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URBANIZATION AND SAND DUNES IN ISRAEL: DIRECT AND INDIRECT EFFECTS

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ABSTRACT

Considerable attention has been given lately to the effects of habitat fragmentation and destruction on wildlife. Here, we summarize their effects on animal abundance and plant cover during a three-year study period (1987–90) of the sand dunes of the coastal plain of Israel. Populations of the gray monitor *Varanus griseus*, the spur-thighed tortoise *Testudo graeca*, and the mountain gazelle *Gazella gazella* in the study area declined markedly and plant cover increased significantly. Habitat destruction and fragmentation, introduced animals (especially dogs and carrion crows), a continuing change in the native herbivore fauna, and blockage of wind-borne sand are all believed to be responsible for the observed changes. We recommend that small areas, unsuitable for full protection, be declared "city reserves," to be used for educational and recreational purposes. Nature reserves need to be managed in order to maintain the existing fauna and flora.

INTRODUCTION

While studying the life history and reproductive ecology of the fringe-toed lizard *Acanthodactylus scutellatus* (Lacertilia: Lacertidae) in Israel (Perry and Dmi'el, 1994), we became aware of significant changes in its sand-dune habitat. Like many other habitats (Mader, 1990), sand dunes in Israel are disappearing because of the growth in urban areas. Of the 350 km^2 of sand dunes comprising the coastal plain of Israel, mostly considered useless and undesirable at the beginning of the century, less than half remains intact. Habitat destruction is especially severe in the central and northern regions, where only 25% of the original sandy area remains undeveloped (Yom-Tov and Mendelssohn, 1988). This unique habitat includes both Saharan and Mediterranean faunistic and floristic elements, and habitat destruction has reduced the distribution and abundance of many species (Yom-Tov and Mendelssohn, 1988).

McDonnell and Pickett (1990) have pointed out that the study of natural areas within urban concentrations is becoming increasingly important, since human life and quality of living are becoming intimately involved with such areas. We wanted to study the

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effects of human activities on such a habitat, and whether it could be used for conservation purposes.

MATERIAL AND METHODS

The study site was a sand dune situated within the city limits of Holon, on the coastal plain of Israel (34°45'N 32°00'W). Its total area was approximately 1.5 km^2, and plant cover (measured by the random transect method) varied from 0% in some areas to 100% in others. The most common plants in densely vegetated patches were the mugwort (*Artemisia*) and the retama (*Retama*); the figwort (*Scrophularia*) and the rest-harrow (*Ononis*) were predominant in relatively open areas.

Data were collected from July 1987 until July 1990. The study site was visited at least once a month, usually for 24 h or longer. A slow walk was employed to survey the entire site during each visit. All vertebrates and vertebrate tracks observed were recorded, and the type of habitat in which they were seen, as well as time of sighting, were categorized. A follow-up visit to the site was conducted in December 1992. Names, both scientific and common, follow those given by Ashkenazi and Hakham (1987).

RESULTS

Thirteen reptile and nine mammal species were observed on the study lot during the three-year study; eight bird species were comparatively common (Table 1). Of those, the populations of two reptile species (the spur-thighed tortoise, *Testudo graeca*, and the gray monitor, *Varanus griseus*) and one mammal (the mountain gazelle, *Gazella gazella*) declined markedly during the study. One mammal species (domestic dogs, *Canis familiaris*) and two bird species (the kestrel, *Falco tinnunculus*, and the carrion crow, *Corvus corone*) became more common during this period (Table 2).

During the study period, human activity on the study site increased due to rapid urbanization (Fig. 1). Concurrently, an increase in the numbers of dogs, carrion crows, and falcons was noted, followed by a reduction in *V. griseus, T. graeca,* and *G. gazella* sightings. In several cases, dog tracks were found paralleling those of *G. gazella*, apparently indicating feral dog packs chasing mountain gazelles. Dead young tortoises, with their shells intact but their heads (and sometimes limbs) missing, were often found on the study site during the same period. Towards the end of the study period, only the tracks of adult tortoises could be observed. Dead tortoises were more common in open areas than in ones with high plant cover. With the exception of the lizards *Acanthodactylus scutellatus* and *A. schreiberi*, we did not closely monitor the abundance of small vertebrates and invertebrates. It appears, however, that there were no major changes in their populations during this study.

