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The impact of motorcycle traffic on soil and vegetation of stabilized coastal dunes, Israel

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Abstract. This study aimed to assess the response of soil and annual plant vegetation of stabilized coastal dunes in Israel, to varying intensities of off-road motorcycle (ORM) traffic, and to assess their resistance and resilience to such a disturbance. A standard experimental procedure that included 0, 20, 50, 100 and 200 ORM straight passes and 150 ORM turn passes was used. Plant ground cover, mean plant height, species richness, species diversity, soil penetrable depth, organic matter and moisture contents were measured on several dates within a period of 372 days after the experiment. Results have shown that: (1) ORM passes had a significant immediate impact on annual plants that increased with traffic intensity. The impact on the soil was detected only as an increase of penetrable depth. (2) The maximum impact on annual plants was observed in the wheel ruts and turn areas. The impact on the area between the wheel ruts and on the margins outside the wheel ruts was indirect and smaller. (3) Annual plant ground cover and mean plant height were less sensitive parameters than species richness and species diversity for determining the impact of ORM traffic on the area. (4) One year after the experiment, soil and annual plant vegetation in all passes were very similar to their pre-experimental condition. This indicates high resilience and recovery potential of the Mediterranean stabilized coastal dune ecosystem to ORM disturbance.

Abbreviation: ORM = Off-road motorcycle.

Introduction

Recreational use of off-road motorcycles (ORMs) began in Israel in the 1990s. Over 1993-1996, 9200 ORMs were sold in Israel. In 1997, sales dropped to hundreds (Steinman 1998, editor of the monthly journal 'Moto', pers. comm.). Observations in the field as well as the testimony of a professional authority in the ORM arena showed that ORM and jeep drivers heavily use the coastal areas for recreational trips.

Hiking or uncontrolled riding in open spaces causes ecological damage that can be expressed in soil properties (Cole 1987; Kuss 1986), overland flow-erosion relationships (Deluca et al. 1998; Weaver & Dale 1978; Whilshire & Nakata 1976; Wilson & Seney 1994), and vegetation (Bowels & Maun 1982; Burden & Randerson 1972; Cole 1987; Hylgaard & Liddle 1981; Kuss 1986; Rickard et al. 1994; Shaw & Diersing 1990; Sun & Liddle 1993). Vehicle traffic was found to cause more damage to soil and vegetation than pedestrian traffic. This is a function of the mass per unit of a vehicle relative to that of a single pedestrian (Deluca et al. 1998; Rickard et al. 1994; Weaver & Dale 1978; Liddle 1997). Furthermore, capability of off-road vehicles to access remote, isolated and topographically difficult places and to attain faster speeds on wide turns leads to larger spatial soil and vegetation damage than that caused by hikers (Rickard et al. 1994; Weaver & Dale 1978; Whilshire & Nakata 1976; Wilson & Seney 1994).

The degree of damage caused to soil and vegetation depends on many factors, including climatic conditions, soil type, plant composition, type of vehicle and frequency of passes made by the vehicle. Based on studies carried out to date, several conclusions can be drawn, though it should be stated that most studies were carried out in temperate regions and only some in the subtropics (Liddle 1997). Changes in soil and vegetation in arid and semi-arid regions caused by vehicle traffic have a long-term impact (tens to hundreds of years) on geomorphic processes (such as overland run-off-erosion relationships) and ecological processes (such as plant productivity and diversity) (Braunack 1986; Whilshire & Nakata 1976). Sandy habitats are thought to be the most sensitive to recreational use; stabilized dunes are considered to be more susceptible to damage by off-road vehicles than shifting dunes (Bowels & Maun 1982; Burden & Randerson 1972; Rickard et al. 1994). The damage caused by animal, pedestrian and vehicle traffic generally increases logarithmically (Liddle 1975; Liddle & Greig-Smith 1975; Kuss 1986; Whilshire & Nakata 1976). Herbaceous plants, especially annuals, are more resistant to pedestrian and vehicle traffic than woody plants (Cole 1987; Kuss 1986; Sun & Liddle 1993; Yorks et al. 1997). Intense and/or frequent vehicle traffic alters plant composition from perennials to herbaceous annuals (Shaw & Diersing 1990). Less damage is caused to soil and vegetation by vehicle traffic in straight and level courses than in turns and steep courses (Rickard et al. 1994; Shaw & Diersing 1990; Weaver & Dale 1978).

The impact of pedestrian and vehicle traffic on the environment may be studied either in areas under recreational use or through controlled experiments on previously undisturbed sites, usually on small plots. Although an experiment is not the 'real world situation', it is the most convenient way of establishing direct and quantitative relationships between the intensity of recreational use and changes in the environment. It is for these reasons that many studies have adopted the experimental approach (e.g. Cole & Bayfield 1993; Hylgaard & Liddle 1981; Rickard et al. 1994; Shaw & Diersing 1990; Sun & Liddle 1993).

