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Coastal Management for Sustainable Development: Analysing Environmental and Socio-Economic Changes on the UK Coast

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Littoral areas of the British Isles present an array of properties and features which have long been exploited by human populations and have contributed to the wealth and the quality of life of the nation. Past and ongoing differentiation in uses of coastal zones has led to conflicts ranging from deleterious effects on supporting ecosystems to symbiosis with human activities. This paper aims to elicit the main forces influencing the development of coastal areas and the means available to assess the present use and manage future exploitation of the coastal zone, following the P-S-I-R Framework and an ecosystem function-based valuation methodology. A variety of pressures and their trends is analysed (climate change, population and tourism changes, port development, hydrocarbon and marine aggregate extraction and pollution). All these factors are examined in the context of the sustainable use of coastal resources and on the basis of an interdisciplinary ecological economics approach.

KEY WORDS: UK, coastal zone, evaluation methods, impacts, policy analysis, pressures.

ONE OF BRITAIN'S PRINCIPAL geographical features is its extensive coastline (12 429 km) created by a multitude of land and ocean processes, subjected to anthropogenic influences and characterized by a variety of formations and coastal environments. Coastal areas are increasingly valued by society, both directly and indirectly, and undoubtedly provide an essential overall service to humankind (CCIRG, 1996). The total UK annual turnover by the marine related sector of the economy has been estimated at £51.2 billion (1994–95 prices) and the total marine related value added has been put at £27.8 billion (OST, 1997).

From an ecological-economics perspective, it is possible to characterize coastal zones in terms of inter-related physical, bio-chemical and socio-economic systems with particular processes and functions. Coastal resource systems, therefore, generate a diversity of economic goods and services (Fig. 1) of significant value to current and future generations. Many of these outputs, such as, for example, the capacity to assimilate wastes, biodiverstiy services and the storm buffering function of coastal wetlands, are not priced through markets but nevertheless represent very valuable resources. Globally such services have been approximately valued at $1.28 trillion (US) per annum or 71 per cent of the Global Gross National Product per annum (Costanza *et al.*, 1997). These global estimates require heroic assumptions to overcome the temporal, cultural and spatial specificity of ecosystem functional values and the aggregate totals should not be taken seriously (Turner, Adger and Brouwer, in press). Nevertheless, there is ample evidence available to indicate the economic significance of changes in individual ecosystem function services (Heywood and Watson, 1995).

Ecological economists lay great stress on the need for an historical perspective on socio-economic – natural systems interactions, in order to progress the analysis and debate on the long-run dynamics of human-nature interactions (Faber, Manstetten and Proops, 1996). They tend to favour an evolutionary perspective and believe that the concept of open systems far from equilibrium is a useful heuristic for describing technological and socio-economic change. Such change is seen to be sensitively dependent on small historical events and characterized by path dependency ('lock-in' effects) and the unpredictability of outcomes. An attitude of openness is advocated because of the existence of irreducible ignorance and the related concepts of surprise and novelty. In other words, some systems changes may not, in principle,

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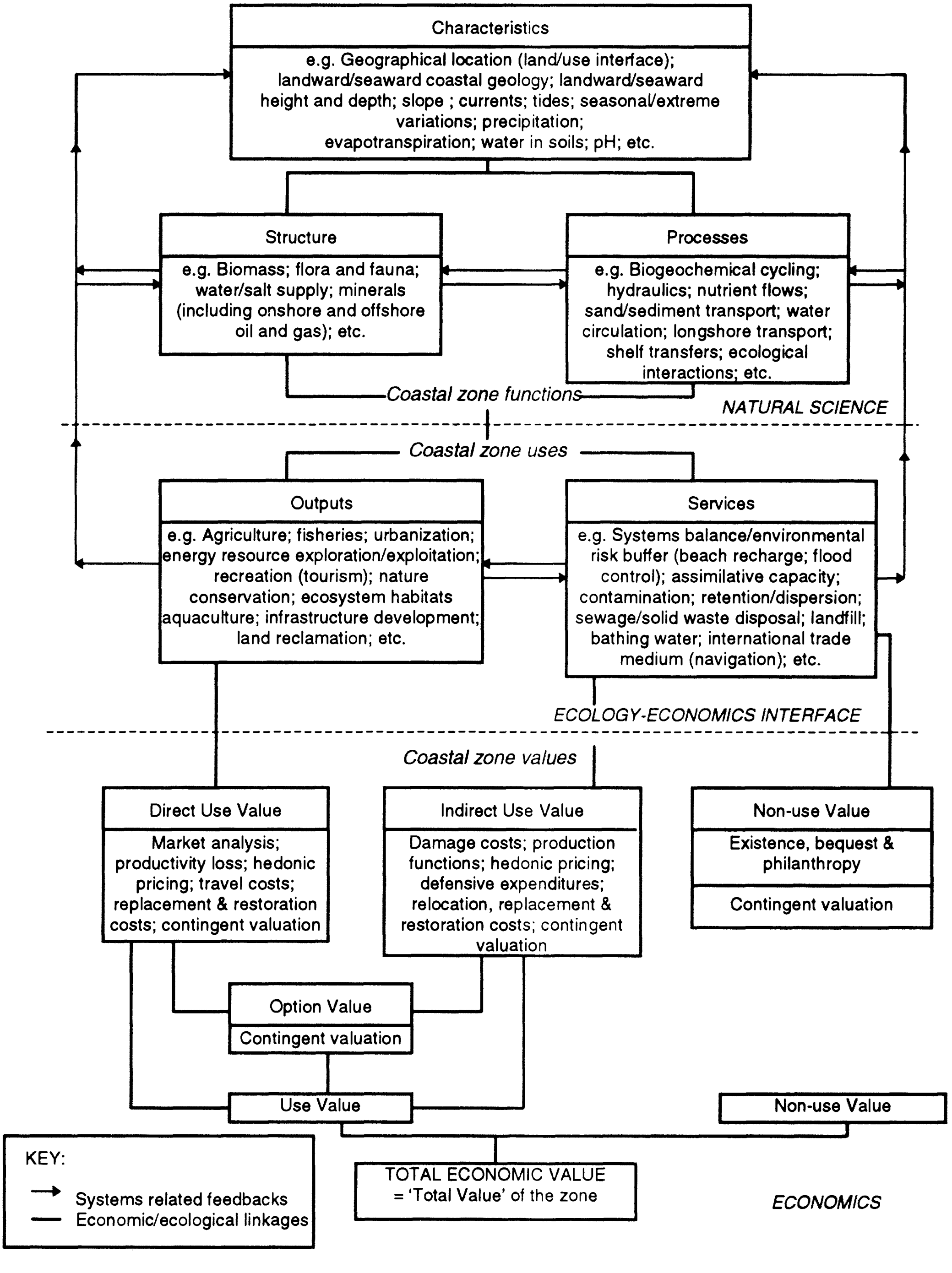