Human activity consisted not only of direct habitat destruction through construction, but also of jeep and motorcycle cross-country driving and of leisure activities such as strolling and picnicking. Human presence inhibited the activity of large organisms (mostly *G. gazella* and *V. griseus*), but there were no signs of disturbance to smaller

Table 1
Vertebrates found at the study site

	Species	Comments		Species	Comments
Reptiles:	*Acanthodactylus schreiberi*	+		*Columba* sp.	
	Acanthodactylus scutellatus	!		*Corvus corone*	! +
	Chalcides ocellatus			*Falco tinnunculus*	! +
	Chamaeleo chamaeleon			*Passer domesticus*	
	Hemidactylus turcicus			*Prinia gracilic*	
	Lytorhynchus diadema	!		*Tyto alba*	
	Malpolon monspessulanus				
	Psammophis schokari		**Mammals:**	*Canis aureus*	
	Sphenops sepsoides	!		*Canis familiaris*	+
	Stenodactylus sthenodactylus			*Felis catus*	
	Testudo graeca	–		*Gazella gazella*	–
	Varanus griseus	–		*Gerbillus andersoni*	!
	Vipera palaestinae			*Hemiechinus auritus*	
				Jaculus jaculus	
Birds:	*Alectoris chukar*			*Lepus capensis*	!
	Burhinus oedicnemus			*Vulpes vulpes*	

The list for birds is partial, and includes only common species. Increase and decrease in population size are marked by "+" and "–", respectively. "!" marks a species that was very abundant. Names follow Ashkenazi and Hakham (1987).

Table 2
Changes in the abundance of selected vertebrate species at the study site from 1987 to 1990

	Approximate observation frequency (animals/day)	
Species	1987	1990
Canis familiaris	0.25	4
Corvus corone	1	>20
Falco tinnunculus	0.5	3
Gazella gazella	3	0
Testudo graeca	5	0.01
Varanus griseus	4	<0.01

The numbers reported include both fresh tracks and actual sightings.

species, and no killed animals were ever found. Damage to plants, however, was sometimes considerable, especially where jeeps repeatedly drove over a specific bush.

Plant cover increased rapidly in much of the study area (Fig. 1), and such changes were followed by changes in the micro-distribution of the fauna. In densely vegetated areas, the skink *Sphenops sepsoides* was replaced by another skink, *Chalcides ocellatus*.

