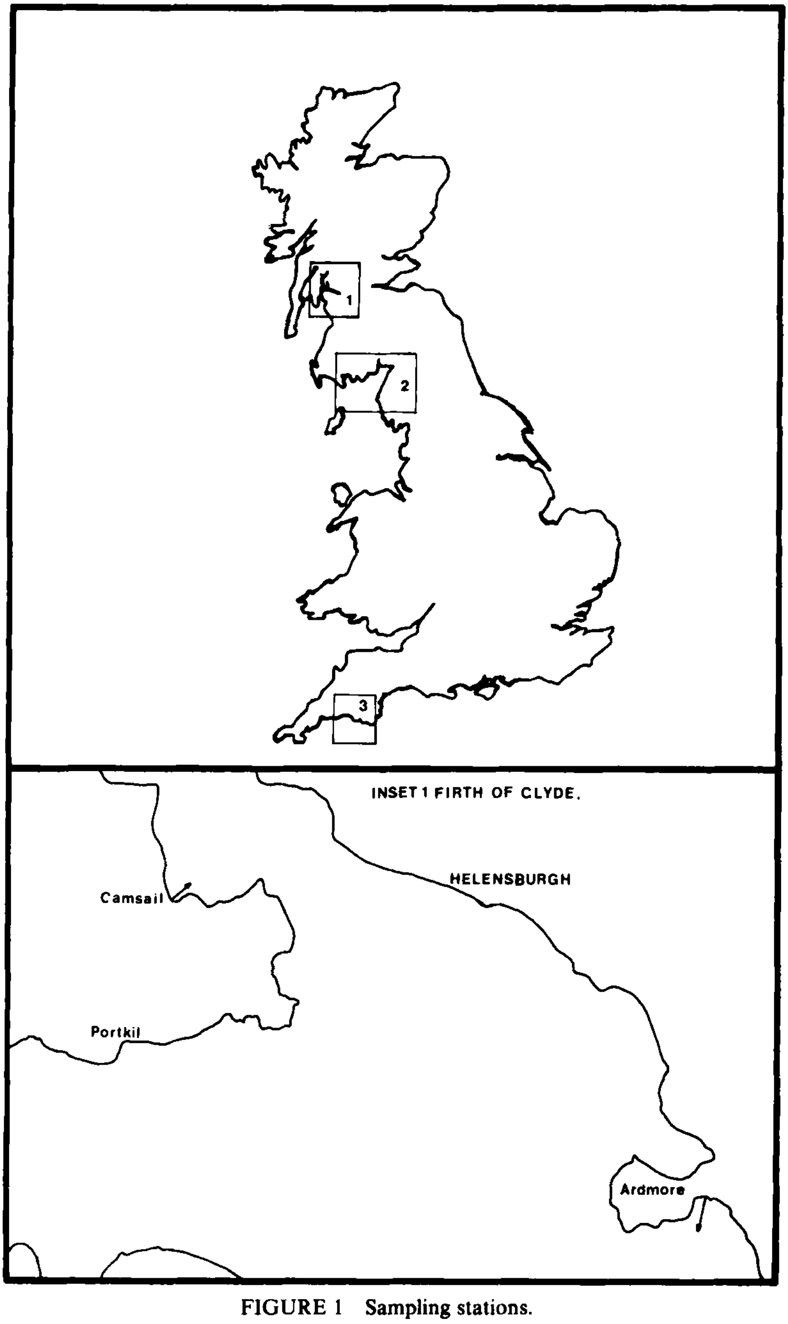
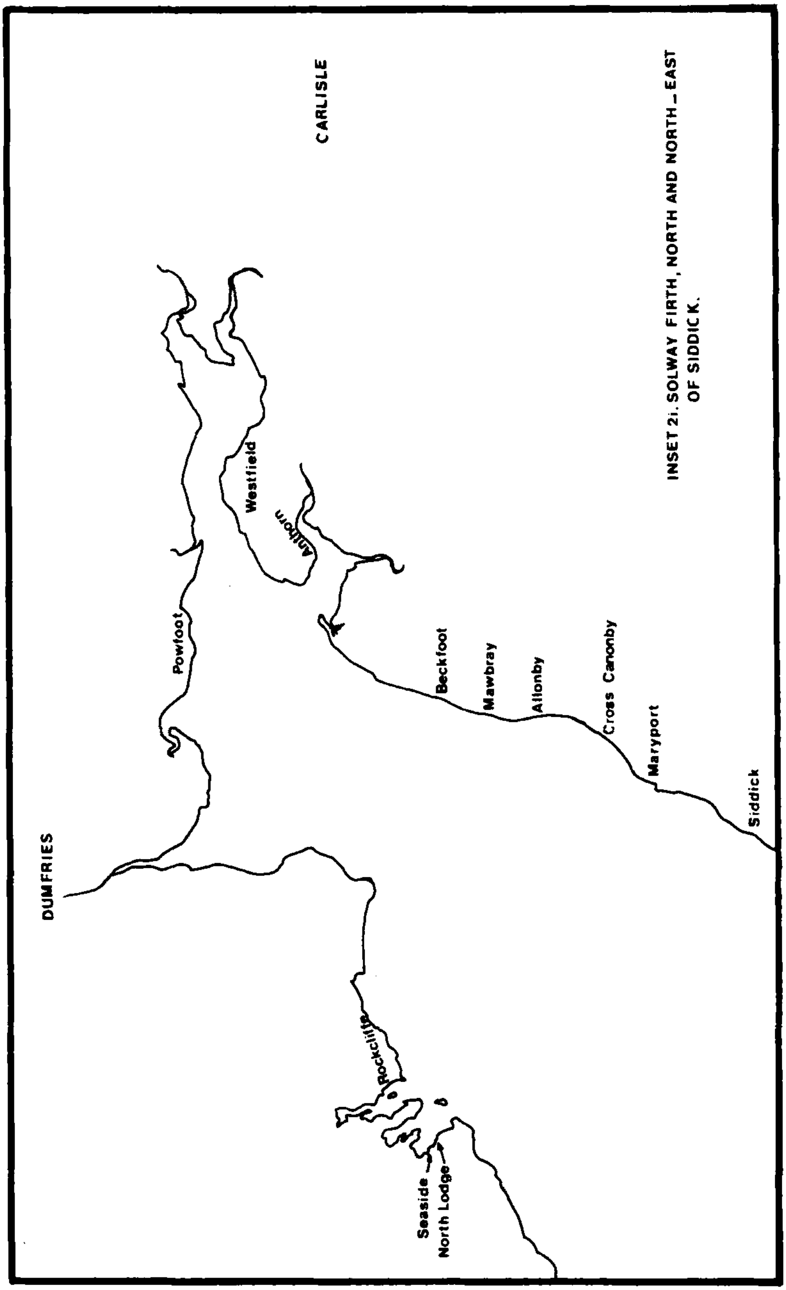