Fig. 1. Coastal zone functions, uses and values

be predictable but a proper recognition of that unpredictability will still be important and useful for policy responses. Given contexts in which combinations of irreversibility effects, surprise outcomes and irreducible ignorance exist, the appropriate policy response should be a flexible one. Policy should be conditioned by the precautionary principle and notions such as safe minimum standards, with due regard for the cost effectiveness of option choices and social opportunity costs. Coastal management by contrast has in the past been dominated by a more closed attitude which has sought to buffer socio-economic activities and assets from natural hazards and risks, via hard engineering.

More fundamentally, many ecological economists believe that the key to the mitigation of environmental problems (and in particular pollution and waste assimilative capacity limits problems) lies outside the realm of science and technology. They have focused on the realm of ethics and philosophy. Policy analysis must, in their view, fully incorporate the concept of full and actual compensation for pollution and other damage sufferers and should concentrate on the consequences of the distribution of costs and benefits among multiple stakeholders. But justice is not to be seen as exclusively a matter of income distribution, it is also a question of procedures which define the resulting distributional outcome. This then necessarily involves questions about community, social norms and collective preferences. The analytical framework should also be extended to cover the ethical analysis of intertemporal and interspecies choice (Costanza, Perrings and Cleveland, 1997).

All coastal areas are facing an increasing range of stresses and shocks, the scale of which now poses threats to the resilience of both human and environmental coastal systems (cf Klein *et al.*, 1998). Resilience can be defined in terms of the magnitude of disturbance that can be absorbed before a system flips from one state to another. As biomass accumulates, ecological systems, for example, are thought to become more susceptible to shocks and hence to a change of state. In economic systems the accumulation of capital can serve to increase the 'brittleness' of the system (Turner, Perrings and Folke, 1997). The pressures 'forced' by a cumulative process of change may result in modifications to the Earth System which in turn will impact on future human use of coastal space and resources. Human welfare will then be affected as wealth creation and quality of life services linked to coastal resources are adversely impacted. Socio-economic systems and 'natural' systems are, to a greater or lesser extent, now locked into a co-evolutionary path, characterized by joint determinism and complex feedback effects. The joint systems can respond differently to stress and shock depending on where either the socio-economic system and the biogeochemical systems are relative to system equilibria and the characteristics of these equilibria. Seemingly minor changes to a system close to a threshold can have catastrophic effects. Systems pushed beyond carrying capacity become more sensitive (less resilient) to external stress and shock. Institutional conditions also have an important role to play and can lock systems into unsustainable development paths. Human activities and influences on coastal areas in the UK have increased their vulnerability by limiting their capacity to co-evolve with the variability of natural processes (CCIRG, 1996).

There are capacity (scale) limits, such as fish stocks and coastal waters waste assimilation, which have already become binding and have stimulated increasing maintenance and other cost burdens. Expenditure on protecting the marine environment is very difficult to estimate but is dominated by work to clean up waste water discharges to the sea, largely prompted by the EC's *Urban Wastewater Treatment Directive*. Over the period 1995–2000, an investment of £900 million per annum is projected for construction of treatment plants and related facilities. Operating costs have been assessed at £300 million per annum. North Sea pollution abatement policy, for example, has been based on a series of regulatory measures with consequent opportunity cost burdens. The phasing out of sewage sludge disposal and hazardous waste incineration in the North Sea has led to difficult alternative disposal investment and maintenance cost versus environmental impact problems.

Without sustainable management, the future of marine fisheries is bleak. World population growth and increasing popularity of fish products associated with increased income imply a major increase in demand for fish which cannot be met by conventional resources. Sustainable management can be improved by the adoption of a precautionary approach to fisheries management and through support for further research and information-gathering to reduce the range of scientific uncertainty in factors affecting productivity.

Sea-level rise and other climate change related pressures will put increasing strain on the UK's sea defence and coastal protection works (Davidson *et al.*, 1991). Some 4300 kilometres of coastal defence works currently cost around £300 million per annum to maintain. The historic reliance on hard engineering defences will require significant modification towards a more adaptable 'mixed' protection and flexible response strategy, based on an integrated coastal management approach which goes well beyond the current efforts at shoreline management (Leafe *et al.*, 1998).

