Effects of Microhabitat Destruction on Reptile Abundance in Sonoran Desert Rock Outcrops

by

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Abstract: While the effects of large-scale habitat loss on biodiversity are well known, effects of microhabitat loss have received less attention. Certain methods of reptile collection result in destruction of cracks, crevices, and other cool, moist microhabitats in desert rock outcrops. Microhabitat loss has become extensive and locally severe in some desert mountain ranges in the southwestern United States and northwestern Mexico. We hypothesized that this type of microhabitat loss results in decreased abundance of reptiles. To test this hypothesis, we established plots in lightly and heavily disturbed areas and assessed them for microhabitat destruction and reptile abundance. Our results support the hypothesis that plots with higher disturbance levels have lower relative abundance of certain species of diurnal lizards. Of the four diurnal lizard species studied, relative abundance of two saxicolous (rock-dwelling) species was negatively correlated with level of microhabitat destruction while that of two non- saxicolous species was not. To help combat this serious and growing problem, we recommend careful management and protection of desert rock outcrops and education of collectors.

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Introduction

Habitat loss is widely recognized as the leading threat to global biodiversity (Ehrlich 1988; Wilson 1992; Tilman et al. 1994). While difficult to precisely categorize, habitat loss occurs on an overlapping continuum from small-scale to large-scale and from complete destruction to subtle degradation. Examples of large-scale habitat destruction are deforestation and development of land for agricultural or urban uses. Timber management (Bury 1983; Thiollay 1992), livestock grazing (Fleischner 1994; Oldemeyer 1994), and habitat fragmentation in general (Harris 1984) often occur on a large spatial scale, but may result in less conspicuous habitat degradation. Activities such as recreational off-highway vehicle use (Webb & Wilshire 1983) occur on a smaller scale, but may lead to destruction in a confined area or degradation over a larger area. This paper is concerned with the impact of habitat loss on a much smaller spatial scale. We address the effects of a largely overlooked form of habitat degradation: destruction of desert rock outcrops. We believe this problem to be analogous to degradation of coral reefs and caves. Destruction of these sensitive habitats and the effects on animal communities which use them, such as coral reef organisms (Aronson 1990; Bunkley-Williams & Williams 1990; Ward 1990; Golden 1991) and bats (Manville 1962; Mohr 1972; Tuttle 1979; Brown & Berry 1991; Richter et al. 1993; Thomas 1995), have received considerable attention in both scientific and popular publications, and resulted in extensive legal protections. Damage to desert rock outcrops may warrant similar concern and action.

Many forms of anthropogenic habitat disturbance are known to impact herpetofaunal communities (Herrington & Larsen 1985; Dodd 1987, 1990; Brattstrom 1988; Herrington 1988; Van Rooy & Stumpel 1995). For example, logging (Buhlmann et al. 1988; Welsh 1990; Petranka et al. 1993), off-highway vehicle activity (Luckenbach & Bury 1983), and livestock grazing (Jones 1981; Szaro et al. 1988; Bock et al. 1990) have been demonstrated to negatively impact reptile and amphibian abundance. With growing human populations and increasing urbanization, interest in reptiles as food, pets, or raw materials for clothing and curios has increased (Dodd 1986). The effects of this increased use on reptile and amphibian populations are largely unknown. Several studies have called attention to the effects of rattlesnake roundups on rattlesnake populations and habitats (Campbell et al. 1989; Reinert 1990; Warwick 1990; Weir 1992) and on non-target species (Speake & Mount 1973). Harvest of gopher tortoises has negative impacts not only on tortoises, but on other species (e.g. *Crotalus adamanteus*) inhabiting their burrows (Landers & Speake 1980; Diemer 1986, 1987; Spillers & Speake 1988). Direct take of animals or eggs, whether intentional or incidental, has been implicated as a source of population declines and/or endangerment for some species, such as red-legged frogs (*Rana aurora*, Jennings & Hayes 1985), loggerhead sea turtles (*Caretta caretta*, Crouse et al. 1987; Crowder et al. 1994), timber rattlesnakes (*Crotalus horridus*, Brown 1993; Brown et al. 1994), and New Mexico ridgenose rattlesnakes (*C. willardi obscurus*, Baltosser & Hubbard 1985).

