An ecosystem-based spatial conservation plan for the South African sandy beaches

L. R. Harris

2012

An ecosystem-based spatial conservation plan for the South African sandy beaches

By

Linda R. Harris

Submitted in fulfillment of the requirements for the degree of
Doctor of Philosophy to be awarded at the
Nelson Mandela Metropolitan University

December 2012

Promoter: Dr R. Nel
Co-Promoter: Dr D.S. Schoeman

CHAPTER 8

Ecosystem-based spatial conservation planning for sandy beaches: a coup d'état on the *tyranny of small decisions*

The value of sandy shores

Sandy beaches are valuable ecosystems, from any perspective. As has been highlighted throughout this Thesis, they support a unique collection of species, found nowhere else on earth, and many of these species are also endemic to very restricted areas (Chapter 3). These biota, coupled with the key ecological processes underpinning ecosystem function, jointly provide important ecosystem services, including water filtration (McLachlan, 1979, 1989; McLachlan et al., 1985) and nutrient recycling in biogeochemical cycling hotpots (Anschutz et al., 2009; Coupland et al., 2007; Rocha, 2008). Additional services provided by beach ecosystems include buffering the hinterland from accentuated wave energy during large storms and tsunamis, and providing scenic vistas for tourism, recreation and other cultural activities (Defeo et al., 2009). Beaches therefore play a key role in the health and well-being of society, and together with other coastal ecosystems, can be vital to meeting the basic needs for survival in coastal rural communities (Millennium Ecosystem Assessment, 2005). Further, they can be significant contributors to both local and national economies, primarily through their role as tourist attractions (Dwight et al., 2012). In short, sandy beaches are national assets that are deserving of good governance and inclusion in well-designed conservation plans.

The tyranny: Historical mismanagement of sandy beaches

The legacy of poor management for sandy beaches was laid out at the start of this Thesis; how one small decision after another can compound, and can lead to a general demise of sandy beach ecosystems, sometimes with severe outcomes. Odum (1982) describes this phenomenon as the "*tyranny of small decisions*". One of the key reasons why beaches are vulnerable to the "*tyranny of small decisions*" is the mismatch in ecosystem stability, resistance and resilience within the littoral active zone: dunes are stable and vulnerable; beaches are dynamic and resilient (McLachlan and Burns, 1992), and yet the two function as a single geomorphic unit. Further, being poorly recognised as ecosystems has meant that sandy beaches have been only managed (and generally, not well), with little regard for their conservation. Where beaches are represented in marine protected areas, the reserve boundaries tend to stop landwards at the high water mark, leaving the primary dunes open to transformation, which in turn negates the attempts at conserving sandy shores. Because this fact is not recognised, beaches are assumed to be sufficiently protected. Therefore, to "overthrow" this "*tyranny of small decisions*" (Odum, 1982), I present ecosystem-based spatial conservation planning as the start of a paradigm shift, or *coup d'état* for sandy beach conservation and management.

PUBLICATIONS

Schlacher, T.A., Jones, A., Dugan, J.E., Weston, M., Harris, L., Schoeman, D.S., Hubbard, D., Scapini, F., Nel, R., Lastra, M., McLachlan, A., Peterson, C.H., in press. Open-coast sandy beaches and coastal dunes, in: Lockwood, J.L., Maslo, B., Virzi, T. (Eds.), Coastal Conservation. Cambridge University Press (Series in Conservation Biology).

