**Geo-Ecology of Dunes along the Mediterranean Coast of Israel**

1. **Brief Description**

Coastal dunes are essential for human beings as they provide several ecosystem services, such as protecting the coast from erosion and supporting groundwater storage and tourism. Despite these services, coastal dunes have become increasingly damaged and almost disappeared in many cases due to the progressive deterioration of coastal landscapes as a result of anthropogenic activity. Half of the global population lives along coasts. Unsurprisingly, coastal dunes are thus currently listed among the most endangered ecosystems worldwide (Defeo et al., 2009). The situation is similar in the Mediterranean Basin, which is recognized as the second-largest global Biodiversity Hotspot (Myers 1988 & 1990, Medail & Quezel. 1999, <https://www.conservation.org/priorities/biodiversity-hotspots>)) encompassing both terrestrial and marine environments. Mulen & Salman (1996) were the first to report that almost 75% of the Mediterranean coastal dunes were damaged or destroyed from 1960 - 1990.

The European Threatened List of Habitats (2016) classified the European coastal habitats, especially the coastal dunes, as "threatened". Damage to these coastal dunes is particularly noticeable on the coast of the Mediterranean Basin, where they have experienced a widespread decline in extent and quality, facing common threats including intensive urbanization, infrastructure development, tourism, and the spontaneous spread of invasive alien species. The fate of the coastal dunes in this region is particularly uncertain, as the consequences of climate change, rising sea levels, and extreme weather events are predicted to be especially severe.

Studies of coastal dune ecology have been conducted in countries in the Mediterranean Basin, particularly in European nations including Italy, Greece, France, and Spain. These studies have primarily focused on vegetation-related issues, perennial vegetation, and their database is from only a limited number of years. For example, one recent analysis of 75 kilometers of coastal dune systems located along the Tyrrhenian and Adriatic coasts of Central Italy based on vegetation data from 10-15 years revealed significant changes in plant community structure and composition due to species loss. Together with the disappearance of 23% of historical plots and substantial losses of focal species, these results suggest that coastal dune habitats are subject to intense degradation processes within as little as 15 years, with these effects being most pronounced on the upper beach and shifting dunes.

Israel lies in the eastern Mediterranean Basin and is included in one of the ten most important areas of the biodiversity hot spots in the region (Medail & Quezel. 1999). The coastline along the Mediterranean Sea in Israel is 195 km long. The sand dunes in this strip are continuously connected to the desert sand dunes of the Negev, a region in the southern part of the state of Israel, northern Sinai, and the sand dunes of north Africa. This connection provides a corridor for the northward distribution of desert (Sharo-Arabian) species. Although most of the coastal sand dunes in Israel are under Mediterranean climatic conditions, the desert species distribution is possible because of the sand dune are under harsh physical conditions. The instability of the sand, low soil moisture, and nutrient availability transform these coastal dunes into a xeric ecosystem. Survival is relatively more difficult for plants and animals in this kind of ecosystem than in the mesic and humid habitat in the Mediterranean region.

The situation of the coastal dunes in Israel is no different from that which exists in the Mediterranean Basin and, in general, in the rest of the coastal areas in the world. More than half of the Israel population lives along the Mediterranean coast, with a density ranging from 2,000 to 16,000 people per square kilometer. The highest density is found in the Central District. In addition to residential buildings, this area is home to extensive transport infrastructure, industrial facilities, power plants, desalination plants, sewage treatment plants, ports, and other. Over the years, vast dunes along the coasts have given way to built-up areas, and the sand has been used for construction. From the establishment of the State of Israel in 1948 through the end of the 20th century, 20 million cubic meters of sand were torn off the coast: about 10 million cubic meters were mined for construction from 1949-1964, and more than 10 million cubic meters have been trapped to date in ports, marinas, breakwaters and around every body of water built along the coastline. The coastal dunes are also a highly sought-after tourist resource owing to their adjacency to the sea and large urban centers. The dimensions of development and tourist activity on the Israeli Mediterranean coast have intensified over the years. The most crucial coastal dunes nature reserves are the Caesarea dune area and the coastal dunes south of Tel Aviv – Palmachim, Nizzanim, Zikim, and Netiv Ha'asara. These nature reserves occupy only 32 square kilometers, about 90% on the southern coastal plain.

