

Function analysis as a coastal management tool: the South Wales coastline, UK

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Abstract Fifteen beaches from the Swansea Bay coastal sediment cell, South Wales, UK, were analysed via function analysis, involving assessment of specific environmental and socio-economic indicators. These were allocated scores from field surveys and extensive desktop studies, which included beach awards, relevant shoreline management plans, planning and conservation designations and current legislation. Normalised scores allowed production of a conservation/development matrix, enabling beach location in conservation, development or conflict fields, which results appropriately identified. Conservation field beaches tended to have a low density residential hinterland with little or no commercialisation. Conversely, beaches that leant towards the development field had a high density residential hinterland and were highly commercialised. Evaluation showed the importance of planning legislation in conflict areas and identified locations of development potential, where significant environmental consequences would be unlikely. This representation could be used for evolution of conservation/development status within coastal areas, enabling policy adjustment as necessary. It will also enable future sustainability assessment and it is suggested

that indicators could be modified to reduce environmental emphasis and provide a more uniform socio-economic consideration.

Keywords Conservation · Beach · Development · Indicators · Matrix · Socio-economic · Coastal management

Introduction

Escalating coastal area pressure has led to a greater need for sustainable development, as coastal margins provide considerable economic wealth (Turner 1988; Turner et al. 1996). Consequently, development needs tend to intensify through urbanisation (Nicholls and Leatherman 1995). According to Leatherman (2001, p. 181) ‘increasing populations and development are placing significant stresses on coastal resources’, a position supported by Benoit and Comeau (2005), who highlighted concerns in coastal areas, such as pressure on water resources, energy and transport infrastructure, land degradation, pollution, ecosystem destruction and population growth. Furthermore, Wascher (2001) observed that many natural landscapes have now become cultural landscapes and consequences have led to environmental degradation. He also highlighted that the percentage of total land area allocated to landscape protection compared with nature conservation in the northwest Europe bio-geographic region, is 14:2.6. Therefore there appears to be (a) opposition between cultural and natural landscapes and (b) conservation and environmental protection. However, it must be noted that proximity of nature conservation areas can be a positive factor for tourism development and citizen well being. The growing use of coastal areas affects sustainability since needs are created and subsequently attained by the

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formation of amenities. These result in an alteration of social, economic and environmental functions and interactions are produced (Jorge et al. 2002). Without an element of sustainability and measurable indicators within an integrated coastal management strategy, deterioration of the coastal environment is likely to persist (Charlier and Bologna 2003). Consequently, scientific indicators are needed to establish adequate and measurable data for implementation of sustainable development (SDU 2005).

Increased human interference has meant that management of coastal regions is paramount (Schroeder 2000). The rise of Integrated Coastal Management (ICM) has led to management repercussions requiring a flexible approach (McGlashan and Duck 2000, 2002). It has been argued that the objectives of sustainable development are tantamount to ICM (Schiewer and Schemewski 2002), which can be the key to effective management. Coastal management techniques are changing and solutions to current problems have leant towards flexibility and sustainability by using temporary structures and natural systems to defend the coast (Golem 2003).

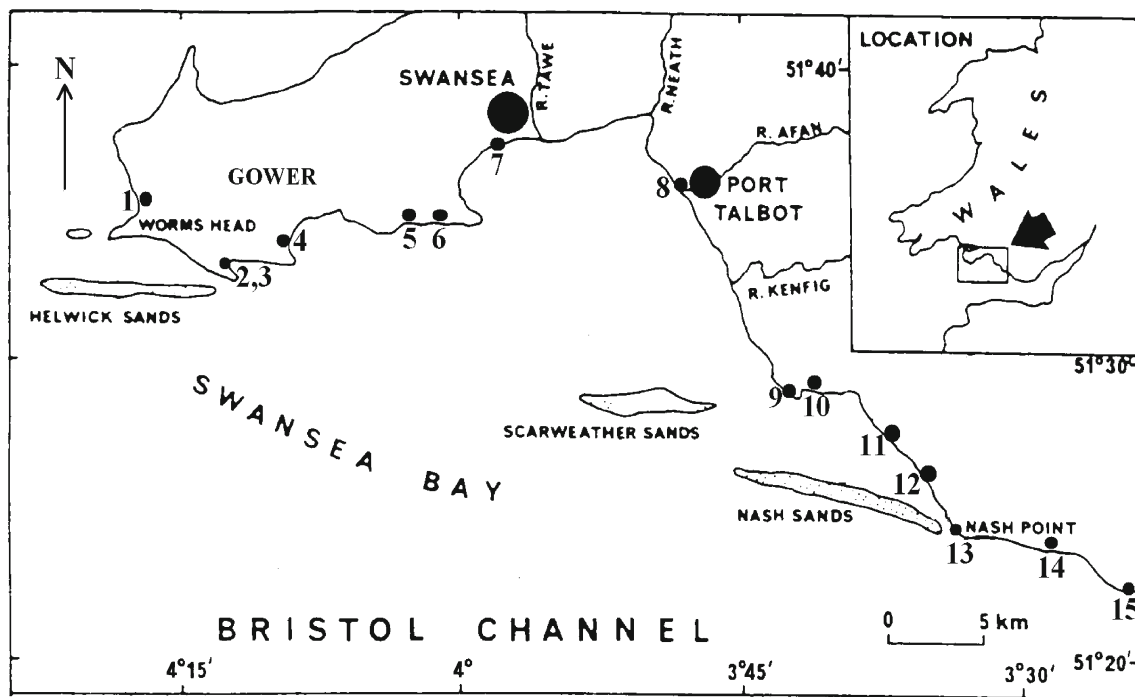
Therefore, indicators or tools are needed to achieve both sustainable development and ICM, but due to issue complexity and stakeholder conflict of interest, this has proven difficult (Coelho et al. 2003; van der Maarel 1978, 1979). De Groot (1992), attempted to create a management strategy by considering the goods and services or functions that the environment provides and this was taken further by Cendrero and Fischer (1997). They proposed indicators that could be used to assess an areas' environmental quality and development potential by utilising an assessment system, perhaps in conjunction with high resolution remote sensing such as Ikonos, Quick Bird or Spot 5. This has proved complex for application by coastal managers within ICM strategies, and this paper gives a simplified tool for managers, which can at best be integrated within the much greater scope of remote sensing capabilities, perhaps as an initial assessment. Van der Weide et al. (1999) and Micallef and Williams (2003) adapted the work of Cendrero and Fischer (1997), using a simplified methodology for application in coastal regions. This gave results that could be used for ICM strategies and to identify change. It assessed each indicator relevant to the studied area by allocating a score between 1 and 3 which could subsequently be normalised. Results were then used to assess conservation and development potential and assess conflict. This paper develops the methodology further by allocating indicator scores between 1 and 5 and incorporating regional planning, government data and designated conservation status. The technique is subsequently applied to fifteen South Wales, UK beaches, which are part of Swansea Bay coastal sediment cell 8b (SBCEG 1999) and results are used to justify conservation/development, as part of a sustainable coastal management strategy.