The coup d'état: ecosystem-based spatial conservation planning

A strategic approach: vision, objectives and goals for beaches

A vision is key to a strategic approach for conservation and management. It should answer the question: what is the desired state of the system that we aim to achieve? For sandy beach ecosystems, the vision is this (Schlacher et al., in press): to have an adequate, representative network of beaches and dunes maintained in a near-pristine state, supporting fully diverse, functional ecosystems, and sustainable low-impact human uses. From this vision, four key objectives are listed (Schlacher et al., in press):

1. *To have a network of beaches that is of sufficient size and configuration that it is capable of maintaining natural connectivity processes among sandy beach habitats and their associated biota (i.e., sufficient to support metapopulations).*
2. *To manage surf-zones, beaches and dunes as a single geomorphic unit: the littoral active zone.*
3. *To ensure sufficient representation of beach diversity (from genetic to shorescape diversity) and function (at all spatial and temporal scales).*
4. *To make provision for regulated activities by multiple users, and controlled access on sandy shores.*

To achieve each of these objectives, and thereby realize the vision for sandy beaches, governance of the shoreline needs to consider beaches as social-ecological systems. Consequently, the focus should be split to deliberately achieve conservation-centred goals, and management-centred goals in spatially explicit areas (see Table 8.1).

Application of ecosystem-based spatial conservation planning: framework and tools

Ecosystem-based spatial conservation planning is presented in this Thesis as the framework to achieve the strategy for sandy beach conservation and management, laid out above, in an efficient and defensible way. The dual approach ensures both conservation- and management-related goals are achieved, and provides guidance for when to prioritize each of these in a way that, most importantly, contributes to a greater, large-scale conservation and management plan. The framework and related tools are described below (see also Table 8.2 and Box 8.1).

Step 1: Identify areas of ecological importance for conservation

Systematic conservation planning (Margules and Pressey, 2000; Moilanen et al., 2009) is the key tool used in the conservation component. It is used to identify a sufficient proportion (Chapter 6) of ecologically important areas that are irreplaceable (Chapter 7), based on spatial patterns of: habitats and unique habitat features (Chapter 2; Appendix 2); biodiversity and important assemblages; and ecosystem processes/services (Chapter 3; Appendix 2). To put this in South African biodiversity-planning terms, these irreplaceable beaches are the critical biodiversity areas (CBAs). It would be mandatory to proclaim generous setback lines for sandy beach CBAs (under NEMA: ICMA (No. 24 of 2008)) in order to ensure their persistence in perpetuity (*i.e.*, include an ecological support area (ESA) as a buffer between the CBA and coastal urban development), with strong application of the precautionary principle. To strengthen the approach, it is recommended that the area between the setback line and nearshore is declared a formal reserve across its full extent (see Box 8.1, Scenario 4). Depending on the biodiversity features represented in the CBA, the protected area may need to

Table 8.1. *Key goals for sandy beach conservation and management listed under an overarching goal for each. Adapted from coastal zone management aims for beaches listed in McLachlan and Brown (2006).*

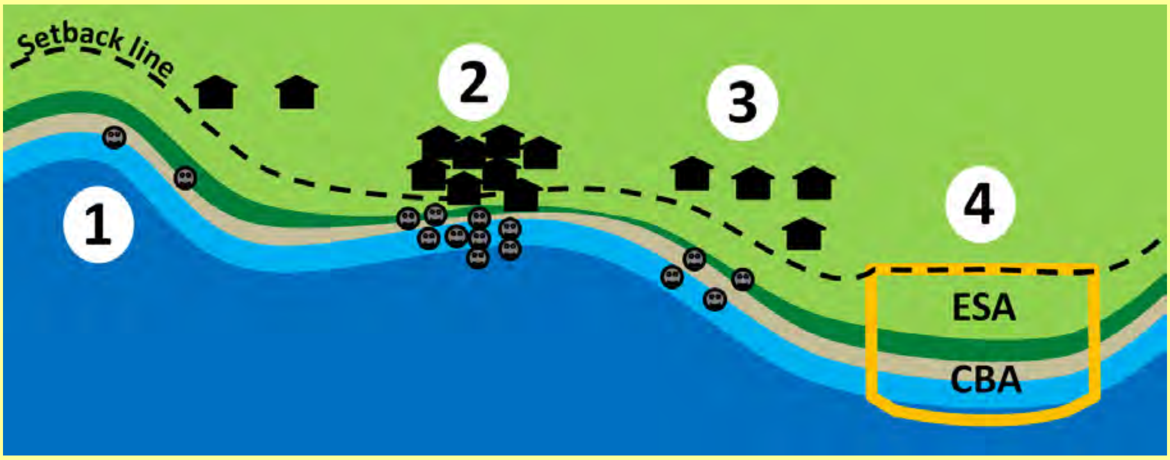
Conservation and Management Goals	
CONSERVATION	**MANAGEMENT**
Protect important (irreplaceable) sandy beaches, their associated diversity, sensitive and unique features, and ecological functions and services	**Promote sustainable, multiple use of sandy shores in a safe and healthy environment, and restore and maintain as much of the natural functioning as possible**
1. Design priority areas to include the entire littoral active zone in any single location 2. Conserve biodiversity in all its forms, including special assemblages 3. Protect sensitive and unique habitat features 4. Promote the natural functioning of ecological processes 5. Restore degraded ecosystems and exclude future threats (as far as possible) 6. Raise awareness of the value of sandy beaches as ecosystems	1. Manage beaches as socio-ecological systems 2. Involve stakeholders from all sectors in an integrated, participatory approach 3. Protect society against natural hazards • maintain an intact littoral active zone • implement scientifically-determined setback lines 4. Promote sustainable, multiple use and resolve conflicts (user-user and user-environment) by zoning activities 5. Regulate all forms of pollution to meet public health and safety requirements