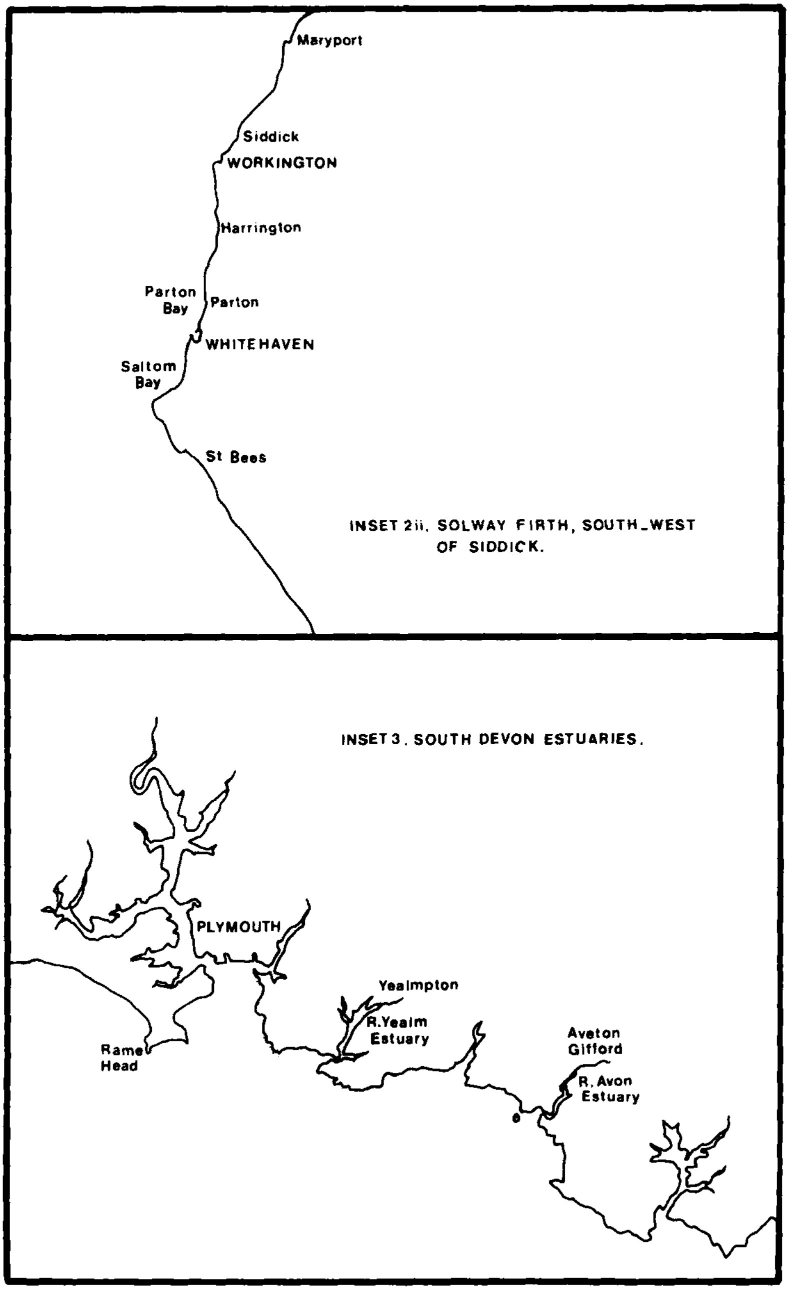