Roads and built-up areas fragment these reserves. The lack of spatial contiguity between the nature reserves and the intensive construction near them affects the ecosystems that characterize the coastal dunes and threatens their integrity and continuity. Despite all this, the coastal dunes are still characterized by diverse of psammophile species. These include the lizards *Acanthodactylus scutellatus*, *Sphenops sepsoides,* and the largest (ca. 160 cm) lizard in Israel, *Varanus driseus*, as well as the sand snake *Lytorhynchus diadem*, the rodents *Gerbillus pyramidum* and *Meriones sacramenti*, the only endemic mammal in Israel, and the sand hedgehog *Hemiechinus auritus aegyptius*. Most of the endemic species of the coastal dunes are desert species or phylogenetic derivations of Mediterranean species. The phylogenetic derivations of Mediterranean species have not been researched thoroughly, and knowledge about them is scarce (Prof. A. Zahavi pers. comm.; Shmida 1982). Rare plants and animals can also be found in the coastal plain. Some of these are in danger of extinction (Fragman et al. 1999). An estimated 140 plant species found in the central and the southern coastal plain are considered in various degrees of rarity. Of these, 43 species are 'rare' (species that grow in 31 - 100 sites), 80 species are 'very rare' (species that grow in 4 – 30 sites), and 17 species are considered to be on the verge of extinction (data for 2000 received from the Israel Plant Information Center). It is also is essential to emphasize the small number of plant species from the sandy and sandy loam soil habitats that have become extinct: 3.9% of the total extinct species in Israel. This is despite the extensive destruction of these habitats since establishing the State of Israel in 1948 (Naveh & Kutiel 1990). Although there has been a drastic reduction in the rare plant populations in these habitats since 1948, this has not led to widespread extinction (Fragman et al. 1999). In total, 173 psammophilic plant species are known to grow in Israel's sand and sandy loam soil habitats (8.2% of Israel's total flora species). There are 11 additional species typical of coastal cliffs (0.5% of Israel's entire flora species) (Fragman et al. 1999).

Geomorphological and ecological studies have been carried out over the years at various sites along the coast, especially in what has been one of the largest and most relatively preserved nature reserves until recently, the Nizzanim LTER nature reserve. Data on plants and animals (arthropods, reptiles, and rodents) have been collected in Nizzanim for 15 years. This book aims to present all the available information on the geo-ecology of the coastal dunes accumulated from studies done in this region. All published books about coastal dunes generally focus mainly on the geomorphology and vegetation of diverse habitats in the coastal area, including shifting and fixed dunes. In contrast, the book proposed below focuses only on the shifting semi-fixed and fixed dunes, and includes four different taxa (plants, arthropods, reptiles, and rodents) that exhibit spatial and temporal variations depending on the dune state of fixation.

Moreover, Israel's biogeographical location, the richness of desert and Mediterranean plant and animal species found in it and in the coastal sands, and the large and significant number of geomorphological and ecological studies conducted in Israel and published over the years in scientific journals in Israel and abroad justify this work as a particularly robust case study of the drivers and effects of coastal dune loss the Mediterranean Basin and in the world in general, due to significant impacts of human activity. The book also proposes ideas and tools to conserve and manage the coastal dune ecosystems, as well as new indexes that can be used to accurately define the degree of species and communities' affinity to the degree of dune fixation (Chapters 5 and 6) or the ecological value of an ecosystem for conservation using the "Aggregate Ecological Value" index (chapter). These factors make this book a source of interest not only for Israelis but also for a global audience that includes dune researchers, students, and even nature lovers and tourist guides who are interested in the sensitive and exciting coastal dune ecosystem.

The book includes 12 chapters that cover geomorphology, soil, plants and animals, conservation, and the management of coastal dunes.

1. **Outline / Table of Contents**

**Introduction**

**Acknowledgments**

**Chapter 1**

Ecological Studies in the Levant Region

This chapter reviews the ecological studies conducted in the coastal dune ecosystems of North Africa and the Middle East, from Morocco in the west to Eygpt and Lebanon in the east. The coastal dunes of Israel (and the western Negev) are an integral part of the coastal dune ecosystems in the regions mentioned above. Hence, the area shares a significant proportion of the plants and animal species. The purpose of this chapter is to emphasize the contribution of the studies conducted in Israel that allow for a broader understanding of the characteristics and processes existing in the coastal dunes in the Xeric part of the Mediterranean Basin

**Chapter 2**

**Structure and Geomorphological Processes of Coastal Dunes**

This chapter describes dune types on the coast along the Mediterranean Sea in Israel, their characteristics, the processes involved in their formation, the sources of the sand, and the periods of their invasion into our region.

