A Strategic Environmental Assessment for Saldanha Bay to Determine Natural Capital and Ecosystem Service Thresholds

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Abstract

A Strategic Environmental Assessment (SEA) was undertaken for the Saldanha Bay region to estimate the proximity of natural capital features and ecosystem services to critical thresholds. The assumption being that, should such thresholds be exceeded as a result of substantial environmental stressors or disruptions, the system could shift toward an undesirable high-risk and low-resilience state.

The chapter introduces key concepts (e.g., natural capital, ecosystem services, risk and resilience) and methodologies (e.g., Drivers–Pressures–Impact, and risk and resilience assessment, multiauthor teams) that underpinned the Saldanha Bay SEA process. Important findings revealed by this SEA process are presented and a potential, integrated decision-making solution to monitor and assess ecological thresholds is explained. The risks identified across natural capital features in the Saldanha Bay region are intrinsically interconnected. A change in one area can cause a cascade of changes in another, potentially pushing the system past a tipping point and into a new, less desirable state. Such systemic shifts can have profound and long-lasting impacts, both ecologically and socioeconomically, and are typically difficult, if not impossible, to effectively reverse. This underscores the importance of proactive management strategies, which both seek to mitigate risk and enhance resilience of Saldanha Bay's natural capital and associated ecosystem services.

Keywords

Strategic environmental assessment · Natural capital · Ecosystem services · Thresholds

Saldanha Bay: The Need for a Strategic Environmental Assessment

Saldanha Bay is located on the west coast of South Africa, about 105 km north of Cape Town. The Bay supports a natural deep-water harbor and is located adjacent to the Saldanha Bay Industrial Development Zone, which

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promotes economic development and job creation through industrial growth. The main economic activities currently include agriculture, fishing and aquaculture, light industry, petrochemicals, and tourism. Because of its deep-water port and strategic position along the coast, Saldanha has been identified as a hub for future economic activities.

Over the next decade, it is expected that a variety of new developments will commence, including projects involving liquefied petroleum gas and liquefied natural gas import facilities, green hydrogen production from onshore wind and solar PV, seawater desalination, aquaculture development zones, phosphate mining activities, crude oil storage, and many other light-medium industrial projects.

Located within an exceptionally sensitive natural environment, development proposals of this nature, scale, and magnitude have concerned local policymakers and stakeholders for some time. The Saldanha Bay region is known for its unique marine and terrestrial biodiversity hotspots, many of which have become increasingly threatened. The scenic coastline, which has gradually become occupied by hard infrastructure, now struggles to support natural sediment dynamic processes, while freshwater resources in the region are either deteriorating in quality, diminishing in quantity, or both.

The mixed emotions surrounding the decision to industrialize Saldanha Bay reflect the tradeoffs and challenges inherent in balancing planned economic growth with sustainability objectives in a rapidly changing national and global context (Welman & Ferreira, 2014). Balancing tradeoffs among socioeconomic policy objectives, ecological integrity, and existing and future local livelihoods required a cross-sectoral, integrated assessment – one capable of guiding future decision-making processes with a strategic view of natural capital and ecosystem service thresholds.

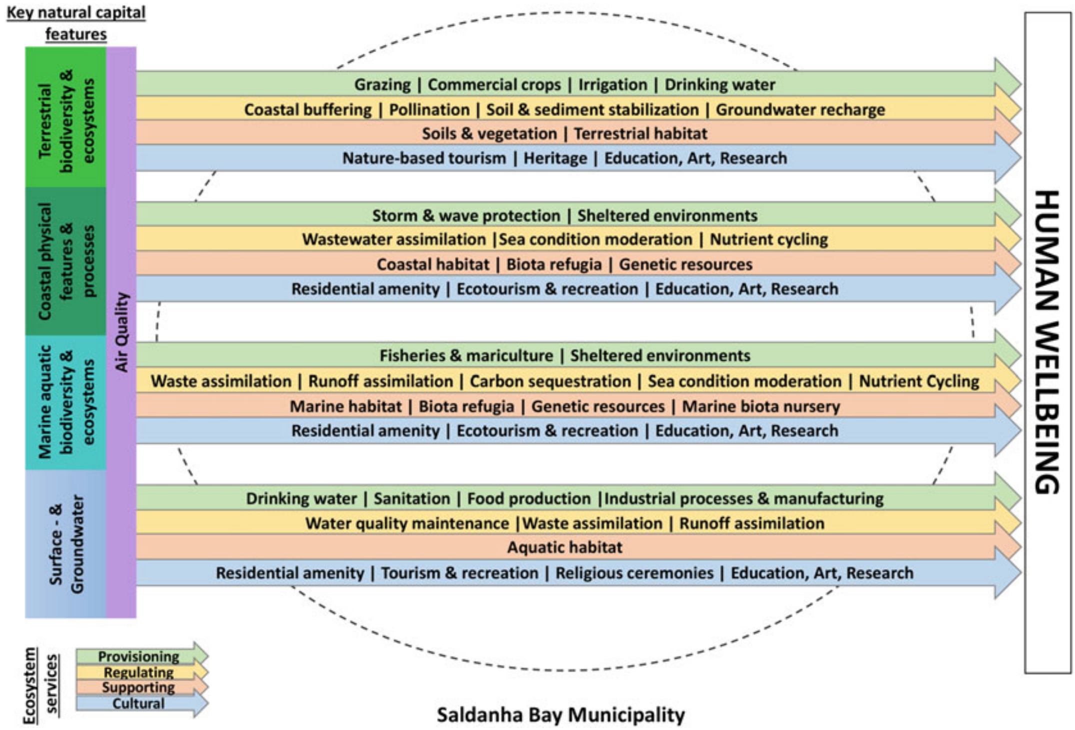
For this reason, in 2018, the Western Cape Department of Environmental Affairs and Development Planning (DEA&DP), in collaboration with local community groups, authorities, and stakeholders, asked the Council for Scientific and Industrial Research (CSIR) to initiate a Strategic Environmental Assessment (SEA) for the Saldanha Bay region https://bit.ly/SBSEA (DEA&DP, 2019). The main purpose of the SEA was to estimate the proximity of natural capital features and ecosystem services to critical thresholds. The assumption being that, should such thresholds be exceeded as a result of substantial environmental stressors or disruptions, the system could shift toward an undesirable high-risk and low-resilience state.

