From geomorphology to resilience of barrier islands: transferring concepts from theory to application

K. Kombiadou[1], S. Costas[1], A.R. Carrasco[1], T.A. Plomaritis[1,2], Ó. Ferreira[1], A. Matias[1]

[1] Centre for Marine and Environmental Research (CIMA), University of Algarve
[2] Faculty of Marine and Environmental Science, University of Cadiz

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Introduction

Motivation

Resilience has multiple levels of meaning and has been used with different objectives and over a broad contextual frame.

Distinct views and definitions coexist even in the same scientific discipline.

Resilience is being conceived as a perspective, rather than a clear and well-defined concept.

Increasing interest regarding ecological resilience.

We focus on clarifying resilience terminology.

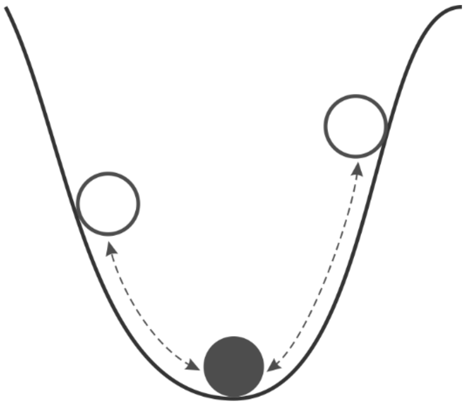
This is one of the main emerging issues for bridging the gap between geomorphology and resilience.

Resilience principles and concepts are transferred to coastal systems.

Multidecadal geomorphological dimensions from an inland-migrating barrier are used to express key resilience aspects.

Objectives

Schools of thought on resilience

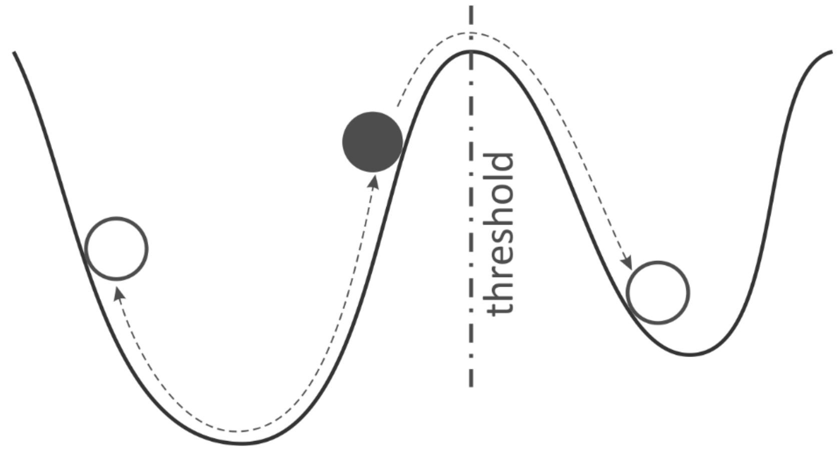


Engineering Principle

Focus on **recovery and return time** after a disturbance → maintaining **efficiency** of function

Considers a **single basin** (no thresholds) and focuses on if the ball can **remain at the bottom**.

Ability to resist departure from equilibrium (basin bottom) and to minimise return time after disturbance.



Ecological Principle

Focus on **how much a system can be disturbed and still persist** without changing identity → maintaining **existence** of function

Accepts **multiple basins** (and thresholds) and focuses on whether the system can **remain within the basin**.

Even if recovery time can also be important, the ability of the system to recover at all is much more relevant.

Ball-and-cup analogy: *The cup represents the 'basin of attraction' (or regime), defined by all possible values of system variables of interest, and the ball represents the state of the system at a given temporal point.*

Ecological resilience theory

and links to barrier island geomorphology

Ecological resilience

"

…the capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same **functions**, **structure**, **identity** and **feedbacks**.

(Flood and Schechtman, 2014; Folke, 2006; Walker et al., 2004)

Flood, S., & Schechtman, J. (2014). The rise of resilience: Evolution of a new concept in coastal planning in Ireland and the US. *Ocean & Coastal Management*, 102: 19–31.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, 16(3): 253–267.