Physical background

Fifteen beaches located along the South Wales, UK coastline (Fig. 1) formed the study area, and this included Gower and the Glamorgan Heritage Coast. All beaches are in the Bristol Channel/Severn Estuary, which is subject to the second highest tidal range in the world. In 1956, Gower was designated as the UK's first Area of Outstanding Natural Beauty (AONB). It has four national nature reserves (NNRs), 17 local nature reserves (LNRs), an internationally important RAMSAR site, 27 sites of special scientific interest (SSSIs) and 55 ha of heritage coast (Bridges 1997). The Gower beaches (Rhossili, Port Eynon, Horton, Oxwich and Caswell) and Langland tend to be popular, offering tourists the opportunity to relax in unindustrialised surroundings, while being in close proximity to the city of Swansea.

Rhossili is approximately 5 km of sandy beach with a dune system on the northern limits. Hang gliding is popular since the hinterland is approximately 90 m above sea level permitting 360° views of the Gower Peninsula. Port Eynon has approximately 1 km of sandy foreshore with a sand dune hinterland and is popular for water sports. To the west, there is a designated nature reserve and it was awarded Blue Flag status (FEE 2007) in 2004. Horton is to the east of Port Eynon and these beaches form either side of Port Eynon Bay. The beach at Horton is mainly composed of pebbles and has a rural hinterland. Oxwich is an approximately 4 km long sandy beach and its hinterland comprises sand dunes, salt marshes and climax woodland. The beach is wide at low tide and has nature conservation and geological designations. It has good amenities and a large car park which backs onto the beach. Caswell is a popular beach, primarily due to easy access and on-site amenities. The area is used by climbers due to the variety of rock formations and the beach, which was first awarded Blue Flag status in 2002, is especially popular with surfers. Langland is a sandy beach popular for swimming, surfing and canoeing and has two easily accessible car parks. This beach was also awarded Blue Flag status in 2002.

To the east, the beaches of Swansea, Aberavon and Porthcawl (Rest Bay and Coney Beach) were fashionable in the 1950's and 1960's but popularity has declined through the years and this corresponds with an apparent steady decline of quality. Swansea is an urban beach, approximately 4 km long and the shoreline is largely defined by walls and a developed city hinterland. Aberavon beach is adjacent to a steelworks and tidal harbour and consequently, the seawall behind the beach has needed additional rock armour protection. Away from the tidal harbour's influence, the beach is well nourished and the area is currently undergoing significant regeneration. The beach faces south-



Key to Beaches	
Rhossili	1
Port Eynon	2
Horton	3
Oxwich	4
Caswell	5
Langland	6
Swansea Bay	7
Aberavon	8
Rest Bay	9
Coney Beach	10
Merthyr Mawr	11
Southerndown	12
Nash Point	13
Llantwit Major	14
Barry Island	15

Fig. 1 Location of beaches

west and wind sports are popular. Rest Bay is located to the west of Porthcawl and the large sandy beach is popular with families and surfers. It has a high value residential hinterland while further east, Coney beach is a traditional resort beach with many facilities including a funfair.

Further eastwards Merthyr Mawr, Southerndown, Nash Point and Llantwit Major are situated in the Glamorgan Heritage Coast (designated in 1973) where historic, artistic

and archaeological sites are plentiful. The majority of Merthyr Mawr is privately owned although public access is permitted. There are no amenities at this beach but has been designated a SSSI for nature conservation and geology. Southerndown has been designated a SSSI due to geological significance of viewable faults and deformation folds (SBCEG 1999). The beach is busy during the summer and was initially awarded blue flag status in 2004.

Nash Point is not easily accessible as there is a long and steep walk from the car park to the beach. Amenities are limited and there are frequent rock-falls from the Lias Limestone cliffs which range between 35 and 50 m high. Llantwit Major is popular with surfers and the cliffs, freshwater stream and woodland area provide a superior habitat for birds and plants. The final beach studied was Barry Island which is a typical urban family seaside resort.

