Ekológia (Bratislava) - Journal of the Institute of Landscape Ecology, Slovak Academy of Sciences Vol. 40, No. 1, p. 48–53, 2021
doi:10.2478/eko-2021-0006

DISTRIBUTION AND POPULATION STRUCTURE OF *Avicennia marina* (FORSSK.) VIERH IN RELATION TO THE ENVIRONMENTAL GRADIENT ALONG THE RED SEA COAST OF EGYPT

RAMADAN A. SHAWKY

Plant Ecology and Ranges Department, Desert Research Center; 1 Mathaf El-Matariya st., Cairo, Egypt; e-mail: ramadan_salam@hotmail.com

Received: 22 August 2020 / **Accepted:** 4 November 2020

Abstract

Shawky R.A.: Distribution and population structure of *Avicennia marina* (Forssk.) vierh in relation to the environmental gradient along the Red Sea Coast of Egypt. Ekológia (Bratislava), Vol. 40, No. 1, p. 48–53, 2021.

This paper presents an assessment of changes in *Avicennia marina* population along the Egyptian coasts of the Red Sea. A retrospective analysis of the mangrove cover and distribution was carried out. The populations in Sharm El-Bahary and wadi El-Gimal lack at least one or more volume class stages, while all volume classes are represented in the last two populations occurring in wadi Al-Qu'lan and Sharm El-Madfa'a. The relationships between the individual diameter and canopy volume of *A. marina* population are simply linear. Strong correlation coefficients are obtained (r^2=0.92) for the population of Sharm El-Bahry and the weak correlation coefficients are obtained (r^2=0.63) for the population of wadi El-Gimal. On the other hand, the relationships between the individual heights and canopy volume of *A. marina* population are simply linear. Strong correlation coefficients are obtained (r^2=0.72) for the population of Sharm El-Bahry and the weak correlation coefficients are obtained (r^2=0.46) for the population of wadi El-Gimal. All growth performance of *A. marina* species differ significantly at the four localities except the circumference. The comparison of soil characteristics *A. marina* populations in the four study localities showed significant variations in all variables except the silt content and SO_4.

Key words: mangrove, *Avicennia marina*, distribution, Red Sea, population structure.

Introduction

Mangrove areas in Egypt are dispersed in numerous small sites along the Red Sea coast, although the overall area of mangroves is relatively small. The present estimates indicate that there are approximately five km^2 of mangroves in Egypt. The limited mangrove areas of Egypt suggest that this is a vulnerable ecosystem and needs an effective management to ensure its ongoing survival (Saenger, 2002). The mangal vegetation of the western coast of the Red Sea was investigated by Kassas, Zahran (1965, 1967) and Zahran (1977, 1982).

The population structure of an individual tree or the structure of the population can be conceived as comprising a series of stages (e.g. seedling, juvenile, mature trees etc.). The size class structure indicates a successful regeneration of forest species (Curtis, McIntosh, 1951; Saxena, Singh, 1984). Also, Harper and White (1974) and Harper (1977) suggested that the tree size may be a better predictor of reproductive output than age and that balanced or stable size distributions in higher plants may be analogous to balance or stable age distributions in higher plants. Natural disturbance plays a critical role in mediating old-growth forest dynamics and disturbance vary in type, scale, and effect on stand structure (Pickett, White, 1985; Pickett et al., 1989).

The structure of a plant population is the result of the actions of biotic and abiotic factors upon the growth and mortality rates of individuals and of past recruitment events (Hutchings, 1997). The size structure of plant populations has been frequently used to assess the regeneration status and to predict future population changes by assuming that populations with many small stems in relation to larger ones are self-replacing or increasing, whereas populations with relatively few small stems are believed to be declining in abundance (Hay, 2002; Buyavejchewin et al., 2003; Baker et al., 2005; Bastian et al., 2020). Also, the tidal inundation influences a number of edaphic factors including salinity, pH, and concentrations of nutrients that are known to influence growth and distribution of mangrove vegetation (Ball et al., 1988; McKee, 1993).

The aims of this study were to investigate, from an empirical data set, whether measures of size structure is related to future trends in the number of plant populations, as can be derived from the population growth rates and the edaphic factors.

Material and methods

Study area

Four main localities encompass the entire coastlines of the Egyptian Red Sea. The natural variation of *Avicennia marina* populations subjected to different climatic, physiographic, and human impact conditions were selected for this study. The first transect was in Sharm El-Bahry (south El-Qusair), the second in Wadi El-Gimal (south Marsa Alam), the third Wadi Al-Qu'lan (north Hamata), and the fourth in Sharm El-Madfa'a (south Shalatein). The exact location and altitude of the study sites are shown in Table 1 and Fig. 1.

