

**The response of biological communities to spatial and  
temporal changes in a regenerating coastal dune  
forest along the north-east coast of South Africa**

by

**Theresia Ott**

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*We shall never achieve harmony with land,  
any more than we shall achieve absolute justice or liberty for people.*

*In these higher aspirations, the important thing is to strive.*

*Aldo Leopold (Leopold 1966)*

# **The response of biological communities to spatial and temporal changes in a regenerating coastal dune forest along the north-east coast of South Africa**

Student: Theresia Ott

Supervisor: Professor Rudi J. van Aarde

Conservation Ecology Research Unit  
Department of Zoology and Entomology  
University of Pretoria  
Pretoria  
0002  
rjvaarde@zoology.up.ac.za

Degree: Doctor of Philosophy (Zoology)

## *Abstract*

Ecological restoration that aims to reinstate indigenous processes may be constrained by regional and local conditions, especially those that drive dispersal and colonisation. Local conditions can be managed, while regional conditions cannot. The management of costly rehabilitation programmes is considered best practice when scientifically informed. My thesis documents the responses of biological communities to a range of local conditions developing in coastal dune habitats in response to ecological

restoration. Here, landscape-level (spatial structure of patches of tree canopies) local conditions were distinguished from site-level (topography, soil nutrient content, woody plant community richness, microclimatic variables) local conditions.

The spatial structure of tree canopies varied over time and differed between the mining lease site and the relatively undisturbed benchmark site prior to (1937-1970), and after (1990-2006) mining. For example, approximately 20% of the mining lease site and 40% of the benchmark site was covered by tree canopies prior to mining. However, after mining and rehabilitation, the structure of tree canopies began to converge towards that of the benchmark. The topographic profile of coastal dunes was less heterogeneous after mining and rehabilitation than before. Aspect, elevation and gradient of dune slopes were also different and had shifted in space.

Variability in the structure of tree canopies could not explain variability in species richness, forest-associated species richness and proportion of benchmark species for the millipede, dung beetle and bird communities as had been expected. However, species composition did change (though idiosyncratically) with age-related changes in soil nutrient availability and tree species diversity. Temperature, relative humidity and light intensity varied with dune topography, but soil nutrient content (C:N ratio and pH) was better accounted for by the age of the regenerating forest than by dune topography. Similarly, analysis of covariance suggested that tree canopy density, woody plant richness and millipede species richness only responded to the aspect, elevation and gradient of restored coastal dunes when age was taken into account as a covariate. However, the response of keeled millipedes to dune topography, regardless of regeneration age, suggested that the microclimatic variability brought about by topographic heterogeneity may provide these specialists with suitable microhabitats.

Throughout my thesis, the age of regenerating patches of indigenous canopies was often more important as an explanatory variable than habitat conditions *per se*. Age itself is not a determinant of biological communities, but merely the axis along which habitat conditions change with succession, and later, patch dynamics. Therefore, as elsewhere, my thesis has highlighted age as a useful proxy for the response of biological communities to local conditions. It seems that managing local variables such as those considered in my assessment is not an avenue through which to enhance restoration. After kick-starting initial conditions, best practice rehabilitation management should therefore focus on minimizing external disturbances rather than interfering with natural processes.

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*“...a PhD doesn’t mean ‘I have’ Teri; it means ‘I can’...”*

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## Disclaimer & Declaration

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The present dissertation includes six independent chapters. All except Chapter 5 are prepared in accordance with the requirements of the journal *Restoration Ecology*.

Chapter 5 was prepared for and accepted by the journal *Landscape and Ecological Engineering* (DOI: 10.1007/s11355-013-0211-1).

I, Theresia Ott, declare that this thesis is my own work and has not previously been submitted by me for a degree at this or any other institution.

Signature:

Date:

## Glossary of Terms

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<b>Term</b>	<b>Definition</b>
<b>Benchmark</b>	A reference site that can serve as a model or target for planning and evaluating an ecological restoration project (SER 2004).
<b>Dune morphology</b>	The topographic profile of sand dunes based on the aspect, elevation and gradient of their slopes.
<b>Ecological restoration</b>	The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER 2004).
<b>Historical context</b>	Also known as the historical contingency, land-use legacy or historical landscape of a site, this considers year-on-year effects. In this thesis, I illustrated the land-use legacy and its effect on the historical landscape.
<b>Landscape-level factors</b>	Factors such as the habitat mosaic, inter-patch connectivity and patch structure that influence the dispersal and colonisation of species at the local scale (Watson 2002; Brudvig 2011). This thesis focuses on the structure (area, shape and isolation) of old- and new-growth forest patches.
<b>Lease site</b>	The land leased by the mining company from the landowner for mining activities until mine closure (mineral lease area).
<b>New-growth forest</b>	Regenerating coastal dune forest.
<b>Old-growth forest</b>	Relatively undisturbed indigenous coastal dune forest.
<b>Patch</b>	A continuous indigenous tree canopy that may differ in species composition.
<b>Patch structure</b>	The spatial structure of patches of indigenous tree canopies determined using spatial analysis procedures to quantify patch area, shape, and isolation.
<b>Post-mining</b>	Refers to the period from the end of mining at a defined area in the lease site until 2006, within which patch structure for 1990, 1998 and 2006 (13, 21 and 29 years after mining and rehabilitation, respectively) was assessed.
<b>Pre-mining</b>	Refers to the phase prior to the onset of mining on the lease site in 1976, within which I assessed patch structure for 1937, 1957 and 1970 (40, 20 and 7 years prior to mining, respectively).
<b>Regional factors</b>	Factors that impact whole regions, (where a region is defined as an area composed of landscapes with the same macroclimate and tied together by human activities (Forman 1995) that are usually associated with climatic shifts and anthropogenic land transformation leading to large-scale changes to landscapes.
<b>Seral stage</b>	An intermediate stage of ecological succession, but progressing towards a climax state. In this study three seral stages were recognised according to Grainger (2012), based on the age of regenerating stands one = 1-10, two = 11-25, and three >25 years.
<b>Site</b>	Portions of the study area delineating either the mineral lease areas (directly exposed to disturbances associated with mining) or the relatively undisturbed benchmark.



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<b>Site-level factors</b>	Abiotic and biotic factors operating within a site that filter biological diversity and are often monitored and manipulated as part of rehabilitation programs.
<b>Spatial structure</b>	A collective term used in this thesis that refers to canopy coverage, patch area, shape and the isolation of patches.
<b>Stand</b>	Regenerating area of known age.

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