

Managing the coastal zone: learning from experience?

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Introduction

The coastal zone has evolved in response to many natural and anthropogenic factors and processes. Therefore, it is logical these should be integrated within management strategies. Climate change and sea level rise now pose significant threats to coastal regions and consequently, many tourism destinations. Accepted strategies to manage coastal areas under threat are:

Hold the line;
Advance the line;
Retreat from the line;
Do nothing.

However, each of these options comes with their own problems and consequences. Ketchum (1972) identified six major spheres of human activity in the coastal zone: residency, recreation and tourism; industrial and commercial; waste disposal; agricultural, aquaculture and fishing; conservation; military and strategic, which still hold true. However, these activities are increasingly in conflict with one another as well as with natural processes. Consequently, the point at issue is how to protect and manage our coastal resources while accommodating growing development pressures. An evaluation of the present day status of a coastline is fundamental in deciding whether to actively manage or refrain from intervention (Simm, 1996). In many vulnerable coastal areas beaches lie in front of built defences and it is important to differentiate between the general health of a beach and its function in coastal defence. A beach may be at a very low level and its volume may be reducing, but this does not necessarily mean that the beach needs managing to improve its defensive capability (Simm, 1996). Micallef and Williams (2002) argued that very little research work adequately addressed beach management needs and addressed this in their recent book (Williams and Micallef, 2009). Managing the coastal zone involves policies at various geographical scales and the implementation of techniques to achieve these policy objectives. Consequently, this chapter will examine coastal management in response to climate change and sea level rise. It will consider problems caused by human interaction with physical processes, assess options for protecting coastal assets, examine policy options based on available capacity and conclude with strategic management recommendations.

Coastal problems

The following case studies give examples of development and consequences of human attempts to provide a stabilised shoreline. Figure 1 shows a recently constructed cliff-top road in Praia, Cape Verde. It represents a significant infrastructure investment to support tourism development in the island.



Figure 1: Praia, Cape Verde

There is already evidence of settlement and repairs have been undertaken. Unfortunately, undercutting and erosion will be an ongoing process, causing further future problems. The decision to site the road at this location highlights a common coastal problem, in that coastal processes are not considered in development planning. Another example of an inappropriate development location is shown in Figure 2. Here a property along the same coastal frontage in Praia is threatened by cliff retreat and the problem has been managed using rock armour at the cliff toe. However, ground movement has reduced armour effectiveness and further remedial actions will be necessary to prevent this property falling into the sea. Protection will be an ongoing and expensive process.



Figure 2: Property under threat, Praia, Cape Verde.

Cliff-top development in Albufeira, Portugal is clearly threatened by erosion (Figure 3). This is a common problem along the Algarve coastline and some properties are now uninhabited. They are left vacant, in some cases by local authority enforcement, as a safety precaution due to the risk of collapsing into the sea.



Figure 3: Coastal development in Albufeira.

Figure 4 shows cliff protection measures near Cadiz, Spain. A hotel at the cliff top is the only property under threat should there be extensive cliff-falls. The local authority placed rock armour at the cliff-toe along the coastal frontage and secured the cliff face with netting to contain rock falls and prevent potential injury to beach users.



Figure 4: Cliff protection measures

These cliff protection measures represent a significant investment by the municipality while the beach itself evidences erosion and narrowing at many locations along its length. This increases the incidence of storm waves attacking the cliffs, resulting in further management costs. The paradox is that cliff material should naturally replenish the beach and adopted management strategies have reduced local sediment input. Consequently, this has increased beach erosion and has resulted in greater wave energy/storm impacts along the whole coastline. It could therefore be argued that the local authority has invested in long term shoreline degradation.

Military land at Barry Buddon, near Dundee, Scotland has evolved naturally with little disturbance and consequently, the coastal dune system shows no evidence of degradation (Figure 5).



Figure 5: Military coastal land.

Adjacent land to the west has for centuries been used for various industries and activities. It has also been used as a landfill site and latterly for recreational activities. Human use over time has necessitated stabilisation and these measures have themselves caused erosion. Figure 6 shows rock armour protecting the dunes, but in reality, it is preventing natural reworking of the shoreline. In front of the armour, embryo dunes form as part of the natural process of coastline evolution.



Figure 6: Rock armour protecting dunes

South Wales, UK has many examples of development subsequently being in conflict with coastal processes. In Porthcawl, the Esplanade seawall of 1887 was replaced in 1906 and again in 1934, as erosion continually undermined previous constructions (Carter, 1988). Beach levels continued to fall and in 1984, the coastal protection authority paved the beach with bitumen macadam (Figure 7). While not aesthetically pleasing, only minor repair works have subsequently been needed and high value human infrastructure has been protected.