Population size structure

Demographic survey of *A. marina* population was performed through field work during 2017. The size was estimated by measuring the height and mean crown diameter. The tree size was calculated as a spherical shape, in form of the canopy volume V following Hegazy, Elhag, 2006; Mosallam et al. (2018) according to the equation: V=4/3*ab, where a is the average canopy radius and b represents the canopy height. The size class values were then used to classify *A. marina* populations into seven size-classes (A<1 m^3, B=1–10 m^3, C=10–50 m^3, D=50–100 m^3, E=100–200 m^3, F=200–300 m^3 and G>300 m^3) separated the populations into different sizes (Alatar et al., 2015). Density was calculated as individuals per hectare. The mean and standard error of circumference, height, diameter, size index, and height to diameter ratio per individual in each size class were then determined (Shaltout, Ayyad, 1988; Alatar et al., 2015).

Soil and data analysis

A composite soil sample was collected from each stand as a profile of 50 cm depth and air-dried. Organic carbon was determined by the loss on ignition method. $CaCO_3$ was estimated using Collin's calciminer. Soil-water extracts (1:5) were prepared for the estimation of electric conductivity (EC) using electric conductivity meter, soil reaction using pH meter, chlorides by direct titration against silver nitrate using 5% potassium chromate as indicator, and bicarbonates by titration against HCl using methyl orange as an indicator. Soil extracts of 5 g air-dried soil were prepared using 2.5% v/v glacial acetic acid for estimation of sodium, potassium, and calcium by flame photometer and magnesium by atomic absorption (Allen et al., 1989; Rayan et al., 2001). All the edaphic variables were assessed statically using COSTAT software for Windows version (4.6) and one-way analysis of variance was applied to assess the significance of variations using SPSS for windows version (25).

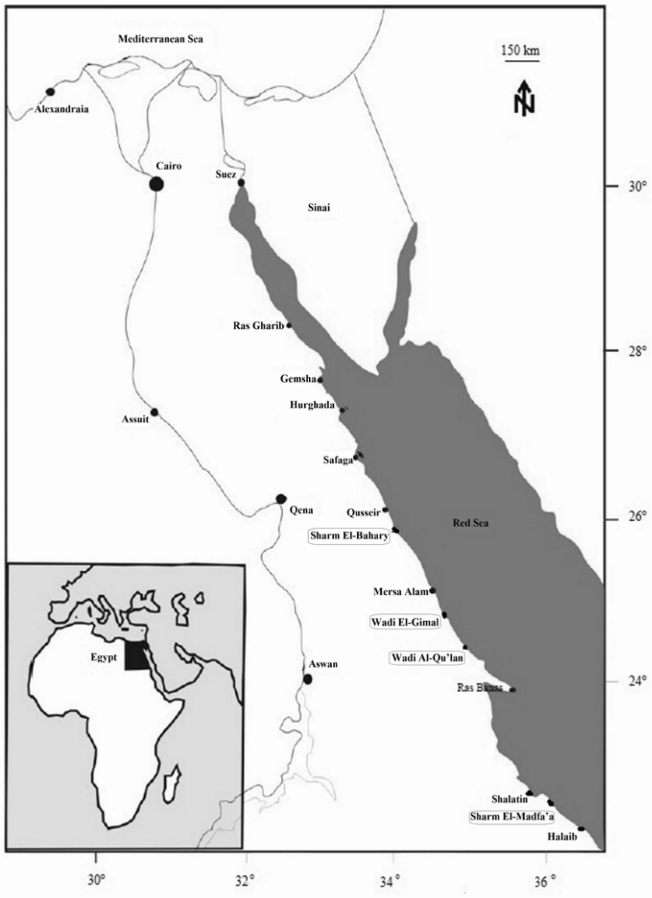

Fig. 1. Map of Egypt showing the studied localities along the Red Sea Coast.

Table 1. Study locations with Global Positioning System (GPS) readings along the Red Sea Coast, Egypt.