Given its flexibility and ability to manage novel conceptual frameworks and methodologies, SEA was selected as the science-policy tool most fit for the task. SEA is well known as a systematic process that can assist decision-makers in integrating environmental considerations into planning and decision-making, with improved social and ecological outcomes. The purpose of this chapter, primarily aimed at environmental assessment practitioners, is to showcase some of the novel SEA approaches adopted in the Saldanha SEA process, then discuss the key findings and points of learning, and finally convey the recommended management actions co-developed by the project team.

Natural Capital and Ecosystem Services: Supporting Life in Saldanha Bay

Natural capital is defined as a "stock" of renewable and nonrenewable resources such as plants, animals, air, water, soils, and minerals that combine to yield a flow of ecosystem services that benefit people (Ash et al., 2010; Kareiva et al., 2011). These benefits, commonly categorized into *provisioning*, *regulating*, *cultural*, and *supporting services,* encompass everything from food and water supply, climate regulation, pollination of plants, and recreational and spiritual benefits, to foundational aspects like nutrient cycling and soil formation that make all other ecosystem services possible.

Saldanha Bay's ecosystem services provide numerous services essential for the region's health, economy, and cultural identity, including a myriad of life-sustaining provisioning resources



A Strategic Environmental Assessment for Saldanha Bay to Determine Natural Capital and Ecosystem Service Thresholds, Fig. 1 The essential ecosystem services (categorized into *provisioning*, *regulating*, *supporting*, and *cultural* ecosystem services) that support life in the Saldanha Bay region. (Source: DEA&DP, 2019)

(Fig. 1). Its marine biodiversity is incredibly diverse, teeming with various fish, shellfish, and other aquatic organisms, underpinning local commercial and subsistence fishing, which has become a cornerstone of food security and income. The Bay also contributes toward regulating services, acting as nature's homeostasis. The surrounding fynbos vegetation, comprising a biodiversity hotspot unique to this part of the world, plays a pivotal role in carbon sequestration, which is instrumental in mitigating climate change. Wetlands serve as natural pollutant filters and sediment traps that maintain water quality and prevent siltation of the Bay. The biological diversity within the Bay and its surrounds supports a healthy predator–prey balance that aids in the control of pests, also beneficial to the agriculture and fisheries sectors in the area.

As a haven of natural beauty, Saldanha Bay attracts both local and international tourists, giving rise to a vibrant tourism industry, including a magnificent spring flower season, bird watching to beach activities. Its serene landscapes and diverse ecosystems, although interspersed with industrial and agricultural activities, resonate with deep aesthetic values. Some locals and visitors find a sense of fulfillment as they connect with the natural systems of Saldanha Bay, enhancing their quality of life. The region further provides a rich ground for scientific research and environmental education, sparking curiosity and a deeper appreciation for environmental systems.

Equally important are the Bay's supporting services, including nutrient circulation and cycling essential for algal and plant growth with ripple effects into the aquatic food web. The diverse terrestrial and aquatic habitats of the region also support a wide range of species contributing to its unique character.

Conceptualizing Thresholds: The Intersection of Risk and Resilience

The approach to the Saldanha Bay SEA involved the identification of key indicators or "early warning signals" of ecosystem health, determining the levels at which these indicators might signify a high risk of a regime shift ("critical thresholds"), and then developing management strategies to reduce the risk of crossing thresholds that potentially could result in undesired high-risk and low-resilience states.

The project team was faced with the challenge of developing a robust framework to integrate different knowledge domains for a transdisciplinary assessment. The approach had to be practical enough to produce usable, replicable outcomes, while still being understandable and adaptive. After consultation with stakeholders, the conceptualization of ecological thresholds at the intersection of risk and resilience was considered to be the most epistemologically vigorous and practical approach (Slootweg & Jones, 2011).

Risk is a concept describing the *potential* for a negative outcome or adverse event resulting from a particular action, decision, or situation. It is an inherent part of life and can present in various facets such as finance, health, safety, environment, and social aspects. Risk is expressed as a combination of two elements: the *likelihood* of an adverse event occurring, and the *consequence* of impact in the event of its occurrence. In the risk assessment, the state of the baseline ecosystem services functioning, combined with a scenario assessment of the intensity and frequency of future disturbances emanating from key economic drivers planned for the region, was considered.

Risk consequence ratings, ranging from "slight" to "extreme," were calibrated across all study components. This "risk consequence calibration" exercise (see Sect. 5) ensured consistency in how risks were measured, both for ease of integration across different study components and in providing a common conceptual understanding and spatial interpretation of risk. The potential impact of risk on various natural (receiving) environments was qualitatively assessed against a predefined set of criteria using a rating system of "very low," "low," "moderate," "high," and "very high."