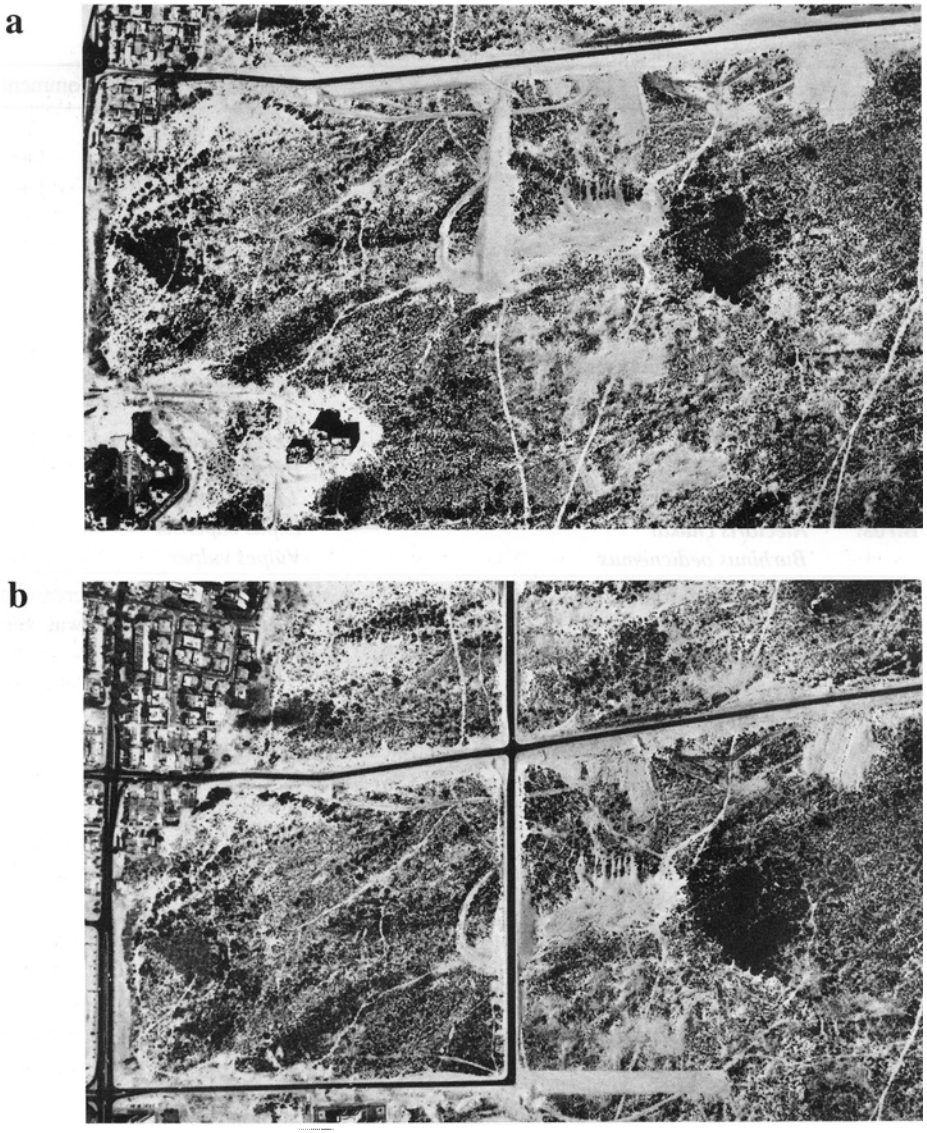

Fig. 1. Aerial photographs of the study site in (a) 1986 and (b) 1989. Aside from additional roads, the 1989 picture also shows changes in plant densities in several locations.

Acanthodactylus scutellatus was replaced by the closely related *A. schreiberi*. In other, less disturbed sites, such changes were not evident (Perry, 1990).

Marked changes from the vegetation found in 1988 were noted during the 1992 visit. Changes were noted in both plant cover and plant community structure. Plant cover increased from 2.26% (SD = 1.97%) in 1988 to 19.85% (SD = 15.32%) in 1992. The

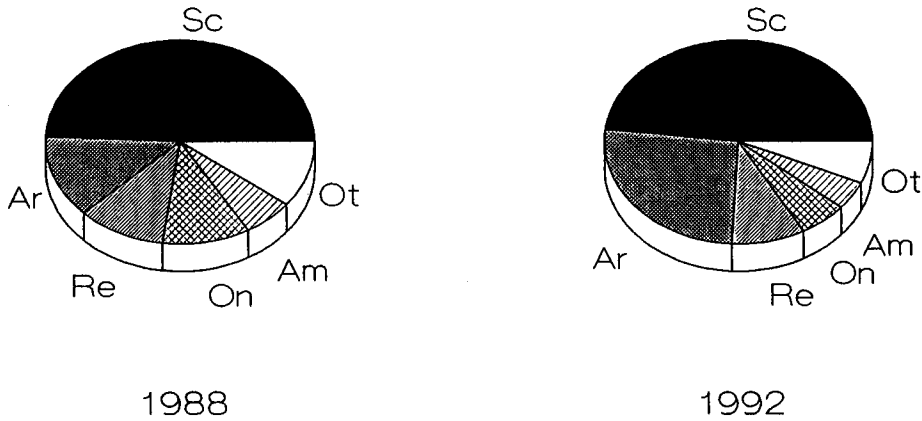

Fig. 2. Proportions of the common plant species in Holon, Israel, in 1988 and 1992. Total plant cover increased from 2.3% in 1988 to 19.9% in 1992. Ar: *Artemisia*, Am: *Ammophila*, On: *Ononis*, Re: *Retama*, Sc: *Scrophularia*, O: other.