Location	Latitude and altitude
Sharm El-Bahry	34° 24' 52" E / 25° 52' 05" N
Wadi El-Gimal	35° 05' 33" E / 24° 40' 08" N
Wadi Al-Qu'lan	35° 15' 73" E / 24° 22' 36" N
Sharm El-Madfa'a	35° 42' 12" E / 22° 54' 39" N

Results

Population size structure

The canopy volume class distribution of the four study populations are shown in Fig. 2. The populations in Sharm El-Bahary and wadi El-Gimal lack at least one or more volume class stages. The volume class distribution in the first population (Sharm El-Bahary) shows the presence of five classes, B to F. The volume class E is the highest, making up 36.1% of the total population, while class B is the lowest, comprising 4.7%. Alternatively, the volume class distribution in the population of wadi El-Gimal demonstrates five classes, A to E. The maximum contribution for volume comes from class C, which makes up 31.6% of the total population, while the lowest contribution is from class A, which comprises 10.5% (Fig. 2). All volume classes are represented in the last two populations occurring in wadi Al-Qu'lan and Sharm El-Madfa'a. The volume class C in wadi Al-Qu'lan population shows the highest contribution (33.9%), while both classes D and E have only a presence of 1.6%. Population in Sharm El-Madfa'a has the highest volume class F (25.7%) and the lowest two classes are A and G making up 1.4% (Fig. 2).

Population features relations

The relation between the diameter and canopy volume of *A. marina* population showed a positive relationship (Fig. 3). Strong correlation coefficients are obtained (r^2=0.92) for the

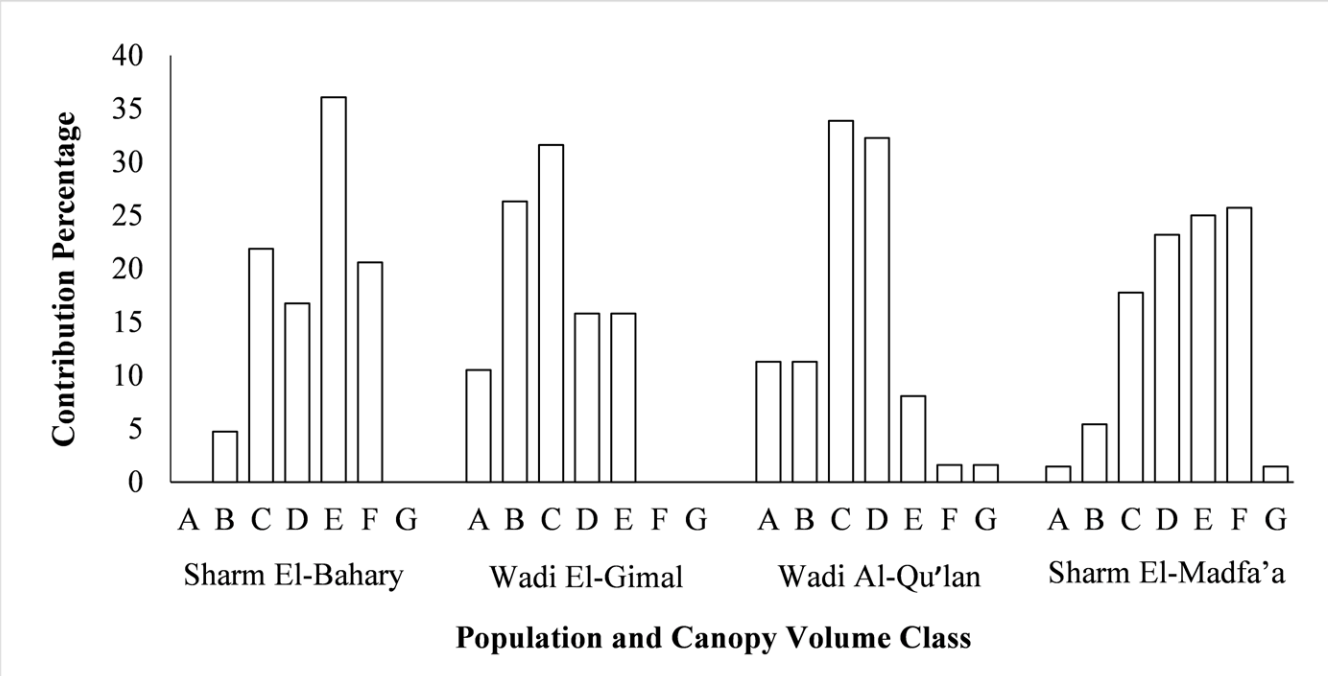

Fig. 2. Canopy volume class distribution in the four study populations of *A. marina*: Volume classes are: A<1 m^3, B=1–10 m^3, C=10–50 m^3, D=50–100 m^3, E=100–200 m^3, F=200–300 m^3 and G>300 m^3.