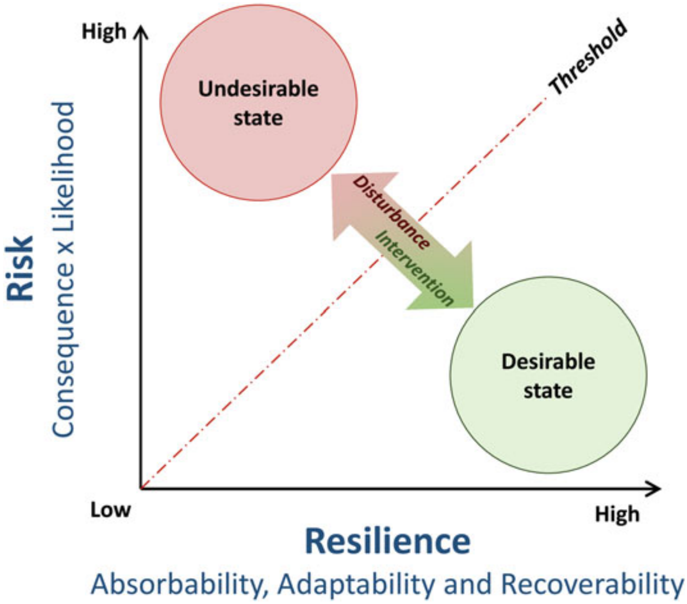
The concept of resilience, on the other hand, refers to the capacity of an ecosystem to absorb disturbance and ability to retain its original structure, function, and feedback (Scholes et al. 2013), often conceptually considered a product of absorbability, adaptability, and recoverability. A highly resilient system can experience significant disturbances and yet return to its original functional state. If resilience is low, even small disturbances could push a system past a critical threshold, leading to a potentially undesirable shift in its structure (Van Jaarsveld et al., 2005). The combination of high risk and low resilience suggest a high likelihood of crossing critical thresholds, while low risk and high resilience suggest greater stability (Fig. 2).

Doing Transdisciplinarity: The Multiauthor Team Model

Transdisciplinarity refers to an approach that transcends the boundaries of individual disciplines to address complex problems or issues. It integrates and synthesizes insights from multiple academic disciplines, professions, and even nonscientific sources to come up with comprehensive, holistic understandings and solutions (Timpte et al., 2018). The best way of doing transdisciplinarity is by adopting multiauthor team models for problem framing and content generation.

First pioneered by the Intergovernmental Panel on Climate Change in the early 1990s, the multiauthor team approach has been replicated elsewhere for various knowledge-policy processes, although not commonly in applied SEAs. The multiauthor team model refers to a collaborative approach where multiple authors contribute to a single, integrated, and transdisciplinary assessment. Each author brings their unique expertise, perspectives, and insights to the table, allowing the work to be comprehensive, diverse, and nuanced (Scholes et al., 2017).

For the Saldanha Bay SEA, a collection of integrated author teams was assembled to estimate



A Strategic Environmental Assessment for Saldanha Bay to Determine Natural Capital and Ecosystem Service Thresholds, Fig. 2 Risk and resilience provided a framework for predicting change thresholds. By estimating the risk and resilience inherent to natural capital features in Saldanha Bay (in the face of projected development drivers), it was possible to estimate the likelihood of an ecosystem crossing a threshold and moving into a different, potentially undesirable, state. (Source: DEA&DP, 2019)

the risk and resilience of the identified impact on key natural capital components (Table 1). Author roles and responsibilities were shared and divided according to each team member's skills and experience. Some authors contributed more to the initial drafting phases, while others focused on the contribution of niche data, text, figures, or tables.

Adopting the multiauthor team model brought a variety of epistemological benefits. It enabled the integration of a variety of perspectives, an essential component of building knowledge related to complex socioecological problems. Each team member brought a unique set of disciplinary perspectives, theoretical insights, methodological skills, and lived experiences, serving to enhance the depth, breadth, credibility, and balance of the SEA and its findings. Personally, experts participating in the multiauthor teams had the opportunity to foster innovative epistemological practices and develop a new skill set for their careers.

From a project management perspective, the diversity in authorship meant that different authors could tackle different facets of the research, contributing to a more holistic and comprehensive assessment. Dividing the research tasks among several authors made the project more manageable and efficient, and assisted in

A Strategic Environmental Assessment for Saldanha Bay to Determine Natural Capital and Ecosystem Service Thresholds, Table 1 Multiauthor team composition across the five SEA topics

Topic		Multiauthor team composition
1	Air quality deterioration	Two experts from CSIR, two from DEA&DP, and two from the Saldanha Bay Municipality
2	Degradation and loss of terrestrial ecosystems	Three experts from CSIR, one from DEA&DP, and one from the provincial conservation authority
3	Groundwater and surface water quality and quantity	Three contracted ground- and surface-water experts
4	Degradation and loss of marine aquatic ecosystems	Two experts from the CSIR
5	Alteration and degradation of physical coastal processes	Two experts from CSIR, one from the University of Stellenbosch, and one expert subcontracted from the private sector

producing outputs of a high standard. It also offered an excellent platform for networking and relationship building, opening new opportunities for future research and collaborations.

Thinking in Systems: The Driver, Pressure, and Impact Model

Systems thinking is an approach to problem-solving that views systems as a whole rather than simply a collection of individual parts. It emphasizes the interrelationships and interactions among system components, recognizing that changes in one part of a system can cause changes in other parts, often in complex and unpredictable ways (Systems Innovation, 2020). Conventional Environmental Impact Assessment (EIA) is often criticized for not being sufficiently capable of systems thinking for the following reasons:

- It focuses on specific, individual projects or developments and assesses direct impacts in a localized context and may not adequately consider the cumulative impacts of multiple projects or the broader systemic interactions within a landscape or region.
- It relies on a linear model of cause-and-effect, which can overlook complex, nonlinear interactions and feedback loops characteristic of natural and socioecological systems.
- It is often limited by predefined temporal and spatial boundaries, making it challenging to fully grasp long-term effects and broad-scale impacts that extend beyond these boundaries.
- It can struggle to integrate social, economic, and environmental aspects into a cohesive whole, often resulting in segmented and compartmentalized assessments that fail to account for interconnections and interdependencies.
- It is reactive, not proactive. EIA is typically conducted late in the planning process, after certain key decisions have already been made, making it more of a reactive tool rather than a proactive one that can guide strategic planning from the outset.