The present study used a standard experimental procedure to examine the potential response of soil and annual plant vegetation of Mediterranean stabilized coastal dunes in Israel to varying numbers of ORM passes. Its aim was to assess their resistance (the ability of annual plants to withstand traffic before being injured or impaired) and resilience (the capacity of annual plants to survive or regenerate after the disturbance has ended).

Study area

The Sharon National Park in the northern Sharon region of Israel extends from the city of Hadera in the north to the Alexander stream in the south, and from the Mediterranean Sea in the west to road no. 4 in the east. It covers a total area of 600 ha (Fig. 1). 20% of the plant cover is made up of scattered woody plants such as the carob tree (*Ceratonia siliqua*), the Tabor oak tree (*Quercus ithaburensis*) and the mastic shrub (*Pistacia lentiscus*). The remaining 80% are annual herbaceous plants. These include more than 70 different species, some of which are endemic to the coastal plain in Israel (Kutiel et al. 1979/1980; Kutiel 1998). The soil is a sand calcaric Regosol (the organic horizon Ah is ca. 2-5 cm thick and beneath it lies the parent sand material, the C-profile (Dan & Kutiel 1997) and mean annual rainfall varies between 500 and 600 mm. The winter of 1997/1998 was considered average with a rainfall of 538 mm; the next winter was much drier with only 253 mm.

Methods

Four replicate experimental plots separated by a distance of more than 30 m were established (Fig. 2). Each plot had a size of 220 m^2 and consisted of five lanes. Each lane was 2 m wide and 10 m long. One lane served as a control and received no treatment; the other lanes received 20, 50, 100 and 200 ORM passes, respectively. Thus, there were four replicates of control lanes and four replicates for each intensity pass. Treatments were randomly assigned to lanes.

Two subplots (0.5 m × 2 m) for quantifying the effect of ORM turns on soil and annual plant vegetation

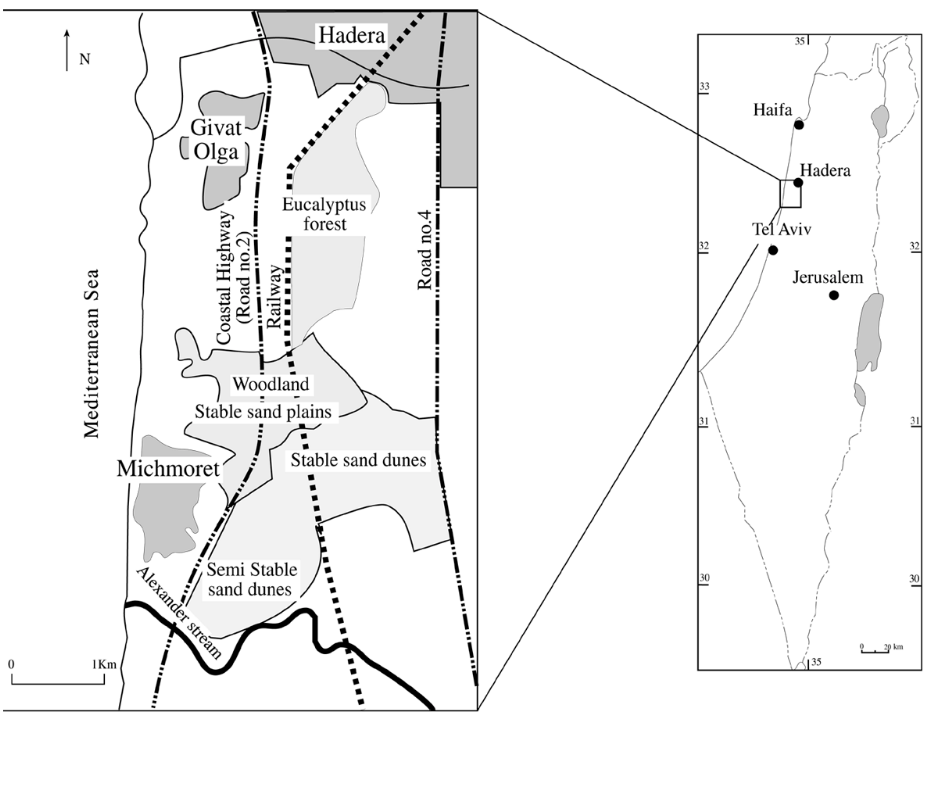

Fig. 1. Study site.