Depending on methods of take, loss or degradation of habitat and microhabitat may accompany removal of individuals from wild populations. Degradation of microhabitats providing refuge from harsh environmental conditions may be especially critical. In arid regions, rock outcrops support diverse assemblages of species, including reptiles and amphibians, many of which do not occur in surrounding habitats (Maser et al. 1986). Caves, crevices, and cracks are inhabited by larger animals. Interstitial spaces between rocks or spaces underneath rocks lying on the soil surface are sealed from the external environment by fine soils, detritus, or vegetation and are inhabited by smaller species. These spaces provide shelter from heat and desiccation. When rock outcrops are dismantled, loss of these microhabitats has the potential to directly affect all species that use them, not just reptiles.

While collecting methods that destroy microhabitats have been employed for decades (Klauber 1935), reptile collection for the burgeoning pet trade has led to accelerated microhabitat loss and degradation in recent years (Grismer & Edwards 1988; Mellink 1995). Some reptile collectors use their hands, crowbars, hydraulic jacks, or other tools to displace (often permanently) or break rocks, tear apart rotting stumps and logs, or otherwise expose reptiles in their shelters. Similar damage is caused by collection of rocks by hobbyists or for use in construction and landscaping (Schlesinger & Shine 1994). Although this damage has been implicated in the endangerment of at least one snake species in Australia (*Hoplocephalus bungaroides*, Shine & Fitzgerald 1989), microhabitat loss has been rarely documented (cf. Harris & Simmons 1975; Fritts et al. 1982; Grismer & Edwards 1988; McGurty 1988; Brown 1993; Mellink 1995) and its effects on herpetofauna have only been systematically studied once (Schlesinger & Shine 1994).

We hypothesized that high levels of microhabitat disturbance result in decreased abundance of reptiles. To test this hypothesis, we conducted a comparative field study to determine the relationship, if any, between microhabitat destruction and reptile abundance. We compared an index of relative abundance of lizards on heavily and lightly disturbed plots in which we also quantified and categorized habitat damage.

Methods

Study Area

The South Mountains lie immediately south of Phoenix, Maricopa County, Arizona. This range is almost entirely encompassed by Phoenix South Mountain Park (PSMP), the largest municipal park in the United States (Weir 1986). We chose PSMP as a study site because: (1) it is easily accessible, by several paved roads, to an urban population of approximately 2.5 million people; (2) it is well-known to reptile collectors; and (3) it supports at least four particularly prized species: tiger and speckled rattlesnakes (*Crotalus tigris* and *C. mitchelli*), Gila monsters (*Heloderma suspectum*), and chuckwallas (*Sauromalus obesus*). The park is characterized by rocky slopes with numerous outcrops, providing extensive habitat for a variety of saxicolous (rock-dwelling) species, including lizards, snakes, and other animals that use deep crevices and exfoliating granite as refugia.

Vegetation in the study area is Sonoran Desertscrub, Arizona Upland series (Turner & Brown 1982), with triangle-leaf bursage (*Ambrosia deltoidea*) and brittlebush (*Encelia farinosa*) being the dominant perennial plants. Common cacti include saguaro (*Carnegia gigantea*), prickly pears and chollas (*Opuntia* spp.), and barrel cactus (*Ferocactus wislizenii*). Trees, often abundant along washes, include foothill palo verde (*Cercidium microphyllum*), ironwood (*Olneya tesota*), and mesquite (*Prosopis juliflora*). Elevation in the park ranges from 430 to 897 m.

Quantifying Microhabitat Destruction

We developed methodologies for quantifying microhabitat disturbance through observations on lichens, vegetation, soil disturbance, rock displacement and damage, and other habitat attributes (Table 1). In February and March of 1994, we assessed frequency and quality of disturbance events by running ten 25 m x 10 m transects on each plot. These were randomly selected from 40 possible transects, providing 25% coverage of the plot. Each incidence of habitat disturbance encountered was evaluated for presence/absence of attributes in three categories of disturbance type: herp collection-related, unnatural, and recent (Table 1). If any one attribute within a category was present, the incident was scored as positive for that category. In addition to our three categories of disturbance, we tallied total number of individual disturbance events regardless of category.

