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Research Article

Ecological Assesment of Flora and Fauna Following Dune Stabilization in the El Mesrane Region (Djelfa, Algeria)

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Abstract:

Dune stabilization is wildly applied in arid and semi-arid regions of Algeria, representing one of the most effective ecological restoration strategies against desertification, yet its ecological outcomes remain scarce. This study evaluate the influence of dune fixation on soil properties, vegetation structure and faunal assemblages in The El Mesrane dune system (Djelfa, Algeria).Six stations, including three stabilized dunes and three adjacent mobile dunes were surveyed through soil analyses, floristic survey, and standardized sampling of invertebrates, reptiles, birds and small mammals. Stabilized sites showed improved edaphic conditions, along with higher species richness and diversity for all biological groups. Diversity indices (Shannon, Simpson and evenness) confirmed a more structured and balanced community in fixed dunes. Statistical analyses indicated significant differences between dunes types for both soil parameters and biodiversity metrics. These findings highlight the positive efficiency of dune fixation on habitat structure and biological diversity in arid steppe ecosystems of central Algeria.

1. Introduction

Desertification and land degradation are major environmental challenges in arid and semi-arid regions, particularly in North Africa, where climatic aridity, wind erosion, overgrazing and the depletion of natural vegetation cover accelerated ecosystem decline [1, 2]. In Algeria, large portions of the steppe and pre-Saharan zones have experienced severe land degradation, resulting in soil erosion, vegetation loss, and declining biological productivity [3, 4]. Steppe ecosystems play a crucial role in both ecological and socio-economic balance, and their restoration has therefore become a national priority.
Since the 1970s, dune fixation has been widely implemented as part of large-scale restoration programs aimed at stabilizing mobile sands and rehabilitating degraded steppe ecosystems. Mechanical stabilization combined with biological fixation, through the planting of woody and shrubby xerophytic species remains one of the most effective technique for reducing aeolian sand mobility and enhancing soil stability [5, 6]. Despite the long history of intervention, most studies have addressed either pedology or vegetation dynamics [7], while integrated assessment simultaneously examining soil properties, flora and fauna at the dune-system scale remain scarce. Understanding how dune fixation modifies both abiotic and biotic processes is essential for evaluating restoration trajectories.Stabilized dunes often create microhabitat that facilitate vegetation recovery and the return of faunal communities, particularly soil arthropods, which are recognized as sensitive bioindicators of environmental due to their rapid respond to changes in vegetation structure, organic matter and soil moisture [8]. The El Mesrane dune system (Djelfa, central Algeria) represents a typical Saharo-steppe environment, where fixation operations have been undertaken since 1982. This area provides an appropriate context to assess the ecological outcomes of dune stabilization.

This study aims to evaluate the effects of dune fixation on soil properties, vegetation structure and faunal assemblages in the El Mesrane dune system, to assess the ecological benefits of restoration on soil stability and biodiversity. Specially, it assesses (i) the physicochemical properties of soils in fixed and mobile dunes, (ii) the changes in floristic composition and richness, and (iii) the response of arthropod and reptile assemblages to vegetation recovery. By integrating multiple biological component, this work provides an updated baseline on the ecological functioning of stabilized dunes and contributes to a better understanding of ecosystem restoration strategies in arid steppe region of North Africa.

2. Material and Methods

2.1 Study Area

The study was conducted in El Mesrane region, within th municipality of Hassi Bahbah, 32 km north Djelfa province (central Algeria). The area is located in a depression along the northern edge of the Saharan Atlas steppe zone, and represents a transitional zone between the semi-arid steppes of the north and the pre Saharan expanses of the south. This particular geographical position is vulnerable to desertification [9]. El Mesrane dune extends over 200 km in length and 4-7 km in width. Soils are essentially sandy to sandy-loamy, very poor in organic matter. The natural vegetation consists of xerophytic and steppe taxa such as Field Wormwood (Artemisia campestris L.) and Dwarf Esparto Grass (*Lygeum spartum L.*). In addition to several introduced species that have been planted as part of dune fixation programs to combat sand encroachment including Barbary fig (*Opuntia ficus-indica (L.)* MILL.), French tamarisk (Tamarix gallica L.), Mediterranean Saltbush (*Atriplex halimus L.)*[10].

2.2 Sampling design

Six study stations were selected to compare fixed and mobile dune. Three fixed stations were chosen, each stabilized by different intoduced species, and characterized by distinct vegetation cover:

(i) French tamarisk *(Tamarix gallica L.)*,
(ii) A combination of Aleppo Pine (*Pinus halepensis* MILL.) and Barbary fig (*Opuntia ficus-indica (L.)* MILL.),
(iii) A combination of Mediterranean Saltbush (*Atriplex halimus L.)* and White Weeping Broom (*Retama raetam* (FORSSK.) WEBB& BERTHEL).

