



Review

From a millennium base line to 2012: Beach litter changes in Wales

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ABSTRACT

Forty-five beaches at 41 bathing area locations in Wales were analysed for litter in 2000 and 2012, via a standard seven category checklist. Fourteen resorts, 2 urban, 11 village, 15 rural 3 remote, were graded, A to D. A grade beach numbers changed from 5 to 19; B, 27 to 24; C, 9 to 2; D, 4 to 0, many beaches maintaining their current status. Assuming trend continuance within the next 12 years, the A:B grade ratio would approach equilibrium of 44:56, with no grade C or D beaches. Recreational litter was ubiquitous; fishing materials prevalent along Cardigan Bay. New water treatment plant investment reduced sewage related debris. Despite apparent increased awareness of beach litter, improving visitor behaviour through information/education should be a future priority. Removing a few gross items could improve beach grades at little cost to local authorities and benefits to the Welsh economy.

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1. Introduction

Litter is a massive global issue that is of concern to governments, and the general public, as it despoils beaches, is non-aesthetic and frequently a health hazard. Litter that accumulates on beaches is derived from three main sources: *marine*, e.g. commercial fishing vessels, cruise ships, recreational vessels, together with sea disposed industrial and domestic wastes; *riverine*; and *beach user* recreational discards, e.g. water bottles, crisp packets. Litter may be found floating on the sea surface or

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hanging in the sea column, on beaches, and in the deep sea (Pichel et al., 2007; Santos et al., 2009; Lee et al., 2006) and many surveys have recorded that it mars holiday enjoyment (Williams et al., 2013).

Larger landfill materials and illegal 'fly tipping', e.g. tyres in particular, are 'land borne litter', although the latter could have a riverine origin prior to beach deposition. Marine litter may be defined as the solid materials of human origin that are discarded at sea or reaches the sea through waterways or domestic or industrial outfalls (Williams and Micallef, 2009). Marine litter adversely affects coastal development sectors, especially the tourism industry, as it curtails beach enjoyment and eliminating litter at source should be the aim. This is difficult, but crucial. However, before it can be achieved robust assessments are needed, requiring close links between field surveys and management activities (Tudor and Williams, 2001).

One of the largest problems of the 21st Century is plastic litter (Goldberg, 1995), which may comprise some 40–60% of litter found on a beach (Derraik, 2002). Until recently, most litter research involved tabulating counts of various litter types (bottles, tyres, etc.), usually in conjunction with 'beach clean-ups', but with scant regard to either sourcing or site comparisons (Williams et al., 2000). The litter found is usually eclectic in character. Largely as a result of public awareness, litter has recently become an important issue, especially with the growth in outdoor activities and tourism. In response to this, an EC initiative – The Marine Strategy

Framework Directive (MSFD) – was issued and applied to all European seas, aiming to ensure, 'Good Environmental Status', through the use of 11 descriptors, with Descriptor 10 specifically relating to marine litter (EC, 2008). It is interesting to note that, at the International Berlin litter meeting of 13.03.2013 (www.seas-at-risk.org/n2_more.php?page=583 (accessed 10.05.13)), it was revealed that no EU country had set quantitative reduction targets for marine litter, for reasons of lack of knowledge and baseline data.

Many studies have attempted to assess the amounts of land-sourced debris and sources of litter but global knowledge is mainly 'educated guestimates'. For example, Myers (2007) pointed out that globally some 6 million items enter the sea daily. The Ocean Conservancy (2009) gave a figure of 11,439,086 for the worldwide total of marine debris items although this total is obtained from small areas (Santos et al., 2005; Sol and Coast, 2007). Hall (1998) showed that litter exerts a powerful influence on the economics of bathing areas, as tourists will avoid such areas due to aesthetics and health reasons. Other researchers, e.g. Williams, 2011, McKenna et al. (2011), argue that clean beaches are fundamental for attracting the tourist trade, especially at resort and urban beaches. *Toxicaria canis* (resulting from dog fouling), is now becoming a large issue in beach litter clean-ups and a maximum of £1000 can be imposed on dog owners for not picking up the waste. Additionally, potential dangers to tourists are broken glass, syringes and nails, etc. which can cause foot lacerations (Phillip et al., 1995) and sharps containers have been issued to lifeguards who are