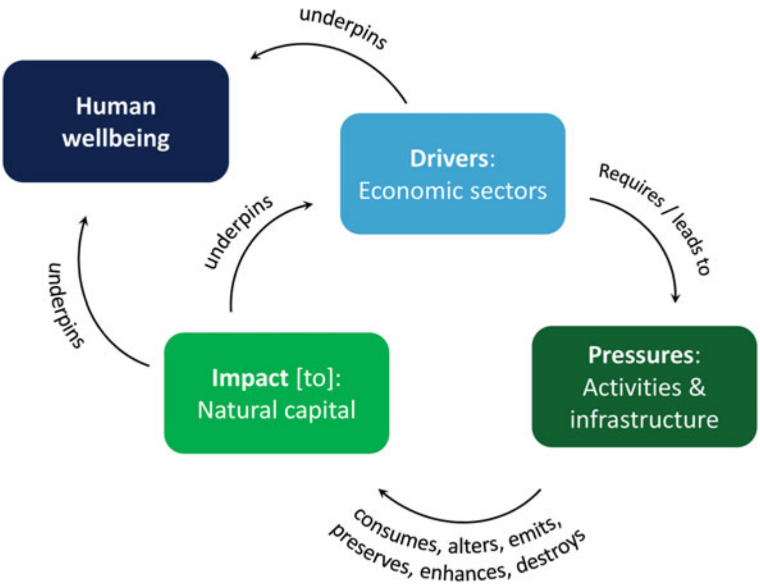
SEA, on the other hand, allows for novel frameworks and methodologies based on systems thinking to be integrated into its conceptual framework (Retief et al., 2016; Snyman-van der Walt et al., 2022). For the Saldanha Bay SEA, applying systems thinking in practical terms made it necessary to clearly characterize the nature of the interactions between driving economic sectors, natural capital features, and ecosystem services (Fig. 3).

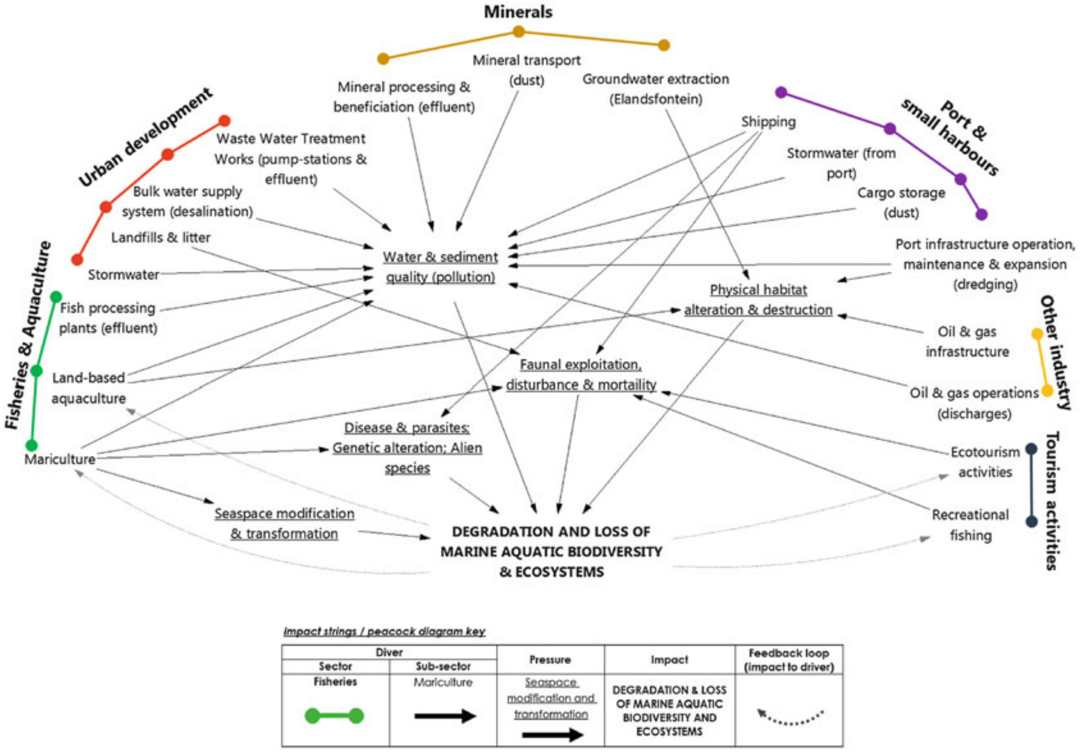
For this purpose, *Drivers* were defined as the main existing and planned economic sectors operating at regional scales that will affect long-term socioeconomic development trends. *Pressures* were defined as the activities and infrastructure that can exert pressure on natural capital and ecosystem services at local scales. *Impacts* were defined as the processes that result from pressures that either diminish or enhance the functioning of ecosystems. This approach to system modeling was based on the Driver–Pressure–State–Impact–Response (DPSiR) framework (EAA, 1999), which has been adapted and applied in a variety of science-policy processes for several years.