Three additional control stations were established on nearby mobile dunes, characterized by sparse vegetation, dominated by xerophytic species such as Mediterranean saltwort (Salsola vermiculata L.) and Three-awn grass, locally known as Drinn (Stipagrostis pungens (Desf.) DE WINTER). For each station, the GPS coordinates, altitude, and slope were recorded in the field together with vegetation type and soil cover. (Table1).To situate the study area, Figure 1 illustrates the sampling station location at three spatial scales: national, regional, and local.

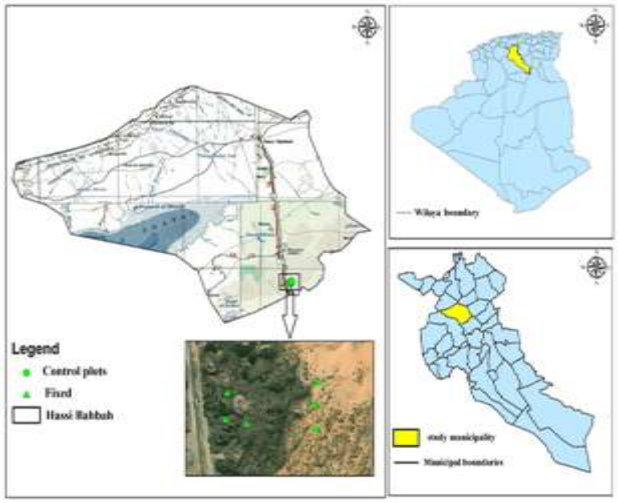

Figure 1. *Location of the study area at El Mesrane (Hassi Bahbah municipality, Djelfa province, Algeria) at three spatial scales national, regional, and local.*

2.3 Climate

The El Mesrane region belongs to saharo-steppe bioclimatic zone, it has an arid to lower semi-arid climate (ONM, 1980-2020). Annual precipitation averges 250 and 290 mm, with high inter-annual variability During the sampling year (2020 –2021), only 230 mm were recorded. Temperatures range

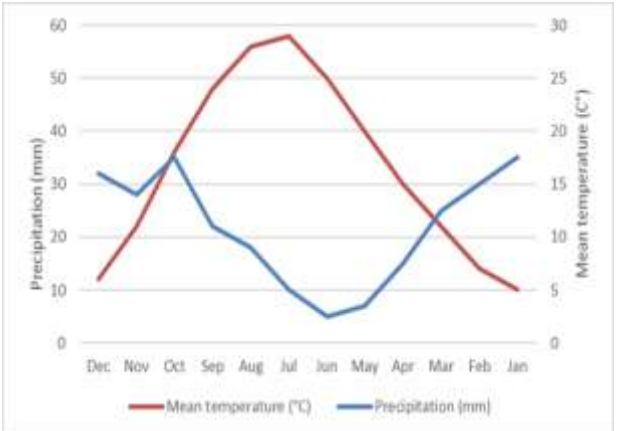

Figure 2. *Ombrothermic diagram of El Mesrane (Djelfa, Algeria,1980-2020).Data from Djelfa meteorological station (ONM)*

Table 1. *Main characteristics of the sampling stations at El Mesrane (Djelfa, Algeria)*

Station	Type	Dominant species	Altitude [m]	Slopes [%]	General observations
F1-F3	Fixed	*Tamarix gallica L. Pinus halepensis Mill.Opuntia ficus-indica (L.) Atriplex halimus L. Retama raetam (FORSSK.) WEBB & BERTHEL*	966-985	3.1-4.6	Old plantation, presence of litter , shrub formation
C1-C3	Control	*Peganum harmala L Salsola vermiculata L Stipagrostis pungens* (Desf.) DE WINTER	970-973	2.1-5.2	Mobile dunes, scarttered vegetation Active shifting dunes,

from 7°C in winter to over 40°C. These climatic constraints reduce vegetation cover and affect fauna ,exert a strong influence on soil properties and dynamics increasing their vulnerability [4,7].

2.4 Pedological characterization

A total of 24 soil samples were collected. In the fixed sites, three replicates were taken under *(Tamarix gallica* L.*)*, six under the mixed plantation of *(Opuntia ficus-indica* (L.) MILL.) and (*Pinus halepensis* MILL) (three per taxon), and six under the mixed plantation of (*Atriplex halimus* L.*)* and (*Retama raetam* (FORSSK.) WEBB & BERTHEL).In the mobile dunes, three samples were collected from each control station. Analyses included particle-size distribution, pH, Organic matter (OM), Electrical conductivity (EC), and Total carbonates.

2.5 Vegetation cover characterization

Floristic surveys were conducted during the spring of 2020 and 2021, ensuring that the vegetation data could be directly related to the ecological context of faunal observation. In each station, three 10×10 m quadrat were used to record perennial species, with three 1×1 m sub-quadrats for annual and short cycle species. This nested design commonly applied in arid-zone studies [11].Nomenclature was updated according to recent checklist and the Algerian national protection list.