Coastal management in Wales

The Welsh coastline attracts >4 million visitors per year (contributing >£350 m/annum to the economy, which with multiplier effects equates to >£700million/annum) and approximately 60% of the population live in the coastal strip (MMWC 2007). This encompasses many organisations grouped together by the Welsh Assembly, interested in coastal management of which, The Wales Coastal and Maritime Partnership (WCMP), set up in March, 2002, is probably the most important. The WCMP acts as an advisor providing integrated and co-ordinated advice on coastal and maritime policy to the National Assembly for Wales, and plays a key role in the implementation of the EU Recommendation on Integrated Coastal Zone Management in Wales. It is composed of 28 organisations taken from the public, private and voluntary sectors.

The myriad of organisations encompassing ICM in Wales, for example encompasses: five coastal defence groups, local based Coastal Care groups, Special Areas of Conservation Management, (concerned with the sustainable future of 90 areas), Archeological Trusts, Sea Fisheries Committees, Port and Harbour Authorities, National Parks, Unitary Authorities (17 of the 22 are coastal), Academia, The Environment Agency, Welsh Water, Countryside Council for Wales. The main ICM future strategy is to:

- Ensure that effective co-ordination arrangements are in place amongst all levels.
- Ensure that ICM principles are integrated into relevant schemes.
- Develop a better system of planning and management to ensure that the proposed Marine Bill linked to the land-based planning system is effective.
- Develop a sound coastal knowledge base (*economic, social, environmental and physical*) and disseminate information.
- Regularly monitor (via indicators) the ICM progress and publish information.

A progress report will be published annually and a review (2010) will enable the strategy to be updated i.e. new developments, legislation, etc.

Function analysis

Goods and services have socio-economic value, while processes and components represent natural environment characteristics. This is environmental function analysis (EFA) which may be employed as a planning and decision making tool (Micallef and Williams 2003). The work of van der Maarel (1978, 1979), later developed by De Groot (1992), resulted in the classification of four main functions:

- Production functions—including all kinds of renewable and non-renewable resources.
- Carrier functions—providing space and substrate for human activities.
- Information functions—provision by nature of reflection, spiritual and cognitive enrichment and signal functions.
- Regulation functions—capacity of ecosystems to regulate essential ecological processes which in turn, contribute to a healthy environment (for example, clean air, water, soil).

In EFA, the ability of a natural ecosystem to provide goods and services (environmental functions) depends on its environmental characteristics (natural processes and components). Cendrero and Fischer (1997) proposed a technique for assessing environmental quality of coastal areas through the evaluation of conservation value and use/development potential. This could then be used to effectively integrate scientific evaluation into coastal planning and management decision making processes (Micallef and Williams 2003). The technique involved the following four stages:

1. Definition of area boundaries and selection of homogeneous land-use units within this boundary.
2. Identification of characteristic parameters for the environment in question, that describes and distinguishes between the environmental and socio-economic components of that environment. Based on an exhaustive list of environmental components and characteristics, Cendrero and Fischer (1997) considered aspects specific to coastal areas in order to identify the relevant environmental characteristics that describe the ecological (natural) and socio-economic (human use) components of that environment.
3. Allocation of values to the characteristic parameters identified.
4. Comparison of natural (ecological) value with human (use/development potential) value to determine potential management conflict (Fig. 2).

Therefore, Cendrero and Fischer (1997) created a methodological structure that was able to comparatively identify coastal environmental quality which aided decision

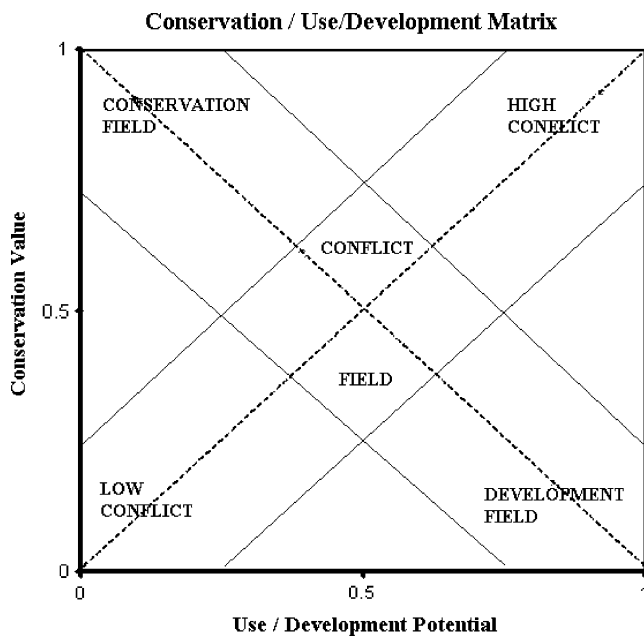


Fig. 2 Conservation/development matrix. Source: Cendrero and Fischer 1997, p. 742

making processes and development of management strategies. The matrix (Fig. 2) was modified by Van der Weide et al. (1999) to identify appropriate management options for two coastal wetlands in Turkey, and by Micallef and Williams (2003) for bathing beaches in Malta. Coastal areas located on the top left quadrant should be managed for conservation and those at the lower right of the matrix should be managed for development. Van der Weide et al. (1999) suggested that conflicts be resolved by utilising in-depth studies to develop an appropriate management strategy, based on analysis of environmental indicators and anthropogenic components (Cendrero and Fischer 1997; van de Weide et al. 1999; Micallef and Williams 2003). Assessment of coastal areas conservation and development status is likely to improve the effectiveness of any management plans.