We specifically chose plots to reflect extreme differences in disturbance level. We selected three plots each in lightly disturbed versus heavily disturbed areas. All plots were 1 ha (100 m x 100 m) and similar in elevation, slope, vegetation, and amount of exposed rock. Heavily disturbed plots exhibited pervasive evidence of collecting or other destructive activities which damage reptile microhabitats. Evidence included freshly exposed surfaces lacking desert varnish (Dorn 1983), large amounts of unnaturally displaced rock, and exposed crevices. These characteristics were far less common on lightly disturbed plots. Heavily disturbed areas were more accessible (by road or trail) than lightly disturbed areas. We performed *a posteriori* statistical tests to confirm our assignments of plots to disturbance category (heavy vs. light).

Based on our experiences, the training of field assistants, and comments from other workers with whom we discussed the topic, it is clear that detection of the type of habitat damage we studied requires close observation and detailed knowledge of the appearance of both undisturbed and disturbed rock outcrops. Even from a short distance (several meters), disturbance may not be readily evident. As indicated by the criteria listed in Table 1, close and detailed inspection of habitat is necessary in order to reliably identify disturbance.

Reptile Sampling

Because frequency of encounter was low for most species of reptiles, we confined our analyses to four common diurnal lizards: tree lizards (*Urosaurus ornatus*), side-blotched lizards (*Uta stansburiana*), western whiptails (*Cnemidophorus tigris*), and chuckwallas (*Sauromalus obesus*). For each plot, our sampling protocol consisted of multiple runs of a permanent 290 m x 10 m transect during periods of high lizard activity (modified after Lowe & Rosen, in press). The arrow-like transect (Fig. 1) design avoids potential biases resulting from linear features of the habitat such as long, rocky escarpments or washes. All lizards observed were identified to species and tallied. Weather conditions were similar for samples on all six plots. Transects were sampled beginning two hours after sunrise and continuing until one run after the highest (peak) number of individuals per run was obtained for each species (i.e. until the number of individuals observed had reached its highest value for that morning and begun to decline). This always occurred within four or five runs, by which time lizards began returning to retreat sites to avoid midday heat.

Peak values were standardized by dividing peak number of lizards seen by total time required to complete a transect run, yielding a peak encounter rate (lizards per minute) for each species. We sampled each plot twice during periods of high lizard activity (April 6 through May 27, 1994) and used the highest peak encounter rate from the two periods as an index of relative abundance for each species.

The four species of lizards studied fall into two distinct ecotypes: saxicolous species were *S. obesus* (e.g., Abts 1987) and *U. ornatus* (e.g., Dunham 1981), and non-saxicolous (ground-dwelling) species were *C. tigris* (e.g., Anderson 1993) and *U. stansburiana* (e.g., Turner et al. 1982). *U. ornatus* and *S. obesus* were observed more frequently on rocks than away from rocks (χ^2, all $p << 0.05$), so we combined peak encounter rates of these species and examined treatment effects on saxicolous lizards in some statistical comparisons. In contrast, *C. tigris* was found away from rocks more frequently than on rocks (χ^2, $p << 0.05$) and was categorized as a non-saxicolous lizard. While the frequency at which we observed *U. stansburiana* away from rocks was higher than on rocks, this difference was not quite significant (χ^2, $p = 0.055$). Because this species is well-known for its ground-dwelling habits (e.g. Tinkle 1967; Wilson 1991), and tended to avoid rock outcrops in our observations, we grouped it with the non-saxicolous *C. tigris* in some statistical comparisons. Because quantified habitat damage focused on rocky habitats, we tested the hypothesis that its effect on saxicolous lizards would be greater than on ground-dwelling lizards.

We compared numbers of destructive events by performing ANOVA on $\log_{10}$ transformed data. The relationship between ecotype and categories of destructive events was explored using Pearson product-moment correlation for each ecotype (saxicolous and non-saxicolous) and category of disturbance combination (herp collection-related, unnatural, recent, and total). For saxicolous lizards we performed a one-tailed test and for non-saxicolous species a two-tailed test of significance. We used factorial ANOVA to compare the effects of ecotype, level of disturbance, and the interaction of these factors. Assumptions of all statistical models were tested and met in all analyses performed. Statistical tests were generated using SPSS for Windows v. 6.02 (SPSS 1993). We set a criterion level of $\alpha = 0.05$ for all statistical tests.