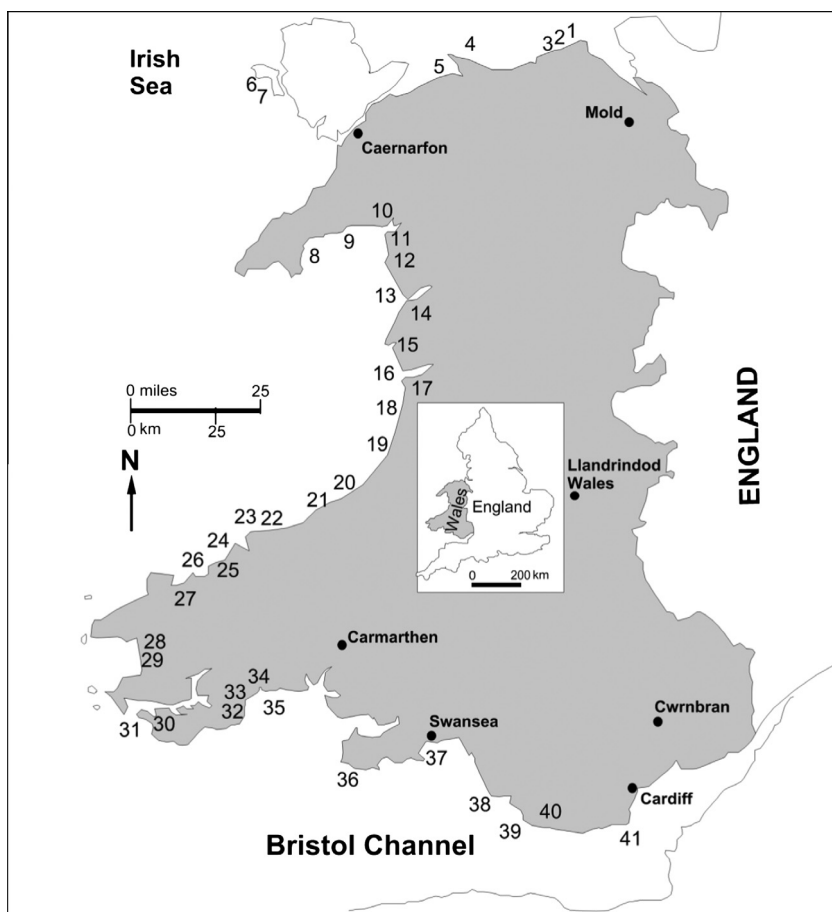


Fig. 1. Location of investigated beaches. **KEY:** 1 Rhyl, 2 Kimmel Bay, 3 Abergele, 4 Llandudno, 5 Penmaenmawr, 6 Porthdafach, 7 Llanfynach, 8 Pwllheli, 9 Criccieth, 10 Morfa Bychan, 11 Harlech, 12 Talybont, 13 Barmouth, 14 Fairbourne, 15 Towyn, 16 Aberdovey, 17 Borth, 18 Aberystwyth, 19 Newquay, 20 Llangrannog, 21 Tresaith, 22 Aberporth, 23 Mwnt, 24 Poppit, 25 Newport, 26 Dinas, 27 Goodwick, 28 Nolton, 29 Broadhaven, 30 Freshwater West, 31 Angle, 32a Tenby North, 32b South, 33 Wisemans Bridge, 34a Amroth, 34b Amroth Castle, 35 Pendine, 36 Port Einon, 37 Swansea Bay, 38a Porthcawl Rest Bay, 38b Sandy Bay, 38c Trecco Bay, 39 Southerndown, 40 Llantwit Major, 41 Lavernock.

frequently advised not to go barefoot at some beaches (Garrity and Levings, 1993). Sewage related debris (SRD) and medical waste has also been found on some beaches (Rees and Pond, 1995; Nelson and Williams, 1997).

2. The study area

The Principality of Wales covers an area of circa 20,779 km² (8023 square miles) with over 1200 km (746 miles) of coastline, including offshore islands, the largest being Anglesea (Fig. 1). Geologically, this hard rock area (Palaeozoic) resulted in a crenulated coastline, on which a wide spectrum of cities, resorts, towns, villages and hamlets have developed, all of which have varying issues with regard to litter, depending upon place and cleaning regimes (if any). Forty-five beaches spread over the Principality (Fig. 1), were selected for a litter study, utilising the EA/NALG (2000) protocol – see Section 4.

3. Definitions

3.1. Resort

Different people have different interpretations of this term, which epitomizes Humpty Dumpty's comment that, 'words mean whatever I want them to mean'. Walton (2000, 21), asked the question regarding UK resorts: 'How important does the holiday industry have to be in a town before it can be classed as a resort? Intuitively the term is understood and recognisable as a distinctive town type. In 1951, more than 100 resorts had 5.7% of the UK population (Theroux, 1983, 21). In Europe it conjures up the Club Med concept, i.e. self-contained entities that fulfil beach users' recreational needs to different degrees, the majority of whom reside at the beach-associated accommodation complex integrally linked to management of the beach. However in the UK, especially Wales, it is more as Theroux (1983, 349) wrote:

'The character (of seaside resorts) was fixed, and although few coastal places matched their reputation, every one was unique. ... And there was such a thing as a typical resort on the coast. ... There was always an Esplanade, and always a Bandstand on it; always a war Memorial and a Rose Garden. ... A Lifeboat station and a Lighthouse, and a Pier. A Putting Green, a Bowling Green, a Cricket Pitch, and a church the guidebook said was Perpendicular. The pier has been condemned. It was threatened with demolition. ... The railway had been closed down. ... and the fishing industry folded five years ago. The art-deco cinema was now a bingo hall. ... The new bus shelter has been vandalised. It was famous for its whelks. It was raining.' At several Welsh resorts, e.g. Porthcawl, a fun-fare and donkeys on the beach may be added to the definition.

Indeed a totally different perception. That is why places especially along the North Wales and Cardigan Bay beach stretch e.g. numbers 1–5, 13–16 respectively (Fig. 1), are classed as resorts and they represent such a high proportion of the places investigated in Fig. 1. The northern Cardigan Bay holiday areas, e.g. Fairbourne, Towyn, could equally be classified as urban. All owe their nomenclature for being in the main, the standard two week holiday break destinations for many Midland personnel in the 20th century.