2.6 Invertebrates

Eight Barber traps were installed, one per control station, and one under each main fixing species in stabilized dunes. Traps were operated monthly over a full annual cycle (June 2020-May2021).

2.7 Vertebrates

2.7.1. Reptiles

Reptiles were surveyed through visual encounter and opportunistic capture, completed by indirect evidence such as tracks, shed skins and burrows [12].

2.7.2 Birds

Qualitative observations were conducted during morning (6:00-9:00) and late afternoon (17:00-19:00) activity peaks. All birds seen or heard were recorded following the general principles of point-count survey previously applied in the Chebika steppe (Djelfa region).[13]

2.7.3 Mammals:

Mammals were detected mainly through tracks, pellets, burrows, feeding traces, and occasionally dawn observation [14].Complementary information on elusive species was obtained from local forest guards familiar with the area.

2.8 Ecological indices

Species richness (S) was defined as the total number of species per station. Diversity metrics included : Shannon-Weiner diversity was used to quantify diversity : (H')

$$H' = -\Sigma\, pi\, ln\, pi. \quad (1)$$

Were pi represents the relative abundance of species i.

Species evenness (E) which measures how uniformly individuals are disturbed among taxa:
$E = H'/\ln S$ (2)

Simpson's index of diversity (1-D) was computed to evaluate dominance patterns:

$$1 - D = 1 \sum p_i^2 \quad (3)$$

When parametric assumptions were met, one-way ANOVA was applied to compare dune categories.

3. Results

3.1 Pedological properties:

Soil analyses revealed clear differences between dune stations (Table 2). Stabilized sites displayed slightly finer textures, with higher proportions of silt and clay together with increased organic matter. while mobile dunes was dominated by sand and very loworganic content. The results indicate a gradual stabilization of the surface layer in vegetated areas. Soil pH remained alkaline acroos all sites, slightly lower values recorded under *Atriplex halimus* L. and *Retama raetam* (FORSSK.) WEBB & BERTHEL.Electrical conductivity (EC) remained low, with slightly elevated values in plots dominate by the *Tamarix gallica* L.

Table 2. *Main pedological characteristics of stabilized and non-stabilized station in El Mesrane (Djelfa, Algeria)*
******* *EC = Electrical Conductivity. Values correspond to the mean of surface samples (0-20 cm depth)*

Station	Sand [%]	Silt [%]	Clay [%]	pH	Organic Matter [%]	EC [dSm^{-1}]
Fixed dunes (mean)	79.4	14.7	5.9	7.9	0.66	0.44
Mobile dunes(mean)	90.5	7.1	2.4	8.2	0.23	0.28

3.2 Floristic composition

The floristic survey was conducted during relatively dry year with an annual rainfall reaching approximately 230mm, slightly below the regional average (250-280mm). A total of 43 vascular plant species, belonging to 18 botanical family were recorded from the six study stations, with, Amaranthaceae, Asteraceae, Fabaceae, and Poaceae being the most represented families. Table 3 presents the most representative and ecologically significant taxa, observed in both fixed and mobile dunes. Stabilized dunes were dominated by perennial xerophytic taxa such as, *Atriplex halimus* L, *Retama raetam* (FORSSK.) WEBB & BERTHEL., and *Lygeum spartum* L. In contrast, mobile dunes were mostly clolonized by psammophytic ephemeral herbs including *Stipagrostis pungens* (Desf.) DE WINTER, *Malcolmia aegyptiaca Spr*.Several of the recorded species, hold patrimonial or conservation interest Notably *Retama raetam* (FORSSK.) WEBB & BERTHEL., *Peganum harmala* L., *Stipagrostis pungens* (DESF.) DE WINTER., and *Saccocalyx satureioides* COSS. & DUR are cited in national conservation list, due to their ecological roles, restricted distribution and ethnobotanical values [10].