Table 8.2. *Ecosystem-based spatial conservation as a strategy for sandy beach conservation and management. First, areas of key ecological importance are identified using systematic conservation planning (SCP) tools. Most importantly, the resilience of these beaches must be protected by conserving the dune-beach interface as an uninterrupted, intact littoral active zone, ideally in a no-take land-sea protected area. Second, the cumulative threat assessment (CTA) ranks beaches according to their relative levels of pressure, from which the appropriate management interventions are determined. Most importantly, as far as possible, multiple stressors at a single site should be disaggregated in space or time, particularly if the interacting threats have a synergistic impact.*

Ecosystem-based Spatial Conservation Planning	
CONSERVATION	**MANAGEMENT**
Conservation Planning	**Marine Spatial Planning**
• Use SCP to determine areas of ecological importance (critical biodiversity areas) • Promote resilience in those areas – Well-buffered setback lines – Land-sea protected areas – No-take MPAs – Regulate access to the shore – Exclude threats (as far as possible)	• Use the CTA to determine relative levels of pressure on beaches • "Sacrifice" beaches that are too impacted • Mitigate on beaches below ecological thresholds – Spatial or temporal disaggregation of threats • Invoke the precautionary principle on beaches with low impacts

be designated as a no-take reserve, *e.g.*, if it contained resource species such as clams *(Donax),* crabs *(Ocypode, Hippa,* or *Emerita)* or bloodworms *(Arenicola)*, or wrack accumulations at the strandline. Alternatively, sandy beach CBAs could be aligned with existing terrestrial reserves or CBAs, *e.g.*, the St Lucia and Maputaland Marine Protected Areas are contiguous with the terrestrial iSimangaliso Wetland Park in northern KwaZulu-Natal; and the Greater Addo Elephant National Park in the Eastern Cape is proposed to include the existing terrestrial Addo Elephant National Park, coastal Alexandria dunefield and shoreline, and extend into the ocean to include some of the inshore