Figure 7: Bitumen revetment

A tidal harbour at Port Talbot, constructed for importing iron ore and coal, subsequently caused significant erosion of the adjacent coastline. The promenade and tourism infrastructure were themselves all constructed in a former sand dune area. Here seawalls constructed to protect the promenade were undermined and coastal defence measures to protect seawalls fronting the promenade and industrial hinterland include rock armour revetments (Figure 8; Phillips, 2009).



Figure 8: Aberavon promenade

The construction of the Millennium Park, Millennium Coastal Path and Earth Structure at Llanelli, South Wales, UK stimulated a tourism and domestic property redevelopment strategy. However, this took place without due consideration of coastal processes and location. Furthermore, because of previous dereliction and lack of valuable infrastructure, temporal coastal data had not been collected as part of strategic monitoring. Consequently, following storm events the coastal path suffered catastrophic failure (Figure 9), the Earth Structure suffered erosion and significant damage became apparent on many newly

constructed homes. Existing seawalls were undermined and required rock armour protection and their ability to protect recent developments is now in question. Causes and effects included inappropriate siting of infrastructure, advancing the line without due consideration of coastal processes and relocation of nearshore river channels. Lessons had not been learned following similar construction patterns elsewhere (Phillips et al. 2009).

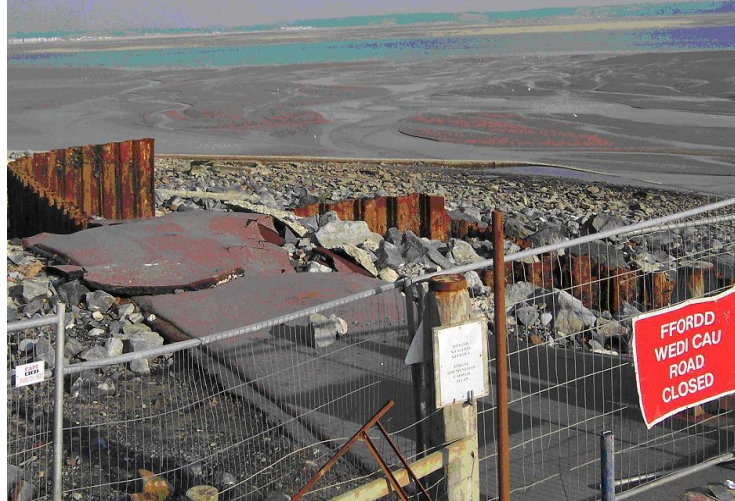


Figure 9: Catastrophic failure of coastal path

Protecting coastal assets

Without sufficient data to enable accurate assessment of coastal processes and dynamics, it is unlikely that effective long-term protection of coastal assets will be achieved. However, the collection of quantitative data is often expensive and time consuming (Galofre and Montoya, 1995). Phillips (2008a) identified unique short term changes in coastal processes which had caused significant infrastructure failure and similar work at another location showed marine aggregate dredging was not the significant cause of local beach erosion (Phillips, 2008b). Without analysis of long-term datasets neither of these outcomes would have been achieved. Qualitative data should enable identification of socio-economic and environmental values associated with coastal use. Ideally, collection of data on coastal processes and sediment-related characteristics should include both physical and environmental components and be complemented by subsequent long-term monitoring programmes. Identification of local characteristics and/or problems and the socio-economic value of resources are vital for effective decision-making. Protection measures should be considered as a function of socio-economic pressures and physical environmental constraints. Micallef and Williams (2002) considered analysis in this context was often linked to understanding an environmental system, examining active management if present and identifying problems. Spatial assessment should evaluate external events such as resort development which can influence natural beach dynamics while temporal analysis should address timeline variation and causal change, such as sea level trends. Therefore, as argued by Bowman and Pranzini (2008), it is necessary to decipher the effects of time and space at different scales, on shoreline behaviour when designing an optimal coastal monitoring strategy. Remote sensing technologies utilising satellite imagery, LiDAR and video systems are increasingly used to assess coastal change, and these are supported by numerical models which generate wave climates, sediment transport mechanisms, etc. Importantly, as stressed by Barale (2008), both in-situ and remote sensing techniques should be integrated. In the UK, Shoreline Management Plans based on sediment cells, provide large-scale risk assessments associated with coastal

processes such as tidal patterns, wave height, wave direction and movement of beach and seabed materials. Their aim is to help reduce risks to people and the developed, historical and natural environments.