3.2. Urban

These serve large populations which have well-established public services, e.g. primary school(s), bank(s), religious centre(s), internet cafes with a clearly demarcated central business district,

commercial activities, e.g. harbours and marinas. Urban beaches are, in the main, freely open to the public.

3.3. Village

These are located outside the main urban environment and have a small, permanent population reflecting an organised but small-scale service structure (such as a primary school(s), religious centre(s), shop(s) and public/private transport. This also includes 'ribbon development' between urban and rural environments. It is arguably the most difficult definition of the five bathing area types.

3.4. Rural

These would be found outside the urban/village environment and not readily accessible by public transport having virtually no facilities – perhaps a small summer shop, car park and/or toilet. Housing is limited in number (generally 0–10 but may be more depending on the size of the coastal stretch) and usually of a temporary (summer) nature, but no permanent community focal-centre exists (religious centre, primary school, shops, cafes, bars). The beaches have little or no beach front development and are greatly valued by beach users for their quietness and natural (unspoilt) qualities.

3.5. Remote

These may be defined by access difficulty largely by boat or foot – a walk of 300 m or more. They can be adjacent to either village or rural areas but rarely with urban ones. They are not supported by public transport and have very limited (<5 if any) temporary summer housing. Few people access these beaches.

4. Methods

The UK Environment Agency (EA National Aquatic Litter Group) monitoring protocol and classification scheme, finalised after a 3 year investigative period, was used to assess the aesthetic quality of coastal and bathing beaches (EA/NALG, 2000). The scheme has a standardised approach of counting seven parameters: sewage related litter, potentially harmful litter items (glass, syringes), gross (large) litter (e.g. a supermarket trolley), general litter (water bottles, metal cans, crisp packets, etc.), accumulations of litter, oil pollution, and occurrence of non-human faeces (Table 1). Items belonging to these seven categories were counted along a 50 m beach width either side of the main beach access point (EA/NALG, 2000). Counting commenced at the strand line and ended at the back of the beach (seawall, dune etc.). Litter lying between

Table 1
EA/NALG (2000) protocol litter table summary (Litter categories).

Category	Type	A	B	C	D
1 Sewage related debris	General	0	1–5	6–14	15+
	Cotton buds	0–9	10–49	50–99	100+
2 Gross (large) litter		0	1–5	6–14	15+
3 General litter		0–49	50–499	500–999	1000+
4 Harmful litter	Broken glass	0	1–5	6–24	25+
	Other	0	1–4	5–9	10+
5 Accumulations	Number	0	1–4	5–9	10+
6 Oil		Absent	Trace	Nuisance	Objectionable
7 Faeces		0	1–5	6–24	25+

Table 2

Percentage of debris at EA/NALG (2000) transect areas of some beaches (N = total amounts of litter found).

Location & position	Rhyl N = 47	Llandudno N = 17	Harlech N = 46	Barmouth N = 64	Towyn N = 49	Aberdovey N = 63
Above highest strand line	8	1	0	0	4	5
Highest strand line	19	85	65	3	14	18
Zone between strand lines	4	0	5	13	5	1
Current strand line	67	13	30	82	75	75
Below current strand line	2	1	0	2	2	1

**Fig. 2a.** Towyn, an old fashioned resort with a new Sterling £11 million seawall.**Fig. 2c.** Pendine.**Fig. 2b.** Swansea.**Fig. 2d.** Southerndown car park during the January 2014 storms.

the strand line and sea has been shown to represent *circa* 2% of beach litter (Table 2), therefore much time is saved in litter counts by ignoring this area (Tudor and Williams, 2001). Insertion into Table 1 of the number of litter items found enables a researcher to attach a litter grade to each parameter/bathing area. The overall beach litter grade is given as the lowest grade obtained. For example, a beach could have A grades (best) for all categories, apart from a D grade (worst) in gross litter. Hence the beach would be given a D grade, and this system enables managers to concentrate on items that need to be eliminated in order to achieve higher grades.

Forty-five beaches at 41 bathing areas were selected for study to cover a spectrum, as classified by Williams and Micallef (2009) and Williams (2011) ranging from:

- resorts: Porthcawl, Rhyl, Prestatyn, Towyn, (Fig. 2a); Llandudno;
- urban: Swansea (Fig. 2b), Aberystwyth, Barmouth;

- village: Poppit, Pendine (Fig. 2c); Port Eynon;
- rural: Southerndown (Fig. 2d), Lavernock;
- remote: Harlech, Mwnt (Figs. 3a and 3b).

At Porthcawl, three beaches were investigated (Sandy Bay, Trecco Bay and Rest Bay); at Amroth, the Main beach and Castle beach; and the North and South beaches of Tenby. A base line study carried out in the Millennium year – 2000, with the help of Youth Clubs in Wales (Williams and Jones, 2000), was repeated in the summer of 2012 by the authors of this paper, on either the same day or within one day either side of the original date, all days being dull and cloudy. Each volunteer group in 2000 (a group contained at least three and a maximum of six persons) was trained in beach litter assessment. Training involved accurately defining litter types prior to volunteers identifying litter on transects of various widths (5–100 m) and comparing results with ‘expert’ analysis of the same transect. Williams et al. (1999), have shown that after such training, no significant statistical difference exists between



Fig. 3a. Mwnt, a remote pocket beach.