**Chapter 3**

**Soil Development Processes and Characteristics**

This chapter describes dune soil formation processes during their fixation from shifting dunes to fixed dunes. There is a reference to soil structure and measures of texture, soil moisture, field capacity, hydraulic conductivity, and soil organic matter at the macro level (shifting, semi-fixed, and fixed dunes) and at the micro level (differences in soil properties under shrubs and in the open spaces between the shrubs).

**Chapter 4**

**Main Dune Areas on the Coastal Plain**

This chapter describes the changes that have occurred from 1980 to the present day with respect to the size of the dune areas along the coast of Israel, their characteristics, and their ecological uniqueness.

**Chapter 5**

**Flora and Vegetation**

This chapter focuses on perennials and annual plants, which belong to three main biogeographical regions: Mediterranean, Irano-Turanian and Sharo-Arabian. The chapter begins with a discussion of perennial plants, their uniqueness, their impact on dune fixation, and changes in soil properties during dune fixation (Environmental Engineers). This is followed by a description of the perennial communities. An extended sub-chapter is dedicated to *Artemisia monosperma*, a dominant psammophytic dwarf shrub distributed in the East Mediterranean region and Arabian Peninsula, considered a keystone species. This chapter continues with an overview of the importance and uniqueness of annual plants in the sandy dune habitats and the degree of their communities' affinity for the level of sand mobility determined by the Sandiness Index developed for this purpose. This index can be used for the same purpose for other taxa. Likewise, the spatial distribution and the temporal stability of the annual plant communities are described. An additional sub-chapter is dedicated to the annual plants' seed bank.

**Chapter 6**

**Arthropods**

The chapter focuses on arthropods in sandy dunes. The chapter begins with a brief overview of global studies of arthropods, especially beetles, in dunes, and continues with a discussion of studies carried out in Israel through the year 2000. From here, the chapter continues with a survey of all the knowledge accumulated in Israel since then, derived from the studies carried out primarily in the Nizzanim LTER nature reserve over 12 consecutive years. The chapter describes the relationship between dune types (mobile, semi-fixed, and fixed) and the patch types (under the shrubs and in the open among the shrubs) and arthropod communities as well as their affinity for the dune mobility state using the Sandiness Index. A summary table with a list of endemic species in the Levant accompanies this sub-chapter with details of the species, the characteristic habitat for each species, its geographical distribution, and its Sandiness Index. Another sub-chapter is dedicated to two flagship species, one of which characterizes mobile dunes and the other fixed dunes, and to the unique ants characteristic of the coastal sands in Israel.

**Chapter 7**

**Reptiles**

The chapter focuses on the reptiles in the coastal sand dunes of Israel, which most of the originate in desert areas adjacent to Israel. It begins with an overview of the adaptations to the limiting factors characteristic of the dunes developed by the reptiles. It further compares the distribution patterns of the reptiles in the coastal dunes to those in other sandy areas in Israel. Two tables are included in this chapter: One presents a list of the reptile species found in the Nizzanim LTER nature reserve, the distribution of each species and its prevalence rate in each of the dune types (mobile, semi-fixed, and fixed dunes), while the second is a list of reptile species with a high affinity for sand and details about each of these species (distribution, food, activity times, conservation status, etc.). Another sub-chapter presents a detailed review of studies focused on three characteristics of lizards in the coastal sands (*Acanthodactylus scutellatus*, *A. schreiberi,* and *Varanus griseus*).

**Chapter 8**

**Rodents**

The number of rodents in the coastal sands in Israel is low and amounts to four main species, one of which is endemic to Israel. In this chapter, is an overview of each species' association with the dune mobility state is presented, as are their relationships in areas where their ecological ranges overlap. The temporal stability of the rodent community is also discussed.