3.3 Faunistic composition:

The analysis of the arthropods collected by Barber traps revealed a diverse assemblage. A total of 2112 individuals were identified, strongly dominated by insects (92.3%) followed by Arachnides (6,8%) and Myriapods(0,9%). These individuals belong to more than twenty families disturbed across the fixed and mobile dunes stations. The main taxonomic groups and their representative species are summarized in the table 4.The highest diversity and abundance are found in fixed dunes with more than 80% of all captures, it reflects how vegetation and litter accumulation provide favorable microhabitats. Among insects, Formicidae (28.7%), Tenebrionidae (25.5%) and Carabidae (14.6%) were the most dominant families; they are a key component of arid and steppe ecosystem, contributing to soil aeration, organic matter recycling [1; 15]. The presence of Carabidae and Scarabaeidae, particulary abundant under *Pinus halepensis MILL.*, *Tamarix gallica.*, indicated improved soil conditions in stabilized dunes [16] . Arachnids, although less abundant, were mainly represented by Lycosidae, Gnaphosidae and Dysderidae, mostly associated with stabilized sandy substrates, while *Buthus occitanus* (AMOREUX, 1789) occurred infrequently across both habitats. The occasional detection of Opiliones and Solifugae emphasize the gradual recolonization of higher trophic level predators [10,17]. Amongst the dominant species, Formicidae in particular *Cataglyphis bicolor* (FABRICIUS, 1793) and Messor barbarus (LINNE, 1767) were the most abundant and far-reaching all fixed dunes. These ants are known for their ecological role in arid system, by dispersion of seeds, bioturbation, soil aeration, contributing to enhancement, of soil porosity and nutrient cycling [16]. Furthermore Tenebrionidae principally presented by *Akis goryi* (SOLIER, *1837*), *Blaps gigas* (LINNE,1767), often found beneath *Pinus halepensis* MILL. and *Tamarix gallica.* As detritivorous beetles, they are one of key decomposers in sandy habitats, contributing to liter decomposition and organic matter enrichment. Their freauent presence within fixed dunes reflects improved microclimatic conditions and trophic conditions [10,16] .

Table 3. *Representative flora of the El Mesrane dune system (Djelfa, Algeria, 2020-2021).*

Family	Representative species	Life form	Ecological group/Role	Occurrence	Abundance
Amaranthaceae	*Atriplex halimus* L	Shrub	Halophytic stabilizer (introduced)	Fixed	Dominant in fixed dunes
	Salsola Vermiculata L	Shrub	Halophytic,salt tolerant	Fixed/ Mobile	Frequent
	Noaea mucronata (FORSSK.) ASCH. & SCHWEINF.	Shrub	Xerophytic steppe shrub	Fixed	Rare
Apiaceae	*Thapsia garaganica* L	Perennial herb	Xerophytic/ Toxic steppe plant	Fixed/Mobile	Occasional
Asteraceae	*Artemisia campestris* L.	Shrub	Transitional xerophyte	Fixed/Mobile	Less frequent
	Atractylis serratuloides SIEBER ex CASS.	Perennial herb	Xerophytic, medicinal	Fixed/Mobile	Occasional
	Carduus getulus POMEL	Biennial herb	Thorny xerophyte	Fixed/Mobile	Locally Frequent
	Onopordum arenarium (Desf.) POMEL	Biennial	Thorny xerophyte, semi fixed dunes	Fixed	Occasional
	Nolletia chrysocomoides (Desf.) CASS. ex LESS.	Herb	Xerophytic	Fixed/mobile	Occasional
	Senecio gallicus VILL.	Annual herb	Ephemeral	Mobile	Rare
Brassicaceae	*Eruca vesicaria* L. *Car.* ssp. *pinnatifida* (Desf.) E. et M.	Annual	Ruderal to psammophytic	Fixed/Mobile	Less Frequent
	Malcolmia aegyptiaca Spr.	Annual	Ephemeral psammophyte	Mobile	Less frequent
	Pseuderucaria teretifolia (Desf.) O. E. SCHULZ	Annual	Psammophyte Cruciferae	Mobile	Occasional
Cactaceae	*Opuntia ficus-indica* (L.) Mill.	Succulent	Introducted dune stabilizer (Green Dam project)	Fixed	Locally abundant
Caprifoliaceae	*Scabiosa arenaria* FORKS.	Perennial	Psammophytic, fixed dunes	Fixed	Frequent
Elaeagnaceae	*Elaeagnus angustifolia* L.	Tree/shrub	Introduced nitrogen-fixing species,dune stabilizer	Fixed	Less frequent
Euphorbiaceae	*Euphorbia guyoniana* BOISS. & REUT.	Sub-shrub	Xerophytic, semi-arid indicator	Fixed/Mobile	Frequent
Fabaceae	*Retama raetam* (FORSSK.) WEBB & BERTHEL.	Shrub	Native stabilizer/introduced	Fixed/Mobile	Dominant in fixed dunes
	Astragalus incanus L.	Perennial Herb	Steppe indicator	Fixed	Frequent
Geraniaceae	*Erodium glaucophyllum* (L.) L'HER.	Perennial herb	Sand tolerant, semi fixed dunes	Fixed/Mobile	Occasional
Lamiaceae (Labiatae)	*Saccocalyx satureioides* COSS. & DUR	Perennial sub-shrub	Aromatic xerophyte, characteristic of steppic dunes	Fixed /Mobile	Frequent
	Marrubium deserti (de NOE) COSS	Perennial	Steppe xerophyte	Fixed	Frequent
Pinaceae	*Pinus halepensis* MILL.	Tree	Introduced dune stabilizer	Fixed	Dense to dominant locally
Plantaginaceae	*Plantago albicans* L.	Perennial herb	Steppe colonizer, semi fixed dunes	Fixed/Mobile	Abundant
Poaceae	*Cutandia dichotoma* (FORSSKo.) TRAB**.**	Grass	Psammophyte	Mobile	Less frequent
	Cynodon dactylon (L.) PERS.	Grass	Pioneer grass, soil binder	Mobile	Dominant
	Lygeum spartum L.	Grass	Steppe colonizer	Fixed/Mobile	Frequent to dominant (depending on station)
	Stipagrostis pungens (DESF.) DE WINTER	Grass	Psammophytic dune builder	Mobile	Dominant in mobile dunes
Solanaceae	*Lycium arabicum* SCHWEINF. ex BOISS.	Shrub	Native xerophyte, thorny protector of semi fixed dunes	Fixed/Mobile	Less frequent
Tamaricaceae	*Tamarix gallica*	Shrub	Native halophyte, riparian stabilizer	Fixed/Mobile	Frequent
Thymelaeaceae	*Thymelaea microphylla* COSS. & DURIEU ex MEISN.	Sub-Shrub	Psammophytic stabilizer	Fixed	Frequent
Zygophyllaceae	*Peganum harmala* L.	Perennial herb	Xerophytic medicinal plant, steppe - dune transition	Fixed – Peripheral	Peripheral (rare to occasional)