change was most evident on the edges of the study site, where cover increased to approximately 50%, and is statistically significant ($p < 0.01$, Mann–Whitney U-test). The proportion of *Artemisia* in the community increased significantly ($p < 0.01$, χ^2 test), from 13.1% of the vegetation in 1988 to 25.9% in 1992 (Fig. 2). Other species decreased slightly, but no statistically significant change in plant composition as a whole was found between the two visits ($p > 0.1$, χ^2 test).

DISCUSSION

Habitat destruction was the most obvious cause of change on the study site (Fig. 1). Roads further served to bisect the study site into several smaller pieces and to inhibit free movement of animals between them.

The effects of recreational use of the site appear to have been more pronounced on large animals and (to a lesser extent) plants, than on small animal species. Human activity inhibited mountain gazelle and monitor activity and caused lasting damage to some *Retama* and *Artemisia* bushes, but seemed to have little or no lasting effect on small animals such as lizards, rodents, or invertebrates. However, increased recreational use has been shown to have great effects on coastal floras and faunas (Carlson and Godfrey, 1989), and cannot be ignored as a possible cause of disturbance.

Fragmentation into small pieces is often followed by powerful edge effects (Laurence and Yensen, 1991). In the present study, introduction of animals from ouside the habitat had a marked impact on the study site. All the animals whose populations increased during this study (Table 1) are intimately linked to man: dogs (abandoned as puppies and gone feral), carrion crows (attracted to refuse), and kestrels (for whom buildings provide ideal novel resting and nesting places). Fragmentation was shown to be one of the reasons for the decline of other lizard species (Corbett, 1989).

We believe that the proliferation of dogs was a main factor in the virtual disappearance of mountain gazelles and monitors from the study site. Stanner (1983) reports a monitor killed by a dog near our study site, and Lunney et al. (1990) found that 10% of the summer food of feral dogs in Australia was reptiles, including monitors (*Varanus varius*). Canine tracks following mountain gazelle tracks indicate chase, and there have been reports of feral dogs attacking gazelles in other locations (Daniels and Bekoff, 1989).

Carrion crows were most likely a major factor causing the reduction in *T. graeca* populations. Although we have not observed an incident of carrion crows attacking tortoises, it was not until carrion crows became common on the study site that dead tortoises started being found. Moreover, carrion crows are the only birds that could have caused the kind of damage observed: only their strong, straight beak would be able to grasp and pull out the head of a young tortoise. That more tortoises were killed in open areas, where they would be easier to spot from the air, also indicates that carrion crows were the predators. Berry (1989) described common ravens posing a similar threat to *Gopherus agassizi* in North America. As in the US, however, mature tortoises are not affected. The spur-thighed tortoise is not considered in immediate danger (Perry, 1984; Stubbs, 1989). In Israel, it is considered to be out of danger throughout most of its range (Ashkenazi and Hakham, 1987). Generally, habitat destruction is the major threat facing this species, and depletion due to collecting is also a factor (Corbett, 1989; Stubbs, 1989). This is also true outside of dune areas in Israel.

Plant cover on parts of the study site increased markedly during the study period (Fig. 1), and we attribute this to long-term effects related to demographic changes and off-site building projects. Both the winds and the sand they used to carry inland (Dan, 1988) have been blocked, to a large extent, by a barrier of buildings between the study site and the sea. Additionally, the herbivores, which served to reduce plant cover, have practically been eliminated. Similar to the findings of Putman et al. (1989) and Burgess et al. (1990), the result is an increase in stabilized areas with high plant cover. We also found indications of a change in the relative abundance of *Artemisia* (Fig. 2), and this may indicate a long-term change in plant diversity. Such changes have also been noted in other parts of the coastal plain of Israel (Yom-Tov and Mendelssohn, 1988). This creates conditions which are favorable to Mediterranean species (Yom-Tov and Mendelssohn, 1988; present study), which are then able to replace the original Saharan inhabitants. In our site, the result is reduction in the numbers of *Sphenops sepsoides* and *Acanthodactylus scutellatus*, and increases in *Chalcides ocellatus* and *A. schreiberi* (Table 1). Corbett and Tamarind (1979) noted similar changes in lizard faunas in England following major changes in plant cover. At various sites where plant cover has changed considerably, Putman et al. (1989) and Burgess et al. (1990) have found similar trends in other animal groups.