FIGURE 1 Sampling stations.



INSET 2i. SOLWAY FIRTH, NORTH AND NORTH_EAST OF SIDDICK.


Maryport
Siddick
WORKINGTON
Harrington
Parton Bay
Parton
WHITEHAVEN
Saltom Bay
St Bees
INSET 2ii. SOLWAY FIRTH, SOUTH_WEST OF SIDDICK.
INSET 3. SOUTH DEVON ESTUARIES.
PLYMOUTH
Yealmpton
R.Yealm Estuary
Rame Head
Aveton Gifford
R. Avon Estuary

materials in addition to that from Thames Board. Comparisons are made with sediments from the Firth of Clyde and the coast of Devon.

The location of the stations sampled is given in Figure 1.

METHODS

Sieve residues

All of the samples of substratum taken either by 1/16 m^2 quadrat box or 1/10 m^2 grabs were passed through a 300 mm diameter Endecott sieve having a 1000 μm mesh aperture. In addition to the infaunal inhabitants, the sieve retained variable amounts of coarse mineral particles, including stone, coal, shale and slagcrete (Perkins and Kendrick, 1978), plus similarly variable amounts of plant and animal litter, together with material of anthropogenic origin, e.g. sewage, plastics and Thames Board derived wood fibre and Parkwood screenings.

The litter particles were separated from the sedimentary coarse fraction either by flotation or by hand picking; the latter being used to separate the individual components. Once separated, these components were washed thoroughly in distilled water to remove as much salt as possible. After washing they were oven dried at 110°C. In some cases, the whole litter sample was washed, oven dried at 110°C and weighed before separation by hand picking; the individual litter components were weighed as before. In those cases where it was necessary to dry the coarse fraction before proceeding, hand picking of the litter components was still possible.

While the differing contributions of Thames Board derived and other litter are recorded on a w/w basis, comparison of amounts of litter of different origin, viz., land, freshwater, marine, synthetic and sewage derived to the whole is expressed in terms of the number of particles of each: a consequence of the physical difficulty of hand picking to such fine levels of discrimination.

It was noted by Perkins and Kendrick (1978) that a 25 cm × 25 cm × 25 cm quadrat sampling box could be assumed to contain 25 kg of soil when full (by the same methods, the grabs employed may be assumed to have contained 24 kg when full). By using this assumption, the concentration of the coarse and litter fractions in the original soil quadrat sample may be obtained. Clearly the accuracy of the method is lower than that which employs the measurement of wood fibre dimensions. Unlike the latter, however, it provides an appreciation of litter deposition through the body of the soil rather than at its surface where, observably, it may be disproportionately high or low.