Table 4. *Relative abundance and dominant taxa of invertebrate recorded in the El Mesrane dune system.*

Class	Oder	Family	Represantive species	Dominant habitat/host plant	Relative abundance
Arachnida	Araneae	Dysderidae	*Dysdera hamifera* (SIMON, 1911)	Fixed dunes (*Tamarix gallica)*	1.2
		Gnaphosidae	*Nomisia castanea* (DALMAS,1921), *Zelotes aeneus* (SIMON, 1878)	Fixed dunes	1.0
		Lycosidae	*Alopecosa albofasciata* (Brullé, 1832), *Lycosa tarantula*	Fixed dunes (*Atriplex halimus* L, *Retama raetam* (FORSSK.) WEBB & BERTHEL.	2.1
		Zodariidae	*Zodarion kabylianum* (DENIS, 1937)	Semi fixed dunes,(*Atriplex halimus* L)	0.7
	Opiliones	-	*Opilione sp*	Semi-fixed dunes	0.5
	Scorpiones	Buthidae	*Buthus occitanus* (AMOREUX, 1789)	Fixed dunes (*Tamarix gallica)*	0.6
	Solifugae	-	*Solifugae sp*	Fixed dunes (*Tamarix gallica)*	0.7
Inescta	Coleoptera	Aphodiidae	*Aphodius sp*		1.8
		Carabidae	*Anthia sexmaculata* (FABRICIUS, 1787), Graphipterus serrator (FORSKAL , 1775), *Cymindis setifeensis* (LUCAS, 1842)	Fixed dunes (*Tamarix gallica, Retama raetam (FORSSK.) WEBB & BERTHEL., Pinus halepensis MILL.)*	14.6
		Chrysomelidae	*Timarcha punctella* (MARSEUL, 1870)	Semi-fixed dunes	1.7
		Cryptophagidae	*Cryptophagus sp.*	Fixed dunes	1.0
		Curculionidae	*Curculionidae sp., Plagiographus-sp*	Fixed dunes (*Atriplex halimus* L.)	3.0
		Geotrupidae	*Thorectes intermedius* (COSTA, 1827)	Fixed dunes	0.9
		Histeridae	*Hister sp.*	Fixed dunes (*Atriplex halimus* L. *Pinus halepensis MILL.*)	0.8
		Scarabaeidae	Rhizotrogus sp, *Scarabaeus sacer* (LINNE, 1758)	Semi-fixed dunes (*Retama raetam (FORSSK.) WEBB & BERTHEL))*	5.0
		Staphylinidae	*staphylinus sp*	Fixed dunes (*Pinus halepensis MILL.)*	1.1
		Tenebrionidae	*Adesmia metallica, Akis goryi* (SOLIER, *1837*), *Blaps gigas* (LINNE,1767), *Stenosis minuta* (*SOLIER*, 1838), *Pimelia mauritanica (*SOLIER, 1836)	Fixed dunes (*Pinus halepensis MILL., Retama raetam (FORSSK.) WEBB & BERTHEL) , Tamarix gallica,)*	25.5
	Diptera	-	*Diptera sp*	Fixed dunes	3.2
	Collombola		*Collembola sp*	Humid microhabitats under (*Atriplex halimus* L)	1.0
	Hymenoptera	Formicidae	*Cataglyphis albicans (ROGER,1859) Cataglyphis bicolor* (FABRICIUS, 1793), *Camponotus barbaricus, Messor barbarus* (LINNE, 1767)	All fixed station, maximum under *Pinus halepensis MILL., Tamarix gallica.*	28.7
	Lepidoptera	-	*Lepidoptera sp*	Fixed dunes	1.6
	Orthoptera	Acrididae	*Acrotylus patruelis* (HERRICH–SCHAEFFER, 1838)	Fixed dunes (organic matter zones)	2.4
		Pyrgomorphidae	*Pyrgomorpha cognata* (KRAUSS, 1977)		
Myriapoda	Chilopoda	Scolopendridae	*Scolopendra morsitans* (LINNE, 1758)	Fixed dunes (*Atriplex halimus* L.)	0.9