Using this approach, the entire socioecological system of the Saldanha Bay region was mapped out and elaborated in a stakeholder workshop. From this holistic model, it was then possible to identify key “impact strings,” where *Drivers* and *Pressures* interacted to manifest as *Impacts* on natural capital features and ecosystem services. From this exercise, the following Driver–Pressure–Impact strings were identified: (1) air quality deterioration; (2) degradation and loss of terrestrial biodiversity and ecosystems; (3) degradation and loss of marine aquatic biodiversity and ecosystems; (4) depletion of freshwater quantity and decreasing freshwater quality; (5) degradation of groundwater quality and volume; (6) alteration and degradation of physical coastal processes (including hydrodynamics and sediment dynamics); and (7) deterioration of coastal and marine water quality. Each of the seven strings were unpacked into manageable and interpretable formats using so-called “Peacock diagrams” (Fig. 4).

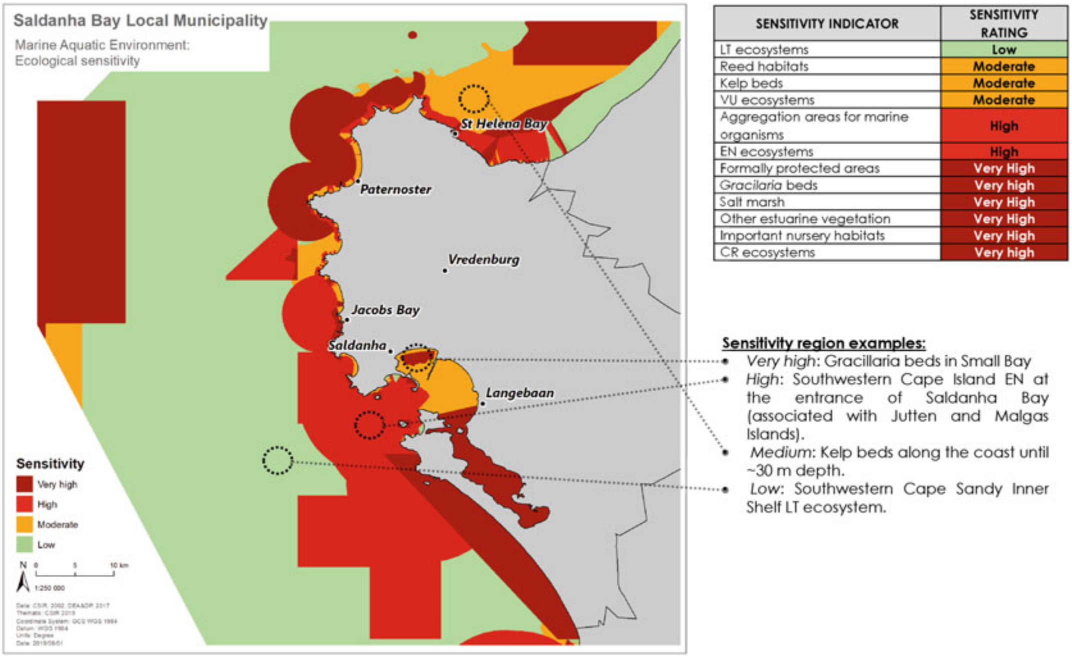
Working in collaboration, the multiauthor teams responsible for each impact string

A Strategic Environmental Assessment for Saldanha Bay to Determine Natural Capital and Ecosystem Service Thresholds, Fig. 3 The impact model adopted for this SEA, showing the relationships between Drivers, Pressures, and Impacts, and their contribution to ecosystem services that support human well-being. (Source: DEA&DP, 2019)





A Strategic Environmental Assessment for Saldanha Bay to Determine Natural Capital and Ecosystem Service Thresholds, Fig. 4 Each peacock diagram for each impact string described the relationship between Drivers (colored icons on top), their relationship with specific system Pressures (underlined text), and this manifestation in net Impact to the natural capital feature in question (bold uppercase text). The example provided above was used for the impact string: degradation and loss of terrestrial biodiversity and ecosystems. (Source: DEA&DP, 2019)



SENSITIVITY INDICATOR	SENSITIVITY RATING
LT ecosystems	Low
Reed habitats	Moderate
Kelp beds	Moderate
VU ecosystems	Moderate
Aggregation areas for marine organisms	High
EN ecosystems	High
Formally protected areas	Very High
Gracilaria beds	Very high
Salt marsh	Very High
Other estuarine vegetation	Very High
Important nursery habitats	Very High
CR ecosystems	Very high

Sensitivity region examples:

- *Very high*: Gracillaria beds in Small Bay
- *High*: Southwestern Cape Island EN at the entrance of Saldanha Bay (associated with Jutten and Malgas Islands).
- *Medium*: Kelp beds along the coast until ~30 m depth.
- *Low*: Southwestern Cape Sandy Inner Shelf LT ecosystem.