Future coastal management needs to be buttressed by an overarching 'integrated assessment' framework which provides policy-relevant information. The framework must include coupled or integrated

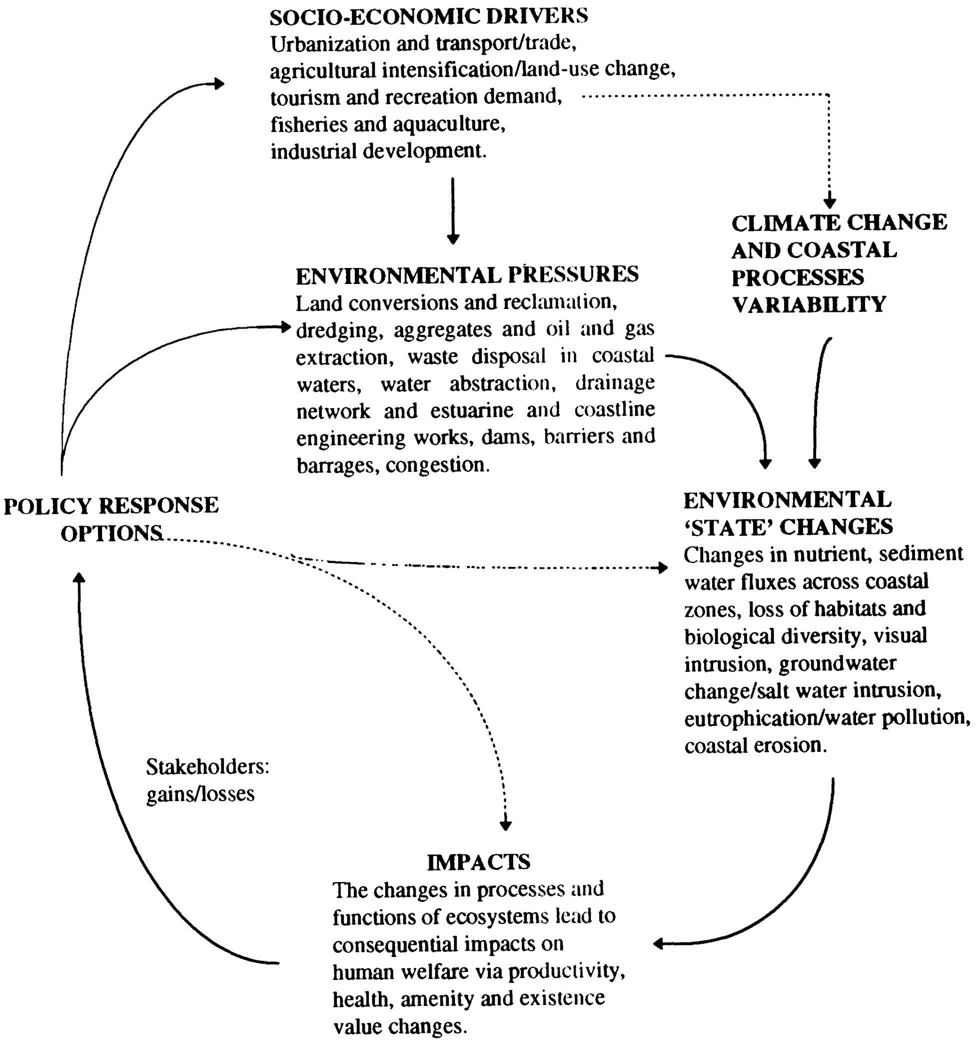

Fig. 2. P-S-I-R Framework: continuous feedback process in coastal areas

models (bio-geochemical and socio-economic) but it is not limited to just this. According to Rotmans and Van Asselt (1996) integrated assessment is:

> an interdisciplinary and participatory process of combining, interpreting and communicating knowledge from diverse scientific disciplines to allow a better understanding of complex phenomena.
>
> Rotmans and Van Asselt, 1996: 327.

Valuation in this process is more than the assignment of monetary values and includes multi-criteria assessment methods and techniques in order to identify practicable trade-offs.

Given the complications involved, one way of analysing coastal change and resources management is through the P-S-I-R (pressure-state-impact-responses) conceptual framework, see Figure 2. P-S-I-R is not a formal model but a framework for a scoping exercise. It is a way of identifying the key issues, questions, data/information availability, land use patterns, proposed developments, existing institutional frameworks, timing and spatial considerations, etc.

The P-S-I-R Framework, in combination with ecosystem function-based valuation and evaluation methods and techniques, can play a significant role in the formulation and further refinement of an integrated assessment process for coastal areas. Integrated assessment will be required to underpin the future development of more flexible and integrated coastal resource management and policy.

The P-S-I-R Framework applied to the UK coastal zone
For any given coastal area (defined to encompass its related drainage network) there will exist a spatial distribution of socio-economic activities and related land uses. This spatial distribution of human activities reflects the final demand for a variety of goods and services (Fig. 1) within the defined area and from outside the area. Changes in the intensity and extent of economic activity set up the pressure trends and the multiple use demands (often conflicting) on coastal resources (Fig. 2).

The economic production activities result in different types and quantities of residuals (discharged/emitted into the ambient environment), as well as goods and services. Environmental processes will transform the time and spatial pattern of the discharged/emitted residuals into a consequent short-run and long-run time and spatial environmental quality pattern. Coastal areas are also subject to a high degree of natural variability and climate change effects.

These state environmental changes impact on human and non-human receptors resulting in a number of perceived social welfare changes (benefits and costs). Such welfare changes provide the stimulus for management action which depends on the institutional structure, culture/value system and competing demands for scarce resources and for other goods and services in the coastal zone. Since the Rio Conference in 1992, policy is supposed to be guided by the principles of sustainable development, which are efficiency, equity and precaution.