Historically, human development in coastal areas has been protected from the sea by hard engineering structures, such as seawalls, breakwaters and groynes. A worldwide tendency to coastal erosion (Cipriani *et al.*, 2004) has been locally aggravated by some of the very strategies implemented to reverse the pattern (Gillie, 1997; Weerakkody, 1997). While reducing coastal erosion locally, these structures tend to interfere with the natural transport of sand and cause coastal erosion further down the coast. Following port developments at Marina di Massa, Tuscany, Cipriani *et al.* (1999) reported that in order to protect the seaside resort, each kilometre of coastline was protected by 1.4km of hard structures. Later work identified 2.2km of hard structures protecting every kilometre at Marina di Pisa, Tuscany (Cipriani *et al.*, 2004). Of the 875km of European coastlines that started to erode within the past 20 years, 63% are located less than 30km from coastal areas altered by recent engineering works (Europa, 2007a). Europe's coast is under increasing threat from erosion. A fifth of the enlarged EU's coastline is already severely affected, with coastlines retreating by between 0.5 and 2m year⁻¹ and by 15m in a few dramatic cases (Europa, 2007b). However, Basco (1999) believed there are many misconceptions that seawalls increase erosion and believed policy decisions to locate infrastructure in the coastal zone are the cause. Seawalls are needed to protect inappropriately sited construction from storm damage but then are blamed for subsequent beach erosion. Kosyan *et al.* (2005) highlighted a similar situation when seawalls were built to protect the Black Sea coastal railway. Wiegel (2002) considered that seawalls cause erosion in special circumstances where they prevent erosion of an upland source of sand for a beach downdrift whilst, van der Weide *et al.*, (2001) recognised that engineering works along the coast often cause erosion and accretion.

Because of the problems associated with hard engineering in the nearshore zone, not least cost and maintenance, alternative soft engineering techniques that work in conjunction with natural coastal processes are increasingly being used. These include the construction of submerged breakwaters that reduce the effective depth offshore and consequently reduce wave power and beach erosion (Aminti *et al.*, 2002). Beach nourishment is another soft engineering method used on eroded beaches worldwide. Although some argue it is unsustainable in the long term, it improves beach conditions, supports tourism and enhances beach appearance. A good example is Miami Beach which by the mid 1970s had virtually no beach. Following beach nourishment and infrastructure improvements, visitor numbers grew and this has resulted in an annual return of almost \$500 in foreign exchange alone, for every \$1 invested (Houston, 2002). Beach nourishment was undertaken at Marina di Massa, Italy, where offshore sand was dredged and dumped on the beach (Cipriani *et al.* 1999). The project was funded by bathing establishment owners and the local authority. The mean grain size of the borrow material was finer than the native beach sediment which resulted in approximately 66% of borrow material disappearing within one year. Beach quality also worsened due to the fine sediments making the beach dusty. Although financially successful in terms of tourist revenue, it led to a loss of faith in a soft engineering solution by private owners, tourism operators and local authorities alike. Subsequent work by Micallef *et al.* (2001) on a proposed beach nourishment project at St George's Bay, Malta showed a high probability (0.95) of a mild impact during the post-construction phase with fine-grained sediment as against a high probability (0.86) of a negligible impact with coarse-grained sediment. Had these findings been applied at Marina di Massa, nourishment would have been more successful. Nourishment is commonly practised along the North Adriatic coast and 10 million m³ has

been used in 10 years along a 45km coastal stretch. Studies of beach nourishment's potential to reconstruct beach/dune systems are currently being evaluated and early results showed beach management practices and shoreline orientation to be critical (Bezzi et al., 2009). However, Bochev-van der Burgh et al.'s (2009) studies on the central Netherlands coast found that noticeable changes in foredune morphology were not evident until several years after commencement of nourishment activities. The lesson is beach nourishment can be a sustainable way to manage coastal erosion provided that coastal processes are appropriately considered. Following nourishment, the new wider beach protects the shore from storm impacts while increasing recreational benefits and tourism related opportunities (Benassai et al., 2001). Issues include estimation of required sand volumes, locating sediments on the continental shelf, environmental compatibility, extraction techniques and projected costs (Lupino and Riccardi, 2001). Beach nourishment is now the preferred U.S. coastal erosion response (Leatherman, 1997; Harris et al., 2009) and as argued by Symes and Byrd (2003), there is a natural symmetry to combating coastal erosion with sand won from the sea. However, as specified by Williams and Micallef (2009), when carrying out beach nourishment it is important to adhere to established guidelines and procedures, otherwise repercussions include large scale changes to geomorphological and ecological characteristics.