Fig. 3b. Gross litter (old TV set) at Mwnt.

Table 3
Numbers of beaches of each grade in 2000 (rows) and in 2012 (columns), and proportional changes in parentheses (Transition Matrix of probabilities).

	Grade A	Grade B	Grade C	Grade D	Totals 2000
Grade A	2 [0.4]	3 [0.6]	0	0	5
Grade B	13 [0.464]	15 [0.536]	0	0	28
Grade C	3 [0.429]	4 [0.511]	0	0	7
Grade D	1 [0.2]	2 [0.4]	2 [0.4]	0	5
Totals 2012	19	24	2	0	45

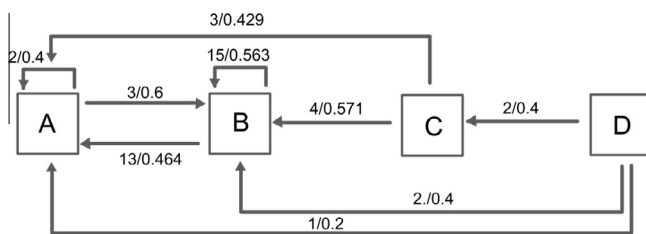


Fig. 4. State (transition) diagram, illustrating the transition matrix of the Markov model.

litter counts carried out by ‘expert’ evaluators and volunteers. The sole exception to this was mis-identification of a single hazardous container by one volunteer group. The study provided educational

Table 4

Change in beach grading over the survey period and modelled future projections.

YEAR	Grade A	Grade B	Grade C	Grade D
2000	5	28	7	5
2012	19	24	2	0
2024	19.6	25.4	0	0
2036	19.63	25.38	0	0

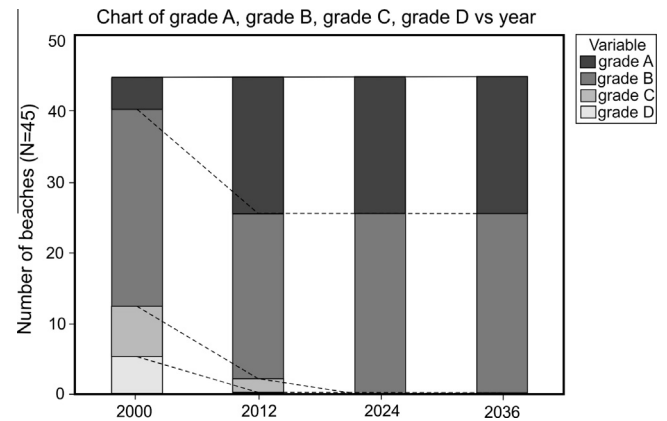


Fig. 5. Change in beach grading over the survey period and modelled future projections.

value for participants as a raised environmental awareness of the scale of the litter problem, as well as obtaining a Level 2 credit rating (code QA32WE001) from the Open College Network.

Changes in grading of beaches (Table 3) were modelled using a discrete-time Markov chain analysis to predict future grades on the basis of the changes observed between 2000 and 2012. This approach has been applied, for example, to predicting the dynamics of ecological succession in a raised mire ecosystem, whereby changes occur between a series of defined ‘states’ (plant communities) over defined time periods (Jeffers 1972). A set of linear coefficients, representing the transition probabilities for all possible changes between grades A, B, C, D, were calculated as proportions of the total numbers of beaches for each grade in 2000, using the observed changes over the study period (Table 3). The Markov model is illustrated by a state diagram (Fig. 4), which reflects the transition matrix of changes in beach grades between 2000 and 2012. If the assumption is made that future changes of state will reflect the current set of observed transitions (i.e. the transition probabilities remain constant), then the likely numbers of beaches of each grade can be predicted for future 12-year time-steps (Table 4; Fig. 5). This is achieved simply by multiplying the current number of beaches in states A to D by the transition matrix, and repeating this process for successive time-steps. The aim of the analysis is to anticipate future trends in beach quality based on recent observed changes.

5. Results and discussion

Fig. 6a and b is a summary of litter items found during the summer period in the years 2000 and 2012 for 14 resorts, 2 urban, 11 village, 15 rural and 3 remote beaches in Wales. Local authorities could scan the detailed results and hopefully take appropriate steps to reduce litter. In many instances it would be relatively easy to improve beach grades. For example, an A grade would result simply by removing the small amount of general litter found in 2012 at Port Eionon beach or by removing at Broadhaven beach small quantities of general litter plus a buoy; or the TV set at Mwnt