A Strategic Environmental Assessment for Saldanha Bay to Determine Natural Capital and Ecosystem Service Thresholds, Fig. 5 A four-tier spatial sensitivity overlay was developed for each receiving natural environment (study component). (Source: DEA&DP, 2019)

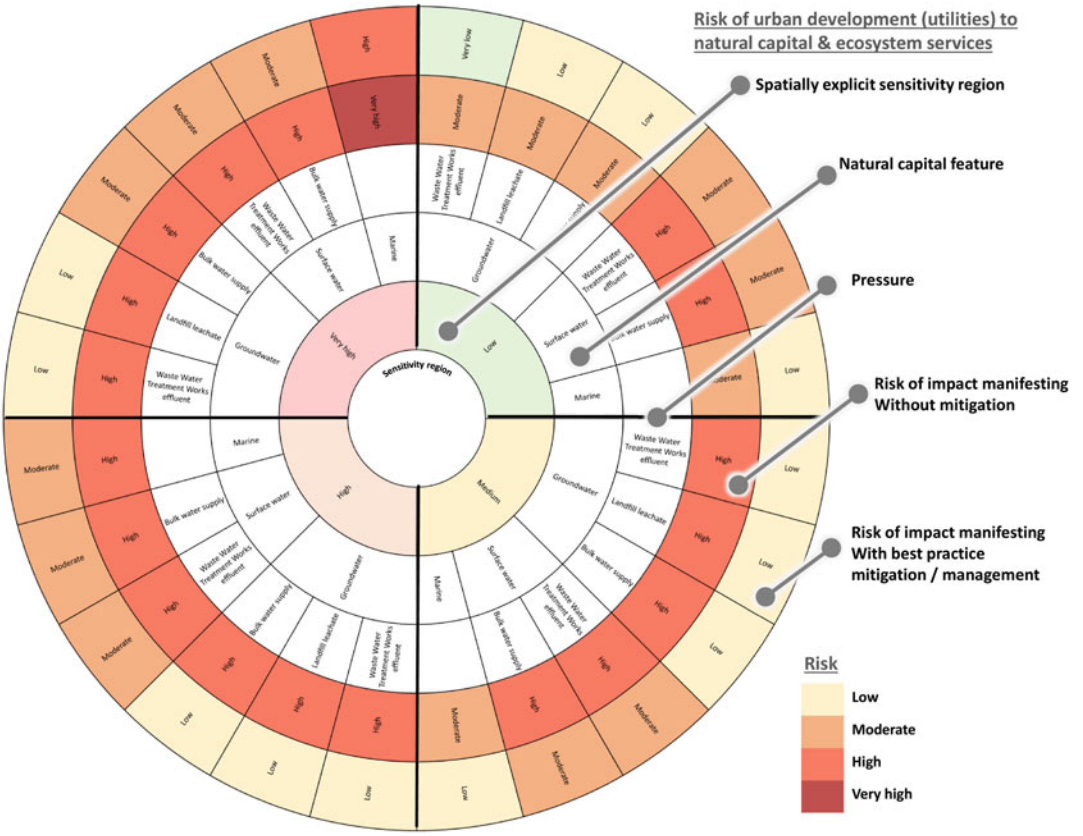
developed a four-tier sensitivity spatial overlay of the different receiving natural environments, classified as "very high," "high," "medium," or "low" sensitivity. Sensitivities were assigned to key features of each impact string and assigned to spatial units. For each impact string, the relationship between each Driver and Pressure was described and then, per sensitivity class, the likelihood and consequence of potential risks were assessed using the calibrated risk rating systems (Fig. 5).

After estimating individual risk likelihood and consequence per spatial sensitivity class, it was possible to define risk levels within a predefined set of criteria across all the impact strings. This allowed for inter-impact risk comparisons necessary for evaluating tradeoffs in decision-making between different natural capital features. The multiauthor teams, across all the impact strings, assessed the relative risk and resilience of the multiple interactions between the *Impacts* and their *Pressures* emanating from the sectoral *Drivers*. This amounted to hundreds of Driver–Pressure–Impacts risk assessments, considered with and without mitigation across different spatial sensitivity classes (Fig. 6).

Key Findings: Natural Capital Features Approaching Critical Thresholds

For each of the impact strings, risk language was calibrated across the specialist domains, meaning that the risks estimated across all issues were comparable, thus allowing for integration. It was then possible to "stack" risks one on top of the other, to assess cumulative risk and the proximity of certain natural capital features to ecologically critical thresholds. *High* and *Very High* Risks (after mitigation) were considered to be suitable proxies for estimating ecologically critical thresholds (Schreiner & Snyman-Van der Walt, 2018), where

- *High* risk assumed the likely materialization of impacts with serious consequences. In these instances, ecosystem services would be



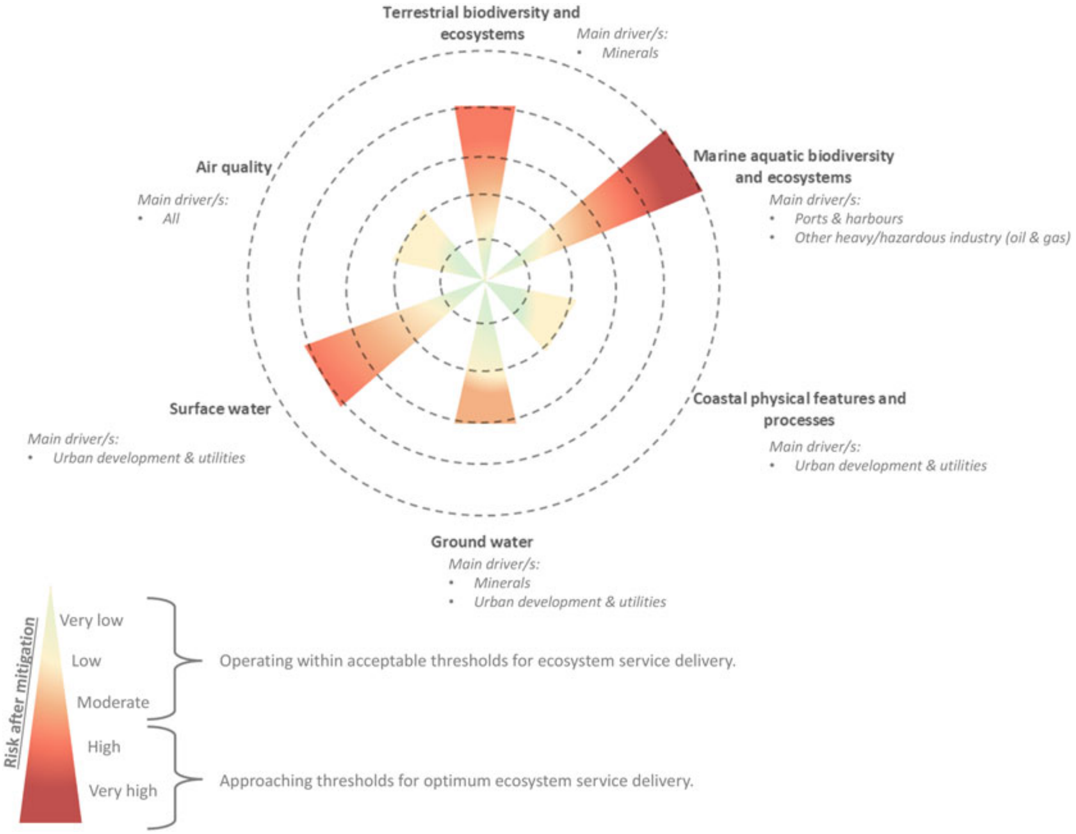
A Strategic Environmental Assessment for Saldanha Bay to Determine Natural Capital and Ecosystem Service Thresholds, Fig. 6 Risks to natural capital features were assessed, with and without mitigation, per spatial sensitivity region, for each pressure emanating from each sectoral driver. The resulting risk assessments were summarized visually in risk diagrams. (For example, risk of urban development to natural capital and ecosystem services, adapted from DEA&DP 2019)