Surface litter deposits

Transient deposits of litter may be present in the troughs of ripple systems, such accumulations may occur either within the individual trough or in relatively massive aggregations in flood channel barblets (Perkins, 1977a). The dimensions of such deposits are not easily measured and expressed in terms of concentration, though the proportions of the components by weight may be determined for the individual sample.

Samples of such material were carefully lifted in a plastic spoon, and transferred to the laboratory in a 125 ml polythene jar with a polypropylene cap. Here, duplicate aliquots of each were placed in water and the components separated by hand picking. Each component was thoroughly washed in distilled water; oven dried at 110°C, weighed and the results expressed as a percentage of the total litter present.

Surface soil samples

To provide another view of litter deposition at the surface of shore soils, 200 g samples were skimmed off the soil surface, placed in a 250 ml polystyrene jar with a plastic cap and preserved in 10% sea-water formalin.

In the laboratory, the sample was passed through a 500 μm sieve. The litter residue was removed to water in a small dish where it was hand picked and treated as above. Since the wet weight of the original sample was known the results are expressed as p.p.m. litter (dry) in soil (wet).

RESULTS

Sieve residues

The concentration of litter in the 1000 μm sieve residues is reported as mean values in Table I. The variation between individual samples

TABLE I

The mean concentration of litter including materials derived from Thames Board in 1 mm sieve residues

Station	Year	n	Mean concentration (p.p.m.) Thames Board derived	Non T.B. litter	Composition (%) Thames Board derived	Non T.B. litter
SHORE						
Siddick	1978	21	5.14	8.26	38.4	61.6
	1979	42	2.25	2.94	43.4	56.6
	1980	26	21.8	5.70	79.4	20.6
Maryport	1981	30	0.61	16.7	3.54	94.46
Cross	1974–75	20	0.13	0.92	12.4	87.6
Canonby	1980	17	0.38	1.58	19.7	80.3
Allonby	1974–78	13	0.90	8.34	9.8	90.2
(South)	1979	15	0.28	3.05	8.3	91.7
	1980–81	21	0.09	0.62	12.3	87.7
Beckfoot	1973–75	20	1.33	8.68	13.3	86.7
	1976	16	2.40	12.51	16.1	83.9
	1978	8	0.42	4.33	8.9	91.1
Powfoot	1973–75	20	0	68.6	0	100
Westfield	1974–76	14	0	175.4	0	100
SEA BED						
Parton Bay	1979	28	0.11	2.73	3.76	96.24
Saltom Bay	1980	12	0.22	2.15	9.08	90.92

TABLE II

Variations in the amounts of litter present in sieve residue samples.

	Coefficient of variation (%) Non T.B.D.	T.B. derived
Siddick		
1978 (9)	1109	1200
1979 (3)	320	242
1979 (10)	137	188
1980 (3/4)	300	206
1980 (8)	69	162
Parton Bay, 1980 (5)	120	190
Saltom Bay, 1979 (9/10)	87	300

Bracketed figure indicates month.

was very large, so that at Siddick in 1978, the mean litter concentration in 21 samples was 8.26 p.p.m., range 0.18 to 134.47, similarly the mean value of the Thames Board derived material was 5.14 p.p.m., range 0–90.3. In these circumstances calculation of the standard deviation has little meaning, except in the further calculation of a Coefficient of Variation which is a useful expression of the differences observed. Such a use is exemplified in Table II for samples from Siddick, Parton Bay and Saltom Bay. In this case, one must clearly be careful in making comparisons. Nevertheless, it is apparent that the total mean concentrations at Siddick were little different from those in shores of similar exposure to wave action at Maryport and Allonby (South). These total mean concentrations were, however, much less than those at Powfoot and Westfield both more than 40 km upstream of Siddick. The proportion of Thames Board derived material was, as expected, much higher (38–79% of the total) at Siddick than elsewhere, but at no other station did it exceed 20% and none was recovered by this method at Powfoot and Westfield. Comparison with the sublittoral sediments of Parton and Saltom Bays is less certain, though even allowing for the imprecision of the method there was a much lower concentration of total litter in these sediments and the proportion of Thames Board derived material was much lower than in the shores examined between Siddick and Beckfoot.