Table 5. *Reptile species recorded across fixed and mobile dunes at El Mesrane (Djelfa, Algeria).*
Symbols: + = occasional; ++ = frequent; +++ = abundant

Family	Species	Ecological status	Fixed dunes	Mobile dunes
Chamaeleonidae	*Chamaeleo chamaeleon* (LINNE, 1758)	Arboreal, heliophilous	+	-
Lacertidae	*Acanthodactylus scutellatus*. (AUDOUIN 1827)	Psammophilous,abundant	+++	++
Lacertidae	*Acanthodactylus boskianus (DAUDIN, 1802)*	Xerophilous,thermophilous	++	+
Lacertidae	*Mesalina guttulata* (LICHTENSTEIN, 1823)	Sand-dwelling opportunistic	++	+++
Boidae	*Eryx jaculus (LINNE,1758)*	Fossorial, nocturnal	++	+
Lamprophiidae	*Malpolon monspessulanus* (HERMANN, 1804)	Opportunistic predator	+	-

Table 6. *Bird species recorded across fixed and mobile dune stations in El Mesrane dunes (Djelfa, Algeria).*
Symbols: + = occasional; ++ = frequent; +++ = abundant

Family	Species / Common name	Fixed dunes	Mobile dunes	Seasonal activity peak
Alaudidae	*Alauda arvensis* (Linnaeus, 1758) / Eurasian skylark	++	-	Winter-Spring
	Ammomanes deserti (LICHTENSTEIN, MHK, 1823) / Desert lark	++	+++	Spring-Summer
	Galerida cristata (LINNE , 1758) / Crested lark	+++	++	All year
Columbidae	*Streptopelia decaocto* (FRIVALDSZKY, 1838) / Eurasian collared dove	+	-	All year
Falconidae	*Falco tinnunculus* (LINNE, 1758) /Common kestrel	+	+	Spring-Summer
Glareolidae	*Cursorius cursor* (Latham, 1787) / Cream-colored courser	+	++	Spring-Summer
Laniidae	*Lanius excubitor* / Great grey shrike	++	+	Spring-Summer
Muscicapidae	*Oenanthe deserti* (TEMMINCK, 1825) / Desert wheatear	+	++	Spring-Autumn
	Saxicola rubetra (LINNE, 1758) / Whinchat	++	-	Spring-Autumn
Pteroclidae	*Pterocles alchata* (LINNE, 1766) / Pin-tailed sandgrouse	+	++	Summer-Autumn
Sylviidae	*Sylvia deserticola* (TRISTRAM, 1859) / Common blackbird	+++	+	Spring-Autumn

Table 7. *Mammalian species recorded in the dune cordon of El Mesrane (Djelfa, Algeria).*

Family	Species /Common name	Habitat preference	Occurrence
Canidae	*Vulpes vulpes* (LINNE, 1758) / Red fox	Fixed & mobile dunes	+
Felidae	*Felis lybica* (FORSTER, 1780) / African wildcat	Semi-fixed dunes Tamarix understorey	+
Muridae	*Gerbillus campestris* (LOCHE, 1867) / North African gerbil	Semi-fixed and mobile dunes ; sandy soils and sparse shrub cover	++
	Meriones shawi (DUVERNOY, 1842) / Shaw's jird	Fixed dunes (Burrows, tracks)	+++

Symbols: + = occasional; ++ = frequent; +++ = abundant

Table 8 *Diversity metrics comparing fixed and mobile dunes in The El Mesrane dune system*

Parameter	Fixed dunes (mean ±SD)	Mobile dunes (mean ±SD)	t-value	*p*-value	Significance
Plant species richness	43±3	27±2	3.42	0.019	Significant

Shannon H'	2.41±0.08	1.74±0.11	3.18	0.024	Significant
Shannon H'-Invertebrates	2.47±0.12	1.46±0.09	3.95	0.011	Significant
Simpson1-D Invertebrates	0.83±0.04	0.62±0.05	3.27	0.022	Significant
Evenness (E)	0.79±0.05	0.53±0.07	2.87	0.034	Significant

3.4 Reptiles

Reptile observations revealed six species belonging to four families across the fixed and mobile dune station (Table 5).The assemblage was dominated by psammophilous, Lacertidae, such as *Acanthodactylus scutellatus*. (AUDOUIN 1827) and *Mesalina guttulata* (LICHTENSTEIN, 1823) which are adapted to arid sandy substrates. They represent characteristic dune-dweling lizards which expands across the northen Sahara and the arid high plateaus of Algeria [12]. An isolated observation of *Chamaeleo chamaeleon* (LINNE, 1758) in *Tamarix gallica L* dominated sites, the common Chameleon is generally restricted to Mediterranean and steppe ecotones [12].These findings suggests the emergence of arboreal microhabitats following dune stabilization. Compared to the mobile dunes, fixed dunes maintain a slightly higher species richness, due to vegetation cover and presence of litter that provides shelter to for both prey and reptiles [16, 18].