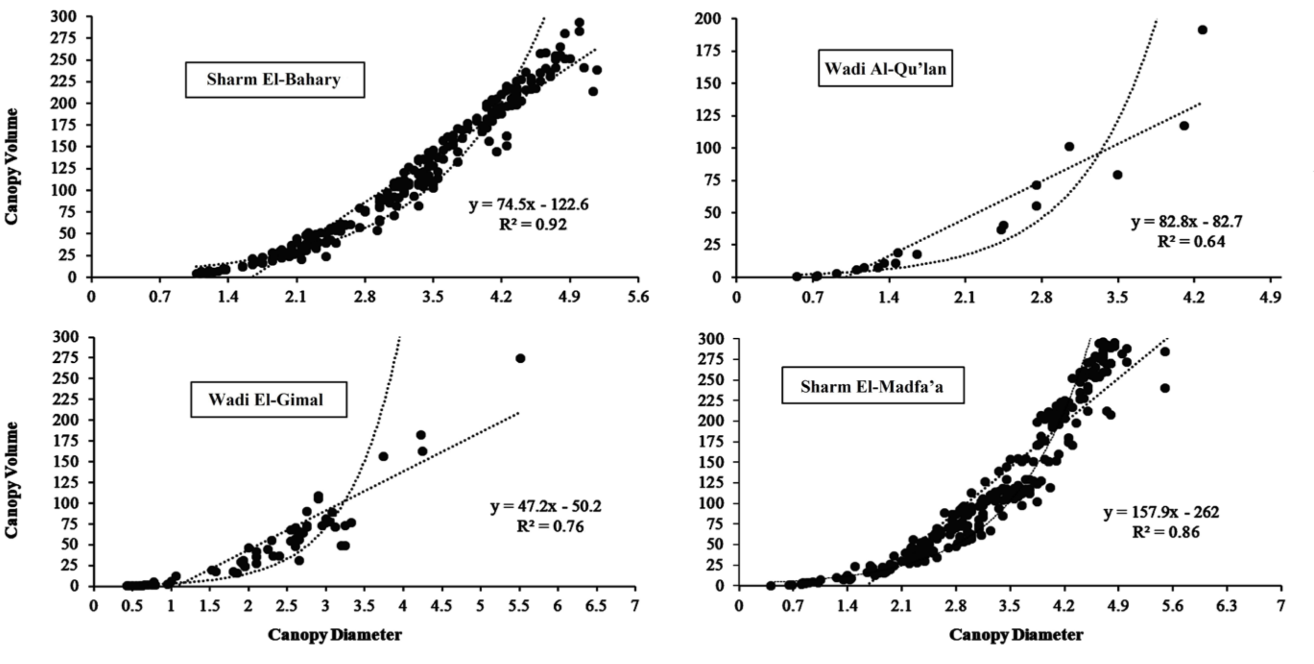

Fig. 3. The relationships between the individual canopy diameter and canopy volume of *A. marina* populations in the four study localities.