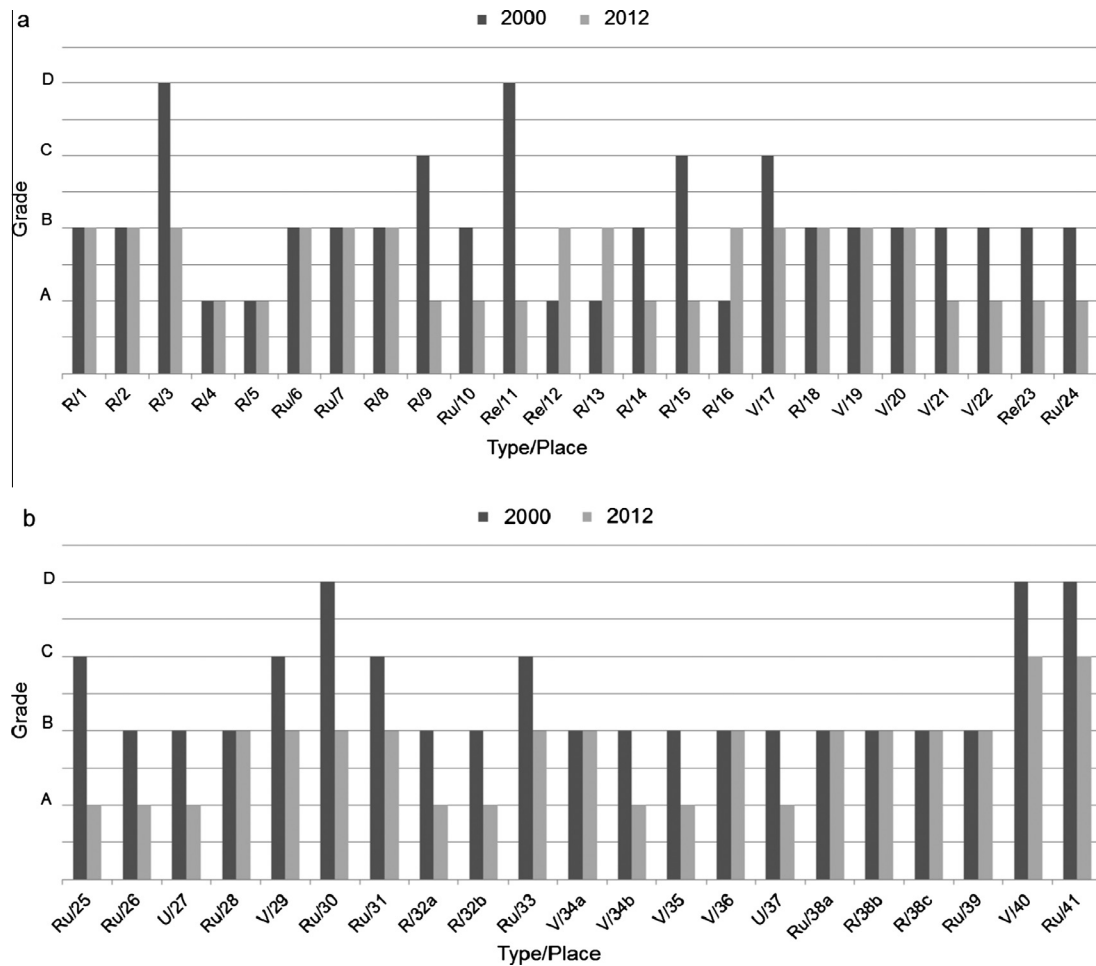


Fig. 6. (a and b) Beach grade changes 2000–2012.



Fig. 7. Fishing twine found at many places along the Harlech coastline.

(Fig. 3b). Some sources of litter are outside the control of a Local Council, e.g. Combined Sewer Outfalls (CSO) that discharges into nearby rivers, but understanding litter origins is vital to bringing about such desired improvements. Glass was found on beaches on only 14 occasions in 2000 and twice in 2012 (on both of the Anglesey beaches). Although this is an encouraging sign, it should be noted that glass is ranked as litter item number 9 on the MSC (2012) Beachwatch Big Weekend beach litter survey, as on over

90 km of beach cleans more than 5000 glass items were found. Glass reduction is probably one of the few good findings to come from society's increased usage of plastics, and it was plastic items that constituted the bulk of the litter found. Oil was noticeable by its absence.

Most frequent litter types: Lemonade/Coca Cola cans, lids, cotton bud sticks, manufactured wood, rope, polystyrene pieces, bottle corks, plastic (all sorts), paint brushes, milk cartons and crates, tissues, old trainers (shoes), fishing gear (nets, boxes, etc. Fig. 7), sewage waste, cigarette tips and lighters, sweet wrappers, dog droppings, plastic bottles/cups, crisp packets.

Dangerous Litter: Syringes, bottles of liquid, large containers with tar/chemical residue, broken bottles, jagged tin cans, wood planks with nails, rusty metal pieces.

Other/Unusual Litter: Golf tees, coat hangers, items of clothing (underpants, shirts, socks etc.), rubber gloves, traffic cones, bicycle seats, supermarket trolleys, shotgun cartridges, car tyres (often very big), asthma inhalers, Calor Gas bottles, door mats, side mirrors, bicycles, dummies, horse manure.

Changes in bathing area grading over the investigated time period are given in Fig. 6a and b, but in summary:

A grade: the number increased from a base of 5 beaches to 19. It should be noted that of the original 5 grade A beaches, 3 were down-graded to B.

B grade: reduced slightly from 28 to 24 beaches, mainly as a result of 13 B grades being re-classified as A grades.

C grade: Again, a net improvement from 7 to 2 beaches.

D grade: 5 beaches recorded as D grade in 2000; zero in 2013.