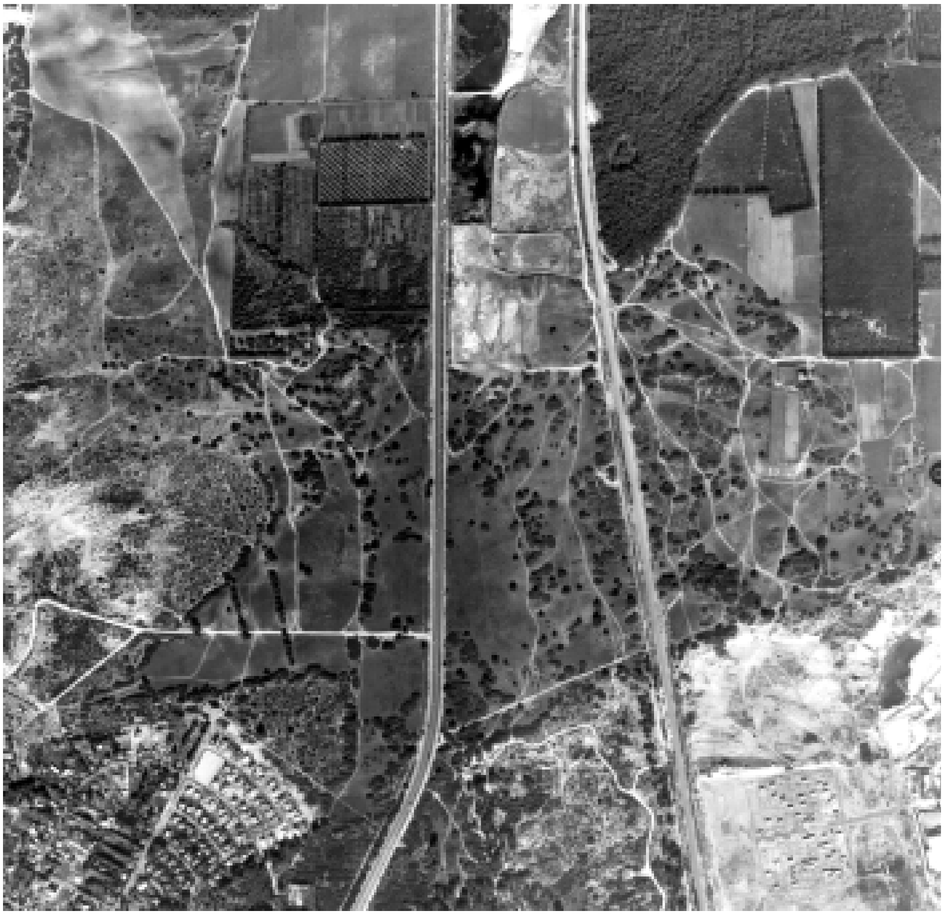

Fig. 2. Aerial photo of the study area.

were demarcated close to each plot, at places where the ORMs turned in order to get into the lanes. There were 150 turns in each subplot.

A pass was defined as a one-way drive along the lane. The ORM was a 250 model Trail Boss weighing 203 kilograms. It was 112 cm wide and had four wheels, each with a wheel span of 20 cm. ORM passes were applied over the course of one day (19 January 1998) for all intensity passes in all four replicate plots. Herbaceous ground cover was at a maximum and at least half of the growing season remained (the average length of the growing season is about six months). The elaborated design was based on a standard experimental procedure developed by Cole & Bayfield (1993). They indicated that this experimental procedure can be applied in a wide variety of vegetation types.

Vegetation parameters in each lane were monitored in two adjacent subplots (0.5 m × 2 m). In each subplot, the annual plant ground cover (visually estimated), mean plant height (25 records per one subplot divided by the number of non-zero values), composition and relative cover for each species were recorded separately for the wheel ruts and the surrounding area (henceforth ‘edges’) within each subplot. The results relate to the area in the wheel rut (the area of maximum damage) and to the overall subplot area (wheel ruts and edges), using an average that corresponds to the ratio between the wheel rut areas and the edges. In the turn areas, the results relate to the overall damage caused on the whole area of the subplot.

Species diversity was calculated according to the Shannon-Wiener Index. This Index takes into account the number of species and the relative contribution of each species to the overall plant cover, according to the following formula:

$$H' = -\sum_{i=1}^{S} P_i \ln P_i \qquad (1)$$

where S is the number of species and P_i is the relative contribution of the species to the total cover (e.g. Kutiel 1998).

Initial vegetation observations were made immediately before the experiment. Follow-up observations were made 18, 45 and 372 days after the ORM passes.

Soil compaction was based on the penetration depth, measured at horizontal intervals of 25 cm by penetrometer. The penetrometer had a stick of 50 cm long, loaded by a 235 g body weight that was dropped from the head of the stick towards its base. The depth to which the stick penetrated into the soil was measured (Karpanchevsky et al. 1980). Measurements were executed one day, 72 days and one year after the experiment. Liddle & Greig-Smith (1975) point out that in sandy soils the penetration depth is a more reliable parameter than soil density, the latter also being much more difficult to measure.