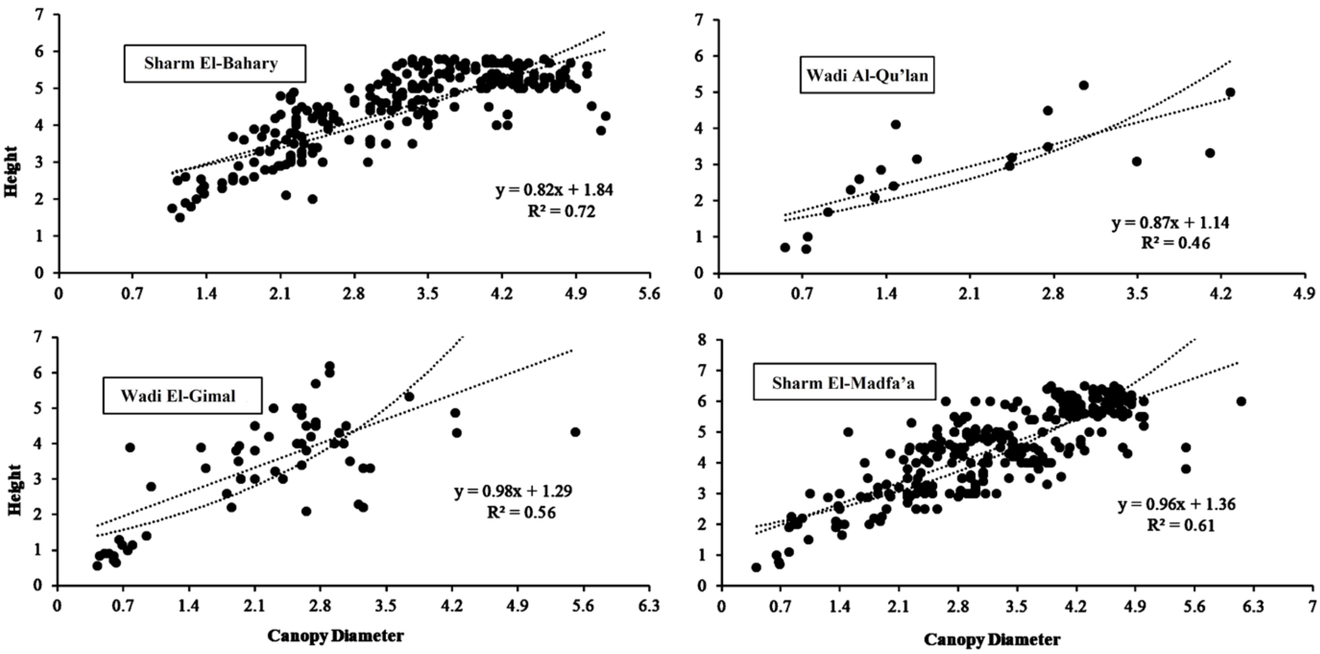

Fig. 4. The relationships between the individual height and canopy volume of *A. marina* populations in the four study localities.

Table 2. Comparison of growth performance (mean±SE) of *A. marina* populations in the four study localities, Significance levels are shown as (*): p<0.05, df=3.

Site	Sharm El-Bahry	Wadi El-Gimal	Wadi Al-Qu'lan	Sharm El-Madfa'a	T value	p value
Circumference	1.09±0.03	0.83±0.06	1.01±0.06	1.66±0.05	0.78	0.49 ns
Height	4.51±0.07	3.45±0.20	3.19±0.20	4.49±0.08	8.67	0.003*
Crown Diameter	3.28±0.07	2.22±0.14	2.36±0.14	3.17±0.07	6.17	0.009*
Crown Volume	245.6±10.6	109.4±15.3	138.1±15.3	255.5±11.3	5.02	0.015*
Height/Diameter	1.43±0.02	1.69±0.10	1.51±0.10	1.43±002	7.07	0.006*

population of Sharm El-Bahry and the weak correlation coefficients are obtained (r^2=0.63) for the population of wadi El-Gimal. Also, the relation between the individual heights and canopy volume showed a positive relation (Fig. 4). Strong correlation coefficients are obtained (r^2=0.72) for the population of Sharm El-Bahry and the weak correlation coefficients are obtained (r^2=0.46) for the population of wadi El-Gimal. All growth performance of *A. marina* differ significantly at the four localities except the circumference. Table 2 shows that circumference has the highest value (1.66 m) in Sharm El- Madfa'a and the lowest value (0.83 m) in Wadi Al- Gimal. The mean height has the highest value (4.51 m) in Sharm El-Bahry and the lowest value (3.19 m) in Wadi Al-Qu'lan. The variation in the canopy volume was the highest (255.5 m^3) in Sharm El-Madfa'a and the lowest (109.4 m^3) in Wadi El-Gimal. In addition, the crown diameter has the highest value (3.28 m) in Sharm El-Bahry and the lowest value (2.22 m) in Wadi El-Gimal. The mean height/diameter ratio was the highest (1.69) in Wadi El-Gimal and the lowest value (1.43) in Sharm El-Bahry and Sharm El-Madfa'a, respectively. The comparison of soil characteristics of *A. marina* populations in the four study localities showed significant variations in all variables except the silt content and SO_4 (Table 3).

Soil characteristics

Sand and silt contents have the highest values (81.7 and 8.1%, respectively) in Sharm El-Bahary and the lowest value (71.6 and 4.7%, respectively) in Sharm El-Madfa'a. The electric conductivity has the highest value (164.5 mmohs cm^{-1}) in Wadi El-Gimal and the lowest value (134.5 mmohs cm^{-1}) in Wadi Al-Qu'lan. The soil reaction (pH) has the highest values (8.15%) in Sharm El-Bahary and the lowest value (7.88) in Sharm El-Madfa'a. Organic carbon and $CaCO_3$ have the highest values (1.76 and 12.8%, respectively) in Wadi Al-Qu'lan and the lowest value (71.6%) for organic carbon in Sharm El-Bahary and 11.5% of $CaCO_3$ in Sharm El-Madfa'a. Sodium and calcium have the highest values (513.1 and 14.5 m-equiv l^{-1}, respectively) in Sharm El-Madfa'a and the lowest value (250.4 and 28.2 m-equiv l^{-1}, respectively) in Wadi El-Gimal. Potassium has the highest value (70 m-equiv

Table 3. Comparison of edaphic factors (mean±SE) of *A. marina* populations in the four study localities, Significance levels are shown as (*): p<0.05, df=3.