The total litter concentration on each shore showed marked temporal variation, as did concentrations of Thames Board derived material. The tendency at Allonby (South) and Beckfoot for a much reduced concentration of Thames Board derived material is consistent with the decline in the number and intensity of strandings observed visually. In contrast, at Siddick, the apparent increase in concentration of this material in 1980 and its increased contribution to the total amount of litter is at best only partly true, these strandings are very patchy, both spatially and temporally, and a few abnormally high values distort the whole. Most probably the 1980 sampling programme coincided with an adventitious increase in the supply of Thames Board derived material: a conclusion consistent with the lower concentrations reported at Allonby (South) where such effects are likely to have become "smoothed out."

The proportions of the components derived from the land, freshwater, marine and synthetic sources, but excluding Thames Board derived material and measured as the number of litter particles is reported in Table III and their variability in Table IV. Curiously, even in samples

TABLE III

The proportions of the components contributing to the total number of litter particles in 1 mm sieve residues, excluding those derived from Thames Board

Station	Year	Proportion (%)				
		Land	Freshwater	Marine	Synthetic	Sewage* derived
SHORE						
Siddick	1978	26.7	0	69.9	3.4	3.2
	1979	53.3	Tr	45.1	1.6	1.8
	1980	59.5	0	36.9	3.6	0.4
	Overall	49.8	Tr	48.2	2.0	1.8
Cross Canonby	1974–76	36.9	0.6	62.5	0	0
Allonby (South)	1974–79	56.9	0.2	42.6	0.3	4.5
Beckfoot	1975–79	42.5	0	54.9	2.6	1.3
Westfield	1976	99.8	+	0.2	0	0
SEA BED						
Parton Bay	1980	46.9	0	51.7	1.4	3.3

* Sweage derived litter comprising land and synthetic components is treated separately.

TABLE IV

Variations in the number of litter particles of different origins in sieve residues

Station	Year	Coefficient of variation (%) Land	Freshwater	Marine	Synthetic	Sewage
SHORE						
Siddick	1978	165	—	129	297	152
	1979	397	528	312	185	263
Beckfoot	1975–76	104	—	96	290	191
SEA BED						
Parton Bay	1980	141	473	114	246	264

TABLE V

The proportions of plant, animal, synthetic and Thames Board derived (T.B.D.) components contributing to the total number of litter particles retained in a 1 mm sieve

Station		Proportion (%) Plant	Animal	Synthetic	T.B.D. PS	Fibre	Σ
SHORE							
Siddick	1978	22.4	32.3	1.9	20.0	23.4	43.4
	1979	36.6	28.6	1.1	15.8	17.9	33.7
	1980	23.8	14.4	1.4	15.1	45.3	60.4
	Overall	32.7	27.5	1.2	16.4	22.2	38.6
Cross Canonby		28.8	39.9	0	17.6	13.7	31.3
Allonby (South)		47.0	26.4	0.2	21.8	4.6	26.4
Beckfoot		31.5	37.5	1.9	15.5	13.6	29.1
SEA BED							
Parton Bay		44.4	47.7	1.3	5.4	1.2	6.6

T.B.D. = Thames Board Derived
PS = Parkwood Screenings

from Parton Bay the marine component was not as dominant as might have been expected; The freshwater component was always small and that from the land relatively substantial. At Westfield, not unexpectedly the land component comprised 99.8% of all the litter particles. Because sewage derived particles viz., onion skin, potato peel, tomato seeds and skin, and toilet paper are drawn from two of the categories in Table II, they are expressed as a separate column in this table. It will be seen that these materials were recovered from Siddick, Allonby (South), Beckfoot and Parton Bay, though not from Cross Canonby and Westfield. In this analysis, however, there is considerable uncertainty relating to the category to which a particle should be allocated. Thus, for example, all leaves were allocated to the land component, but this is not strictly correct for litter derived from salt-marshes contains leaves or leaf fragments (the latter being especially difficult to ascribe to source plant). Furthermore, considerable numbers of tea leaves must be carried to the sea by sewers, and though indistinguishable from other leaves, should correctly be ascribed to the sewage derived component. In terms of animal material, e.g. chitin fragments, there are similar difficulties.

To avoid such problems, it seemed more logical to ascribe the components to plant, animal, synthetic and Thames Board derived (T.B.D.) (Table V) at selected stations from the Cumbrian coast: the T.B.D. being ascribed to fibre and Parkwood screenings. As one might expect from the foregoing, the particles of Thames Board component were generally more abundant at Siddick than elsewhere. Parkwood screenings were evident in samples from each of these stations, but compared with the fibre were relatively more abundant at stations distant from Siddick. Presumably this arises in part through differences in the rate of transport of the two materials and in part through differences in their rate of breakdown by bacteria and fungi. In this respect, the occurrence of the Parkwood screenings is deceptive for in any group of such particles examined, the morphology of each is broadly similar, but the colour may vary between the creamy-yellow of freshly broken wood to a grey or dark brown colour. The former are firm to the touch of a mounted needle, the latter are friable and have clearly undergone substantial decomposition.