Two soil samples were taken within each lane and adjacent to the two subplots (n = 8 for the control and for each intensity pass) from a depth of 0-2 cm after removal of the plant ground cover and the litter layer. Soil samples for estimation of the organic matter content were taken in April 1998, at a time of maximum soil decomposition activity (Lavee et al. 1995). Organic matter was determined by wet combustion with dichromate at 450 °C, after the samples had been air-dried and cleaned of

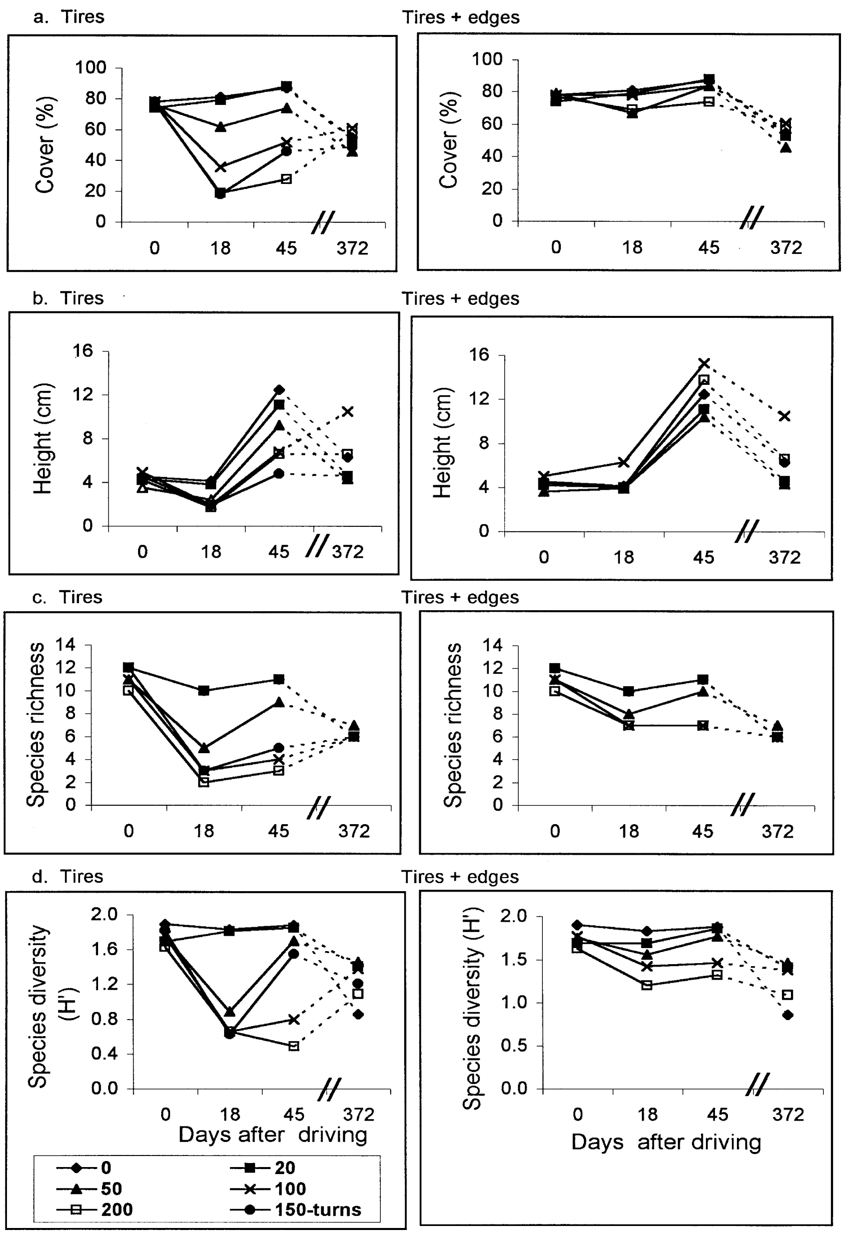

Fig. 3. Change in **a**. annual plant ground cover, **b**. mean plant height, **c**. species richness, and **d**. species diversity in the wheel ruts and on the overall area (wheels + edges). Recorded according to various ORM pass intensities on four dates within 372 days (the species richness for 0 and 20 passes are similar in the area of 'wheel ruts + edges').

Table 1. Significant ($p = 0.05$) differences among ORM pass intensities and dates after the experiment for annual plant ground cover, mean plant height, species richness and species diversity. (The vertical capital letters refer to significance of the difference between the measurements taken on each date. The horizontal lower-case letters refer to significance of the difference between the dates. Similar letters = not significant; different letters = significant).