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social – ecological Systems. *Ecology and Society*, 9(2): 5.

Ecological resilience

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For barrier islands

Identity: strip of sand and/or gravel, backed by a shallow coastal bay, separated wholly or partly from the mainland shore.

Functions: provide support to habitats, species and human activities and storm protection and sheltering to the lagoon, its supported habitats and the mainland.

Structure: a potential subdivision for the subaerial barrier can be wave-, wind- and tide-dominated parts (or simply beach, dune and marsh).

Feedbacks are highly linked to the considered structure.

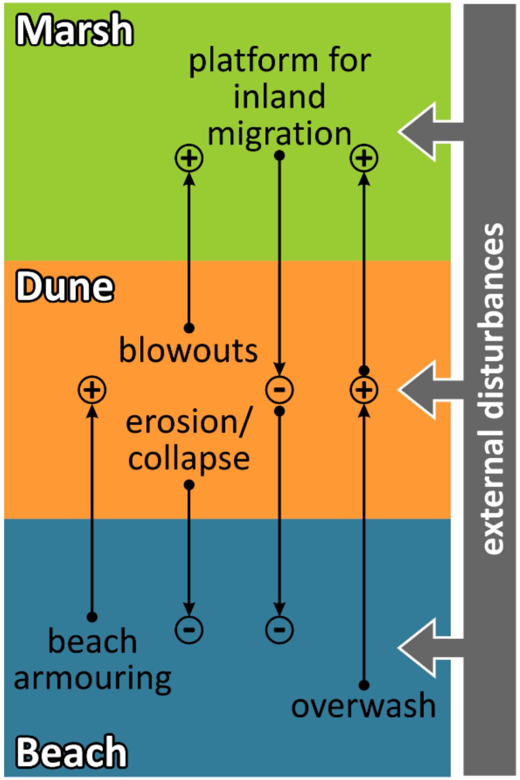


Fig. Beach-Dune-Marsh feedbacks

Ecological resilience

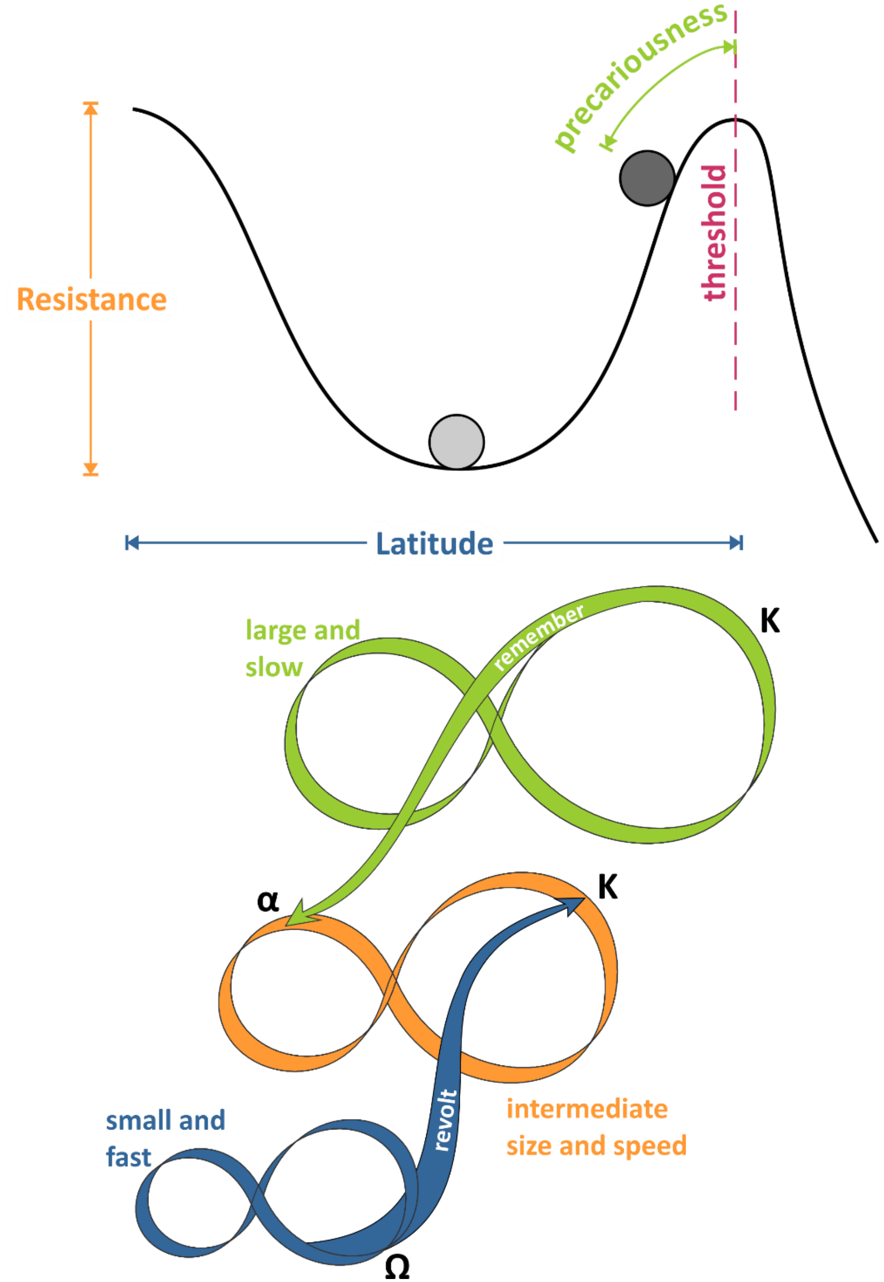
Four basic resilience aspects:

1. **Latitude**: maximum amount a system can be changed before losing its ability to recover within the same state; equal to the basin width

2. **Resistance**: difficulty of changing the system; equal to the basin depth

3. **Precariousness**: how close the current system state is to a limit or "threshold" that, if breached, makes reorganization difficult or impossible

4. **Cross-scale interactions**: influences from system components at scales above and below the particular focal scale



Ecological resilience

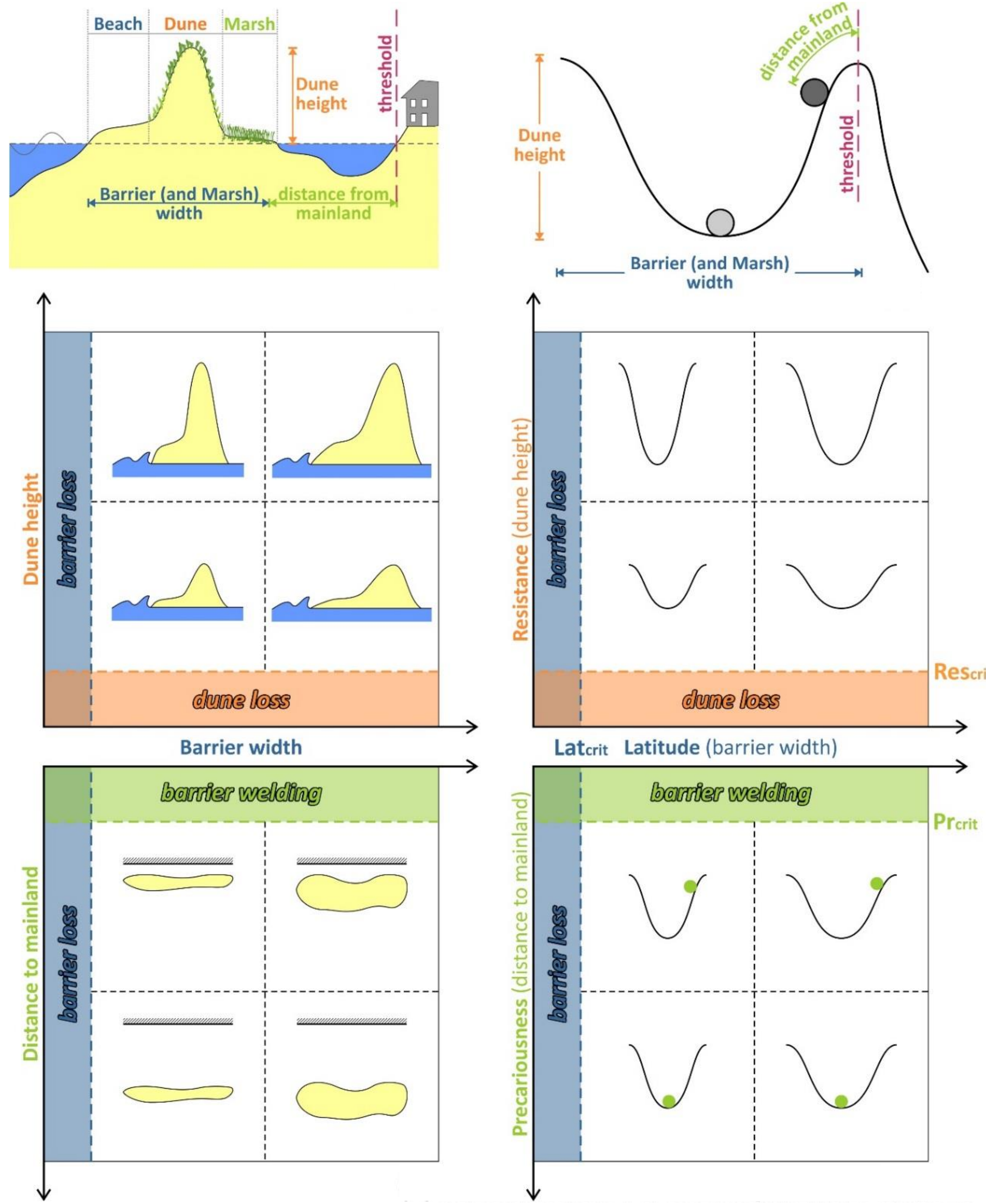
Four basic resilience aspects:

1. **Latitude** (basin width): total width of all units (sandy barrier and perched marsh)

2. **Resistance** (basin height): dune height (indicator of the difficulty of the barrier to be inundated)

3. **Precariousness**: proximity of the backbarrier to mainland (space for inland migration)

4. **Cross-scale interactions**: Beach-Dune-Marsh can be considered as relevant levels of analysis



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Ecological resilience

Resilience trajectories

variation of **latitude**, **resistance** and **precariousness**

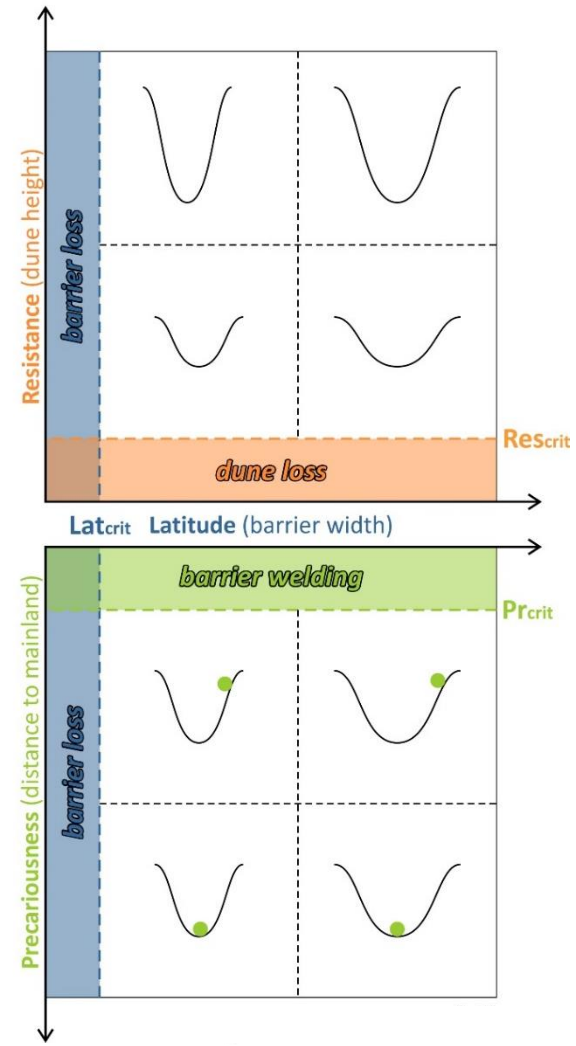
shows changes to the **shape of basin** of attraction (top) **and the system state** (bottom)