Statewide Surveys

To assess the extent of collector-caused habitat destruction in Arizona, we photo-documented habitat damage throughout the state, within the habitats of several reptiles, including night lizards (*Xantusia vigilis*), chuckwallas (*S. obesus*), rosy boas (*Lichanura trivirgata*), Arizona mountain kingsnakes (*Lampropeltis pyromelana*), Gila monsters (*Heloderma suspectum*), and three species of montane rattlesnakes (*Crotalus willardi, C. lepidus, and C. pricei*). Numerous reported collecting localities in a total of 11 mountain ranges were visited in order to gain an understanding of the nature and extent of the type of habitat destruction with which we were concerned. Although we did not survey randomly selected sites or mountain ranges, it is still interesting that we found habitat damage, often extensive, at every known or suspected reptile collecting site visited.

Results

On PSMP study plots, our measures of levels of disturbance were significantly different (greater on heavily disturbed than lightly disturbed plots) for each of the three log-transformed disturbance criteria (recent, unnatural, and herp collection-related) and for the log-transformed totals (Table 2, one-way ANOVA, $F_{1,4}$, all $p < 0.05$).

All habitat disturbance categories and total disturbance events were highly significantly correlated with one another (Table 3). There was no association between categories of disturbance or total disturbance events and peak encounter rates for non-saxicolous lizards (Table 4). In contrast, the relationship between these variables and peak encounter rates of saxicolous lizards was highly significant and negative in every instance (Table 3), with herp-collection related and unnatural categories having the strongest negative correlations.

Factorial ANOVA of level of disturbance and ecotype was significant for each main effect and interaction of main effects (Table 5 and Table 6). To gain insight into the interaction effects, we performed one-way ANOVA on all pairwise comparisons and found that in addition to all peak encounter rates of non-saxicolous being lower than saxicolous, peaks for saxicolous lizards were significantly lower on heavily disturbed than lightly disturbed plots (Bonferroni adjusted $\alpha = 0.05$, $g = 6$, $df = 8$).

Discussion

We have shown a negative correlation between habitat disturbance and our index of relative abundance of two species of saxicolous lizards, but we have not demonstrated causation. The observed depression of lizard abundance on heavily disturbed plots could be due to any one of several or a combination of causes. Possibilities include: damage to habitat resulting in reduced carrying capacity (including all of its direct and ancillary effects, such as actual habitat loss, decreased food availability, increased competition for resources, etc.), actual collection of lizards, elevated mortality resulting from proximity of heavily disturbed plots to roads and trails, increased shyness (decreased observability) of lizards on heavily disturbed plots, or emigration of lizards from heavily disturbed plots. In fact, there may actually be no depression of lizard abundance on heavily disturbed plots, but rather, abundance of lizards may have been elevated on our lightly disturbed plots. Because we did not gather data on lizard abundance prior to disturbance, we are unable to address this question directly. MJG is currently gathering data in a pre- and post-disturbance study to test the effects of disturbance directly.

We recommend further experimental testing of alternative hypotheses (not directly associated with habitat damage) that could explain the observed negative relationship between disturbance and lizard abundance. If habitat damage is shown to be an important causative factor, the proximate cause of population depletion remains unclear and may vary from one species to another. For some, the loss of shelter from predators may be important while for others the relevant impact may be loss of food resources (e.g. many lizards feed on invertebrates that may be impacted), loss of shelter from heat or desiccation (potentially important for many animals and for plants whose root systems are exposed by disturbance), or loss of important microclimates for thermoregulation, hibernation, or oviposition.