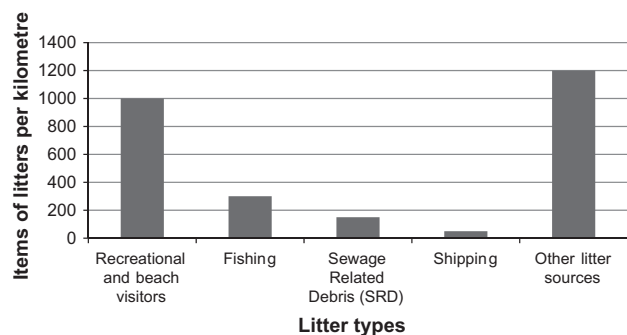


Fig. 8. Litter sources for Wales (amended from, MCS, 2010).

All north Wales resort beaches either obtained the same grades (e.g. Llandudno and Penmaenmawr), or showed an increase in beach cleanliness (Fig. 6a and b). A mixture of results can be seen for Cardigan Bay, in that Talybont, Aberdovey and Barmouth beaches went down from A to B grade, whereas e.g. Borth, Tresaith and Aberporth improved a grade, whilst Towyn improved by two, and Harlech by three grades. Only 3 out of the 45 bathing areas scored lower grades over the investigation period, which declined from grade A to B (Table 3).

As shown in Fig. 4, many changes of state along the “chain” resulted in up-grade (e.g. 13 beaches changed from B to A grade), a total of 17 beaches retained either A or B status in the 12 year period, and a small number of down-grades occurred (3 beaches out of 5 in 2000 changed from A to B). Projecting these trends over the next 12-year period, grade B Beaches are likely to remain the largest number, grade A beaches increase slightly, but no grade C beaches remain (Table 4, Fig. 5). Over successive time steps (powers) the matrix rapidly reaches a state of equilibrium, with the probability of 19.6 (43.6%) grade A beaches and 25.4 (56%) grade B, with zero occurrences of C and D grades (seen also in Fig. 5). In view of the apparently improving pattern of change over the study period it is perhaps surprising that the equilibrium ratio of beaches is in favour of grade B. This results from both a higher transition probability of A declining to B (0.6) than of its remaining as A (0.4), and similarly a lower transition probability of B improving to A (0.46) than of its remaining as B (0.54) (Table 3; Fig. 4). It should be noted that only 5 beaches of grade A were observed in 2000, a small proportion of the 45 bathing areas surveyed, hence these few cases exert a relatively large influence on the dynamics of the model system and predictions arising from it. This illustrates the importance of having a robust data set when attempting to predict general trends. For example, if there had been just 2 down-grades from A and 3 that had stayed as A (out of 5), then the probabilities would be 60/40, not 40/60, so the final equilibrium ratio of A and B in the model would have been *circa* 70% A to 30% B (instead of 44% A to 56% B). Similarly, if no down-grades from A to B had been observed, then the “chain” would be unidirectional (i.e. the matrix would have an “absorbing” state), with all beaches ultimately becoming A grade.

The aim of the Markov chain analysis was to show that, in this case, the system equilibrates with a constant proportion of A to B grade beaches. Although the components of the model are linear (i.e. the transition probabilities denote observed proportional changes of state), the response of the whole system is not a predictable straight line projection. The explicit assumption was made that the calculated changes of state continue during future 12-year time steps, whereas possible changes in management or other interventions could affect future results. As indicated above, the model would be sensitive to such actions at specific beaches, which might alter the transition matrix and hence change the outcome.



Fig. 9a. Newgale beach after the January 2014 storms.

Hence the model can provide a measure against which to compare future data sets, and to evaluate observed improvements at beaches against a “no change” projection.

It is gratifying to note that, for example, glass at Rhyl, syringe at Dinas, planks with nails at Goodwick, both of the latter at Llantwit Major, faeces at Morfa Bychan, gross litter at Trecco and Sandy bays, found in 2000 were markedly absent 12 years later. Similarly, the number of plastic bags (recorded within general litter) was greatly reduced, which can be attributed to the cost of buying such bags, a result of the Welsh Government’s 2011 levy on single use plastic carrier bags. Trecco bay is backed by Parkdean caravan development and their management approach is exemplary with respect to beach cleaning; Sandy bay had a council run caravan park backing the beach, but this has been demolished over the investigated period. Water quality has undoubtedly become better over the past decade, e.g. at the turn of this century Swansea upgraded their sewage system with a new £90 million water treatment plant. Such major investment is now common in Wales and it is only following storms that CSO inputs cause water quality problems. The MSC (2012) Beachwatch survey noted that sewage related debris has dropped out of their top 10 litter items, but sewage was still in evidence on beaches surveyed for this paper. Findings generally concurred with those of the MSC (2012) survey (Fig. 8), in that the main sources of beach litter were the ubiquitous recreational litter (plastic water bottles, crisp packets, cardboard food containers, plastic cutlery, lids and caps, etc.) together with fishing materials (nets, thick ropes, monofilament lines, etc.) especially along Cardigan bay beaches. Relative numbers of the latter were in broad agreement with those found by the MSC (2012). Some 134.3 items/km of crisp/sweet/lolly wrappers were found by the MSC (1012) survey but these figures conflicted in several instances on many beaches investigated for this paper. Additionally, the current MCS (2014) September spot check survey found 4,402.5 items/km, obtained from 26 Welsh beaches (mainly Gwynedd and South Wales), a coastal length totaling 7.03 km. The conclusion was that between 2012 and 2013, litter on Welsh beaches had increased by 60%. It should be noted that the MCS surveys related to bin bag collection (174.25) in the instance mentioned above, so a direct comparison cannot be made.