Sustainable coastal development can be described as the proper use and care of the coastal environment borrowed from future generations. Because of the existing heavy usage pressures on the UK's coastal zone, a principle of sustainable utilization of resources seems to be a reasonable guiding concept. The resource base includes produced capital, human capital and natural capital assets. These natural assets, which include raw materials, waste receptors, landscape and amenity assets, should, as far as possible, be managed sustainably (OST, 1996).

From an economic perspective, sustainability requires a non-declining capital stock over time to be consistent with the criterion of inter-generational equity. Sustainability, therefore, requires a development process that allows for an increase in the well-being of the current generation, with particular emphasis on the welfare of the poorest members of society, while simultaneously avoiding uncompensated and 'significant' costs on future generations. Policymakers will have to grapple with the need for a 'sustainability balance' between three main decision-making principles – economic efficiency, equity and precaution. Policy measures should be based on a long-term perspective, they should incorporate an equity as well as an efficiency dimension, and they should also emphasize the need to maintain 'healthy' coastal ecosystems within resilient coastal resource systems. Given the scientific uncertainties surrounding such concepts a precautionary and flexible strategy is required. This is especially the case when substances that are persistent, toxic and liable to bioaccumulate are introduced into the marine environment.

A weak sustainability interpretation effectively assumes unlimited substitution possibilities (via technical progress) between the different forms of capital. A strong environmental sustainability interpretation assumes that natural capital (or 'critical' components of such environmental systems) cannot be substituted for by other forms of capital. Because the coastal zone is the most biodiverse zone, a strong sustainability strategy would impose a 'zero net loss' principle or constraint on resource utilization (affecting habitats, biodiversity and the operation of natural processes). Wetlands, for example, provide a range of valuable functions and related goods/services flows. Salt marshes can play a part in coastal defence, reducing hard defence maintenance costs and/or providing a component of more resilient 'soft engineering' defence systems (King and Lester, 1995). Such systems have also been subject to severe environmental pressures and have suffered extensive degradation and destruction. They may, therefore, be good candidates for a 'zero net loss' rule depending on how critical the functions and systems involved might be. The opportunity costs of the wetland conservation policy (i.e. foregone development, project net benefits) should be calculated and presented to policymakers.

In the scoping exercise that follows, for the sake of simplicity a distinction will be made between climate-related and human-induced pressures. As the following examples suggest, however, influences on the UK coastline and in other regions of the world are all inter-linked and related to each other as the P-S-I-R Framework depicts; therefore, it is often difficult to discern the precise cause and effect of changes occurring at coastal locations.

Climate-related pressures The International Panel on Climate Change (IPCC) recognized in 1996 that 'evidence suggests there is a discernible human influence on the climate' (CCIRG, 1996: i). Modifications of the global climate may lead to a global mean average increase in sea level of 37 centimetres by 2050; however, changes in water heights are likely to vary throughout the globe. In the UK, differences will be even more pronounced between the north and the south of the country, owing to isostatic adjustment following the last ice age (Shennan, 1989). Given calculations for vertical land movements, Scotland is likely to witness a 25-centimetre rise by 2050 resulting from uplift of the land: sea level by the same year

TABLE I

Costs and benefits of sea-level rise and policy responses in East Anglia (1990-2050)

	Sea-level rise (6% discount rate, £ million)			
	20 cm	*40 cm*	*60 cm*	*80 cm*
Protection costs:				
Retreat	–	–	–	–
Accommodate	132	137	151	157
Protect	187	232	292	485
Damage costs avoided (i.e. benefits of defence relative to do nothing 'retreat'):				
Accommodate	1140	1103	1092	1049
Protect	1258	1283	1325	1352
Net benefits:				
Accommodate	1008	966	941	892
Protect	1071	1050	1033	867

Source: Adapted from Turner *et al.* 1995

may be up to 50 centimetres higher in East Anglia (CCIRG, 1996; Tooley and Turner, 1995).

The frequency and severity of local storm surges and other extreme events most likely to affect the vulnerable low-lying areas proximal to UK coasts (below the 5m contour line) is still uncertain, but could be increasing (CCIRG, 1996).

A simple integrated biophysical-economic model combined with cost-benefit valuation and scenario analysis has been applied to one of the most vulnerable stretches of the UK coastline in East Anglia. Table I summarizes the costs of protecting the East Anglian hazard zone, and the net benefits value results (i.e. discounted protection costs minus discounted benefits of protection in terms of damage costs avoided) for the 'accommodate' and 'protect' policy options. The former option would involve the continued maintenance of the current defence system, that is a declining standard of protection over time as and when sea-level rise takes place; the latter requires the continual upgrading of defence to keep pace with future sea-level rise.

A protection strategy was found to be the most economically efficient response on a region-wide basis. However, at a disaggregated and localized scale (obtained by dividing the study area into 184 individual flood and erosion compartments), protection is not always the most economic response. Analysis of the 113 flood-hazard compartments indicates that as the sea-level rise predictions increase, the number of coastal sections in which retreat is the most efficient response also increases (Turner *et al.*, 1995). These results support the need for a more flexible coastal management strategy, one that is less dominated by the hard engineering option.

This case study also illustrates how economic repercussions are influenced by the scale at which coastal management is undertaken. To date, the most frequent approach towards coastal defence has been focused around local problems. Increasingly, coastal management needs to be reorientated towards the scale of natural processes, their interdependence and their repercussions on sections of the coastline. Given these circumstances, coastal management should consider the multi-faceted outcomes of isolated measures and their economic reverberations, such as the artificial protection of an eroding cliff which may result in increased flood protection costs and/or habitat loss further down the coast (Bray *et al.*, 1997).