substantially impaired (5–10% of study area) and medium term in duration (10–20 years). Absorptive, adaptive, and recuperative capacities were close to ecologically critical thresholds.

- *Very high* risk assumed that the impact would cause some components of the natural system to collapse. Ecosystem services would be degraded to the point of not being able to recover (>10% of the study area) and long term in duration (>30 years). Absorptive, adaptive, and recuperative capacities were beyond or very near ecologically critical thresholds.

Based on this approach, it was found that critical thresholds for optimum ecosystem service delivery were being approached (i.e., *high* and *very high* risk level after mitigation) for marine aquatic biodiversity and ecosystems, terrestrial biodiversity and ecosystems, as well as surface water. Therefore, it was proposed that these were the natural capital features that required the most urgent action in terms of monitoring and management interventions (Fig. 7).

It was found that the risks associated with ecosystem services approaching or at their critical thresholds were substantial and multifaceted, impacting not only the ecological integrity of Saldanha Bay but also its socioeconomic viability. With respect to marine ecosystems, it was found



A Strategic Environmental Assessment for Saldanha Bay to Determine Natural Capital and Ecosystem Service Thresholds, Fig. 7 Terrestrial biodiversity and ecosystems, surface water, and marine aquatic biodiversity and ecosystems in Saldanha Bay were found to be at, or very near, their thresholds, whilst air quality and coastal physical features and processes were found to be currently operating within acceptable resilience ranges. (Source: DEA&DP, 2019)

that these systems are approaching their critical thresholds, making the risk of a significant shift in their ecological balance very real, with subsequent ripple effects on food webs and a decline in species that are important for commercial fishing, aquaculture, tourism, and recreational activities. Reduced marine biodiversity in Saldanha Bay will also undermine resilience, making it more vulnerable to future perturbations, such as pollution, climate change, and invasive species introduced through shipping traffic. In turn, these projected shifts can then have cascading impacts on tourism, local livelihoods, and food security.

Terrestrial biodiversity and ecosystems were found to be approaching critical thresholds potentially resulting in increased habitat loss, species extinction, and disrupted ecosystem processes such as nutrient cycling and soil formation. This can impact agriculture (through reduced pollination and pest control services), game farming, and ecotourism. Moreover, a decrease in terrestrial biodiversity may also impact carbon sequestration capabilities, contributing to climate change and further ecological instability.

As regards surface water systems, these were also found to be nearing their critical thresholds, which could lead to altered flow regimes and further deterioration in water quality, with consequential negative impacts on agriculture (through reduced irrigation capacity and crop yields), municipal water supplies, and industries reliant on large volumes of clean water. Deteriorating water quality could also affect human health and aquatic biodiversity.

In summary, marine aquatic biodiversity and ecosystems, terrestrial biodiversity and ecosystems, and surface water features in Saldanha Bay should be considered as approaching their tipping points to sustainably support human well-being and are already being undermined by human activities. Although this broad-scale approach using critical thresholds in assessing natural capital sustainability is based on science, as well as normative social values and legislative rules, it is not an exact prediction. Therefore, this assessment cannot be used to outright prohibit certain kinds of future anthropogenic developments and activities proposed in the region. Such decisions need to be undertaken on a case-by-case basis through mandated EIA procedures that are framed within the context of these thresholds and that address cumulative risk and natural capital critical thresholds.

Recommendations: Fully Integrated Decision Theatres

The risks identified across natural capital features in the preceding sections are intrinsically interconnected. A change in one area can cause a cascade of changes in another, potentially pushing the system past a tipping point and into a new, less desirable state. Such systemic shifts can have profound and long-lasting impacts, both ecologically and socioeconomically, and are typically difficult, if not impossible, to effectively reverse. This underscores the importance of proactive management strategies that both seek to mitigate risk and enhance resilience of Saldanha Bay's natural capital and associated ecosystem services. For this reason, the project team proposed an integrated solution – "decision theatres" – primarily consisting of two key foundational tools: Integrated Assessment Modeling (IAM) and Integrated Monitoring Frameworks (IMF).