Although we became interested in studying the effects of microhabitat loss after direct observation of the aftermath of reptile collecting activities (including our own), it is important to note that collection of rocks and minerals, vandalism, camping, hiking, rock climbing, off-highway vehicle activity, and mountain biking may cause similar habitat damage. Habitat damage by reptile collectors and others is extensive and ongoing in deserts of the southwestern United States. In Arizona, we have found damaged rock outcrops, within short distances of roads, in virtually every mountain range we have visited. In California, destructive collecting practices have been prohibited for many years, but JMH observed damage in 13 of 13 desert mountain ranges visited in southern California in the 1980s. This destruction has extended into Mexico as well, with Baja California being notably impacted (Mellink 1995). As rapid growth of urban centers continues, and collectors and other recreationists from around the country (especially southern California) and the world range further afield, we expect habitat loss in the desert Southwest to accelerate.

Presumably, the direct effects of collection affect target species (those sought as pets and for other commercial purposes) to a greater degree than non-target or incidentally collected species. Of the two saxicolous species studied, chuckwallas are commercially valuable while tree lizards are not. However, tree lizards are collected as food for other captive reptiles and may thus be directly impacted. Undoubtedly, direct take is a more important threat for commercialized species than for those that are only incidentally impacted. The effects of habitat damage may be unpredictable, as noted above, although a working hypothesis might be that influence on target species is likely to be at least as strong as on non-target species, unless damaged microhabitats are unimportant to target species. This could be the case if these habitats are inessential, used only occasionally, or suitable surrogate sites are available even after disturbance.

We have not investigated the impact of this kind of habitat modification on organisms other than reptiles. Small mammals (mostly rodents and bats), a few amphibians, certain birds, a host of invertebrates, and many plants, use the damaged microhabitats we studied (personal observations; Maser et al. 1986). The effect of habitat disturbance on these species is unknown, but in those for which lost microhabitats are essential or important, the effect is likely to be negative. This is especially true for species that inhabit rocky habitats for the same reasons as the lizard species in this study; namely, that they provide moist, cool shelters particularly vital to desert organisms (e.g., Grant & Dunham 1990).

We did not directly observe humans as they damaged rock outcrops, and therefore cannot assign causes to specific damaging events. It may be important to determine relative contributions of the different causes of habitat damage in order to develop adequate solutions to the problem. Regardless of who or what caused the damage and for whatever reason, it (1) results in microhabitat loss; and (2) is strongly correlated with lower abundance of saxicolous lizards. The combination of habitat loss or degradation and concomitant direct collection deserves greater attention from resource managers and conservation biologists.

We encourage resource management agencies to investigate regulatory options that might limit surface disturbing activities that damage rocky desert habitats and the organisms that use them. Our data suggest that habitat damage of the sort we studied, which is often ignored because it is inconspicuous, can impact wildlife populations negatively. These effects may therefore merit agency consideration in management of natural resources, including development of rules, regulations, management plans, and project review and mitigation protocols.

Specifically, we recommend regulation of collecting and other recreational activities, including prohibition of those that are most damaging to wildlife habitat. At another level, disallowing commercial activity involving wildlife may help to remove some of the incentive for collecting activities that damage habitats. Because of the remote locations involved, enforcement of regulations is difficult. We suggest increased enforcement and management attention for rock outcrops as important habitats for many species of wildlife (Maser et al. 1986). Without this kind of protection, these rocky habitats may suffer the same fate as many coral reefs and caves. Regulatory action should be considered as one option for controlling these problems, but regulations against any of these activities are only an attack on symptoms of a broader problem.

Most importantly, we feel strongly that education has the greatest potential for alleviating this problem. Young people who have been given the opportunity to develop a land and wildlife ethic will be far less likely to engage in destructive practices. For example, education of reptile collectors, via local and regional herpetological and conservation societies, should emphasize the importance of leaving habitat in an unaltered state. If specimens must be obtained, effective and non-destructive collecting techniques exist (Stebbins 1985; Gibbons & Semlitsch 1991). Typically, timing collecting efforts with periods of above ground activity of the species being sought, thereby avoiding the collection of individuals from their hiding places, is all that is required. Of course a certain degree of knowledge about the biology of the animals is necessary. At the agency level, educating law enforcement officials (i.e., game wardens) on how to recognize the activities of unethical collectors, will likely result in more effective enforcement practices.