**Chapter 9**

**The Impacts of Humans and Climate Change on Coastal Dune Ecosystems**

This chapter deals with various human influences on coastal dunes that are causing their disappearance from the landscape and fundamental changes in the geomorphological properties and plants and animal composition for the remaining dunes. In addition, there is a reference to perennial vegetation die-off and, consequently, a decrease in vegetation cover due to consecutive years of drought and changes in the rainfall regime. This chapter has several sub-chapters: a. Reductions in sand areas over the years, b. The impact of shrub encroachment on habitat heterogeneity, c. The impact of biological invasion (mainly by *Acacia saligna* and *Heteroteca subexilaris*, two dominant species that cover aversively the coastal dunes and that have been the subjects of several studies) which quite a few studies have been conducted on them) on native plants and animals, d. Plantations of exotic trees, e. The effects of off-road vehicles, and f. Climate change.

**Chapter 10**

**Ecological-Economical Losses Due to the Loss and Fixation of Coastal Dunes**

This chapter deals with the ecosystem services that coastal dunes provide to human beings. The chapter describes several surveys conducted at different coastal dune sites in Israel aimed at evaluating the importance of these services as perceived by people who do and do not visit those sites.

**Chapter 11**

**Conceptual Concepts of Stakeholders Regarding the "Desired Landscape" of the Coastal Dunes**

The chapter deals with the changes that have taken place in the Nitzanim Reserve over the decades due to various conceptions and conflations between stakeholders regarding the designation of the coastal dunes.

**Chapter 12**

**Conservation and Management of Coastal DuneEcosystem**

This chapter deals with the ecological conservation and management of coastal dune ecosystems in Israel. This chapter has four sub-chapters. The first discusses the restoration management of coastal dune ecosystems, which is based on the mechanical removal of local woody vegetation from some of the dunes to turn them into shifting dunes. The second covers grazing by goats and camels to remove local vegetation, primarily the dominant dwarf shrub species *Artemisia monosperm*. The third discusses the rehabilitation of trails created spontaneously by pedestrians, ATVs, and 4x4 vehicles. The final sub-chapter deals with the treatment of invasive plant species.

**Epilogue**

A summary and conclusions from the book author regarding the future of the coastal dunes in Israel and the entire Mediterranean basin.

**Bibliography**

The bibliography includes a list of about 400 citations on studies conducted in Israel and worldwide.

1. About the Author

Bar (Kutiel) is a plant ecologist. The overarching theme of her research focuses on **disturbances** (wildfires, cutting, grazing, trampling and 4x4 vehicles, fragmentation, and invasion of alien plant species) **in arid and Mediterranean ecosystems and their impacts on vegetation** (with particular emphasis on annual plants), **soil and geomorphological processes** (runoff and erosion), and **the relationships among them**. She tries to understand these **vegetation-soil-geomorphic and climate relationships** by working on **various geo-ecological spatial scales** (gradients, ecosystems, habitats, and patches under the trees/shrubs and the adjacent open patches) using data gathered from **structured field observations or experimental manipulations**. Through this multi-scalar analysis and by working on annual plants, which exhibit rapid temporal responses due to (a) seasonal changes and immediate after disturbances and (b) spatially distribute within short distances to form various patches as a result of micro soil properties, she can describe processes at the finer scales (habitat, aspect, and patch), and explain how they shape patterns at the ecosystem scale. Moreover, by comparing various ecosystems along soil and climate gradients, she can evaluate the effects of different environmental settings (at the ecosystem scale) on patterns and processes on finer scales. In this way, she seeks to define general principles, or 'rules,' that underlie complex patterns of vegetation (communities, coverage, life forms, and diversity) in arid and Mediterranean ecosystems.

Bar (Kutiel)’s studies of coastal dunes began in 1975 and have continued to this day. In 2005, she established the LTER site at the Nizzanim coastal dune nature reserve, where she served as the principal scientist. The team of principal investigators was joined by Prof. Amos Bouskila, from the Ben-Gurion University of the Negev, a zoologist specializing in reptiles, and Dr. Elli Groner, an arthropod expert from the Dead Sea & Arava Science Center. With help from many other researchers, including graduate students, data were collected annually for 15 consecutive years and included, among other things, data on soil and four different taxa simultaneously: plants (perennials and annuals), arthropods, reptiles, and small mammals. At the same time, data were also collected from other sand dune sites along the coast.

Bar (Kutiel) currently leads several projects focused on how vegetation encroachment impacts on flora and fauna, the spread and impact of invasive plants, economic issues regarding the evaluation of ecosystem services and goods, and conflicts among land owners in the context of political ecology, all of which are fundamental for management and conservation tools and policy-making. About 20% of the citations in the proposed book belong to publications in local and international scientific journals of which she is the sole author or work completed with her research partners. Twenty graduate students have completed their theses under her supervision.