Pressures resulting from anthropogenic action and change
Patterns of human activities throughout the UK coastline are diverse, and as such exert varied pressures on coastal areas (refer to P-S-I-R Framework in Fig. 2). Estuaries in particular figure as nodal points for economic and environmental activity. In 1989, for instance, activities on 60 per cent of 155 estuarial sites related to, *inter alia*, coast protection, industrial and port, recreational activities, exploitation of resources and visits for scientific and educational purposes (Davidson *et al.*, 1991).

Future demographic changes within the UK are likely to diverge from traditional patterns. It has been forecast that increased prosperity, improved standards of living and behavioural changes will lead to an increase in the number of households at a faster rate than population (DoE, 1996). The most recent household projections based on 1992 figures suggest that there will be an additional 4.4 million households (23% increase) in England by the year 2016, totalling 23.6 million in the same year. Population is predicted to increase by 3.6 million during 1991–2016 (DoE, 1996).

Increases in population will impose greater demands and impacts on natural resources systems and it is likely that a fair proportion of this pressure will be reflected as direct and indirect influences on coastal areas, both as providers of wealth creation and quality of life opportunities. The location of the extra dwellings that will be needed to accommodate the predicted increases in household numbers could be a concern (although the present Government has announced that 60 per cent of new housing within the next ten years should be on brownfield sites). The location of these new dwellings will have to be established by the planning authorities. However, since a substantial proportion of the present UK population is situated near coastlines, 26 million in 'coastal urban agglomerations' (CCIRG, 1996: 212), it is not unreasonable to assume that further growth will occur in these areas; CCIRG (1996) predicted an expansion to 28 million in 2000. The current lack of coordination between planning authorities and agencies/authorities responsible for flood and erosion risk management in the UK is a problem which needs urgent attention.

Tourism Coastlines figure incessantly as popular tourist destinations world-wide, partly as a result of their very diverse characteristics and qualities. The contribution made by tourism to the British economy has been estimated at 3.8 per cent of GDP (European Commission Eurostat, 1995). Surveys over the period 1988–91 suggest that the value to households of a seaside visit is between £1 and £12 per visit, depending on the valuation method used and the type of activity undertaken, i.e. beach visit, cliff-top or promenade walks (Penning-Rowsell *et al.*, 1992).

Pressures on coastal areas arising from tourism are multi-faceted and often inter-related. Social and economic benefits are counterbalanced by congestion impacts and costs and land use competition which threaten the degradation of habitats (Harrison and Price, 1996). As sporting and leisure activity patterns change, a greater demand from the tourist for better access to the coast results in greater pressure on authorities to increase facilities for accommodating greater numbers, which in turn leads to erosion or degradation of existing habitats, reducing their resilience to change. In turn, all these actions could influence the 'ecological footprint' of the activity, thus extending its resource impact further inland.

Climate change could also impact on the tourism industry, especially if a greater percentage of the UK coast becomes fortified by 'hard engineering' sea defences, and if sea-level rise obliterates some of the recreation attractions most favoured today or the 'scenic value' of the coast beside low-lying coastal habitats (CCIRG, 1996). It has been suggested that an increased length of the tourist season, or even warmer and less rainy days in the south of England, could favour the industry. These changes imply modifications to employment patterns, management of visitor numbers and associated issues (parking spaces, increased water-based activities) particularly during peak periods, presenting the tourism industry with the challenge to demonstrate it is adaptable enough to thrive in the future sustainable society.

An indication of the importance of coastal defence enhancement to tourism was estimated in a recent study focusing on evaluation of the benefits from recreation relating to a proposed coast protection scheme on the Norfolk coast at Caister-on-Sea (Bateman *et al.*, 1997). The proposed modification to the coastline consisted of a series of offshore rock bunds which, in conjunction with replenishment of the sand on the beach, would enlarge the beach present at Caister, so that it would be both visible and useable during high tide periods.

In order to gauge the preferences of all the major and potential users of the coastal area, the survey focused on two groups:

1 people making recreational use of the beach; and
2 local residents, both using and not using the seafront.

In the final analysis, the respondents were divided into two distinguishable groups: holidaymakers and all the others living nearby. Statistical techniques applied to the results of the survey showed a mean willingness to pay (WTP) of between £26–£32/household/year, excluding three large outliers. The aggregate recreational benefit for the proposed scheme was £526 678 per annum.

Port and harbour development The compatibility of future port and harbour development (which is currently most intense on the south and south-east coast of England) and nature conservation is a controversial issue. In some cases, expansion projects threaten areas of high conservation value (e.g. intertidal areas). It appears freight volumes are increasing and this trend is likely to be extended into the future, especially in the roll-on-roll-off and lift-on-lift-off sectors. Such expansion requires extra quayside capacity. Research commissioned by RSPB (1997) centred on the possibility of satisfying the projected increase in demand with the existing port capacity: 'inpansion' instead of port 'expansion'. The RSPB have proposed a series of changes in port behaviour and organization, working practices, policies and strategic planning which may postpone the need for increased infrastructure (RSPB, 1997). However, such an approach has been criticized as insufficient to meet the needs arising by the year 2010 for all types of trade. Representatives of the ports industry maintain that in order to retain UK port competitiveness, further port development may be required in the first decades of the next millennium.