The methodology adopted was the modification of Cendrero and Fischer's (1997) procedure by Van der Weide et al. (1999) and Micallef and Williams (2003). However, van der Weide et al. (1999) identified weaknesses, which included a lack of available quantitative data on some parameters such as ecology, water quality and pollution. Consequently, to obtain a more reliable quantitative assessment and to reduce subjectivity, the present study along the South Wales coastline incorporated data from other agencies as part of an integrated management approach. These included Unitary Authority Structure Plans for planning and development designations, Shoreline Management Plans for land use and coastal environment, Blue Flag beach status and Good Beach Guide as indicative measures of beach and water quality, environmental

designations such as an Area of Outstanding Natural Beauty (AONB), Special Area of Conservation (SAC), Heritage Coast, National Trust (NT) and Sites of Special Scientific Interest (SSSI) for physical and ecological parameters and the Environment Agency for air pollution. Economic values were determined from potential for use, development status and human well-being.

Assessment of environmental and socio-economic components were expressed numerically using a qualitative Delphi approach which, as Anastassova (1996) concluded, is a forward thinking procedure using specialist opinion and data collection for good practice and evaluation. Van der Weide et al. (1999) and Micallef and Williams (2003) used a scoring system of 1 to 3 for the indicators established by Cendrero and Fischer (1997); 1 being the lowest (worst) and 3 being the highest (best). Sauer (1963) identified components of landscape while Cooke and Doornkamp (1990) evaluated Leopold's (1969) seminal work on landscape assessment where values ranging from a minimum score of 1 (worst) to a maximum score of 5 (best) were allocated to environmental components. These considered the physical, biological and human-use functions of the natural environment in a similar manner to the methodology adopted in this work. Leopold's (1969) methodology for quantifying landscape, enabled for the first time, an economic value to be assigned to the environment which could subsequently be weighted against development, on a cost-benefit basis (Tietenberg 1994). Assessment methodologies developed for other areas of coastal management such as dune management (Davies et al. 1993) and beach aesthetics (Williams et al. 1993, 2000; Leatherman 1997; Ergin et al. 2002 and 2004) have also used a range of 1 to 5 to assess environmental components. Therefore in this work, the scale was modified to 1 to 5 for indicator assessment. Most checklist and rating schemes used for coastal assessment are open to criticism with regard to subjectivity and weighting, particularly in aesthetics where the viewer's preferences and priorities tend to dominate (Leatherman 1997). However, checklists can be extremely helpful and may be used as an aid to planning and decision making (Leopold 1969).

Consequently, function analysis was used to assess the conservation/development status of the fifteen beaches (Fig. 1). The eight environmental components, broken down into 35 indicators, are shown in Table 1 while the two socio-economic components, comprising 18 indicators, are shown in Table 2. In the methodology of both Van der Weide et al. (1999) and Micallef and Williams (2003), mineral resources were considered as an environmental or conservation component. However, in analysis of this coastline, due to the economic importance of offshore marine aggregate dredging and fishing, these were considered as socio-economic or development indicators. This was seen as

helping redress a disadvantage highlighted by Van der Weide et al. (1999), that the methodology was weighted too heavily towards environmental indicators. Furthermore, high employment or high unemployment could both be argued as being more beneficial to development and in this study, high employment was considered preferable. The function analysis work of De Groot (1992) and adaptation by Cendrero and Fischer (1997) had been designed to accommodate regional differences and enable a more rapid assessment for beach managers. There is an inbuilt flexibility in the methodology, which recognises circumstances change, and that environmental considerations are not fixed. This is essential in assessing current status and being responsive to change. The work of van der Van der Weide et al. (1999) was itself a pilot study for the assessment of conservation and development conflict.

The methodology further involved normalising the score of the individual environmental and socio-economic components to give a parameter score between 0 and 1. For example, air quality for Aberavon (Table 1), scored 10 (3 + 3 + 3 + 1) out of a possible 20 (4×5), normalized to 0.5 (10/20). All components were similarly determined. Overall conservation value/use/development potential values were normalised by dividing the collective score of the parameters by the total possible score. It should be noted that not all indicators apply at every location. For example, if a fresh water supply such as a river is not present, then those indicators are not assessed and N/A is indicated in the tables. The maximum possible score is subsequently reduced for normalisation. Again for Aberavon (Table 2) socio-economic scores were 70 out of a possible 85 (17×5), normalised to 0.82 (70/85). Comparison is made by graphical illustration of normalised scores

Table 1 Environmental indicators

Environmental component	Characteristic	Indicators	Characteristic beach evaluation, Aberavon
Air (A)	Pollution	Gravity (1)	1
		Visibility (2)	3
		Effect on humans (3)	3
		Intensity (4)	3
Coastal waters (C)	Noise	Microbiological pollution (1)	3
		Chemical pollution (2)	3
	Quality	Turbidity (3)	1
		Litter (4)	4
Fresh water (F)	Supply	River flow (1)	3
		Pollution (2)	3
		Turbidity (3)	1
		BOD (4)	3
Terrestrial biota (T)	Quality	Natural vegetation cover (1)	1
		Biological productivity (2)	1
	Quantity	Biological diversity (3)	1
		Species of special interest (4)	1
Marine biota (M)	Quantity	Biomass (1)	2
		Biological productivity (2)	3
	Diversity	Biological diversity (3)	3
		Species of special interest (4)	1
Geological and topographical features (G)	Lithological (1)		N/A
	Geomorphology (2)		N/A
	Quality (3)		N/A
	Size of bathing area (4)		5
Hazards (H)	Coastal erosion (1)		1
	Coastal flooding (2)		3
	Storms (3)		1
	Sedimentation (4)		3
	Cliff/slope instability (5)		N/A
	Soil erosion (6)		N/A
	River flooding (7)		3
Resources (R)	Non-renewable renewable	Soil (fertility) (1)	N/A
		Fish (2)	3
	Landscape	Visual quality (3)	1
		Uniqueness (4)	1