3 thresholds noted on the graph; more (i.e. marsh/beach loss) exist and need to be accounted for

the barrier is **resilient as long as its trajectory crosses no thresholds** → falls within the white-shaded area of the plots

very different from clasical and 'rigid' trajecories proposed by the engineering principle

post-perturbation recovery not restricted to regaining pre-disturbance barrier dimensions; accounting for **maintaining the existence of functions, or the ability to regain them**



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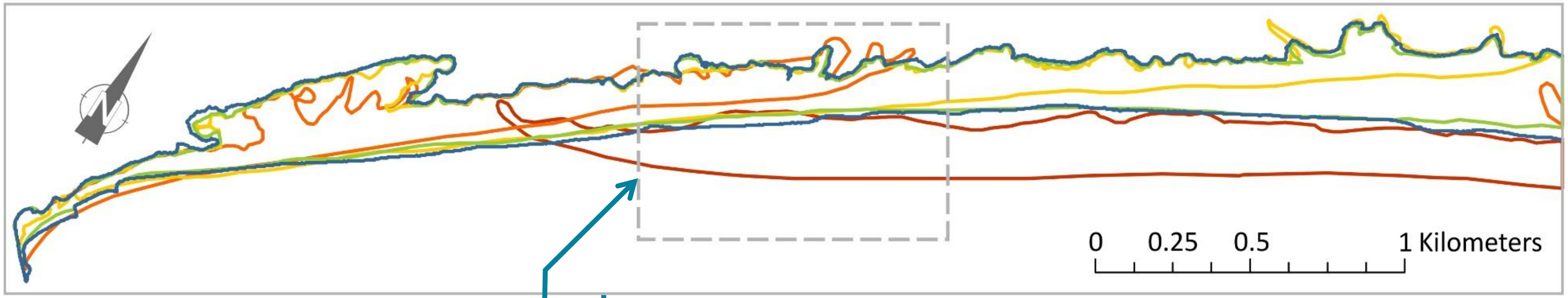
Application to barrier island rollover:

the Cabanas-Cacela barriers (Ria Formosa)

Application

Long-term morphological changes in Cabanas-Cacela:

Tavira Inlet jetties' (longshore drift reduction) forced the system to migrate landwards



area of focus: stretch of 1 km with barrier presence in all years with data availability (1952, 1976, 1986, 2001, 2011)

Application

- **Regime shift** from **BD** (1952) to **SS** (mid to late 1960s).
- By **1976** regained the **B state** (shallow-narrow basin) at a more precarious position.
- **Recovery from 1986 onwards**: from B to BD and to BDM (widening-deepening of the basin, stabilised precariousness).
- **Geomorphology:** Strong changes and a period of full barrier destruction.
- **Resilience:** system's ability to reorganise and adapt to new conditions (reduced longshore drift), to regain its environments (beach and dune) and to develop a new one (marsh).