Localities		**Sharm El-Bahry**	**Wadi El-Gimal**	**Wadi Al-Qu'lan**	**Sharm El-Madfa'a**	**T value**	**p value**
Soil variables							
Sand		81.1±2.45	79.5±1.70	74.2±2.55	71.6±2.30	33.9	0.001*
Silt	%	10.8±0.55	15.4±2.50	20.4±1.25	23.7±0.50	5.91	0.01 ns
Clay		8.1±1.90	5.1±0.80	5.4±1.30	4.7±1.80	6.42	0.008*
EC (mmohs cm^{-1})		144±2.0	164.5±2.50	134.5±4.50	163.5±4.50	20.3	0.001*
pH		8.15±0.05	7.95±0.25	8.05±0.20	7.88±0.15	141	0.001*
OC	%	1.64±0.04	1.69±0.02	1.76±0.04	1.71±0.08	17.1	0.001*
$CaCO_3$		11.9±0.25	12.1±0.20	12.8±0.15	11.5±0.15	40.7	0.001*
Na		426.9±68.6	250.4±210	497.2±94.1	513.1±34.8	6.99	0.006*
K		70±10.0	57±3.0	59±11.0	67±5.0	19.9	0.001*
Ca	**(m-equiv l^{-1})**	31.1±3.11	28.2±0.59	39.4±1.65	41.5±1.81	10.6	0.002*
Mg		84.1±11.2	91.2±4.3	126.3±3.85	118.5±15.8	10.1	0.002*
Cl		434.7±14.0	494.3±31.6	557.5±31.6	652.1±7.0	11.5	0.001*
SO_4		2.83±0.92	2.01±0.34	0.76±0.01	1.84±0.28	2.06	0.131 ns

l^{-1}) in Sharm El-Bahary and the lowest (134.5 m-equiv l^{-1}) in Wadi El-Gimal. Magnesium and chloride have the highest values (126.3 m-equiv l^{-1}) for magnesium in wadi Al-Qu'lan and (652.1 m-equiv l^{-1}) for chloride in Sharm El-Madfa'a, while the lowest values (84.1 and 434 m-equiv l^{-1}, respectively) in Sharm El-Bahary. Sulphate has the highest value (2.83 m-equiv l^{-1}) in Sharm El-Bahary and the lowest value (0.76 m-equiv l^{-1}) in wadi Al-Qu'lan.

Discussion

Mangroves along the Red Sea coast of Egypt are conspicuous and their relative abundance varies with the locality. In dry years or during long-lasting dry periods, tree populations experience high mortality and low recruitment (Ward, Roher, 1997; Wiegand et al., 1999). The results of this study show that plant height, size index, and number growth performance such as height, diameter are more correlated to each other than the circumference. This agrees with the findings of van Rooyen et al., 1994 and Alcorn et al. (2001) for trees along the Nossob River bed in Kalahari Gemsbok National Park.

Size differences in plant populations may be caused directly or through differences in growth rates due to age difference, genetic variation, heterogeneity of resources, herbivory, and competition (Weiner, 1985). In the present study, the population of *A. marina* has positively skewed size distribution. The limited distribution may represent stable growing with low reproductive capacity. Such distributions may indicate a high juvenile mortality as well (Harper, 1977) but they nevertheless seem to represent long-term stability, since in most stable populations one would expect an excess of juvenile over mature individuals (Leak, 1965; Crisp, Lange, 1976; Moore, Bahadresa, 1978; El-Ghonemy et al., 1980; Goldberg, Turner, 1986).

The distribution of *A. marina* along the Red Sea coast of Egypt indicate an overlap in environmental requirements or tolerance of environmental stress. Mangroves are not restricted to specific soil conditions although each community tends to show niche relation to certain soil variable. Hence, several soil properties could serve as indicators for community type differentiation and distribution as well (Ukpong, 1995; Al-Mutairi, 2017). For example, the soil characteristics of *A. marina* populations in the four study localities showed significant variations in all soil variables except the silt content and SO_4. This agrees with the findings of El-Khouly, Khedr (2007) for the zonation pattern of *A. marina* and *Rhizophora mucronata* along the Red Sea Coast, Egypt.