Table 2 Socio-economic indicators

Socio-economic component	Characteristic	Indicators	Characteristic beach evaluation, Aberavon
Human aspects (HA)	Potential for use	Historic, artistic, archaeological sites (1)	3
		Minerals, rocks, construction materials, fuels (2)	N/A
		Fishing (3)	5
		Recreation facilities (4)	3
		Hotel, restaurants (5)	3
		Utilities (6)	3
		Parking (7)	5
		Accessibility (8)	5
		Land use—different types (9)	5
		Land ownership (10)	5
		Extent of development (11)	5
	Human well-being	Population density (12)	5
		Intensity of use (13)	3
		Public health (14)	3
		Unemployment (15)	5
		Education (16)	4
		Crime (17)	3
		Development potential (18)	5

allocated to environmental and human components on the conservation value/use/development potential matrix (Fig. 2), developed by Cendrero and Fischer (1997).

Results

Assessment

The assessed scores of environmental and socio-economic indicators for the fifteen beaches (Fig. 1) are detailed in Tables 3 and 4 respectively. From Tables 3 and 4, normalised scores were determined for all components, as shown in Table 5. This gives a numerical reference/comparison and highlights low normalised scores for examination, for example, terrestrial biota at beach 10 (Coney Beach 0.2—Table 5). Comparisons of conservation and development normalised scores (Table 5) is graphically represented in Fig. 3. This clearly shows those beaches where environmental components outweigh the socio-economic values and vice versa. The former will have a greater need for protection, whereas the latter would be

more suitable for development. The beaches where both environmental and socio economic component values are similar, such as beaches 6 (Langland) and 9 (Rest Bay), require most attention (Fig. 3), as inappropriate management decisions could blight potential for either conservation or development. Although Rest Bay is quiet compared to Coney Beach and largely used for surfing, there may be a need for development, and an offshore wind farm is likely in the near future. Pressure may be as a result of its popularity, recreational space, high class residential occupancy and abundance of nearby facilities. Langland has similar high ecological and socio-economic values (Table 5) due to its proximity to both Gower and Swansea. These issues are further highlighted when results are incorporated into the conservation/development matrix and Fig. 4 shows the overall results for the 15 beaches. Those in the conservation zone (top left quadrant) have a greater need for protection, whereas those situated in the development field (bottom right quadrant) are obviously more suited to development. Areas that find themselves towards the centre of Fig. 4 are in conflict, and this suggests the beaches have similar environmental and socio-economic values.

The various fields

From the matrix (Fig. 4), beaches generally fell into three distinct clusters within the conservation, conflict and development field. Beaches within the conservation group Llantwit Major, Nash Point, Southerndown, Merthyr Mawr, and Rhossili, have a high ecological value and the first four of these are situated on the Glamorgan Heritage coast, while Rhossili is located on Gower AONB. They are all characterised by a lack of residential occupancy in the hinterland (Williams and Ergin 2004). Barry Island, Coney Beach, Aberavon and Swansea Bay were categorised within the development field. Barry Island, although close to the conflict field (Fig. 4), is a typical seaside resort destination with plenty of facilities and a fairly low ecological value (0.55; Table 5). Development field beaches are all situated near large cities or towns that are already highly developed and this has led to further development pressure. Results indicate that there is benefit in developing these areas while conserving other better suited nearby beaches to help achieve a conservation/development balance. Beaches placed in the high conflict group (Rest Bay, Langland Bay, Caswell Bay, Oxwich Bay, Horton, and Port Eynon—Fig. 1) are mainly located in Gower, the exceptions being Rest Bay and Langland. The reason Gower beaches are in high conflict (Fig. 4) results from having appropriate facilities to cater for visitors and tourists, while having an abundance of flora and fauna, evidenced by designations such as, SSSI, NT, and NNRs, etc. Consequently, development pressures are in conflict with their AONB status.