Box 8.1 Conceptual illustration of EBSCP in action



Conceptual illustration of EBSCP along a hypothetical shoreline comprising foredunes (dark green), intertidal beaches (tan) and a surf zone (light blue), with the hinterland (light green) behind the dunes and the ocean (dark blue) beyond the surf. The local setback line is given as a dashed black line, and the boundaries of a shore protected area are given in yellow. Threats to beaches are represented as houses and as faces. 1-3 are management scenarios, and 4 is a conservation scenario. In (1), both management and conservation goals can be met, but because the threat level is so low, conservation goals should be prioritized. In (2), there are too many threats to make investment in ecological restoration worthwhile - the beach and foredune components have been eroded and transformed (denoted with thinner lines and inappropriately-located infrastructure inside the setback line), with little opportunity to rehabilitate either component. Here, management goals should take precedence, and should focus on maintaining the physical aspects of the beach and the water quality by controlling pollution, to support tourism. In (3), both management and conservation goals could be achieved, but management goals could be prioritized. Given that this site is adjacent to a protected area (yellow boundary), however, means that decisions in this area should be made with careful consideration of potential down-stream impacts. Key actions could include rehabilitating the foredunes, which have been degraded by use (represented as a thinner dark green line). In (4), this site is a beach of key ecological importance and should be protected with a shore (land-sea) protected area. This should include the littoral active zone as the critical biodiversity area (CBA) and the hinterland as far inland as the setback line as an ecological support area (ESA). Note that the setback line backing this site is much wider than elsewhere, to provide additional protection to the CBA.

islands. In addition, access to the beach should be regulated by constructing formal access paths, *e.g.*, aerial boardwalks to avoid trampling effects in the dunes. As far as possible, the wilderness property of these sandy beach CBAs should be upheld, and efforts should be made to exclude as many existing and emerging/future threats to these beaches as possible. In CBAs, conservation goals must take precedence.

Step 2: Determine management priorities for the remaining sites

In a second step (Table 8.2), a cumulative threat assessment (CTA) is applied to determine the relative level of pressure on each of the beaches (Chapters 4 and 5). Based on the existing transformation from coastal development and the cumulative impact of other threats, at a site level, the extent of management interventions, and the relative importance of conservation- and management-related goals can be determined. Beaches that are highly transformed by development, *i.e.*, urban beaches, can be prioritized and managed for social, management-related goals. Key priorities would include maintaining sufficient sandy beach habitat for recreation, minimizing user-user conflicts by zoning activities (such as bathing, boat launching, surfing and fishing), and ensuring public health and safety requirements are met by controlling all forms of pollution. Given that these shores have little (if any) resilience to sea-level rise and storms because the dunes have been destroyed, management actions that can restore this habitat feature would be useful (*e.g.*, Nordstrom et al., 2000). However, in most cases these would probably have to be, and function as artificial systems and serve little ecological function, *e.g.*, constructing artificial foredunes with geofabric sand-bags (Fig. 8.1), because they are likely to be heavily impacted in every large storm. Any ecological benefits from urban beaches should be considered as "bonus" features, rather than relying on them specifically to achieve conservation-related goals.

In contrast, beaches with the least transformation and least cumulative threats should be prioritized for conservation-related goals, and flagged as areas where high-impact threats and activities should be preferentially avoided as a precautionary approach. Beaches that are partly transformed and moderately impacted can serve as biodiversity stewardship areas, where both management-centred and conservation-centred goals can be achieved. In these areas, key priority actions to take include reducing user-environment conflicts by disaggregating stressors or threatening activities in either space or time (spatial or temporal zoning - see examples in Chapter 5, and Fig. 8.1). Zoning of activities to reduce either user-user conflicts or user-environment conflicts must take the needs of all stakeholders into account, and should be an integrated, fair and participatory process.

Once the national or regional priority areas (CBAs) have been identified, and the CTA has been completed, conservation and management could then proceed at a local level (either provincial, state or municipal, as appropriate) based on the national or regional plan. While governance of the shoreline would still take place at relatively small scales, the contribution to a bigger conservation and management plan would be a big improvement on existing, piecemeal approaches. However, it is possible that in many countries, the only way to be able to undertake this process is if EBSCP (or a similar approach) is mainstreamed into the national legislation and policy.

The role of legislation and policy

The role of legislation and policy in ecosystem-based spatial conservation planning is to ensure that political or management responsibilities cater for ecological processes. This means that management at local, provincial/state and/or national/federal levels need to take bioregional scales and processes into account. Countries invariably do not have beach-specific legislation; beaches are presumed to be sufficiently represented under the banner of integrated coastal zone management, which tends (simply) to regulate activities along the coast. South Africa, as one of the few exceptions, has particularly good coastal legislation. The National Environmental Management Act: Integrated Coastal Management Act (NEMA: ICMA, No. 24 of 2008) governs coastal zone management, but the National Environmental Management Act (NEMA): Biodiversity Act (No. 10 of 2004) takes effect as soon as either a habitat/ecosystem or species is recognised as threatened. In short, there is a strong need for beaches to be represented specifically in either policy or more ideally, in legislation in order to address beach-specific issues at all scales.