The results so far reported are concerned with those litter particles lying free within the soil. They do not include materials such as chitin still attached to shell or the organic shell matrix. Yet both being organic in nature are theoretically able to contribute to the energy requirements of soil microorganisms. Ultimately, they must contribute to the oxygen demand of a soil, particularly where shell forms a significant proportion of the coarse fraction. To examine this possibility further, mussel shell from a number of samples was weighed and placed in dilute hydrochloric acid until decalcified. The remaining chitin and shell matrix was washed carefully in distilled water and oven dried at 110°C before weighing. This organic residue comprised 1.6% of the shell weight (expressed as dry weights).

The organic contribution from this source (treating all shell as if it had the same content as that of mussel) was compared with that of normal litter and Thames Board derived material for a limited number of samples for whom the contribution of shell to the total coarse fraction

TABLE VI

A comparison between the amounts of ordinary litter, Thames Board derived materials and the organic component of mollusc shells found in Solway Firth shore soils

Station	Year	Proportion of component (%) Organic matter in mollusc shells	Non T.B.M. litter	T.B.M. derived material
Siddick	1978	71.1	17.8	11.1
	1979	79.4	15.7	4.9
Cross Canonby	1980–81	96.1	3.1	0.8
Allonby (South)	1979–81	94.0	5.4	0.6
Beckfoot	1975	95.2	4.6	0.2
Powfoot	1973–75	19.1	80.9	0
Westfield	1974–76	38.5	61.5	0

had been estimated (Table VI). At Siddick, Cross Canonby, Allonby (South) and Beckfoot most of the organic matter retained by a 1 mm sieve was associated with mollusc shell and when compared with this source and normal litter, the Thames Board derived component made a relatively small contribution. At Powfoot and Westfield, mollusc shell made a much smaller contribution to the organic matter, while Thames Board made none.

Surface strandings of litter

Litter may often be deposited in patches of variable size on the surface of sand flats and in flood channel barblets. Of the 19 samples examined (Table VII) the single sample from Allonby (South) contained 74% of Thames Board derived material, but 15 from Mawbray and Beckfoot contained much less, and 2 from Seaside, Auchencairn Bay contained relatively little. These last contained no synthetic material, whereas it was

TABLE VII

The composition of litter deposited at the shore soil surface during 1977. Proportions measured as w/w

Station	n	Proportion (%) Plant	Animal	Synthetic	Thames Board
Allonby (South)	1	16.4	8.2	1.4	74.0
Mawbray (May)	6	73.0	6.5	0.6	19.9
(Aug.)	4	71.6	0.9	0.2	27.3
Beckfoot	5	79.7	3.1	0.1	17.1
Seaside	2	90.5	5.6	0	3.9

present at the other stations. Unlike the coarse fraction retained by a 1 mm sieve (c.f. Table IV), the plant component was much more abundant than the animal component. Since it is reasonable to assume that these surface deposits are representative of the quality of the litter input, these results would suggest that after the initial decomposition of soft tissue, the residual animal material breaks down more slowly than does the plant litter.

Litter content of 200 g surface soil samples

The mean concentration of total litter at the principal stations examined (Table VIII) ranged from 99.7 p.p.m. at Siddick to 8,539 p.p.m. at Westfield, and all were much higher than the estimates derived from the 1 mm sieve residues: characteristically, however, individual samples showed considerable variation (Table X). Not unexpectedly the proportion of this litter comprising Thames Board material was greatest at Siddick (ca 66%), much less at Cross Canonby and Beckfoot (0.24 and 1.3%, respectively) and nil at Allonby, Westfield and the bed of Saltom Bay.

The litter content of the soil samples from these principal stations may be compared with others from the Solway Firth, Ardmore on the Firth of Clyde and from the coast of Devon (Table IX). Characteristically, the litter concentrations, at each station, were very variable, e.g.