Table 3 Environmental indicator beach scores

Environ indicator	Beach (Fig. 1)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A1	5	5	5	5	5	5	4	1	5	5	5	5	5	5	4
A2	5	5	5	5	5	5	5	3	5	5	5	5	5	5	5
A3	5	5	5	5	5	5	4	3	5	5	5	5	5	5	4
A4	5	4	5	3	2	3	3	3	5	2	5	5	5	4	3
C1	5	5	5	3	5	5	4	3	5	3	3	5	5	5	3
C2	N/A	N/A	N/A	N/A	N/A	N/A	3	3	5	5	3	5	5	5	4
C3	3	4	4	4	3	3	2	1	3	1	3	3	4	3	1
C4	5	3	4	5	3	4	1	4	3	1	1	4	5	4	1
F1	N/A	N/A	N/A	N/A	N/A	N/A	3	3	N/A	N/A	3	N/A	N/A	5	N/A
F2	N/A	N/A	N/A	N/A	N/A	N/A	2	3	N/A	N/A	3	N/A	N/A	5	N/A
F3	N/A	N/A	N/A	N/A	N/A	N/A	3	1	N/A	N/A	3	N/A	N/A	5	N/A
F4	N/A	N/A	N/A	N/A	N/A	N/A	2	3	N/A	N/A	4	N/A	N/A	4	N/A
T1	4	4	4	4	3	2	3	1	4	1	5	4	4	3	2
T2	5	5	4	5	3	2	1	1	4	1	5	4	3	3	2
T3	3	5	3	5	3	2	1	1	2	1	5	4	2	3	4
T4	3	3	3	5	3	1	1	1	1	1	5	5	2	3	4
M1	3	3	4	4	4	4	1	2	4	3	3	3	3	3	1
M2	3	3	4	4	4	4	1	3	4	3	3	3	3	3	1
M3	3	4	4	4	4	4	1	3	4	3	3	3	3	3	1
M4	5	5	5	5	5	5	1	1	5	3	4	3	3	4	1
G1	5	5	5	5	5	3	N/A	N/A	3	1	3	5	5	4	5
G2	5	5	5	5	4	3	2	N/A	3	1	5	3	5	3	1
G3	5	5	5	5	5	3	2	N/A	4	1	5	5	5	4	3
G4	5	5	5	5	5	5	5	5	5	5	5	5	2	3	5
H1	5	2	3	4	5	3	3	1	4	3	5	3	4	1	3
H2	5	3	5	5	5	4	3	3	4	5	5	4	4	1	3
H3	1	1	1	2	1	1	1	1	1	1	2	2	2	1	1
H4	4	3	2	5	3	3	4	3	3	2	5	3	5	3	3
H5	5	3	4	4	5	N/A	N/A	N/A	N/A	N/A	3	3	3	4	2
H6	5	N/A	4	4	N/A	N/A	N/A	N/A	4	N/A	5	N/A	3	3	N/A
H7	N/A	N/A	N/A	N/A	N/A	N/A	3	3	N/A	N/A	3	N/A	5	3	N/A
R1	4	4	5	5	5	N/A	N/A	N/A	4	N/A	4	5	3	4	N/A
R2	3	3	4	4	4	4	3	3	5	5	3	3	4	4	3
R3	5	4	3	4	5	3	3	1	5	2	4	5	5	3	4
R4	5	4	3	4	3	3	1	1	3	1	4	5	5	4	3

Site evaluation based on conservation and development potential

Rhossili, situated in an AONB, is a designated SSSI but due to its rural location, is relatively inaccessible compared to the other beaches, while Merthyr Mawr is highly protected from development due to its SSSI and NNR designations and has fewer amenities than adjoining beaches. Conversely, Coney Beach is already highly developed with a high population density whose usage is elevated in comparison with the other beaches. Aberavon and Swansea Bay are both close to industrial and commercial centres with no beach recommendations (MCS 2004) and are likely to benefit from development and subsequent improvement. When analysing the total

ecological parameters against socio-economic parameters (Table 5; Fig. 4), Oxwich, a beach recently voted the most beautiful in Britain and one of the top 10 in the world (BBC News 2007), had the highest ecological value (0.88; Table 5). The area has SSSI, NNR and NT designations that allow protection for various flora and fauna. Aberavon had the lowest conservation score (0.45; Table 5); Coney Beach had the highest development potential (0.88; Table 5); and Merthyr Mawr had the lowest socio-economic value (0.29; Table 5).

Only 4 out of the 15 beaches had elevated socio-economic values compared to conservation values and these four beaches (Barry Island, Coney Beach, Aberavon and Swansea Bay) were expected to fall within this category. Beaches positioned in the conflict field can be

Table 4 Socio-economic indicator beach scores

Soc-econ indicator	Beach (Fig. 1)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HA1	3	4	3	3	3	2	2	3	3	1	3	5	3	4	2
HA2	N/A	N/A	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A
HA3	1	4	5	5	5	4	2	5	5	5	1	3	1	3	3
HA4	4	3	4	5	5	4	5	3	4	5	5	1	1	2	4
HA5	3	3	2	4	1	1	5	3	3	4	1	1	1	2	4
HA6	3	2	3	3	3	2	4	3	3	5	1	2	1	2	4
HA7	3	5	5	4	3	5	4	5	5	5	1	3	2	3	4
HA8	1	5	4	5	5	4	5	5	4	5	1	2	1	3	5
HA9	2	3	3	3	4	4	5	5	3	5	1	1	1	1	4
HA10	2	3	2	3	3	3	5	5	3	4	1	1	1	1	5
HA11	2	2	2	2	3	3	5	5	3	5	1	1	1	1	5
HA12	1	2	3	2	3	3	5	5	4	5	1	1	1	2	5
HA13	4	3	2	3	5	3	3	3	4	5	3	3	2	3	5
HA14	5	5	5	3	5	5	4	3	5	5	3	5	5	5	5
HA15	N/A	N/A	N/A	N/A	N/A	N/A	4	5	4	4	N/A	N/A	N/A	N/A	4
HA16	N/A	N/A	N/A	N/A	N/A	5	5	4	5	5	N/A	N/A	N/A	N/A	4
HA17	N/A	N/A	N/A	N/A	5	5	4	3	4	3	N/A	N/A	N/A	N/A	3
HA18	1	2	2	1	1	1	5	5	2	4	1	1	1	1	4

re-assessed to determine where conflict exists and in which direction the beach should be managed. However, if areas remain in similar positions over time, then sustainability will be achieved due to a balance of ecological and development use. An ecological parameter reduction however, may suggest degradation which will need to be managed accordingly. For all beaches, ecological factors did not fall below a normalised value of 0.45 (Table 5) and most beaches were >0.6 (Table 5). The only beaches that scored <0.6 were Barry Island, Coney Beach, Aberavon and Swansea Bay. This suggests that either environmental quality along the South Wales coast is very good, or despite attempts to place more emphasis on socio-economic factors, there is still too much emphasis on conservation.