Port and harbour, along with other industrial development, is likely to generate more potential land use conflict in the future because of the provisions of the EU Habitats Directive (*EU Directive on the Conservation of Natural Habitats and Wild Fauna and Flora* 92/43/EEC), transposed into UK law through the 1994 *Habitats Regulations* (Gilliland and Francis, 1997). The Directive requires Special Areas of Conservation (SACs) to be proposed by each Member State; once agreed by the European Commission and combined with Special Protection Areas (SPAs) established under the EU Birds Directive (*EU Directive on the Conservation of Wild Birds* 79/409/EEC) these will form the *Natura 2000* network. In the UK, the 1994 Regulations do not apply until the areas are formally designated; nevertheless, candidate sites are being treated as if they were already designated and management schemes are being drafted for them (Gilliland and Francis, 1997). Some 33 potential marine SACs were also selected on the basis of the marine habitats and species present (which may also include coastal interests); the potential subtidal areas under the Habitats Directive add a new dimension to nature conservation encompassing the regulations applicable to marine environments (Torlesse, 1997). All candidate terrestrial and intertidal SACs and SPAs are already designated SSSIs and, therefore, protected by existing conservation measures.

Marine aggregates extraction The extraction of marine aggregates (sand and shingle gravel) is part of a national and North West European international market. The dredging industry in Europe is very competitive and, therefore, beset with data confidentiality sensitivities. Offshore aggregates extraction in 1994 totalled some 11.33 million tonnes (11% of total UK production) and the main end uses supplied were the concrete industry and sea defence/coastal protection uses (beach recharge schemes). Potential environmental impact concerns have been raised in the context of reduced fisheries productivity, effects on shoreline stability and marine habitats degradation (Kenny and Rees, 1996). Damage effects are difficult to quantify and in some cases will depend on whether the areas close to extraction activities have sediments being transported onshore or less problematically offshore. But there may also be a bathymetry problem: aggregates dredging may affect wave energy at the shoreline, enhancing the risk of erosion if 'soft cliff' coasts are involved, and increasing wave energy impinging on flood defences.

The exploitation of marine aggregates is currently expanding with the upturn in the national business cycle and following efforts to substitute, wherever feasible, 'soft engineering' for 'hard engineering' sea defence/coastal protection measures. A more sustainable approach to marine aggregates exploitation requires more scientific data. There is a need for an inventory of available aggregates resources, on a regional scale (North West Europe) and some survey work has begun to quantify available volumes and grades of material. Better science is also a high priority in the form of models able to offer a better shelf-wide understanding of the sea-bed sediment transport regime.

Unconstrained marine aggregates exploitation is not feasible because of problems caused by the presence of cables and pipelines on the seabed, existing waste dumping, military exclusion areas and overall water depth (a depth greater than 50 metres precludes dredging). Billions of cubic metres of sand remain to be exploited, but gravel deposits are much more limited. Potential negative environmental impacts will also serve to restrain extraction but a more acceptable balance between exploitation and environmental conservation is dependent on improved environmental science and data, as well as increased participation by and consultations between the relevant stakeholders.

Waste assimilation and pollution Wastes enter the marine/coastal resources region as a consequence of both land- and sea-based human activities. After discharge to the natural environment, the wastes are affected by, and in turn may affect, various physical, chemical and biological processes. Utilization of coastal resources as a receptor of wastes from land- and sea-based human activities relies on their assimilative capacity (or supposed capacity) to accept and process anthropogenic inputs or perturbations without deleterious effects to the ambient water quality. Changes in ambient water quality affect human health, beach-related recreation and commercial fishing.

Protection of the North Sea, for example, from pollution has largely been based on regulation and the 'precautionary principle'. The foreclosure of the North Sea sewage sludge disposal route, agreed in 1987, was a precautionary action, but also served to highlight the possible drawbacks of such a strategy. The decision involved significant social opportunity costs given that land-based disposal operations would have to be utilized on a more extensive basis; it was estimated that the ban could lead to additional capital expenditure in England and Wales of around £100 million and increased water company operating costs of £0.4 million per annum (WRc, 1990).

According to WRc (1990), in England and Wales *ca.* 1.22×10^6 tonnes dry solids of sewage sludge was generated annually by more than 6000 sewage treatment works. In total, 37 per cent of the sludge was disposed of to agricultural land, 19 per cent to landfill, 25 per cent to the sea and six per cent to incineration. The sewage arising from about 13 per cent of the population of England and Wales remained untreated and was discharged directly to the sea via outfall pipes. Treatment of all this sewage would involve £0.5–13 billion of capital expenditure and increased annual operating costs of £15–33 million, depending on the level of treatment installed.

A UK multi-criteria analysis of sewage sludge disposal options investigated four feasible disposal routes (Table II). All the options were evaluated on the basis of three categories of criteria:

1 discounted financial costs (over a 20-year period at a discount rate of 5%);
2 operational security (a mix of operational and management risk factors plus longer-term general trend changes in land use policy, social acceptance etc.); and
3 environmental impacts.

TABLE II

Multi-criteria analysis of sludge disposal options

Options	*Financial cost (discounted over 20 years)*	*Operational security (rank order)*	*Environmental impact (rank order)*
[a] sludge consolidation followed by incineration and landfill of residual ash	£16.9M (4)	(1)	(1)
[b] sludge consolidation followed by soil injection	£13.45M (1)	(2)	(2)
[c] sludge consolidation followed by anaerobic digestion with combined heat and power, mechanical dewatering and final surface spreading to agricultural land	£15.7M (2)	(4)	(3)
[d] sludge consolidation followed by mechanical dewatering and landfill	£14.6M (3)	(3)	(4)

Source: Adapted from WRc, 1990

On this basis the study identifies incineration of sludge (option [a]), as the preferred option.

The main environmental implications of diverting the majority of the sewage sludge (currently disposed of to the marine environment) to incinerators would be:

1 a redistribution of heavy metals, inorganic material and possibly dioxins to landfill sites, agricultural land and to the atmosphere;
2 a reduction in the direct transmission of dioxins, PCBs, pesticides, organics, and nutrients to the ambient environment;
3 increased emissions of SO_2, HCl and NO_x to the atmosphere;
4 increased direct emissions of CO_2 to the atmosphere; and
5 a small increase in volume of road traffic and related emissions.