TABLE VIII

The mean concentration of litter in 200 g sample of surface sediment (Litter d/w; soil w/w)

Station	Year	n	Mean litter concentration (p.p.m.) Non Thames Board	Thames Board	Total litter	Proportion of T.B. derived material (%)
SHORE						
Siddick	1974–77	7	34.4	65.3	99.7	65.5
Cross Canonby	1974–75	7	4414	10.8	4425	0.24
Allonby (South)	1974–76	5	38.4	0	38.4	0
Beckfoot	1974–75	14	455	5.9	461	1.3
Westfield	1974–75	9	8539	0	8539	0
SEA BED						
Saltom Bay	1976	4	69.3	0	69.3	0

d/w = dry weight
w/w = wet weight

TABLE IX

The concentration of litter in 200 g samples of surface from miscellaneous stations

Station	Year	n	Mean concentration (p.p.m.)
SOLWAY FIRTH			
Anthorn	1974	2	751
Harrington	1974	1	110
Parton	1974–75	1	43
St. Bees	1975	4	11
Powfoot	1975–76	2	1082
Rockcliffe	1974	2	201
Auchencairn Bay			
Lower Shore	1976	2	73
Seaside	1974–77	18	915
North Lodge	1974	1	1478
Seaward (R. Dee estuary)	1974	1	901
FIRTH OF CLYDE			
Ardmore	1975–77	17	1924
DEVON COAST			
Yealm Estuary	1976	4	3602
Avon Estuary	1976	1	2550
Rame Mud (sublittoral)	1976	6	969

TABLE X

The variability of the natural litter concentration in 200 g samples of surface soil

Station	n	Concentration (p.p.m.) Mean	Range	Coefficient of variation (%)
SHORE				
Siddick	7	34.4	3–86	100
Cross Canonby	7	4414	9–26226	206
Allonby (South)	5	38.4	5–81	77
Beckfoot	14	455	2–3738	216
Seaside	18	915	145–6700	164
Ardmore	17	1924	236–5490	66
Yealm and Avon estuaries	5	3391	1313–6029	59
SEA BED				
Saltom Bay	4	69.3	4–220	146
Rame Mud	6	969	308–2364	73

Cross Canonby where natural litter concentration was 4,414 p.p.m., range 9–26,226 (Table X); indeed without labouring the point further, the T.B.D. did likewise. Taking the results overall, it will be seen that

TABLE XI

The number of samples in a given litter concentration range compared with the Imhoff silt content

	Concentrations (p.p.m.)					
Silt content (%)	<10	10–10^2	10^2–10^3	10^3–10^4	>10^4	Total
<1	3	6	0	5	0	14
1–5	1	5	3	4	0	13
5–10	0	2	5	3	0	10
10–20	0	1	5	3	2	11
20–40	0	0	7	2	0	9
>40	0	0	2	0	0	2
TOTAL	4	14	22	17	2	

with the exception of samples from the open shores at Allonby (South), St. Bees and Parton and the lower shore at Auchencairn Bay, the total litter content of the shores at Siddick was less than that of all the others examined, by a factor of 2 to 36 times, and that at Westfield by a factor of 86 times.

The shores at Ardmore and the Devon coast were chosen as comparators normally outside the influence of such materials as may be released in the Thames Board effluent. Ardmore has an aspect and soil grade composition broadly similar to that at Siddick. Thus the median Φ at Siddick ranges from 2.0 to 2.8 and that at Ardmore from 1.8 to 2.8. The Imhoff silt content (see Perkins, 1977b) ranged from 0–10.7% with occasional samples to 36% at Siddick and from 0.3–10.7% at Ardmore. It is, however, in the litter content that the two differ most markedly. Thus the mean litter concentration at Siddick was ca 100 p.p.m. whilst that at Ardmore was 1924 p.p.m., i.e., some 20 times greater. In contrast, the Devon shores samples were much richer in silt, mainly >90%. The total mean litter content of the both shores examined ranged from 10 to 36 times more than that at Siddick.

The concentration of litter in soils tends to increase towards the head of estuaries and sheltered bays, as does the silt content. It would be reasonable, therefore, to conclude that the two might be related. Examination of the 59 results, from the Solway, where the Imhoff silt content and litter concentration can be compared, produced no clear relationship as the matrix in Table XI indicates. Addition of results from Ardmore and the Devon coast did not materially affect this conclusion.