The fishing lines were single-strand, high-density, nylon fishing line used on fishing reels and in the manufacturing of fishing nets. Plastics still dominate litter items. Dog fouling is still a concern and apart from the TV set at Mwnt, (Fig. 3b) no evidence of fly tipping was found. Cigarette stubs were also seen in very small numbers, probably as a direct result of the anti-smoking



Fig. 9b. Southerndown beach after the January 2014 storms (pebbles plus litter).



Fig. 9c. Southerndown beach after the January 2014 storms (litter).

campaign. The MCS (2012) survey gave figures of 67.7/km for this item, but findings from site specific beach surveys in this study, showed lower levels. Beach cleaning operations are part of the 'normal' cycle of summer maintenance on the main public beaches and they tend to remove most material, but this is a task akin to painting the Forth Bridge! Overall, litter amounts were reduced but, despite encouraging signs, there is no room for complacency by authorities regarding the state of their beaches. The ferocious January 2014 storms that bedevilled the Welsh coastline caused massive sediment movement. For example, pebble beaches were moved many metres inland and seaward slope considerably reduced. Fig. 9a shows the pebble ridge movement which covered the main road at Newgale, the 30 mph sign representing the seaward edge of the road. From the viewpoint of litter, this meant that much litter trapped in the interstices of pebble ridges was exhumed and moved landwards pre deposition. This will cause a lessening of buried litter quantities (Williams and Tudor, 2001) that serve as 'litter capital' in the ridge (Figs. 9b and 9c) and should therefore reduce future litter amounts found on such beaches.

With regard to campaigns and public participation schemes that aim to raise awareness and reduce the marine debris problem, a growing number of organizations exist (Williams et al., 2005; see later). Education and public awareness are key elements for marine debris reduction. Public involvement in beach litter management, e.g. as practiced by the Marine Conservation Society (MCS), takes two forms: Direct action such as beach clean-ups and monitoring; and indirect action, such as education, award schemes and legislation. The involvement of the public in beach monitoring and clean-up programs has a dual advantage in that it allows a large sample size to be achieved, and raises awareness among society which will then translate into effective individual action to reduce litter at source. 'Clean-ups,' do make a considerable difference, either through making local beaches/shoreline free of debris or by raising awareness. During June, 2014, the MCS will launch a 'Marine Litter Action Network' one of whose aims is changing people's behaviour with respect to litter.

Currently, a Marine LitterWatch mobile phone App (www.eea.europa.eu/themes/coast_sea/marine-litterwatch (accessed 01.03.14)) enables people to upload beach litter information directly to the co-ordinators of the project, European Environmental Agency, based in Copenhagen. The partners involved are the MSC in the UK, The Perseus FP7 research project, Greece, North Sea Foundation, and the Institute of Water for the Republic of Slovenia. The App is currently available for Android devices and will soon be published for iPhone and iPad and will help support the European Marine Strategy Framework Directive.

On the international scene, schemes devoted to litter include: the 'International Coastal Cleanup (ICC)' – a global project co-ordinated by the 'Ocean Conservancy' (formerly the Center for Marine Conservation, CMC), a U.S. non-governmental organization; The 'National Marine Debris Monitoring Programme', coordinated by the 'Ocean Conservancy's Office of Pollution Prevention and Monitoring' with funding from the U.S. Environmental Protection Agency (EPA); 'Project AWARE Foundation'; 'Clean Up the World', established in 1993, and UNEP has been the programme partner of, for example, 'Clean Up Australia' since then; 'Coastwatch' is an international educational network in 23 European countries with the aim to train and educate volunteer and students in field work, basic reporting methods and relevance of results obtained to policy legislation; 'Keep Bermuda Beautiful'; 'Environment Canada'; 'Keep Baltic Tidy'; 'Seawatch Marine Debris Survey' in New Zealand.

In the UK, similar schemes exist, such as: 'Beachwatch', a campaign organized by the 'Ocean Conservancy' and part of the International Coastal Cleanup (see above). Thousands of volunteers from all across visit their chosen beach, remove/record the litter and send data to the Marine Conservation Society (MCS) where it is analysed and reported in the Beachwatch report; 'Keep Wales Tidy' concerns itself with the Principality. More local schemes include, Cumbria Marine Litter Project promotes the 'Bag It & Bin It Campaign' on the basis that simple steps taken by the public in their homes removes the problem at source; the 'Forth Estuary Forum Coastal Litter Campaign'.