Figure 8.1. *Examples from around South Africa, illustrating various management actions that could be applied in ecosystem-based spatial conservation planning. In (a) coastal development is protected with artificial dunes constructed using geofabric sand bags. (b) These artificial dunes usually get covered with sand, and are vegetated. (c) Dune rehabilitation programmes are supported by protecting dunes from trampling using semi-permanent wooden fences and signs. (d) Similarly, access to the beach through dunes is facilitated by wooden boardwalks that allow dynamic movement of sand underneath them, also limiting trampling impacts. (e) Marker buoys (indicated by the black arrows) are place in the surf zone to separate bathing areas from water-craft-use areas to reduce user-user conflicts. (f) Beach driving is banned in South Africa, except for permit-regulated activities. The sign warns users that penalties for contravening the law includes arrest, seizure of the vehicle and a minimum fine of R2000 (approximately US$240) or six months imprisonment.*

The way forward for conservation and management of beaches in South Africa

The national zoning scheme derived through ecosystem-based spatial conservation planning is presented in Fig. 8.2, highlighting beaches in each of the categories as described above. The critical biodiversity areas, as discussed in Chapter 7, are focussed in three key areas; one for each of the three coastal bioregions. These include iSimangaliso along the north-east coast (Natal-Delagoa bioregion); the Greater Addo Elephant National Park (including the Alexandria dunefields) and Maitlands along the south-east coast (Agulhas bioregion); and the beaches between Cape Town and Elands Bay on the south-west coast (Southern Benguela bioregion). Important areas for management-centred goals are located predominantly in central and southern KwaZulu-Natal, around Durban. Urban beaches in Cape Town, Port Elizabeth, Cape St Francis and Mossel Bay are also flagged as sites for prioritization of management-centred goals. The majority of the sandy shoreline in South Africa is suited for achieving a combination of conservation- and management-centred goals simultaneously, indicating that biodiversity stewardship and ecosystem-based management can be applied broadly, which is a very positive outcome.

While this Thesis has singled out sandy beach ecosystems, they are only one of many coastal ecosystems represented along the South African shoreline. Thus, in terms of the way forward, the study should be extended to include all of these other ecosystems. A fine-scale coastal biodiversity plan has been proposed for the South African shoreline (Driver et al., 2012; Sink et al., 2012), and there appears to be keen interest from National Government to develop this further. The coastal biodiversity plan could be designed to align with the existing (formal and informal) reserves, CBAs and ESAs identified for both the terrestrial and offshore marine ecosystems. The associated prediction is that seamless integration from land to sea (where possible) will likely have synergistically greater ecological benefits overall, and thus a stronger contribution to securing biodiversity, ecological processes, and ecosystem goods and services in perpetuity. It would also contribute to achieving the reserve-network goals outlined in the National Protected Areas Expansion Strategy (Government of South Africa, 2010), and thus to our commitments, as a signatory state, to the Convention on Biological Diversity (UNCED, 1992).

From an implementation, enforcement and management perspective, South Africa stands in a good position because of its strong environmental legislation and policy. While many of the acts and regulations have been promulgated only recently, and consequently, some of the processes and governance structures provided for in the various acts are still in the process of being established, this can also be seen as an advantage. If implementation of the legislation can occur alongside the development and implementation of the coastal biodiversity plan, the relevant laws and regulations can be tailored to suit the needs of the plan from the outset, and *vice versa*. In this light, it would be important to include dynamic threats and reserve-implementation schedules during the systematic biodiversity (conservation) planning process for the fine-scale coastal biodiversity plan (*e.g.*, Possingham et al., 2009; Visconti et al., 2010). Moreover, NEMA: ICMA (No. 24 of 2008) is a key tool that can support implementation of the coastal plan, *e.g.*, through appropriate setback-line proclamation, and expansion of the coastal protection zone in areas that are important for conservation-centred goals. Further, NEMA: ICMA (No. 24 of 2008) creates institutional structures for coastal governance, *e.g.*, municipal, provincial and national coastal committees, and provincial