DISCUSSION

The present work has shown that while each of the elements (1) to (6) noted in the introduction contribute to the organic content, the practice of using small samples of surface soil has lead to the exclusion, from consideration, of such sources as the mollusc shells present in so many sediments. While the present study does not indicate the extent to which this source contributes to the oxygen demand of a soil, it does show that this may be a most important source of organic carbon in marine soils.

The differences in the total litter concentration determinations derived from the quadrat box sieving residues and the 200 g samples of surface soil (compare Table I and Table VIII and IX) may be attributed to two causes other than differences in the sieve used

a) Litter is first deposited at the soil surface before it is reworked into the body of the soil, and

b) Once reworked into the soil breakdown by microorganisms proceeds rapidly (a conclusion consistent with Perkins, 1982).

The surface concentration measurements are therefore likely to be exaggerated when compared with the whole soil column, though this may be subject to marked variations depending upon the rates at which reworking by physical and biological agencies takes place.

Considering the results as a whole, it is evident, that with the exception of Siddick, the material derived from Thames Board has had only a limited impact on the Solway Firth sediments. Even in the upstream areas, where reconcentration might be expected, it did not exceed 20% of the total litter present excluding organic matter derived from mollusc shells. If the latter is included then the proportion falls to less than 1%. These and other comparisons must, however, be treated cautiously in view of the pronounced variability of samples taken at each station.

Interesting comparisons may be made with other shores, thus the total litter content at Siddick was up to 86 times less than that at Powfoot and Westfield in the Solway Firth, and 20 times less than that at Ardmore in the Firth of Clyde. These sediments are all relatively unstable and similar in type. In the more stable soils from the Devon estuaries the total litter content was up to 36 times greater than that at Siddick, and Turner (1982) working at Camsail, Rosneath Bay, Firth of Clyde found mean litter contents of 3918 p.p.m., i.e., ca 140 times greater than the highest mean concentration recorded at Siddick.

Considering Siddick as the primary case (and since the Thames Board concentrations are both lower and a smaller proportion of the whole elsewhere, the argument will apply), it should be noted that the Thames Board derived materials have never exceeded 80% of the total litter content (excluding mollusc shell organic matter) so that this component has not overwhelmed other sources here; further away the proportion is normally less than 20%. Compared to similar unstable shores at Westfield and Ardmore and the stable, silt rich shores of the Devon estuaries and Camsail (which evince no signs of faunal impoverishment associated with the substantial litter content) that at Siddick can probably be regarded as having a litter content significantly below that which it might carry without adverse effect. Given that this is a fair conclusion, then it seems unlikely that an input of Thames Board derived material, at the present rate, is having a detectable influence upon this shore. A conclusion which is consistent with the work of Perkins and Reid (1978).

Taken as a whole the results of this study indicate that the litter supply to any given shore or sea bed is variable, both in amount and composition, and in a manner such that no clear pattern other than this has emerged. Interestingly, the proportion of the land component of litter in Solway Firth sediments seems rather high, but this and the differing contributions of various types of litter upon and within the soil suggest very difficult rates of breakdown for each. Furthermore, if this is true then the supply of breakdown products and smaller, i.e. detrital, particles must be subject to similar variations.

Even if the rate of breakdown of all the components is the same, there are marked discontinuities in the rate of litter supply. Thus the leaves of deciduous trees normally fall in autumn and the principal input to the sea either takes place then or in the winter floods. Similarly, the dead stalks and leaves of *Spartina*, from Auchencairn Bay for example, are normally detached in autumnal and winter storms at which time a major input of algal litter also occurs. While one tends to think of animal growth as a continuous process, it rarely is so, and large numbers of the chitinous exuviae of barnacles, amphipods and shore crabs may appear in the water at times of mass, synchronous moult. With regard to anthropogenic inputs, most industrial effluents are subject to variation depending upon the nature of the process and demand for the product; sewage inputs will clearly exhibit a diurnal variation and, depending upon any given areas attraction to tourists, marked seasonal variations too.

While sediments of higher energy shores tend to have a lower litter content, than those from more sheltered areas, the pattern even here showed marked variations: thus the similarly exposed shores at Ardmore and Siddick showed 20 fold differences, whereas those of the former and the sheltered estuaries were essentially similar in litter content. Finally, the lack of any clear relationship with Imhoff silt content indicates that while the deposition of both litter and silt is favoured by the same conditions one cannot expect to use one as an indicator for the other in terms of the amount expected.

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