Agricultural land application (option [b]) was the second ranked option in the UK study, but topped the ranking list in a US study (US EPA, 1990).

Discharge of sewage into coastal waters has been linked to degradation of bathing water quality and increasing health risks; it is estimated that cleaning up all of Britain's beaches would cost around £9 billion. In 1997, compliance of identified bathing waters in England and Wales with the 1976 EC *Bathing Water Directive* standards was 88.8 per cent (Environment Agency, 1997). The question then becomes: are the public willing to meet the costs of the clean up? A recent economic valuation study undertaken on the East Anglian coastline set out to provide data to enable progress towards answering this question (Georgiou *et al.*, 1996). The contingent valuation method was deployed in order to estimate the stated willingness to pay (WTP) for bathing water quality health risk reductions at two beaches in East Anglia. One beach, Great Yarmouth, failed to meet the EC Directive standard, while the other at Lowestoft passed. The analysis focused on determinants of individuals' WTP, including measures of risk perception and attitudes to health not usually measured in CV studies. Some 57 per cent of respondents to the survey at Yarmouth and 58 per cent at Lowestoft, answered 'yes' to the question posed, i.e. would they be willing to pay higher water rates to preserve or achieve the EC standard at all Britain's beaches? After allowing for those who refused to pay, average WTP was £18 at Great Yarmouth and £16 at Lowestoft per annum, respectively. If these results are scaled up to a national average, for illustrative purposes, the resulting totals would be more than sufficient to pay for current EC proposals on bathing water quality improvements and are similar to the costs of attaining more stringent requirements set out in a House of Lords Committee report (HOL, 1995; Table III).

Pollution of coastal zones and regional seas involves a much more complex set of factors and problems than freshwater pollution because of the complex and variable chemistry of marine waters, exchanges between environmental media (e.g. atmospheric inputs to the North Sea) and long-range transport of effluents (Stebbing and Willows, in press). Marine pollution is three-dimensional, with residual flows derived from a tidally oscillating water mass that are responsible for complex hydrodynamic behaviours of persistent contaminants in solution and absorbed to particles. Many of the inputs have diffuse sources (particularly in the case of estuaries with large catchment areas) which make their origins hard to trace.

To illustrate the difficulties involved, take the case of the Humber estuary which, despite a vast industrialized catchment area, remains relatively unpolluted, with the exception of copper (Cu) and Biological Oxygen Demand (BOD). The estuary has been used as a copper waste disposal option for most of the century. It was expected that the copper would be

TABLE III

The impact on water charges of implementing EC bathing water amendment

Scenario	*Capital cost (£ million)*	*Operating cost (£ million/year)*	*Potential increase in prices in real terms %*	*Potential increase in average annual household bills (£)*
A	1520–3940	50–140	4–12	10–28
B	1050–2240	40–90	3–8	7–17
C	400–1010	20–40	1–3	3– 7
D	20–40	0	0–0.1	0.1–0.02

Source: Georgiou *et al.* 1996
Where:
A The Commission's proposal including the introduction of a mandatory standard for faecal streptococci, set at 400/100 ml, and the enterovirus standard made more stringent.
B The existing Directive made more stringent by making mandatory the standards which are presently the optional Guideline standards.
C The Commission's proposal except for the omission of the more stringent enterovirus requirement.
D The existing Directive plus a new mandatory standard of 1000/100 ml for faecal streptococci.

diluted and complexed in the estuarine waters, and eventually flushed into the North Sea, causing no damage. The majority of the copper is complexed, reducing bioavailability and toxicity, but accumulation effects in the sediment and excessively high loadings have resulted in major increases in the dissolved and sedimentary copper levels. The 5 µg/l Environmental Quality Standard (EQS) for dissolved copper is now failed on a regular basis.

The industries on the Humber banks were considered to be the major cause of the elevated copper levels, and as a result the policy response was to lower the copper discharge consents. Thus, the Cu loadings have been dramatically decreased, however, the estuary is still failing the EQS.

A model of the system has been produced to determine the level of Cu discharge abatement needed to ensure the estuarine Cu levels fall below the EQS. Research is currently being undertaken to determine the predicted cost of this abatement and the most efficient method of achieving it. Preliminary investigations have indicated the costs will run into millions of pounds and further decreases in the industrial copper discharges may not be the most efficient option and may not even have the desired effect. The current elevated levels could be due to copper inputs from other sources; the atmosphere could contribute 19 per cent of Cu inputs to some estuaries (French, 1993). These levels could also be the result of historic anthropogenic inputs with a long latency effect. The Cu is locked in the sediment-biota ecosystem (Vivian and Spiers, 1991) and the residence time of Cu in the Humber has been estimated at 120 years (Millward and Glegg, 1996). These dynamics also indicate that since the inputs have been greatly reduced it could simply be a matter of time before the estuary recovers and flushes the Cu out of the system; further new reductions in industrial Cu inputs may have little effect on this time span. This evidence suggests that while continued abatement of Cu inputs may have little effect on the environment they impose a significant cost burden on industry.

But, the Humber is only one of a number of industrial estuaries around the North Sea basin. Some analysts now believe that the assimilative capacity of the entire North Sea for contaminants, without causing harmful effects to living resources and ecological systems, is being exceeded. They further argue that the present strategy for controlling pollution largely using legislation and monitoring of chemical contaminants, rather than biological indices of health, has underestimated the pollution loading of the North Sea. A new approach to environmental monitoring that has evolved over the last decade to deal with such complexities, is advocated. It is based on the totality of the biological impact of contaminant loading, which is monitored in terms of its biological effect (via representative or sensitive biological systems that can demonstrate the toxic effects of contaminants), rather than attempting to assess and monitor the health of the system by monitoring each chemical or class of chemical contaminant (Stebbing and Willows, in press).