Measurement	No. of passages	Area in wheel ruts Days after ORM passages				Overall area (wheel ruts + edges) Days after ORM passages			
		0	18	45	372	0	18	45	372
Plant ground cover	0	a/A	a/A	a/A	a/A	a/A	a/A	a/A	a/A
	20	a/A	a/A	a/A	b/A	a/A	a/A	a/A	b/A
	50	a/A	ab/A	a/AB	b/A	ab/A	b/A	a/AB	c/A
	100	a/A	b/B	ab/BC	ab/A	ab/A	ab/A	a/AB	b/A
	200	a/A	b/B	b/C	a/A	a/A	a/A	a/B	a/A
	150 (turns)	a/A	c/B	b/C	b/A				
Plant height	0	b/A	b/A	a/A	b/A	b/A	b/A	a/A	b/AB
	20	b/A	b/A	a/A	b/A	b/A	b/A	a/A	b/B
	50	b/B	b/B	a/AB	b/A	b/A	b/A	a/A	b/B
	100	b/B	b/B	ab/BC	a/A	b/A	ab/A	a/A	ab/A
	200	a/B	a/B	a/BC	a/A	b/A	b/A	a/A	ab/AB
	150 (turns)	b/B	b/B	a/C	a/A				
Species richness	0	a/A	ab/A	a/A	b/A	a/A	ab/A	a/A	b/A
	20	a/A	a/A	a/A	b/A	a/A	ab/A	ab/AB	b/A
	50	a/A	b/B	a/A	ab/A	a/A	ab/AB	ab/AB	b/A
	100	a/A	c/B	bc/B	b/A	a/A	b/B	b/B	b/A
	200	a/A	c/B	c/B	b/A	a/A	b/B	b/B	b/A
	150 (turns)	a/A	d/B	c/B	b/A				
Species diversity	0	a/A	a/A	a/A	b/A	a/A	a/A	a/A	b/A
	20	a/A	a/A	a/A	a/A	a/A	a/A	a/A	a/A
	50	a/A	b/B	ab/A	ab/A	a/A	a/AB	a/A	a/A
	100	a/A	c/B	bc/A	ab/A	a/A	a/BC	a/B	a/A
	200	a/A	bc/B	c/B	b/A	a/A	b/C	ab/B	b/A
	150 (turns)	a/A	c/B	ab/A	bc/A				

undecomposed organic residues (Rowell 1994).

Soil samples for estimation of soil moisture were taken at two depths: 0-2 cm and 5-10 cm. Initial soil measurements were taken immediately before the experiment was conducted. Follow-up measurements were taken 19, 45, 61, 73, 86 and 103 days after the experiment. Samples were weighed and dried at 105 °C to constant weight. Moisture percentage was calculated on a dry-weight basis (Rowell 1994).

Statistical analyses were based on plot means to avoid pseudo-replication. Duncan's multiple range test at the $\alpha = 0.05$ level of significance was used to determine the significance differences between treatments and dates (Duncan 1955).

Results

Vegetation

After 18 days, the annual plant ground cover in the wheel ruts of the 100 and 200 pass lanes had decreased significantly ($p = 0.05$) to ca. 33% of that in the control lanes. Even after 45 days impacts were still considerable and did not differ significantly between these two intensities (Fig. 3a, Table 1). Furthermore, the annual plant ground cover in the turn areas did not significantly differ from that in the 100 and 200 pass lanes. An overall significant impact (average between the impact on the wheel ruts and on the edges) of ORM passes on annual plant ground cover was only observed after 45 days in the 200 pass lanes. One year after the experiment, annual plant ground cover in all lanes was very similar, lacking with no significant differences between the lanes (Fig. 3a, Table 1).

18 days after the ORM passes, mean plant height in the turn areas and in the wheel ruts of the 50, 100 and 200 pass lanes decreased significantly ($p = 0.05$) to one half of that in the control lanes (Fig. 3b, Table 1). No significant differences were found between the three intensities. 45 days after the experiment, mean plant height increased significantly ($p = 0.05$) in all lanes, remaining significantly ($p = 0.05$) lower in the turn areas and in the 100 and 200 lanes. No significant differences were found between mean plant height in the 100 and 200 pass lanes and in the turn areas. In the overall area of the lanes, no significant effect of the ORM passes on mean plant height was observed. One year after the

ORM passes, mean plant height in the control lanes and in all pass intensities except the 100 pass lanes, did not differ significantly (p = 0.05) from the pre-experiment situation.

Species richness and species diversity responded very similarly to ORM passes (Figs. 3c, d, Table 1). In the wheel rut, 18 days after the experiment values for variables were significantly lower in the 50, 100 and 200 pass lanes as compared to the control lanes. The effect of ORM passes on these parameters continued to be discernible 45 days after the experiment in the 100 and 200 pass lanes, where species richness and species diversity were less than one half of that in the control lanes (Figs. 3c, d, Table 1). 18 days after the experiment, species richness and species diversity in the overall area of the lanes were lower in the 100 and 200 pass lanes as compared to the control lanes; they continued to be lower 45 days after the experiment. Species richness and species diversity were significantly lower, by 30% and 25% respectively, in the 100 and 200 pass lanes. One year after the experiment, in all lanes parameter values were similar to the pre-experiment values, significant differences being absent (Figs. 3c, d, Table 1).

Table 2. The impact of 500 pedestrian passes and 100 ORM passes on the annual plant vegetation in the coastal stabilized dunes of the Sharon Park (the trampling experiment was conducted on January 16, 1998 and the ORM experiment was conducted on January 19, 1998).

	Hikers			Motorcycle		
Days after experiment	0	21	45	0	18	45
Cover (%)	70	58	70	78	38	49
Height (cm)	4.2	3.8	6.5	4.2	2.0	6.5
No. of species	11	7	9	11	3	4
Species diversity	1.8	1.8	1.6	1.8	0.7	0.8

Table 3. Organic matter content in the upper soil layer (0-2 cm) after various intensities of ORM passes (n = 4; ± = S.D; * significance of the difference between treatments).