However, in all cases, beach assessment was consistent with the area's characteristics (Fig. 4).

Discussion

Several of the factors proposed by Cendrero and Fischer (1997) were not relevant to the South Wales coastline, for example, torrential rain, heat/cold waves, tsunamis, earthquakes and volcanoes. Indicators including red tide, lake volume, aquifer volume, aquifer recharge, timber, and extent of reclamation were omitted due to nil or little presence. Any factors not relevant or applicable to a specific beach were marked as such and not registered in

Table 5 Normalised component scores

Component	Beach (Fig. 1)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Air	1.00	0.95	1.00	0.90	0.85	0.90	0.80	0.50	1.00	0.85	1.00	1.00	1.00	0.95	0.80
Coastal W	0.87	0.80	0.87	0.80	0.73	0.80	0.50	0.55	0.80	0.50	0.50	0.85	0.95	0.85	0.45
Fresh W	N/A	N/A	N/A	N/A	N/A	N/A	0.50	0.50	N/A	N/A	0.65	N/A	N/A	0.95	N/A
T Biota	0.75	0.85	0.70	0.95	0.60	0.35	0.30	0.20	0.55	0.20	1.00	0.85	0.55	0.60	0.60
M Biota	0.70	0.75	0.85	0.85	0.85	0.85	0.20	0.45	0.85	0.60	0.65	0.60	0.60	0.65	0.20
Geog and T	1.00	1.00	1.00	1.00	0.95	0.70	0.60	1.00	0.75	0.40	0.90	0.90	0.85	0.70	0.70
Hazards	0.83	0.48	0.63	0.80	0.76	0.55	0.56	0.44	0.64	0.55	0.80	0.60	0.74	0.46	0.48
Resources	0.85	0.75	0.75	0.85	0.85	0.67	0.47	0.33	0.85	0.53	0.75	0.90	0.85	0.75	0.67
Env Total	0.86	0.79	0.81	0.88	0.80	0.68	0.49	0.45	0.77	0.52	0.78	0.81	0.79	0.71	0.55
Socio-econ	0.50	0.66	0.67	0.66	0.72	0.68	0.85	0.82	0.75	0.88	0.29	0.43	0.36	0.47	0.82

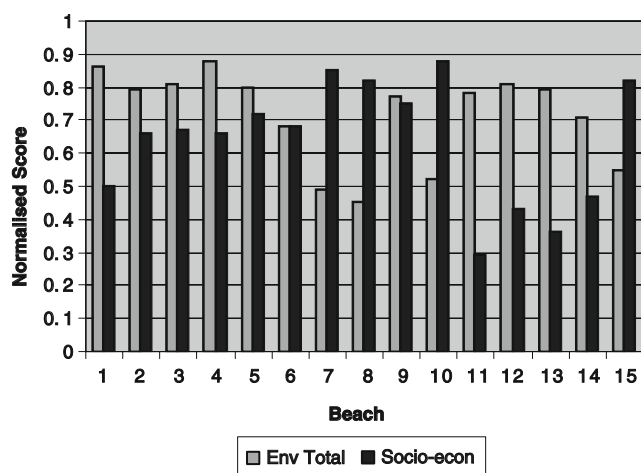


Fig. 3 Overall environmental/socio-economic beach component comparison

the total normalisation score. These included indicators such as fresh water when there was no river proximate to the area, soil erosion as a hazard and soil as a renewable resource. Similarly, unemployment, education and crime in secluded areas were marked not applicable where their effects were considered limited. This enabled more accuracy and also prevented distorted findings. Effects on vegetation with regards to air pollution and incidence to aquatic life and humans in the context of fresh water quality were omitted. These factors were difficult to assess, as data were not available and long-term evaluation would have been required. However, adverse effects on marine life and humans from coastal waters in the UK is under strict control from numerous pieces of legislation, that is, Water Resources Act, (1991), Environment Act (1995), Urban Waste Water Directive (91/271/EEC), Bathing Water Directive (76/160/EEC); while the Water Framework Directive (2000/60/EC), establishing a new framework for Community action in the field of water policy, will require all inland and coastal waters to reach “good status” by 2015. Consequently, water quality has improved, evidenced by increasing numbers of Blue Flag beach awards, which resulted in relatively high scores being assigned to coastal water components (Table 3). Biomass, within the context of terrestrial biota was considered within vegetation cover and fishing was added to the socio-economic indicators (Table 2), as it is an important economic activity on this coastline.