Policy implications

The identified UK coastal pressure source, trends and impacts have been shown to be amenable to an integrated assessment methodology linked to the P-S-I-R scoping framework. Integrated ecological–economic modelling, cost–benefit analysis and multi-criteria evaluation methods all have an important 'internal' role to play in the assessment process. But the characteristics of the process itself are also vital. There is a need for a more open, flexible, integrated and participatory approach to coastal science and management, because of the inevitable uncertainties and irreducible ignorance that exists. An important long-term goal is the provision of support for environmental sustainability decision-making based on the principles of economic efficiency, optimal scale, distributional fairness and justice, participation, legitimacy and precaution. In the face of an increasing degree of environmental risk, uncertainty and ignorance, the distributional incidence of the risks, costs and benefits becomes a key issue. Public consultation and consequent acceptance of the inevitable trade-offs involved will be an important requirement in any legitimization process.

A future more active and conciliatory approach to consultation across and between stakeholders in any given resource allocation and environmental decision-making situation is required. It can be argued that there are strong social, political and economic arguments for widening the consultative arrangements and ensuring a more face-to-face participatory role for representative interests. O'Riordan and Ward (1997), for example, have explored the theory of legitimation and legitimacy in negotiative participatory processes in the context of Shoreline Management Planning in the UK. They have sought to justify the development of empowerment through respect, authenticity and trust in the conduct of mediating exercises. The shoreline management case studies they investigated all posed the policy dilemma of how to provide compensatory equivalents for land and internationally important wildlife resources threatened with inundation because of sea-level rise and/or 'best practice' shoreline management. It was found that local networks can play an essential role. In many cases incipient networks based on personally cooperative individuals exist and can be mobilized and extended. Such networks are vital for sharing information, formulating positions and for mutual education. This is the basis of empowerment.

Similarly, one framework which would facilitate a more comprehensive and coordinated approach to conflict resolution in the context of major developments in estuaries is an Estuary Management Plan. Such an approach was suggested following the cooperation and consultation process related to the development of the Haven Ports (including Felixstowe, the largest container port in the UK) in the Orwell and Stour estuaries (Allen, 1996).

The recently proposed framework Directive for Water Policy and the existing *Habitat Directive* would also provide top-down pressure for change in coastal management processes and practice (Anon, 1997). The aims of the water policy proposal would be reached by adopting a river basin management approach, which should take into account the processes and water flows both above and below ground, in order to decrease the consequences of floods and droughts, provide water (both drinking and for other requirements) and protect the environment. It controversially suggests that water use should be paid at full recovery cost prices, and includes a cost assessment of the implementation of the Directive. Advantages to be gained range from 'improved sustainability of water supply' to greater amenity value of waters. The implementation of this Directive would lead to the repeal of several others; the drinking water, bathing water and pollution and prevention control directives would, however, remain in force (ENDS, 1997a; Anon., 1997). The logic of this proposal suggests that to ensure 'good' water quality, other aspects such as land-use planning and flood defence, should also be included in the directive (ENDS, 1997b).

The conflict between growing development pressures and the maintenance of the UK's natural capital is encapsulated within the 'no net loss' policy, of the Habitat Directive which requires adequate compensation (restoration of habitat) if developments, of overriding public interest, are to take place within a protected *Natura 2000* area. These candidate *Natura 2000* areas, are to be found in many UK estuaries, such as the Humber, and may directly impact on future economic development of the area. Further investigation, such as through cost–benefit analysis (CBA) is, therefore, required to assess the various possible mitigation options towards the sustainable development of coastal resources.

If development in the coastal zone requires the restoration or creation of offsetting habitats at some other location, as implied by the Habitats Directive, then one of the key variables to be considered, and frequently overlooked, is the costs of recreated sites. These have been shown in wetland restoration to be potentially high, both for the restoration phase and for subsequent monitoring. The institutional arrangements by which these management costs are minimized is also open to debate. Habitat 'land banking' or 'mitigation banking' is the creation, restoration or enhancement of an area of a functioning ecosystem as a compensatory measure to offset the collective environmental losses of a number of small-scale development projects. Within the coastal zone, habitat loss is an ongoing problem, particularly small-scale developments which individually do not have a significant effect on the habitat levels but cumulatively may lead to long-term degradation of natural assets.

Some natural habitats in the UK are also under threat from natural changes in coastal processes, such as erosion. The Habitats Directive does not cover these issues, which nevertheless greatly influence the management of the diverse sites under consideration.

The future more integrated, adaptive and participatory coastal management process will consist of a set of tasks carried out by several or many public and private entities. The tasks together produce a 'socially desirable' mix of products and services from the available coastal resources. The management process will need to cope with changing circumstances, changing social tastes, increased knowledge of coastal processes, of human behaviour and 'value' of coastal ecosystems; as well as changing technology, changing factor prices and changing governmental policies (Bower and Turner, in press). The integrated assessment required for this new management approach performs an overall resource auditing role; it forces decision-makers to ask relevant questions relating to coastal ecosystems and processes, coastal zone pressure trends, trade-offs, environmental impacts and various aspects of response strategies, including sources of finance and human/institutional capital resource potential. It also should be a cyclical framework of mutual learning among scientists and stakeholders, a process of informed social dialogue leading to conflict reduction. This process is in marked contrast to the traditional science-management axis that has tended to isolate coastal problems from their wide context, and to seek to maximize control through mechanical/technical means.

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