Another soft engineering solution, which has been used internationally to good effect on eroding coastlines, is beach drainage (Turner and Leatherman, 1997). The link between groundwater flow and beach erosion/accretion has been documented by many authors including Turner and Nielsen (1997). Lower ground water levels allow a relatively large volume of water in the run-up phase to percolate through the beach face, which in turn reduces the erosive back-wash effects. Piccini *et al.* (2006) assessed its application in Ravenna, Italy and found that although successful, the presence of an impermeable clay layer significantly reduced the beach drainage system's efficiency. Bowman *et al.* (2007) showed beach accretion and shoreline advance at Alassio Beach, northern Italy, but also found inefficiencies in the beach drainage system. Conversely at Enø and Hornbæk in Denmark, beach drainage has been completely successful and at the former location, erosion has stopped and annual beach nourishment cancelled. As part of a long term strategy to protect Venice against the effects of climate change and sea level rise, dune systems seaward of the Venice Lagoon are being restored. In Avalon, New Jersey municipal economic resources have been used to enhance landforms as protection structures. Dunes have been restored and heightened, sand fences installed and sediment budgets controlled. Consequently, one of the wealthiest communities ranks in the lowest 1% of state property taxes and has the lowest property insurance costs (Nordstrom et al. 2009). The value of using natural processes to protect coastal assets is becoming increasingly clear.

Coastal Management

The seminal work on Integrated Coastal Zone Management (ICZM) by Cicin-Sain and Knecht was first published in 1998 and it is still the major reference on this topic. It is an academic and practitioners guide for developing and implementing effective coastal management, giving guidance on resolving difficult policy issues. Sauer (1962) identified the general management problems of integrating physical and cultural environments, exemplified by Granja's (2001) assertion that lack of coastal management had irreversibly contributed to the gradual degradation of Portugal's natural heritage, including the landscape that is one of its key elements. She further argued that management implies an understanding of geofoms, their generation, longevity and relationship with the ecosystems dependent on them. Therefore, to promote conservation and management of the coastal zone, it is important to

understand not only present day factors and processes, but also those that have been active in the recent geological past.

“Strategic planning for the management of our coasts relies implicitly upon an understanding of the physical processes responsible for shaping coastal morphology”.

(Reeve and Spivack, 2001, p55)

The coastal zone has evolved from many natural and anthropocentric factors and processes and it is logical that management concepts inherent to these factors should be integrated. This has not always been the case, demonstrated by the coastal examples earlier in this chapter. The approach suggested by van der Meulen *et al.* (2001) is that ICZM is a cyclic process of problem recognition, planning, implementation and monitoring. This includes recognition of the country's institutional setting in terms of stakeholders and the respective mandate, capacity, commitment and financial potential. Calado *et al.* (2009) assessed geographical, environmental, cultural, political and institutional aspects of the Azores archipelago when devising a new management strategy for the Azores Marine Park while, Coutinho *et al.* (2009) recognised the importance of geological classification and hazard assessment in constructing management and constraints maps. It is important to accept differences amongst stakeholders and understand potential conflict when deciding who has most rights. Policy and implementation will be influenced by strategic and socio-economic potential in conjunction with available techniques for defending the coastline. Society's socio-cultural matrix (Ferreira *et al.*, 2009), inefficient institutional frameworks (Mercado *et al.*, 2009) and science-management barriers (O'Connor *et al.*, 2009) are seen as preventing effective ICZM. However, these limitations could be overcome utilising multi-criteria decision making techniques (Mosadeghi *et al.*, 2009).

“... increasing populations and development are placing significant stresses on coastal resources; rising sea level is causing land loss, creating a collision course of social and sea level trends.”

(Leatherman, 2001, p181)

The cost and sustainability of technological solutions will be a critical factor as the use of seawalls to protect the coastline is now being questioned on the basis of expense and effectiveness (Cipriani *et al.*, 1999; van der Weide *et al.*, 2001; Wiegel, 2002). However, as advocated by van der Weide *et al.* (2001), to design appropriate mitigating measures, causes should be properly analysed and the technical and economic feasibility of such mitigating measures should be evaluated. Groyne-field techniques to facilitate sedimentation (Kunz, 1999); submerged groynes to reduce near shore wave energy (Jackson *et al.*, 2002; Robertson *et al.*, 2002); beach drainage (Turner and Nielsen, 1997) and beach nourishment (Cipriani *et al.*, 1999; Benassai *et al.*, 2001; Lupino and Riccardi, 2001; Micallef *et al.*, 2001), work in conjunction with natural coastal processes. Decision-makers will need to consider these aspects when deciding future coastal management policies.

