Design Considerations for the Study of Amphibians, Reptiles, and Small Mammals in California's Oak Woodlands: Temporal and Spatial Patterns[1]

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Abstract.—We monitored pitfall traps for >50,000 trap nights among three study areas in California's oak woodlands. Numbers of captures and trap success varied spatially in comparisons of grids within and among stand types, as well as among study areas. Capture numbers also varied temporally, both within and between the years of study. Dierences in capture rates varied among taxa (amphibians, reptiles, and small mammals) and also varied among species within a taxon. Researchers should design studies to sample temporal and spatial variations in activity patterns to provide a more complete understanding of the habitat associations of the species studied.

The hardwood rangelands of California are coming under increasing land-use pressures. Cattle grazing, fuelwood removal, hydro-electric projects, urban sprawl, and countless other factors are impacting these woodlands at local, regional, and geographical levels (see papers within Plumb and Pillsbury 1987). Unfortunately, little is known of the distributions and ecologies of many of the vertebrates occurring in these areas Werner 1987). As a consequence, resource managers frequently have too little information upon which to base land-use decisions. Thus, a research agenda is required first to obtain baseline information on distributions and habitat associations of these animals, and then to use these data to predict the presence or absence of these species, and ultimately to predict the effects of habitat change on their populations. Research should encompass a hierarchy of spatial scales to account for variations in patterns of habitat use, and also to determine if a species' habitat exhibits consistent and measurable features (Allen and Starr 1982, Block, in press). Study must also be done year-round to sample habitat-use by species during different stages of their life histories, and it also should be done over a number of years to include annual variations in environmental conditions (Halvorson 1984, Morrison, this volume).

As part of an ongoing study to determine habitat relationships of vertebrates in California's oak woodlands, we have been using pitfall traps to sample populations of small mammals, reptiles, and amphibians at three distinct areas. To date we have collected data from greater than 50,000 trap nights distributed among 20 trapping grids. This general design has allowed us to examine spatial patterns of habitat-use both within and among areas. Further, more intensive study has been done at one area to examine temporal patterns in habitat use both within and between years. In this paper we present these data to examine spatial and temporal patterns of habitat use and discuss our results in relation to the general design of studies of small mammal, reptile, and amphibian populations.

STUDY AREAS

The study was done at three areas, all oak or pine-oak woodlands. Study areas were distributed along a latitudinal gradient of about 600 km, and consequently there were notable differences in topography and in composition and structure of the vegetation among the study areas.

Sierra Foothill Range Field Station (SFRFS), Yuba County, was located in the foothills of the Sierra Nevada about 25 km NE of Marysville. Elevation ranged from 200 to 700 m on a general west-northwest facing slope. Blue oak *(Quercus douglasii)*, interior live oak *(Q. wislizenii)*, and digger pine *(Pinus sabiniana)* were the major species of trees with lesser amounts of California black oak *(Q. kelloggii)*, California buckeye *(Aesculus califomicus)*, and ponderosa pine *(Pinus ponderosa)*. Major components of the shrub layer included buckbrush *(Ceanothus cuneatus)*, coffeeberry *(Rhamnus californica)*, and poison oak *(Toxicodendron diversiloba)*. Annual and perennial grasses and forbs dominated cover within a meter of the ground, although there were spatial and temporal variations in species compositions and also in amount of ground cover. Further, the composition and structure of the canopy, shrub, and ground layers have all been modified by historic land-use practices at the Station. Except for 60 ha of fenced areas, the remaining 1800 ha are used for varied research projects usually entailing cattle grazing and often entailing tree removal.

San Joaquin Experimental Range (SJER), Madera County, was located in the foothills of the Sierra Nevada about 40 km N of Fresno. Elevation ranged from 200 to 500 m; the aspect was in a general southwest direction.

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Blue oak, interior live oak, and digger pine were the major tree species. These species occurred in mixed-species stands, stands of blue oak woodland, or as blue oak savannas. Annual and perennial forbs and annual grasses dominated the ground layer. About 20 ha of SJER have been fenced to exclude cattle grazing. Cattle grazing on the remaining 1500 ha has resulted in a sparser shrub understory at SJER than of that found at SFRFS (Duncan et al. 1987). Major shrubs include buckbrush, whitethorn ceanothus (*Ceanothus leucodermis*), redberry (*Rhamnus crocea*), coffeberry, poison oak, and white lupine (*Lupinus alba*). The shrub understory is restricted mostly to widely scattered stands of mature shrubs which have grown above the deer-cattle browse line.

Tepn Ranch (TR), Kern County, was located about 50 km south of Bakersfield in the Tehachapi Mountains. Elevation ranged from 1100 to 1700 m; aspects included all cardinal directions. Major trees found on TR included blue oak, valley oak (*Quercus lobata*), California black oak, interior live oak, canyon live oak (*Q. chrysolepis*), Brewer's oak (*Q. garryana* var. *breweri*), and California buckeye. At lower elevations, these trees generally occurred in pure stands of single species, with mixed-stands of California black, canyon live, interior live, and Brewer's oaks occumng at higher elevations. Buckbrush, redberry, and mountain mahogany (*Cercocarpus betuloides*) were the major shrubs with annual and perennial grasses and forbs comprising the ground canopy. Cattle grazing and fuelwood harvest have modified the composition and structure of the tree, shrub, and herbaceous layers.