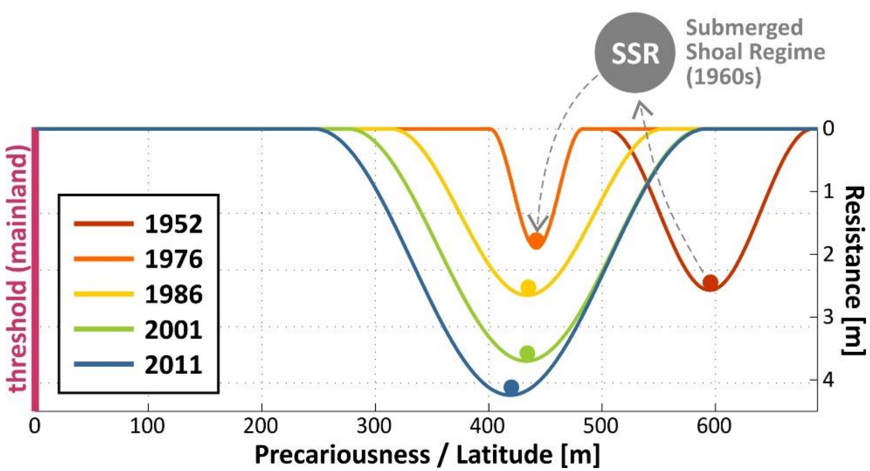


Fig. Changes to the stability landscape

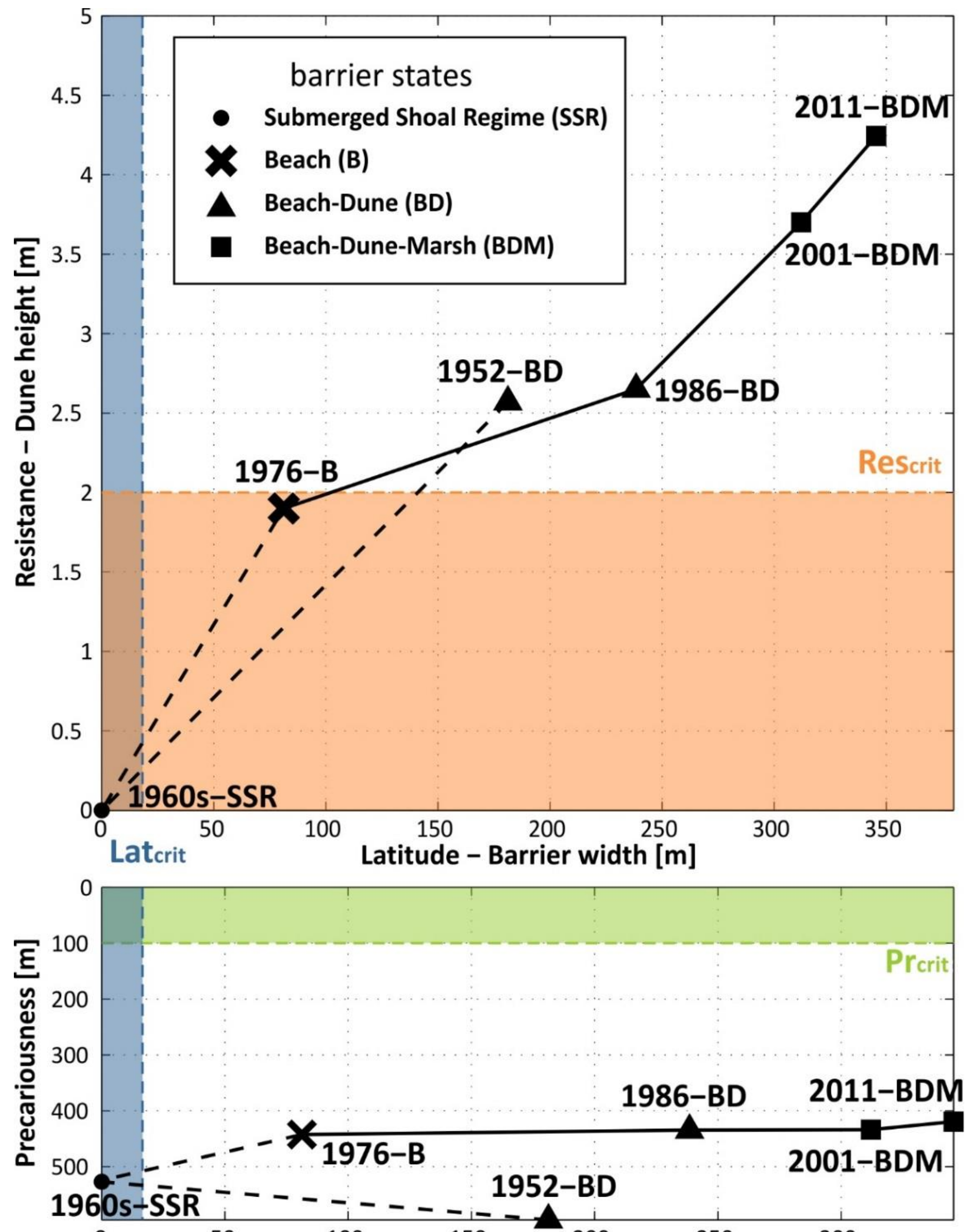


Fig. Resilience trajectories

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