The changes noted above also had an effect on longevity of animals on the study site. Perry (1990) and Perry and Dmi'el (1994), for instance, found that the average life expectancy of *Acanthodactylus scutellatus* on the study site is less than one year. In the 1960s, however, life expectancy for the fringe-toed lizard in this region was

approximately two years (H. Mendelssohn, pers. comm.). We have observed kestrels eating lizards (*Acanthodactylus* spp.) and invertebrates on the study site, but the number of such incidents was apparently too low to cause any marked damage to native populations.

Sprugel (1991) discussed the meaning of the term "natural" in the context of native floras, and pointed out that many systems are in constant flux because of natural disturbance. Thus, there can be several "natural" vegetations for a given area, and the state achieved after a lengthy period without disturbance is not necessarily one of them (Sprugel, 1991). Our observations indicate that the fauna and flora of the coastal dunes of Israel are changing, and we suspect lack of grazing may be a major cause for this change.

Information on coastal dune faunas is lacking (McLachlan, 1991). Though some of the data provided here are preliminary, we felt this shortage and the rapidity and severity of the changes involved warranted publication of a preliminary report. If we are to keep the unique fauna and flora of the sand dune, immediate action is necessary. We believe this should take two forms: establishment of managed dune preserves and establishment of city "preserves."

Managed sand dune preserves: At this time, there are 10 nature reserves incorporating coastal sand dunes in Israel (UNEP, 1989; Frankenberg et al., 1991). Most, however, only include very small sandy areas. Moreover, traditional no-interference preserves do not solve the problem, since plant cover is increasing (Frankenberg et al., 1991), with a concomitant change in fauna. We recommend a controlled number of sheep or goats be allowed on dune preserves, but that their grazing be restricted to ensure maintenance of open sand dune habitat while avoiding overgrazing. Another factor requiring intervention is the effects of human commensals such as dogs, cats, and crows. Unless their numbers are controlled, these organisms can be a major threat to some native species. Our study emphasizes the importance of such indirect effects, and suggests that strict control for human commensals is necessary at other sites as well.

The city preserve: Clearly, small areas close to human habitations cannot be used as nature reserves: habitat fragmentation and secondary effects of human activity affect some species (notably large ones) too strongly. However, many species can survive inside cities, with little or no intervention (e.g., Klemens, 1985). The site described in this paper is certainly smaller than the preserve size found by Cowling and Bond (1991) to be the minimum necessary for avoiding loss of diversity. However, that does not make such areas useless for conservation purposes. Many animal and plant species, as well as certain habitats, hold an aesthetic value for people. Worldwide, increasing numbers of people use nature for recreation purposes (Duffus and Dearden, 1990). Small tracts of land, especially if they are situated close to or within settlements, can serve as recreational sites for the general population. Being close to population centers, such areas are easily accessible to the public, thus encouraging visits. Since such areas are disturbed to begin with, the damage that is always incidental to mass usage will not affect the most sensitive ecosystems. Such "preserves" can also be used for educational

purposes. Increasingly, children who grow up in cities are cut off from nature. These areas would be close enough for school or family day trips; such exposure could increase kids' interest in nature and conservation.

The level of protection of city preserves would be intermediate. No development or cultivation of the land would be allowed, but the taking of animals and plants for educational or scientific purposes (e.g., class projects) would be permitted, though regulated to insure minimal lasting damage.

While not a perfect representation of undisturbed habitats, sites like the one we studied are diverse enough for most educational purposes, as well as many scientific inquiries.

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