Conclusion

The findings of this study help to put forward a management plan to conserve and sustainable use the *Avicennia* trees as based on demography. Also, the distribution of *Avicennia marina* to varying condition of soil factors. However, the influence of other environmental factors needs to be analyzed before the current zonation pattern can be properly understood.

Author contributions

The author has made substantial contributions to study conception, study design, and interpretation of data. The soil analyzed the Lab of Desert Research Center.

References

Alatar, A.A., El-Sheikh, M.A, Thomas, J. Hegazy, A.K. & El Adawy H.A. (2015). Vegetation, floristic diversity and size-classes of *Acacia gerrardii* in an arid wadi ecosystem, *Arid Land Res. Manag*., 29(3), 335–359. DOI: 10.1080/15324982.2014.968692.

Alcorn, P.J., Dingle, J.K. & Hickey J.E. (2001). Age and stand structure in a multi-aged wet eucalypt forest at the Warra silvicultural systems trial. *Tasforests*, 13, 245–259.

Allen, S.E., Grimshaw, H.M., Parkinson, J.A. & Quarmky C. (1989). *Chemical analysis of ecological materials*. London: Blackwell.

Al-Mutairi, Kh.A. (2017). Influence of soil physical and chemical variables on species composition and richness of plants in the arid region of Tabuk, Saudi Arabia. *Ekológia (Bratislava)*, 36(2), 112–120. DOI: 10.1515/eko-2017-0010.

Baker, P.J., Buyavejchewin, S., Oliver, C.D. & Ashton P.S. (2005). Disturbance history and historical stand dynamics of a seasonal tropical forest in western Thailand. *Ecol. Monogr.*, 75, 317–343. DOI: 10.1890/04-0488.

Ball, M.C., Cowan, I.R. & Farquhar C.D. (1988). Maintenance of leaf temperature and the optimization of carbon gain in relation to water loss in a tropical mangrove forest. *Aust. J. Plant Physiol.*, 15, 263–276. DOI: 10.1071/PP9880263.

Bastian, O., Cudlín, P., Pechanec, V., Brzoska, P., Štěrbová, L., Včeláková, R., Purkyt, J. & Grunewald K. (2020). Assessments of biodiversity and habitat services in cities – exemplified by Dresden (Germany) and Liberec (Czech Republic). *Ekológia (Bratislava)*, 39(2), 174–189. DOI: 10.2478/eko-2020-0013.

Buyavejchewin, S., LaFrankie, J.V., Baker, P.J., Kanzaki, M., Ashton, P.S. & Yamakura T. (2003). Spatial distribution patterns of the dominant canopy dipterocarp species in a seasonal dry evergreen forest in western Thailand. *For. Ecol. Manag.*, 175, 87–101. DOI: 10.1016/S0378-1127(02)00126-3.

Crisp, M.D. & Lange R.T. (1976). Age structure, distribution and survival under grazing of the arid–zone shrub *Acacia burkitti*. *Oikos*, 27, 86–92. DOI: 10.2307/3543436.

Curtis, J.T. & McIntosh R.P. (1951). An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology*, 32, 476–496. DOI: 10.2307/1931725.

El-Ghonemy, A.A., Wallace, A. & Romney E.M. (1980). Frequency distribution of numbers of perennial shrubs in the northern Mojave Desert. *Great Basin Naturalist Memoirs*, 40, 34–38. https://www.jstor.org/stable/23376657.

El-Khouly, A.A. & Khedr A.A. (2007). Zonation pattern of *Avicennia marina* and *Rhizophora mucronata* along the Red Sea Coast, Egypt. *World Applied Sciences Journal*, 2(4), 283–288.

Goldberg, D.E. & Turner R.M. (1986). Vegetation change and plant demography in permanent plots in the Sonoran Desert. *Ecology*, 67, 695–712. DOI: 10.2307/1937693.

Harper, J.L. & White J. (1974). The demography of plants. *Annu. Rev. Ecol. Syst.*, 5, 419–463. DOI: 10.1146/annurev.es.05.110174.002223.

Harper, J.L. (1977). *Population biology of plants*. London: Academic Press.

Hay, J.D. (2002). Aspectos da ecologia de populações de plantas nativas no cerrado do Brasil. In Araújo, E.L., Moura, A.N., Sampaio, E.V.S.B., Gestinari, L.M.S. & Carneiro J.M.T. (Eds.), *Biodiversidade, conservação euso sustentável da flora do Brasil* (pp. 153–157). Recife: Imprensa Universitária UFRPE.