Many factors can be both negative and positive, depending on perspective. For example, unemployment may be negative for individuals but positive from a use/development potential, that is, available labour market. Consequently, unemployment factors were considered to have a low value if there was low unemployment, and given high values if there was high unemployment. An area’s potential for development could

well improve its socio-economic score, as combined with high unemployment, there is likely to be labour available to support economic growth. Components of renewable resources such as minerals, rocks, construction materials and fuels were originally considered an environmental component by Cendrero and Fischer (1997), Van der Weide et al. (1999) and Micallef and Williams (2004). If these resources were present then they were often protected by legislation and could not be utilised. For example, sand extraction for construction purposes at Merthyr Mawr beach/dunes was stopped by legislation in 1958. Therefore, this component was placed in the socio-economic category, the rationale being that if these renewable resources are available, it would be beneficial for development or use. Currently 90% of construction aggregates used in South Wales come from marine sources (Bellamy 1999) but being linked to beach erosion, offshore marine aggregate dredging is a controversial issue on this coastline (Phillips and Williams 2007). If legislation prevented the use of a resource or the activity was not considered relevant to a particular beach, the indicator was marked not applicable. This ensured that the final outcome of normalising was more reliable and accurate.

Outcomes of the work of Van der Weide et al. (1999) and Micallef and Williams (2004) determined appropriate management strategies for areas positioned on the lower right quadrant of the matrix (Fig. 4) and the authors argued that these areas should be allocated to development. Conversely, it could be argued that areas located at the top left quadrant of the matrix (Fig. 4) should be given a high level of protection through conservation. Difficulty arises when areas are positioned in the centre, as conservation and development potentials are at similar levels. Van der Weide et al. (1999) proposed that conflicts be identified by utilising in depth studies to aid an appropriate management strategy by either moving towards conserva-

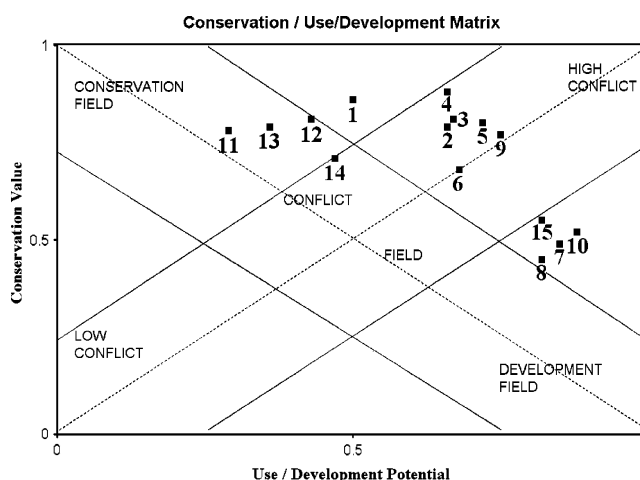


Fig. 4 Matrix showing beach zone location

tion, development, or achieving a balance between the two, thereby ensuring a more sustainable path. For example, Port Eynon, is subject to strict planning controls and therefore is assigned a low development potential score (Table 5). However, if planning restrictions were lifted, the built environment would expand and move the beach towards the development field (Fig. 4). This analysis highlights the importance of planning control. Similarly, marine aggregate dredging provides construction materials and is a socio-economic indicator (Table 2). Once again if policy changed and dredging was stopped, this development component would not be applicable and the Port Eynon conservation value would increase, moving it out of conflict and more in line with its environmental designations. Therefore it is suggested that this methodology will enable impact assessment of policy change.

Aberavon is close to industrial and commercial activities and is currently benefiting from residential development, with little conservation impact having the lowest ecological value (0.45; Table 5). Development field beaches are situated near large cities or towns that are already highly developed, which has led to pressure for further development and increased economic growth. Llantwit Major should be managed for conservation (Table 5; Fig. 4) and Williams et al. (1998) argued that anthropogenic intervention reduced the aesthetic quality of this part of the Glamorgan Heritage Coast. They questioned whether a revetment should have been constructed in a coastal area where emphasis is on natural beauty and later reasoned that an attempt to hold the coastal line in this area of heavy erosion and rapid longshore drift would always be problematic. They argued that buildings should have been relocated inland from this position of natural instability and ironically, after the CPA had spent approximately £750,000 on the revetment, shoreline management adopted an interim policy of managed retreat (SBCEG 1999). Therefore, Function Analysis offers a management based rationale for this decision.

Function Analysis is a useful management tool whose indicators can be modified appropriately for specific coastal regions. This methodology has many applications and can be used to:

- Identify consequences of proposed developments in coastal areas;
- Highlight impacts of planning legislation, as part of a strategic environmental assessment policy;
- Assess change as a result of future land-use policies, as well as evaluating present day values in conjunction with past development strategies;
- Identify whether an area is being managed sustainably, as well as identifying reasons for and specific components of change.

Conclusions

When assessing ecological and socio-economic components of the South Wales coastline, adoption and adaptation of the Function Analysis methodology of Cendrero and Fischer (1997) allowed quantification of coastal sustainability indicators. The methodology applied to 15 beaches in the Swansea Bay coastal sediment cell, demonstrated a positive correlation with recognised environmental designations, indicating the accuracy of the technique which is ideally suited to the small local scale. Normalised scores for beach conservation and socio-economic components and their subsequent location in a conservation/development matrix enabled assessment and comparison. Beaches determined to be in the conservation field tended to have a low density residential hinterland with little or no commercialisation. Conversely, beaches that leant towards the development field had a high density residential hinterland and were highly commercialised. Conflict areas were identified and the methodology was considered appropriate to determine those beaches that would benefit from either development or conservation management. Evaluation further identified areas of development potential, where any significant environmental consequences were unlikely. Function Analysis can also be used to monitor change and facilitate future sustainable development strategies for the South Wales coast. Statutory and planning designations proved significant in the evaluation of particular indicators and for conflict control.

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