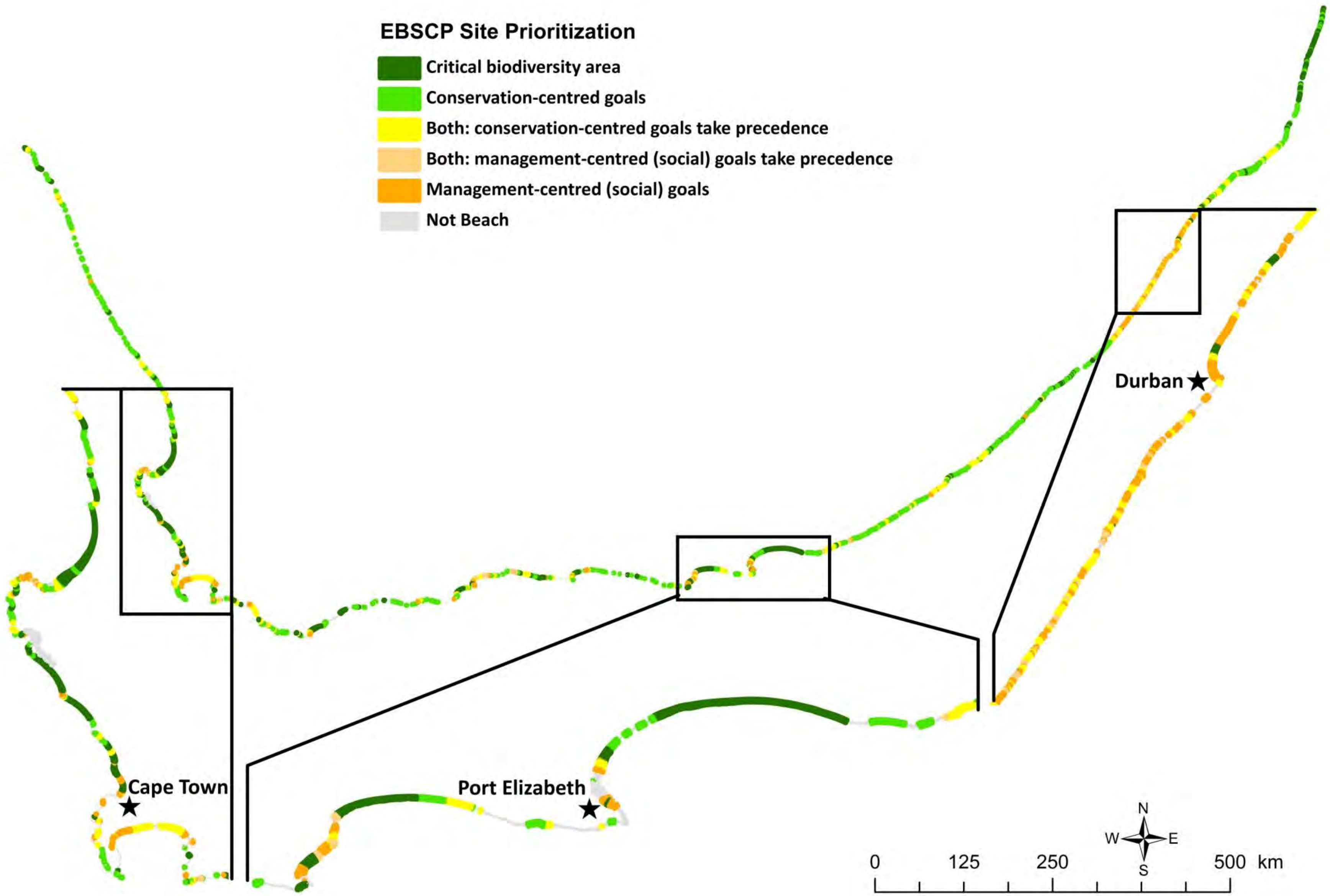


Figure 8.2. *Site prioritization for the South African sandy shores. See text for explanations of conservation and management goals in each of the categories. The sandy shoreline is exaggerated to aid display of the data.*