Granja and Carvalho (2000) recognised that it was unrealistic to believe that all coastlines can be protected from impending sea level rise and subsequent coastal erosion. They suggested managed retreat and selective conservation of parts of the coast that are important to society and to use technological developments, where possible, to halt inland beach migration. It may be argued on socio-economic grounds however, that hard engineering with its associated

problems will still be necessary. If human activities and global change result in coastal zone losses, risk assessments will have to be undertaken to consider overall consequences. These will include costs for defending buildings and infrastructure, environmental issues, and associated socio-economic benefits. Stakeholders will be unwilling to allow areas of high value real estate to be abandoned to the will of the sea unless cost benefit analysis and more importantly, political will prove otherwise. Interestingly, Martins et al.'s (2009) study of coastal community shoreline retreat perceptions found the majority of respondents would accept having their homes relocated, provided there was evidence to support them being in danger.

Beach management and sea defences can be justified on socio-economic grounds for a particular region and community which depend on the beach, even though these may cause the acceleration of coastal erosion further along the coastline. Consequently, the use of risk assessment tools in conjunction with benefit-cost analyses (Granja and Carvalho, 2000) could be used to justify policies of managed retreat where irreversible loss is evident. Strategies for management of the coastal zone generally agree with those suggested for coping with the negative effects of climate change. According to the Environmental Scientist (1999), they include prevention of loss, tolerance of loss and changing activities and location while, the mechanisms to achieve these strategies include institutional, legal, financial and technological aspects. Difficult decisions will need to be taken irrespective of stakeholder interests and there will be economic consequences (Leatherman, 2001). Policies will therefore need to integrate the complex inter-relationships of Ketchum's (1972) spheres of human coastal activity. Geographical Information Systems (GIS) analysis can aid this process by producing spatial datasets that have direct value for coastal stakeholders, planners and decision-makers. Furthermore, these systems can be tailored on a regional basis or for individual shorelines (Kalliola and Laurilla, 2009)

Summary and Future Strategies

According to Johnson and Scholes (1988), strategic management involves the following:

1. Analysis, where one seeks to understand the content of a system, the status of existing management, if any, and whether one should take any action;
2. Choice of the different courses of action available;
3. Implementation, where the chosen option is put into effect.

Strategic management for coastal tourism destinations with respect to climate change and sea level rise must address the following:

- Increased storminess: this will significantly impact on coastal infrastructure.
- Sea level rise: this will vary, even along the same coastline, leading to increased erosion/beach loss. Coupled with increased storms, impacts and coastal damage will worsen.
- Resilience: how quickly will tourism economies of affected coastal communities recover? This will be a critical issue for Small Island Developing States (SIDs).

- Risk: vulnerability analysis and adaptive capacity.

Results of research and monitoring must be evaluated in the context of strategic management, and a management strategy justified for protection of the coastal environment. For climate change and sea level rise, understanding of the coastal region will rely on temporal and spatial data collection. Existing and proposed developments should be assessed in the context of predicted change and management decisions taken on socio-economic grounds. Shoreline trends can be determined from aerial photographs, remote sensing data and physical monitoring techniques. Trend impacts on infrastructure should be analysed in the context of existing management, e.g. seawalls, breakwaters, etc., and economic value. GIS is an excellent planning tool whereby spatial and temporal change can be represented alongside cultural use. From a policy perspective decision-makers can evaluate options such as ‘hold the line’ and subsequently assess available methods by which this can be achieved, using hard or soft engineering. Once implemented, monitoring should continue and strategies re-evaluated on a cyclical basis. Unfortunately, some countries will be restricted on available adaptation choices. For SIDs, climate change and sea level rise problems are compounded by disproportional effects. Inundation of low lying areas and overall low elevations will affect available options. Vulnerability analyses will underpin adaptive strategies which unfortunately will often be based on response capacity. Many SIDs rely on their tourism economies and resilience will be the major driver. If strategic options are not evaluated with appropriate forward planning, coastal destinations will be under even more threat. There is now an opportunity to learn from past mistakes, otherwise we may have to pave all our beaches (Figure 7).

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