Beach enjoyment is affected by debris and 23 years ago Herring and House (1990) concluded that sewage derived contaminants, e.g. condoms, toilet paper, sanitary towels, attain a higher degree of emotional response within the general public than others and have a greater impact than any other aesthetic pollution parameters, e.g. beverage containers, sweet wrappers on the enjoyment of a visit to a beach. Findings by Nelson and Williams (1997) and Williams et al. (2000), suggested, that the public are more affected by what they perceive as a mixture of generic debris categories, i.e. items from visitor discards *together* with SRD, such as condoms and sanitary towel backing strips. However, there is no doubting that the general public perception of debris items on beaches is consistent in those potentially hazardous items – syringes, SRD, being the most offensive items (Tudor and Williams, 2003). The high level of offensiveness attributed to SRD and potentially hazardous items, corroborates the weighting given to these items within the EA/NALG protocol.

The UK's, anti-waste body, 'Waste Resources and Action Programme' (WRAP), estimates that some 500,000 tonnes of mixed household waste plastics (currently 400,000 tonnes), will be

recycled every year by 2020 (www.WRAP.org.UK). In 2002 Ireland introduced a Euro 0.15 charge for a plastic bag – demand dropped by 90%; IKEA now charges 10 pence a bag; Italy on January 1, 2011 was the first European Union country to ban polythene bags, opting for biodegradable bags; Wales, was the first country in the UK to introduce a legal charge (5 pence per single use carrier bag in October 2011), as part of its efforts to dramatically reduce the volume of carrier bags given to shoppers, as in 2009, people in Wales, UK, took home from major supermarket alone, an average of 273 carrier bags per household (www.wales.gov.uk). Better technological solutions regarding litter will undoubtedly occur in the near future, such as, bottle designs using less plastic together with more environmentally friendly materials. Imaginative solutions are needed and will occur, e.g. plastic technological advances in order to produce more bio-degradable and/or recyclable plastics. Some 40 years ago, the ITW Hi-Cone company reduced by 30%, the plastic amount in six-pack holders (Williams et al., 2013). Biodegradable plastics can now be made from corn, soy etc. which easily dissolves in soil and water. All the above can help cut down litter amounts found on beaches and these advances will result in cleaner beaches not only on Wales, but globally. Behavioural changes, i.e. beach users not throwing litter away on a beach are much harder to achieve, but these must be the ultimate goal of work in this field.

According to the present study, if the trends of the past 12 years were to be continued without additional management effort or other policy change, the beaches surveyed would approach a ratio of 44:56 grades A:B. It is likely that, at relatively little additional cost, higher levels of routine operations could bring about considerable improvement towards predominantly A grade beaches around Wales. This would result in enhanced status of the recreational environment for local residents and visitors alike, with increased confidence for the tourist industry which is nowadays such a vital component of the Welsh economy. Future surveys will be vital to determine whether improvements have occurred relative to a scenario of no change.

6. Conclusions

Litter has become an integral part of beach research and standard methodology surveys in 2000, repeated in 2012, of 45 beaches in Wales showed evidence of a marked reduction in litter amounts. The biggest litter category had a plastic origin. Sewage debris dropped as a result of new treatment works being installed. The frequency of recreational litter items was markedly reduced, possibly related to increasing public awareness of the beach litter problem resulting from educational campaigns.

Observed changes in the numbers of beaches graded A to D, showed a general trend of improvement in grading over the study period. Despite the relatively small number of A grade beaches which dropped to grade B (3 out of 5), many beaches maintained their current status and the number of A grade beaches rose from 5 to 19. Assuming these trends to continue, it was predicted that, within the next 12 years, the ratio of grade A to B beaches would approach equilibrium of 44–56%, and no grade C or D beaches would persist.

Surveys, e.g. Williams and Nelson (1997) and Williams et al., (2013) have shown that beach enjoyment is often marred by litter – it has negative implications, yet it is the general public that usually leaves this litter, A 'throw-away society' exists, whereby recreation at a beach results in disposal of cans, bottles, food wrappings, etc. frequently being discarded and left on the beach. Recreational litter was predominant in both of the current surveys, which raises the obvious question of how to bring about the required culture change amongst beach users. However, it is noted that gross litter

items resulted in observed downgrades and these items were *not* recreational litter, e.g. the TV set at Mwnt, a supermarket trolley at Barmouth. These items are large objects that could easily be removed by Local Authorities or by local 'Adopt a Beach' organisations – there is no need of large scale beach cleans. In the two cases mentioned above, such intervention would change beach grades to A (Fig. 6a and b; Table 1), and hence the revised model would over time show a rapid shift towards A grades.

For the examples given in this paper, there exist two cases where, if gross items were removed, instead of downgrading to a B grade, the initial A grade would stay (Talybont and Aberdovey). Similarly, there is one case where a C grade would upgrade to an A grade (Broadhaven) rather than to a B grade and one case where, starting as an A grade, it would downgrade to a B grade (Kimmel Bay). These would obviously change the model by leading (overall) to equilibrium strongly in favour of grade A. This supports the claim that future scenarios for beach grading could be considerably better than currently predicted, given relatively little effort and hence cost.

Legislation alone will not eliminate marine debris and education and public awareness must remain key driving elements in marine debris reduction – easy to state, but hard to implement. On the western coast of Wales, where beaches tended to be more of a village/rural nature, fishing was prevalent and nets etc. associated with the industry were frequently found and litter tended to remain *in situ* longer.

What you leave behind (litter !!!) is not what is engraved in stone monuments but what is woven into the lives of others – attributed to Pericles (died 431 BC).

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