No. of passes	Organic matter content (%)	Significance (p = 0.05)
0	1.28±0.22	*
20	1.23±0.19	*
50	1.21±0.51	*
100	1.03±0.32	*
200	1.25±0.43	*
150- turns	1.25±0.55	*

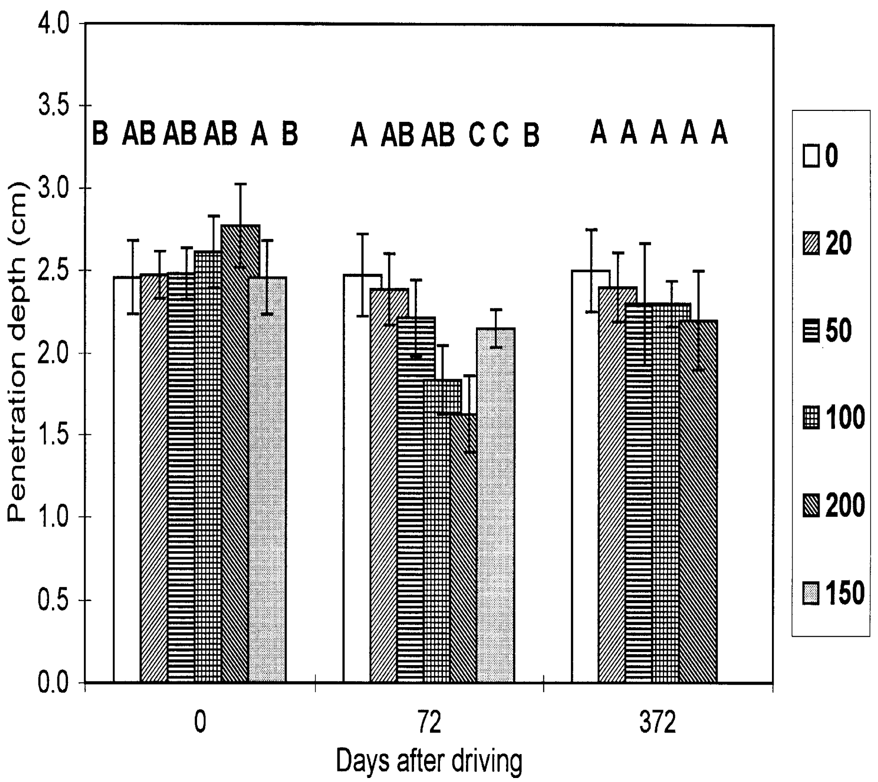

Fig. 4. Depth of soil penetration one day, 72 days, and one year after various ORM pass intensities (level of statistical significance and standard deviations are noted. Similar letters = not significant; different letters = significant at p = 0.05).

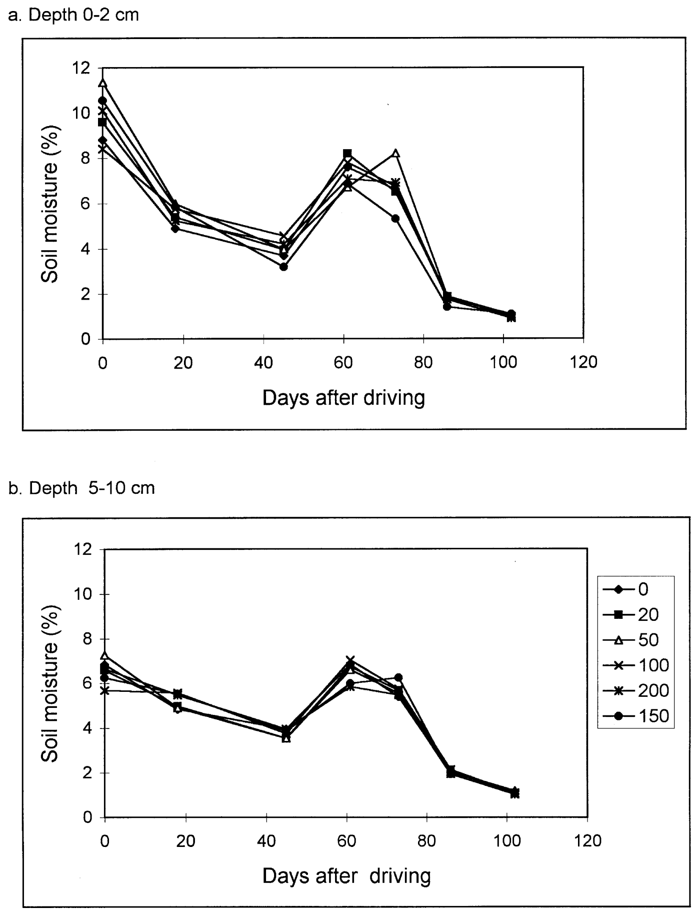

Fig. 5. Change in soil moisture in the upper and lower soil layers during the growing season at various ORM pass intensities.