lead agencies, which provides the start of well-co-ordinated management of sandy beaches (and all other coastal systems), that can and must include all stakeholders.

Strike while the biodiversity-conservation moment is hot

Radeloff et al. (2012) suggest that, as much as conservation concerns where conservation will be most effective, it also concerns when conservation will be most effective. They show that protected-area proclamation, globally, tends to be associated with changes in government. With the rise of democracy in South Africa nearly two decades ago, and the associated reform of the national legislation - which includes key environmental management acts and policies that are still being drafted and promulgated (see Chapter 1), it would seem that South Africa is in a "hot moment for biodiversity conservation" (*sensu* Radeloff et al., 2012). It is therefore important to take advantage of this moment, to ensure that sandy shores (and other coastal systems) are adequately protected in networks of reserves along the coast, and that the remaining beaches are managed in ways that provide for sustainable use and biodiversity stewardship. Not only will this bring long-lasting ecological benefits, but it will also contribute to securing a national asset that contributes directly to the national economy, and provides ecosystem goods and services that support our health and well-being on a daily basis. This Thesis has presented a simple and practical way to achieve this. South Africa now stands poised to implement the ecosystem-based spatial conservation plan for sandy beaches, and to uphold its reputation as a country that implements ambitious biodiversity conservation plans (Balmford, 2003).

Conclusion

This Thesis sought to design a conservation and management strategy for sandy beach ecosystems that takes a holistic, ecosystem-based approach, and to provide a framework that allows for maximized use of sandy shores, whilst still ensuring that the ecosystem persists, and continues to provide goods and services in perpetuity. While this conservation and management strategy was designed and its application demonstrated using the South African sandy shores as a case study, the approach can be broadly and easily applied to any beaches, worldwide. Again, I encourage sandy-beach scientists to take up the research challenges that were highlighted in this Thesis to fill the gaps in our knowledge - particularly with regards to developing our understanding of interactions among threats to beaches, and concomitant ecological thresholds. This in turn will provide robust guidelines for management regarding sustainable use of sandy shores. Finally, the work in this Thesis has made a contribution to sandy beach science and has developed and modified a number of tools such that they apply specifically to beaches. Further application, testing and development of these and other related tools is also encouraged. Given the growing pressures sandy beaches are exposed to in the face of global change, a proactive approach to ensure the conservation and persistence of beach ecosystems will be important. I believe that ecosystem-based spatial conservation planning can provide a key contribution to achieving this.

References

Anschutz, P., Smith, T., Mouret, A., Deborde, J., Bujan, S., Poirier, D., Lecroart, P., 2009. Tidal sands as biogeochemical reactors. Estuarine, Coastal and Shelf Science 84, 84-90.

Balmford, A., 2003. Conservation planning in the real world: South Africa shows the way. Trends in Ecology & Evolution 18, 435-438.

Coupland, G.T., Duarte, C.M., Walker, D.I., 2007. High metabolic rates in beach cast communities. Ecosystems 10, 1341-1350.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M., Scapini, F., 2009. Threats to sandy beach ecosystems: a review. Estuarine, Coastal and Shelf Science 81, 1-12.

Driver, A., Sink, K.J., Nel, J.N., Holness, S., Van Niekerk, L., Daniels, F., Jonas, Z., Majiedt, P.A., Harris, L., Maze, K., 2012. National Biodiversity Assessment 2011: An assessment of South Africa's biodiversity and ecosystems. Synthesis Report. . South African National Biodiversity Institute and Department of Environmental Affairs, Pretoria.