To preserve a significant proportion of the accessible desert rock outcrops in the desert Southwest, the need for prompt management action is becoming more imminent. We suggest regulation of wildlife commercialization and collecting and recreational activities that cause habitat damage, increased enforcement effort, and expanded educational effort. The need is especially important for habitats and microhabitats that support diverse species assemblages and where damage is likely to be long-term. The rocky habitats we studied are ancient, and once lost they require geological time to reform (McAuliffe 1994). For conservation purposes, critical microhabitats are lost forever.

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Table 1. Criteria within three disturbance categories used for quantifying microhabitat destruction. Each instance of habitat disturbance was scored as positive for that category if any one attribute within a category was present.

RECENT

1. lichens/moss absent or nearly absent from exposed surface in suitable microhabitat
2. lichens/moss present on underside of dislodged fragment
3. lichens/moss on dislodged fragment still viable/hydrated but in unsuitable microhabitat
4. weathering/erosion/discoloration completely absent from dislodged fragment and/or exposed surface
5. weathering/erosion completely absent so that dislodged fragment precisely matches exposed parent surface
6. broken rock fragments and/or soil present on exposed surface and/or dislodged fragment
7. depression still damp from fresh exposure
8. vegetation under rock fragment still living
9. vegetation under rock fragment dead but exhibits flowering structures
10. vegetative matter under rock fragment in early stages of decomposition
11. invertebrate activity under rock fragment absent or minimally developed
12. refuse (*e.g.* glass, metal, paper) present under dislodged fragment
13. soil and/or mineral deposits present on exposed overturned rock
14. soil accumulation around dislodged fragment light in area of high soil accumulation potential

UNNATURAL

15. dislodged rock fragment not found or found broken into pieces
16. position of dislodged rock fragment inexplicable by natural means
17. rock fragment size and shape inconsistent with dislodgment by natural means
18. glass, trash or other human indicators under overturned rock

HERP-COLLECTION RELATED

19. evidence of tool use present
20. rock overturned in area of high frequency of overturned rocks
21. crack, crevice or other pre-existing microhabitat clearly disturbed
22. evidence of digging present
23. caprock flake dislodged
24. rock fragment propped up with rock or wood

Table 2. Means and standard deviations for level of disturbance for each category of disturbance (n=3). Abbreviations for categories of disturbance: H=herp-collection related, U=unnatural, R=recent, T=total number of destructive events (n=3 for all means).

	Level of disturbance	
	Light	Heavy
H	1.7 (1.2)	94.7 (580.0)
U	13.3 (8.1)	1840.0 (110.6)
R	13.3 (4.7)	163.3 (101.2)
T	17.3 (6.4)	194.3 (119.3)

Table 3. Pearson product-moment correlation coefficients and level of significance of categories of disturbance with one another (n=6 for all correlations). Abbreviations as in table 2.

	U	R	T
H	0.9973 $p = 0.000$	0.9970 $p = 0.000$	0.9987 $p = 0.000$
U		0.9997 $p = 0.000$	0.9990 $p = 0.000$
R			0.9991 $p = 0.000$

Table 4. Pearson product-moment correlation coefficients and level of significance of correlations between peak encounter rates of non-saxicolous (two-tailed test) and saxicolous (one-tailed test) and each category of disturbance (n=6 for all correlations). Abbreviations as in table 2.

	H	U	R	T
Non-saxicolous	-0.0220 p = 0.967	0.0152 p = 0.945	0.0364 p = 0.945	0.0094 p = 0.986
Saxicolous	-0.9477 p = 0.002	-0.9442 p = 0.002	-0.9393 p = 0.003	-0.9414 p = 0.003