METHODS

Field Methods

At TR we placed three grids in each of three different stand types--blue oak, valley oak, and canyon live oak woodlands—and we placed four grids in four different stands of mixed-oak woodlands (California black, interior live, canyon live, and Brewer's oaks). At SJER we placed four grids, one each in a blue oak and an interior live oak stand, and two in mixed blue oak-interior live oak-digger pine stands. The three grids at SFRFS sampled three stands of mixed blue oak-interior live oak-digger pine woodlands. Selection of stands was not entirely random because we needed to consider accessibility during inclement weather, and possible conflicts with other research projects or with certain management practices (e.g., excessive cattle grazing, fuelwood harvest, road construction) when selecting stands. The actual selection of the grid location within a stand was by a series of random procedures to determine distance of the grid from the stand edge (>100 m from the stand edge to minimize edge effects) and the direction of the grid array.

Each grid consisted of 36 2-gal, plastic buckets arrayed in a 6 x 6 square with 20-m interstation spacings. Buckets were placed within 2 m of each grid point at a suitable trapping location. Buckets were sunk to ground level and left closed (a piece of plywood secured with a rock) for at least one month prior to being opened. This period enabled germination of grasses and forbs to occur thus making the area near the trap appear less disturbed and also allowed small mammals and herpetofauna to become accustomed to the presence of the traps. Traps were opened by propping a plywood lid 5-10 cm above the lip of the bucket using small branches or small rocks and then placing 3-6 cm of water in the bottom of the bucket. Traps were checked once a week and were left open for 1-2 months at a time. We noted the species, date, and trap location of all captures. Dead animals were removed from traps; live animals were removed and relocated to a similar habitat at least one km from the nearest trapping grid.

We monitored pitfall traps at TR from 4 January to 20 May 1987 and from 10 December 1987 to 20 June 1988. We regarded the first year of monitoring as a pilot study to evaluate and refine our methods. Traps were opened and monitored for 30 days using the methods described above. However, in light of a recent article by Bury and Corn (1987), we increased our trapping period from 30 to 60-65 days per grid. Thus, our design at TR for the second year consisted of opening one grid of each stand type for 60-65 days, closing those, and then opening another set of four grids. We repeated this design three times. We opened the four grids at SJER and the three grids at SFRFS each for 60 days from mid-January through mid-March 1988.

Data Analyses

We compared standardized capture numbers among stand types at TR and among the three study areas (TR, SJER, and SFRFS) to determine general distributional patterns of the animals caught. Capture numbers were standardized by pooling all captures of a species within a stand type or within a study area and dividing this number by the total number of trap nights for each grid within that stand type or study area. We calculated Spearman rank-order coefficients (Marascuilo and McSweeny 1977) to test for differences in rankings of captures of species among stand types at TR and then of captures among the three areas. We tested for species-specific differences in capture rates among stand types and among study areas using Kruskal-Wallis analyses (Marascuilo and McSweeny 1977).

We used log-linear analyses (Fienberg 1980) to determine the sources of variation in trap success within and among years, stand types, and study areas. We used data only for the presence or absence of a species at each trapping station, regardless of the number of individuals of the species that were captured at the station. Because the number of trap nights varied between grids, we used this variable as a covariate in all analyses to factor out the bias this might have entered in our analyses.

To test for within-year, spatial-temporal patterns, we restricted our analyses to data collected in 1988. Analyses were done for common species (i.e., those for which we had adequate numbers of samples) and taxon variables of mammals, amphibians, and reptiles. We used data from TR to examine seasonal and stand associations of common species of each taxon.

To examine geographic patterns of captures, we compared trap success among the three study areas. Between-year analyses were done by comparing trap success at TR from 1987 and 1988.

RESULTS

General Patterns

Tejon Ranch

The ranking of species captured in canyon live oak woodlands was not significantly correlated with the rankings of species found in the other woodland types (all r_s values were nonsignificant, n = 21, $P > 0.05$). These differences were attributable to a stronger association of amphibians, particularly *Ensatina* and *Batrachoseps* salamanders, with canyon live oak stands than with the other types of woodlands (Kruskal-Wallis Analyses, df = 2, $P < 0.10$) (table 1). Differences among stands were also noted for captures of *Peromyscus maniculatus*, *P. truei*, *Sceloporus occidentalis*, and *Eumeces gilberti*, which were captured more frequently in blue and valley oak stands than in canyon live or mixed-species oak stands (table 1). In comparisons of rankings of taxonomic groups among stand types, we found a significant positive correlation between mixed-species and valley oak stands, but a significant negative correlation between blue and canyon live oak stands (r_s significant, n = 3, $P < 0.01$) (fig. 1). All other pair-wise comparisons between stand types were nonsignificant.

Table 1.—Capture numbers of amphibians, reptiles, and small mammals within four different oak woodland types at Tejon Ranch, Kern County, California from 1 January 1987 through 20 June 1988.