Soil

The penetration depth decreased with increasing number of ORM passes, becoming significant and prominent after 72 days in the 100 and 200 pass lanes. In the turn areas, the penetration depth was significantly higher than in the 200 pass lanes, but significantly lower than in the control lanes. One year after the experiment significant differences among the various lanes were absent (Fig. 4).

The soil moisture (Fig. 5) and organic matter content were not affected by the ORM passes (Table 3).

Discussion

In previous studies, it has been demonstrated that low intensity wear by a one-time ORM pass causes a notable impact on soil and vegetation (Rickard et al. 1994; Weaver & Dale 1978; Whilshire & Nakata 1976; Wilson & Seney 1994). Our study demonstrated that a one-time ORM pass caused immediate but only temporary changes in annual plant characteristics and, to a lesser degree, in soil properties. The impact on the soil was limited to penetrable depth, which decreased. The amount of organic matter and soil moisture remained unchanged, even after 200 passes.

Similar trends were observed when we examined the effect of simulated trampling on soil and vegetation in the same area (Kutiel et al. 2000). However, in another study that was conducted in the same area, we found that pedestrian and vehicle traffic in long-established trails causes a significant decrease in soil organic matter and moisture content, even at low intensities. This indicates that, in contrast with plants, soil properties gradually change over time and in the course of cumulative pedestrian and vehicle traffic (Kutiel et al. 1999).

The wheel ruts and particularly the turn areas represent the direct and maximum effect of ORMs on vegetation. Vegetation (annual plant ground cover, mean plant height, species richness and species diversity) was seriously affected by as little as 50 passes. The ORM impact continued to be evident during the growing season only in the 100 and 200 pass lanes. In the turn areas, damage to plants is expected to be at a maximum, since the rear part of the ORM rotates upon itself without following the direction of travel. As a result, more sand sprays out of the ruts causing greater plant damage along the sides of the ruts and greater shear forces in the sand (Rickard et al. 1994; Shaw & Diersing 1990). In our study, however, as well as in others that compared the effects of straight and turning vehicles, no significant differences were found in the levels of vegetation damage between turn areas and pass lanes (Brodhead & Godfrey 1979; Rickard et al. 1994).

The overall effect of ORM passes, as manifested by annual plant ground cover and mean plant height in the total area, is smaller than that found in the wheel ruts and in the turn areas. This is because the area under the wheels amounts to only 20% of the total area that is liable to be affected by ORM passes in our experimental lane. The total plant cover was affected only after 200 passes, and even then, the decrease was slight (12%). Similarly, no significant change in mean plant height was observed after the ORM passes.

Although differences in height are often the first visual indicator of trampling and vehicle passage, height has not often been measured in such experiments, "perhaps because interest has been focused on the more dramatic and aesthetically displeasing consequences, such as bare ground and erosion" (Liddle 1997). In our study, even numerous ORM passes did not affect the mean plant height, apparently because of growth rate differences among various species. At the start of the growing season, the majority of the species are in prostrate form; when these have completed their life cycle, graminoids such as *Bromus rigidus*, *B. madritensis* and *Aegilops sharonensis* dominate the area. These species are erect and they reach a height of over 20 cm. Since these species, and graminoids in general, are resistant to pedestrian and vehicle disturbance (Kutiel et al. 1999; Liddle & Greig-Smith 1975; Shaw & Diersing 1990; Sun & Liddle 1993), they continued to grow, strongly affecting the mean plant height.

In contrast, the effect of ORMs on species richness and species diversity was prominent. 30% of the species disappeared after 100 and 200 passes. *Daucus litoralis*, a species unique to sandy soils, vanished after only 50 passes; *Paronychia argentea*, *Onobrychis squarrosa*, *Senecio vernalis* and *Anchusa aggregata* disappeared after 100 passes; *Alopecurus utriculatus*, *Chrysanthemum coronarium*, *Lathyrus marmoratus*, *Lotus halophilus*, *Crepis aculeata*, *Silene colorata*, *Ononis serrata*, *Lupinus palaestinus*, *Trifolium tomentosum* and *T. philistaeum* vanished after 200 passes. The species remaining at the end of the season were *Medicago littoralis*, *Bromus madritensis*, *B. rigidus*, *Trigonella cylindracea*, *Centaurea procurrens*, *Erodium laciniatum*, *Astragalus boeticus*, *Anthemis leucanthemifolia* and *Trifolium palaestinum*.