3.5 Birds

The avifaunal survey revealed a relatively low species richness. Eleven species belonging to eight families were recorded across all the stations (table 6), resident or partial-migrant taxa adapted to open xeric habitats [16, 18]. The assemblage was dominated by larks (*Alaudidae*), notably *Ammomanes deserti* (LICHTENSTEIN, MHK, 1823) and *Galerida cristata* (LINNE, 1758) which remain active year-round and play an important role in seed dispersal and soil turnover [11]. As a shrub-associated species *Sylvia deserticola* (TRISTRAM, 1859) and *Galerida cristata* (LINNE , 1758) were abundant in stabilized dunes, benefiting from the perennial vegetation structure provided by *Tamarix gallica* and *Retama raetam (FORSSK.) WEBB & BERTHEL)* [16]. Conversly, in mobile dunes, *Cursorius cursor* (Latham, 1787) *Oenanthe deserti* (TEMMINCK, 1825) were dorminat,: both psammophilous taxa, are characteristic of sparely vegetated sandy habitats [19].

3.6 Mammals:

A small number of mammals were recorded across the fixed and non-fixed dunes composed mostly of small rodent and generalist carnivores that are typical of arid steppe environment (Table7). These records reflect the common composition of steppe and pre-Saharan mammalian fauna in central Algeria [14].

3.7 Exploitation of results by Ecological Indices:

3.7.1 Sampling quality

The combination of the survey methods (quadrats for flora, Barber pitfall traps for invertebrates, and direct observation for vertebrates) captured a consistent number of taxa over successive months. The capture of both dominant and rare tax across all stations indicates adequate sampling coverage and reliable representation of the main ecological groups present in the study area [11].

3.8 Diversity Indices of Assemblage

3.8.1 Total and Mean Species Richness:

Stabilized dunes have higher species richness across all biological groups. The results of the survey showed, in fixed dunes, 43 plant taxa, 20 invertebrates families and 6 reptiles species, whereas in mobile dunes, 27 plant taxa, 9 invertebrates families and 3 reptiles species. These results clearly shows how dune fixation positively influence on biodiversity and trophic complexity [16, 18]

3.8.2 Shannon-Weaver ,Simpson Indices and Equitability

Diversity indices revealed contrasts between fixed and mobile dunes. (Table8) . These results reflects improved microclimatic and trophic conditions created by dune fixation [8].

4. Discussion

The comparison between stabilized and mobile dunes in El Mesrane reveals a clear ecological impact by dune fixation, confirming its ecological efficiency as restoration strategy in arid steppe environment. From a pedological perspective, the increase in fine particules, organic matter and slightly lower salinity in fixed dunes indicates a gradual improvement in soil structure. These findings are consistent with previous research in the

region [3, 6] who reported that perennial vegetation contributes to wind-erosion reduction ,litter accumulation and the gradual formation of a more stable surface horizon [7] and highliting the role of shrubs such as *Tamarix gallica* in creating microhabitats that buffer against climatic extremes. Floristic patterns also reflected these improvements, Species richness and diversity were markedly higher in stabilized plots where the coexistence of *Atriplex halimus* L, *Retama raetam* (FORSSK.) WEBB & BERTHEL and *Tamarix gallica* facilitates the establishement of annuals and psammophilous grasses.The higher Shannon and Simpson diversity indices in fixed sites further reflect a more balanced distribution of species abundance. The faunal assemblage mirrored this ecological recovery. Invertebrate diversity was significantly higher under stabilized vegetation, demonstrating the role of litter accumulation, shade and soil moisture in structuring arthropod communities, dominated by Formicidae and Tenebrionidae , two families known for their contribution to soil aeration and organic matter cycling [20].The increase in Simpson's index confirms lower dominance and improved ecological balance . Nevertheless, some limitation remain. Bird record were qualitative due to logistical constraints, and mammal observations were partly based on indirect signs, but the bird results indicate that stabilized dunes favor shrub associated species, while mobile dunes are frequently by open-habitat specialists . Despite constraints, the results provide robust evidence that dune fixation contributes significantly to habitat improvement and biodiversity enhancement in the central Algerian steppe. However, differences between stations suggest that restoration outcomes depend on the plant species used and their capacity to generate litter and shade. Therefore, the long- term sustainability of dune fixation will rely on maintaining vegetation health, and integrating restoration neasures within a broader landscape-scale management plan.