1. **Market Consideration**

This book is written for scholars. graduate students, advanced undergraduates, and policy decision-makers interested in ecology and the conservation and management of coastal dunes.

One-tenth of the Earth's land surface is covered with dunes and sand plains concentrated mainly in deserts and along coasts. Therefore, it is unsurprising that many researchers are engaged in dune-related studies. I am exposed to a wealth of ecological research in the field that has been conducted worldwide out of both personal interest in the subject and because I am often invited to review manuscripts dealing with the diverse ecological aspects of coastal dunes.

The book, recently published in Hebrew on a relatively limited scale, is currently distributed mainly by the Israeli Nature and National Parks Authority. Researchers, graduate students, nature lovers, and rangers of sand reserves in Israel approached me with a request to purchase the book. Today, 700 books have been sold out of 1,000 printed copies. The reactions of the people and the local press were exciting, motivating me to write a more detailed text in English for a broader target audience.

The book can also serve as a textbook for advanced courses in ecology, especially those on topics related to the geo-ecology of coastal dunes. The book contains many figures and color pictures, among other things, of unique and exciting plants and animals inhabiting coastal dunes in Israel and the Levant.

1. **Comparable and Competing Books**

Most books published to date focus on dunes on a global scale or in temperate and tropics regions. Some books are devoted to geomorphic phenomena and processes, such as the book authored by Pye, K., & Tsoar, H. (2008) *Aeolian Sand and Sand Dunes*. Springer Science & Business Media. Others relate to the biology /ecology of coastal dunes, emphasizing vegetation, as in the book authored by Maun, M. A. (2009). *The Biology of Coastal Sand Dunes*. Oxford University Press. Some books contain chapters from various researchers on different topics related to coastal dunes, such as the following: Martínez, M. L., & Psuty, N. P. (Eds.) (2004). *Coastal Dunes*. Ecology and Conservation Berlin: Springer Verlag and Martínez, L. M., Gallego-Fernández, J. B., & Hesp, P. A. (Eds.). (2013). *Restoration of Coastal Dunes*.

J. Patrick Doody wrote a few books that included a general review of the habitat and its conservation and management, together with summarized descriptions of the status of the sand dunes in most European countries as in the following:

Doody, J. P. (Ed.). (1991). *Sand Dune Inventory of Europe*. JNCC/EUCC.

Doody, J. P. (2001). *Coastal Conservation and Management: An Ecological Perspective* (Vol. 13). Springer Science & Business Media.

Doody, J. P. (2012). *Sand Dune Conservation, Management and Restoration* (Vol. 4). Springer Science & Business Media.

No books to date have focused on the geo-ecology of coastal dunes in the Mediterranean Basin, particularly for the southern and eastern regions. The proposed book entitled "*Geoecology of Coastal Dunes*" concentrates only on the habitats of the coastal dunes in Israel. The book includes knowledge based on consecutive studies conducted over 15 years, with an in-depth focus on specific topics. Included studies cover aspects of dune geomorphology, soils, vegetation, and animals (arthropods, reptiles, and rodents). The book refers to the spatial distribution of plants and animals, their interactions, and their stability over time. In addition, two chapters focus on human influence on this crucial and sensitive ecosystem and suggestions for managing and conserving the dunes in light of the far-reaching changes that have experienced over the past 70 years. In practice, the book records the current status of these ecosystems in the eastern part of the Mediterranean Basin.

1. **Apparatus / Illustrative Materials**

It is estimated that the book will contain: About 200 photos, 95% of which are in color, while the remainder are in black and white (archival photos). A significant portion of the pictures will be concentrated on boards, such as boards of plant and animal species. The book will also contain approximately 40 figures and 21 tables.

1. **Status of the Work**

The Hebrew version of this book was published in December 2022. Since then, additional new information has been added to that appears in the Hebrew version. In addition, in the proposed book, the introduction will include a broad literature review of the state of coastal dunes and the geo-ecological knowledge that exists pertaining to coastal dunes in the Levant region except for Israel (from Morocco in the west to Lebanon in the northeast). The book will be translated into English and undergo academic editing as required. The book manuscript is expected to be ready within a year and a half since the contract will be signed between all the parties concerned.

1. **Possible Reviewers**

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