Dwight, R.H., Catlin, S.N., Fernandez, L.M., 2012. Amounts and distribution of recreational beach expenditures in southern California. Ocean and Coastal Management 59, 13-19.

Government of South Africa, 2010. National Protected Areas Expansion Strategy for South Africa 2008: Priorities for expanding the protected area network for ecological sustainability and climate change adaptation. Government of South Africa, Pretoria.

Margules, C.R., Pressey, R.L., 2000. Systematic conservation planning. Nature 405, 243-253.

McLachlan, A., 1979. Volumes of sea water filtered through Eastern Cape sandy beaches. South African Journal of Science 75, 75-79.

McLachlan, A., 1989. Water Filtration by Dissipative Beaches. Limnology and Oceanography 34, 774-780.

McLachlan, A., Brown, A.C., 2006. The ecology of sandy shores. Academic Press, Burlington, MA, USA.

McLachlan, A., Burns, M., 1992. Headland bypass dunes on the South African coast: 100 years of mismanagement, in: Carter, R.W.G., Curtis, T.G.F., Sheehy-Skeffington, M.J. (Eds.), Coastal Dunes. A.A. Balkema Publishers, The Netherlands, pp. 71-79.

McLachlan, A., Eliot, I.G., Clarke, D.J., 1985. Water filtration through reflective microtidal beaches and shallow sublittoral sands and its implications for an inshore ecosystem in Western Australia. Estuarine, Coastal and Shelf Science 21, 91-104.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington, DC.

Moilanen, A., Wilson, K., Possingham, H., 2009. Spatial Conservation Prioritization. Oxford University Press, Oxford.

Nordstrom, K.F., Lampe, R., Vandemark, L.M., 2000. Reestablishing naturally functioning dunes on developed coasts. Environmental Management 25, 37-51.

Odum, W.E., 1982. Environmental degradation and the tyranny of small decisions. BioScience 32, 728-729.

Possingham, H., Moilanen, A., Wilson, K., 2009. Accounting for habitat dynamics in conservation planning, in: Moilanen, A., Wilson, K., Possingham, H. (Eds.), Spatial Conservation Prioritization. Oxford University Press, Oxford.

Radeloff, V.C., Beaudry, F., Brooks, T.M., Butsic, V., Dubinin, M., Kuemmerle, T., Pidgeon, A.M., 2012. Hot moments for biodiversity conservation. Conservation Letters, doi: 10.1111/j.1755-1263X.2012.00290.x.

Rocha, C., 2008. Sandy sediments as active biogeochemical reactors: compound cycling in the fast lane. Aquatic Microbial Ecology 53, 119-127.

Schlacher, T.A., Jones, A., Dugan, J.E., Weston, M., Harris, L., Schoeman, D.S., Hubbard, D., Scapini, F., Nel, R., Lastra, M., McLachlan, A., Peterson, C.H., in press. Open-coast sandy beaches and coastal dunes, in: Lockwood, J.L., Maslo, B., Virzi, T. (Eds.), Coastal Conservation. Cambridge University Press (Series in Conservation Biology).

Sink, K., Holness, S., Harris, L., Majiedt, P., Atkinson, L., Robinson, T., Kirkman, S., Hutchings, L., Leslie, R., Lamberth, S., Kerwath, S., von der Heyden, S., Lombard, A., Attwood, C., Branch, G., Fairweather, T., Taljaard, S., Weerts, S., Cowley, P., Awad, A., Halpern, B., Grantham, H., Wolf, T., 2012. National Biodiversity Assessment 2011: Technical Report. Volume 4: Marine and Coastal Component. South African National Biodiversity Institute, Pretoria.

UNCED, 1992. The Convention on Biological Diversity. United Nations Conference on Environment and Development, Rio.

Visconti, P., Pressey, R.L., Segan, D.B., Wintle, B.A., 2010. Conservation planning with dynamic threats: The role of spatial design and priority setting for species' persistence. Biological Conservation 143, 756-767.