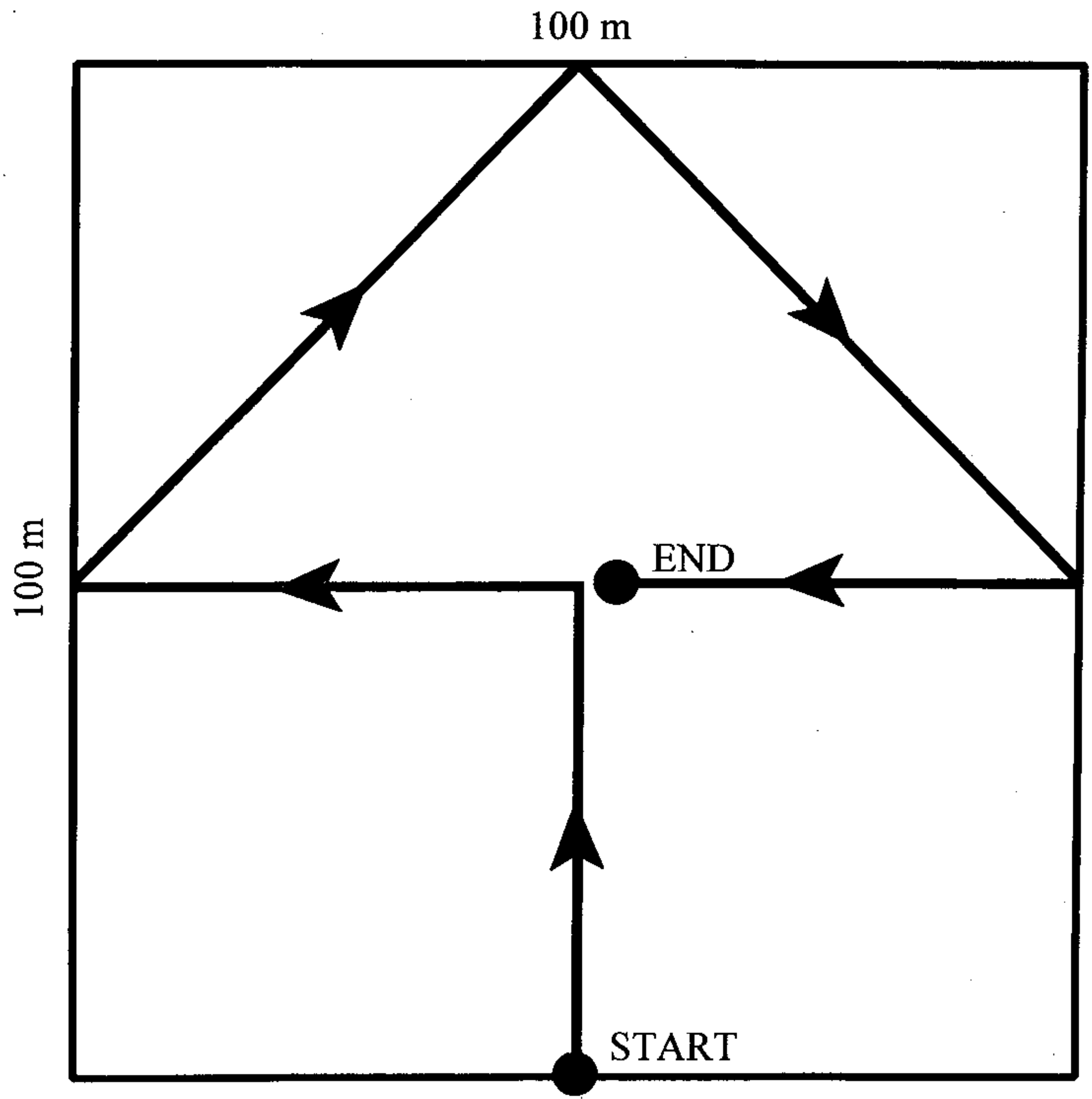
Table 5. Ecotype means and standard deviations for peak encounter rates (lizards per minute) for each disturbance level (n=3 for all means).

	Level of disturbance	
	Light	Heavy
Saxicolous	0.41 (0.03)	0.30 (0.04)
Non-saxicolous	0.18 (0.02)	0.16 (0.04)

Table 6. ANOVA table for $\log_{10}$ transformed peak encounter rates. Values for ecotype are saxicolous and non-saxicolous. Values for level of disturbance are light and heavy.

Source	SS	df	F	p
Ecotype (E)	0.10	1	96.03	0.000
Disturbance (D)	0.01	1	11.46	0.010
D*E	0.01	1	5.37	0.049
Error	0.01	8		

Figure 1. Arrow-shaped transect. A permanent arrow-shaped transect was established on each plot. It was 10 m wide and 291 m long. Its unique shape was designed to avoid any topographical biases due to linear features of the habitat such as washes and rock escarpments.


100 m
100 m
END
START