5. Conclusion

This study highlights the ecological efficiency of dune stabilization, reflected in improved soil properties, increased vegetation diversity and re-establishment of characteristic faunal communities. Stabilized dunes revealed a higher species richness, greater structural complexity and more balanced assemblage for all taxonomic groups. Although some faunal data remain qualitative, the overall results indicate that restoration efforts contribute significantly to reducing land degradation and promoting ecosystem recovery. Long-term monitoring remains essential to assess the steppe region recovery trajectories under increasing climatic pressure

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References

[1] Le Houérou, H. N. (1995). *Bioclimatologie et Biogéographie des Steppes Arides du Nord de l'Afrique*. CNRS Éditions, Paris.

[2] Ozenda, P. (2004). *Flore et Végétation du Sahara*. CNRS Éditions, Paris.

[3] Guerrache, N., & Akkouche, S. (2014). After the Fixating of the Dunes by *Retama retam* Webb., *Tamarix gallica* L. and *Tamarix aphylla* (L.) Karst in the Dunes Cordon of El Mesrane (W. Djelfa) in Algeria. *Journal of Arid Ecosystems*, 10(2): 45–53.

[4] Chenchouni, H. (2017). Environmental Change and Biodiversity Patterns in Algerian Steppes. *Ecological Indicators*, 80: 622–631. DOI:10.1016/j.ecolind.2017.05.042.

[5] Boudy, P. (1955). *Économie Forestière Nord-Africaine*. Tome III. La Maison Rustique, Paris.

[6] Benabadji, N., Ghezlaoui, S. M., & Bouazza, M. (2010). Dynamique et Régénération de la Végétation Steppique du Sud Algérien. *Ecologia Mediterranea*, 36(2): 89–101.

[7] Bencherif, K., Boutekrabt, A., Dalpé, Y., & Sahraoui, A. L. H. (2016). Soil and Seasons Affect Arbuscular Mycorrhizal Fungi Associated with *Tamarix* Rhizosphere in Arid and Semi-Arid Steppes. *Mycorrhiza*, 26(3): 221–232.

[8] Magurran, A. E. (2004). *Measuring Biological Diversity*. Blackwell Publishing, Oxford.

[9] Mainguet, M., & Dumay, F. (2011). *Les Déserts : Genèse, Dynamique et Impacts Environnementaux*. Armand Colin, Paris.

[10] Brague, N., & Bouragba, N. (2006). Systématique et Écologie de Quelques Groupes d'Arthropodes Associés à Diverses Formations Végétales en Zones Semi-Arides. *Revue d'Écologie et de Biologie du Sol*, 43(2): 141–158.

[11] Kent, M. (2012). *Vegetation Description and Data Analysis: A Practical Approach* (2nd ed.). Oxford University Press, Oxford.

[12] Geniez, P., Mateo, J. A., & Bons, J. (2004). *Amphibiens et Reptiles du Maroc (Sahara Occidental Compris)*. Société Herpétologique de France, Paris.

[13] Choukri, K., Souttou, K., & Bensouiah, R. (2009). Composition Avifaunistique dans un Reboisement de Pin d'Alep à Chbika (Aïn Maâbed – Djelfa, Algérie). [Thèse de Magister]. Université Kasdi Merbah – Ouargla, Algérie.

[14] Ahmim, M. (2021). *Contribution à l'Étude des Mammifères dans les Zones Steppiques et Présahariennes d'Algérie : Diversité, Répartition et Enjeux de Conservation*. [Thèse de Doctorat]. Université de Batna, Algérie.

[15] Southwood, T. R. E., & Henderson, P. A. (2000). *Ecological Methods* (3rd ed.). Blackwell Science, Oxford.

[16] Amraoui, S., Bouragba, N., & Meniai, A. (2018). Dung Beetles (Coleoptera: Scarabaeoidea) Between a Natural Forest and a Reforested Steppe (Djelfa, Algeria). *Zoology and Ecology*, 28(4): 315–323. DOI:10.1080/21658005.2018.1558793.

[17] Punzo, F. (1998). *The Biology of Camel-Spiders (Arachnida, Solifugae)*. Kluwer Academic Publishers, Dordrecht.

[18] Senni, N. (2020). *Approche Écologique de la Dynamique de la Végétation dans le Cordon Dunaire d'El Mesrane (Djelfa)*. [Thèse de Doctorat]. ENSA, Alger.

[19] Isenmann, P., & Moali, A. (2000). *Oiseaux d'Algérie*. Société d'Études Ornithologiques de France (SEOF), Paris.

[20] Cloudsley-Thompson, J. L. (2001). *Thermal and Water Relations of Desert Beetles*. Springer, Berlin.