Hegazy, A.K. & Elhag M. (2006). Considerations of demography and life table analysis for conservation of *Acacia tortilis* in South Sinai. *World Applied Sciences Journal*, 1, 97–106.

Hutchings, M.J. (1997). The structure of plant populations. In Crawley, M.J. (Ed.), *Plant ecology* (pp. 325‑358). Oxford: Blackwell Scientific Company.

Kassas, M. & Zahran M.A. (1965). Studies on the ecology of the Red Sea coastal land. II. The district from El-Galala El-Qibliya to Hurghada. *Bulletin of Social Geography, Egypt*, 38, 185‑193.

Kassas, M. & Zahran M.A. (1967). On the ecology of the Red Sea littoral salt marsh, Egypt. *Ecol. Monogr.*, 37, 297–316. DOI: 10.2307/1942326.

Leak, W.B. (1965). The J–shaped probability distribution. *For. Sci.*, 11, 405–409. DOI: 10.1093/forestscience/11.4.405.

Mckee, K.L. (1993). *Determination of Mangrove species distribution patterns in Neotropical forests: biotic and abiotic factors affecting seedling survival and growth*. Ph.D. dissertation, Louisiana state University. Historical Dissertations and Theses. 5656. https://digitalcommons.lsu.edu/gradschool_disstheses/5656.

Moore, P.D. & Bhadresa R. (1978). Population structure, biomass and pattern in a semi–desert shrub *Zygophyllum eurypterum,* in the Turan Biosphere Reserve of northeastern Iran. *J. Appl. Ecol.*, 15, 837–845. DOI: 10.2307/2402779.

Mosallam, H.A., Shawky, R.A & Hashim A.A. (2018). Size structure and floristic diversity of *Acacia* trees population in Taif Area, Saudi Arabia. *Journal of Biodiversity Endangered Species*, 6(1), 1–7. DOI: 10.4172/2332-2543.1000210.

Pickett, S.T.A. & White P.S. (1985). *The ecology of natural disturbance and patch dynamics*. San Diego: Academic Press.

Pickett, S.T.A., Kolasa, J., Armesto, J.J. & Collins S.L. (1989). The ecological concept of disturbance and its expression at various hierarchical levels. *Oikos*, 54, 129–136. DOI: 10.2307/3565258.

Rayan, J., Garabet, S., Harmson, K. & Rashid A. (2001). *Soil and plant analysis laboratory manual.* Aleppo: ICARDA.

Saenger, P. (2002). *Ecological assessment of mangroves in Egypt*. Cairo: FAO.

Saxena, A.K. & Singh J.S. (1984). Tree population structure of certain Himalayan forest association and implications concerning their future composition. *Plant Ecol.*, 58, 61–69. DOI: 10.1007/BF00044928.

Shaltout, K.H. & Ayyad M.A. (1988). Structure and standing crop of Egyptian *Thymelaea hirsuta* populations. *Vegetatio*, 74, 137–142. DOI: 10.1007/BF00044738.

Ukpong, I.E. (1995). An ordination study of mangrove swamp communities in West Africa. *Vegetatio,* 116, 147–159. DOI: 10.1007/BF00045305.

van Rooyen, N., Theron, G.K. & Breedenkamp G.J. (1994). *Population trends of woody species in the Kalahari Gemsbok National Park from 1978 to 1994.* Arid Zone Ecology Forum (AZEF). National Research Foundation, Pretoria, Karoo National Park, Beaufort West.

Ward, D. & Roher C. (1997). Anthropogenic causes of high mortality and low recruitment in the three *Acacia* tree taxa in the Negev desert Israel. *Biodivers. Conserv.*, 6, 877–893. DOI: 10.1023/B:BIOC.0000010408.90955.48.

Weiner, J. (1985). Size hierarchies in experimental populations of annual plants. *Ecology*, 66, 743–752. DOI: 10.2307/1940535.

Wiegand, K., Jeltsch, F. & Ward D. (1999). Analysis of the population dynamics of *Acacia* trees in the Negev desert, Israel with a spatially explicit computer simulation model. *Ecol. Model.*, 117, 203–224. DOI: 10.1016/S0304-3800(98)00199-9.

Zahran, M.A. (1977). Wet formations of the African Red Sea coast. In Chapman, V.J. (Ed.), *Wet coastal ecosystem* (pp. 215–231). Amsterdam: Elsevier.

Zahran, M.A. (1982). Ecology of the halophytic vegetation of Egypt. In D.N. Sen & K.S. Rajpurohit (Eds.), *Tasks for vegetation science* (pp. 3‑20). The Hague: Dr. Junk.