The short-term impact of ORMs on the herbaceous plants of the stabilized coastal dunes is much greater than the impact of pedestrian trampling; this is also the case when the stress imposed on a unit area is rather similar. To demonstrate this, we compared the results from the present study with those from another study that dealt with the impact of pedestrians on annual plants at the same place and time (Kutiel et al. 2000). The weight of the ORM is about 200 kg and the average weight from the pedestrian in the experiment was 65 kg, giving a ratio of 3:1. We compared the wheel rut area (the site of direct contact between the vehicle and the surface) for 100 ORM passes to the trampled area for 500 pedestrian passes (the number of passes that caused significant changes in soil and annual plant attributes; Kutiel et al. 2000). It turned out that 500 pedestrian passes immediately reduced the annual plant ground cover to 50%, but this recovered after three weeks. The annual plant ground cover after 100 ORM passes remained lower than the control during the entire growing season by 47%.

Mean plant height is affected temporarily by trampling and by ORM traffic, but at the end of the growing season it returns, in both cases, to its original condition. This is because of the growth rate difference between the various species, as explained above. However, the temporary decrease in mean plant height in the area of ORM passes was five times higher than the decrease in the area of trampling. The species richness and species diversity decreased in the area of trampling by 19% and 11%, respectively, as compared with 44% and 56% in the area of ORM passes (Table 2).

In a study on the impact of pedestrian and vehicle traffic on the soil and vegetation of long-established trails in the Sharon National Park, we found that the soil and vegetation in 18% of the woodland area of the park was damaged (Kutiel 1999; Kutiel et al. 1999). The damage can be characterized as heavy even when the traffic intensity is relatively low, since the impacts on soil and vegetation accumulate throughout the growing season and over the course of years. However, these trails can be rehabilitated within one or two years following a proper management (Kutiel et al. 1998). A comparison with other studies (Rickard et al. 1994) indicates that two years is a short recovery period.

Stabilized dunes are considered to be more vulnerable to trampling than mobile dunes (Hylgaard & Liddle 1981; Rickard et al. 1994). However, it can be concluded from our research that the stabilized Mediterranean coastal dunes demonstrate high resistance, recovery and resilience potentials to pedestrian and vehicle traffic. One year after a single high-intensity impact was applied, soil and annual plants in the treatment plots recovered to a level resembling that of the control plots. This recovery ability is consistent with the hypothesis that through both ecological and evolutionary processes the vegetation (particularly herbaceous) of the Mediterranean region has adapted to the changing environmental conditions to which it has been exposed for thousands of years (Naveh & Whittaker 1979; Shmida 1985). These conditions include natural physical stresses as well as human perturbations. Hence, annual plants of the Mediterranean coastal dunes that are subjected to harsh conditions such as grazing and nutrient and water deficiencies are expected to be able to recover from recreational impacts more rapidly than vegetation in more benign regions. Furthermore, the fact that the Sharon National Park dunes are flat and covered with annual plants may also explain their high resistance to such stresses. Level areas are known to be damaged less by recreational use than slopes; areas with herbaceous plants are known to be damaged less than those dominated by woody plants (Cole 1987; Hylgaard & Liddle 1981; Kuss 1986; Rickard et al. 1994; Weaver & Dale 1978; Yorks et al. 1997).

Conclusions and Recommendations

ORM passage in open areas, excluding one-time passes, has an immediate but temporary impact on annual plant vegetation. The impact on the soil is a temporary increase in compaction. The immediate effect on annual plant vegetation is noticeable after 50 ORM passes; it increases with traffic intensity. The maximum effect on the annual plants is in the wheel ruts and turn areas. The area between the wheels and in the outer margins is affected indirectly and to a lesser extent. The annual plant ground cover and mean plant height are less sensitive measures than species richness and species diversity for determining the overall effect of ORMs on the area. The two latter measures are most important in areas destined to be nature reserves.

ORM traffic is currently decreases for several reasons (licensing and taxation among them). A problem still exists, however, in the form of off-road vehicles, which because of their size and weight cause even more damage than ORMs. This situation would not have arisen if public areas had been put under the management of an ecologically responsible professional body that, in the interest of limiting environmental damage, would control the number of vehicles entering the area and their paths.

The problem of 'competition' for exploitation of public areas exists everywhere. In some parts of the US, for instance, parts of such areas have been 'sacrificed' to off-road vehicles. These vehicles are prevented from entering the remainder of the area by fences, or they are drawn to the 'sacrificed' area by competitions or other attractions (Steinman 1998, pers. comm.).

In Israel, there is a lack of public awareness about the ecological damage caused by imprudent use of off-road vehicles. In addition, terrain travel enthusiasts are not offered appropriate alternative sites for practising their skills. Therefore, we suggest that authorities in Israel, as well as in other places in the world, should set aside some natural or artificial areas (such as areas built up with challenging obstacles) for off-road vehicles and motor sports. In these areas the authorities can hold competitions and organize additional attractions. It will then be possible to refuse the entry of off-road vehicles to ecologically valuable areas, which can be protected by guards and/or fences. In addition, programs about the ecological and environmental importance of public areas should be organized. These should be aimed at educating the public in general, and off-road vehicle owners in particular, about the damage caused to these areas through reckless use (an example of this approach can be found in the successful education of the Israeli public to refrain from picking protected wild flowers).

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