IAM is a method of analysis that combines results and models from the physical, biological, economic, and social sciences, and the interactions among these components, in a consistent framework to evaluate the status and the consequences of environmental change and associated policy responses (IPCC, 2019). IAMs have been well recognized within the scientific practitioner community since the 1990s (Hamilton et al., 2015) and offer a simplified understanding of a complex system by providing for a virtual laboratory from which to study real-world systems (Verburg et al., 2016).

IAMs become extremely powerful when coupled with an Integrated Monitoring Framework (IMF), and vice versa. IMF is a systematic approach to continuously track, collect, and assess data relevant to specific elements within a system. In relation to natural capital and associated ecosystem services, an IMF can monitor various environmental indicators, providing valuable, real-time insights into the health and functionality of an ecosystem. An IMF can employ various technologies such as remote sensing and on-site measurements and methodologies to facilitate real-time data collection and interpretation (Bustamante et al., 2016).

Coupled IAMs and IMFs can be run as decision theatres, providing physical and/or virtual spaces where diverse knowledge holders meet to generate model inputs and assess outputs of simulations. Within these decision-making environments, information from various knowledge disciplines is simplified, integrated, and visualized, to simulate the implications and tradeoffs associated with various decision options. Decision theatres come in many shapes and forms, utilizing a diversity of fit-for-purpose tools. Some rely heavily on quantitative data (often economics focused). Others are centered on participatory approaches that embrace plurality and rely strongly on qualitative inputs from local knowledge holders, for example, geodesign (Campagna & Matta, 2014) and strategy games (Garcia et al., 2022).

In the case of decision-making for Saldanha Bay, a hypothetical IAM and IMF must be closely coupled. The integration and feedback between the IAM and IMF must occur through a cyclical, iterative process. In this way, the IMF provides the data necessary for the IAM to model and simulate different scenarios; and to understand the possible outcomes of various policy or project interventions. For example, if the IMF indicates that a critical threshold is nearing for marine aquatic biodiversity, the IAM can model the ecological, economic, and societal effects of different management decisions to avert this. The IAM, in turn, informs which environmental variables and indicators are most crucial to monitor in the IMF based on their influence on system behavior and thresholds. This continual interaction and feedback between the IAM and IMF allow for the real-time incorporation of changing environmental conditions into decision-making processes.

Conclusion: Motivating for Coupled IAMs and IMFs

The purpose of this chapter has been to describe the nature of problems facing decision-makers and stakeholders who care about the sustainability of the Saldanha Bay region, South Africa, its sensitive natural capital features, and those who are, at least in part, dependent on the delivery of its essential ecosystem services. The chapter has introduced the reader to key concepts (e.g., natural capital, ecosystem services, risk and resilience) and methodologies (e.g., Drivers–Pressures–Impact, and risk and resilience assessment, multi-author teams) that have underpinned the Saldanha Bay SEA process. The important findings revealed by this SEA process have been presented and a potential, integrated decision-making solution to monitor and assess ecological thresholds has been explained.

Many of the future development decisions regarding this socioeconomically promising, and yet ecologically sensitive Saldanha Bay region, will be made on the basis of accepting insoluble tradeoffs. In most cases, for a selected decision-making pathway, some stakeholders will have their needs satisfied, partially or in full, while others will lose some aspect of whatever they hold to be valuable, whether it be biodiversity or jobs. It is essential, in these instances, to be explicit about who wins and who loses, and to what degree each occurs, so that practitioners can be sensitive to this fact when suggesting management actions for both impact mitigation and benefit enhancement.

Naturally, there will be instances where the opportunity for win-win outcomes exists, but these will need to be heavily negotiated through mandatory decision tools, like EIA, which has its limitations. In our view, a coupled IAM–IMF approach provides several distinct advantages over EIAs or other similar conventional environmental assessment tools. The most important of these advantages being

- **Dynamic**: EIA is typically a one-off assessment conducted at a particular point in time, whereas coupled IAM–IMF functions dynamically, continuously adapting to changing circumstances and emerging data. The combination of real-time monitoring (IMF) and scenario modeling (IAM) allows for proactive and adaptive decision-making that aligns with the current state of the system and predicts future conditions.
- **System-level perspective**: IAMs consider the interdependencies and interactions between various elements of a system, including natural, social, and economic components. This contrasts with EIAs, which often focus on a specific project's direct impacts siloed across study domains. The system-level perspective of an IAM allows for a more comprehensive understanding of indirect and cumulative impacts, feedback loops, and potential cascading effects.
- **Quantification and scenario analysis**: IAMs provide quantitative analysis of different scenarios, including evaluation of potential costs, benefits, and tradeoffs at a systems level. This level of detail is typically beyond the scope of conventional EIA, which is generally qualitative and descriptive at a project level. With an IAM, decision-makers can explore a range of possible outcomes and make informed choices based on quantifiable metrics.
- **Adaptive management**: While EIA is primarily a tool for project approval, the coupled IAM–IMF approach supports ongoing ecosystem management. The constant flow of data

> from the IMF informs the IAM, allowing for the adjustment of management strategies in response to shifts in ecosystem health or human activities. This is crucial for maintaining resilience in the face of environmental changes and uncertainties.

The coupled IAM–IMF approach, while requiring more initial investment in setup and maintenance, provides a more comprehensive, adaptive, and quantitative decision-making process compared to traditional decision-making methods such as EIAs. It could enable decision-makers to stay far more attuned to system health, comprehend indirect and cumulative impacts, anticipate potential regime shifts, and adjust management actions accordingly. In so doing, the resilience of Saldanha Bay, its essential ecosystem services, and the livelihoods it supports can potentially be enhanced.

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