Species	Valley oak (n=7848)[1]	Blue oak (n=8828)	Canyon live oak (n=7848)	Mixed oak (n=8828)
Batrachoseps nigriventris[2]			38	3
Ensatina eschscholtzii[2]	19		53	13
Rana boylii		1		
Sceloporus occidentalis[2]	20	39		31
Eumeces gilberti[2]	28	34		4
Gerrhonotus multicarinatus			1	3
Anniella pulchra	1			
Diadophis pulchellus			1	
Peromyscus maniculatus[2]	42	10		3
P. boylii	33	20	22	24
P. truei[2]	14			6
Perognathus californicus		1	3	
Microtus californicus	2	2	4	1
Thomomys bottae	8	4	2	6
Reithrodontomys megalotis		1		1
Scapanus latimanus			1	1
Sorex ornatus	1		13	6
Total captures	168	112	138	102
Species richness	10	9	10	13

[1]Number of trap nights.

[2]Significant difference ($P < 0.10$) of captures among stand types.

All Study Areas

Rankings of captures of species were weakly correlated only between TR and SFRFS (r_s = 0.37, n = 21, P = 0.052); Spearman rank-order correlations were nonsignificant in all other comparisons. Significant differences were found among areas in the capture rates of *Sceloporus occidentalis*, *Eumeces gilberti*, *E. skiltonianus*, *Batrachoseps attenuatus*, *Batrachoseps nigriventris*, and *Ensatina eschscholtzii* (table 2). In contrast, rankings of taxa were significantly correlated between SJER and SFRFS (r_s = 1.00, n = 3, P = 1.00), but nonsignificant ($P > 0.05$) in all other between-area comparisons. The differences were primarily because of differences in capture rates of reptiles and amphibians (fig. 2).

Log-linear Analyses

Trap success at TR for small mammals, reptiles, and amphibians differed with stand type and trapping period (likelihood ratio chi-squares, $P < 0.01$). Similar results were found for the selected common species. In contrast, fewer differences were found between years for captures of amphibians, reptiles, and small mammals. Only captures of reptiles in blue oak stands and captures of ll mammals within valley oak .ds were significantly different veen years (likelihood ratio chi-ares, P < 0.01). We noted signifi-t differences ($P < 0.01$) in capture {uencies of reptiles and amphibi-. among study areas, but differ-:es were nonsignificant ($P > 0.05$) captures of small mammals.

DISCUSSION

ra-year differences in trap success TR were observed for all common ecies and taxonomic groups tested. uch of the intra-year variation in ap success was probably because of fferences in activity patterns dur-g different times of the year (Welsh)87). Our results further suggested iat activity patterns varied within nd among taxa. For example, few :ptiles were captured from Decem-:r through March; capture rates ien increased dramatically after larch. In contrast, fewer salaman-ers were caught in December, Janu-ry, May, and June than were caught luring March and April. Similar re-ults emerge when comparing activ-ty patterns of species within a taxon. Thus, activity patterns of a species or of a taxon tend to be somewhat spe-:ific to the animal or group studied.

Differences in trap success were not as apparent for interyear comparisons, however. In fact, the only differences that we noted were increases from 1987 to 1988 in trap success for reptiles in blue oak and for mammals in valley oak stands. These results might be interpreted in two ways. First, species compositions are fairly consistent from year to year, or the 2 years of data that we compared were possibly insufficient to detect population or habitat shifts (Halvorson 1984, Morrison, this volume). Undoubtedly, a long-term study is required to determine if these results remain valid with time or if they are an artifact of the sampling period.

Species distributions also varied spatially among the different stand types at TR and among the three study areas. For example, canyon live oak stands contained more amphibians and fewer reptiles than other types of stands, whereas few amphibians and more reptiles were captured in blue oak stands. Valley oak and mixed-species oak stands contained intermediate numbers of amphibians and reptiles. We also noted differences of captures among grids of the same woodland type. However, given the short duration of this study (2 years to date), these differences may reflect temporal differences between sampling periods more than variation within stand types. Variation was also noted on a broader geographical scale of between study areas.

Pitfall traps are one of many techniques used to sample vertebrate populations (Day et al. 1980). As with each technique, however, pitfall traps are not without limitations (Bury and Corn 1987). Inter- and intraspecific difference in motility, mode of travel, and activity range all influence the probability of an animal being captured. Because of probable species-specific biases in catchability, a study design should consider alternative methods (e.g., live traps for small mammals, and active searches for reptiles and amphibians) to sample the population(s) of the species of interest (Halvorson 1984, Raphael and Rosenberg 1983, Welsh 1987).

For example, results from our pitfall data do not completely agree with preliminary results from >6,000 trap nights using live traps or from 20 time-constraint searches, both done at TR (Block, unpubl. data). In particular, we captured more *Perognathus californicus* and *Reithrodontomys megalotis* using live traps than we did using pitfall traps, but have captured no *Microtus*, Sorex, *Thomomys*, or Scapanus in live traps whereas we have caught them in the pitfalls.

Thus, researchers should compare and evaluate results from alternative methods to determine the most effec-

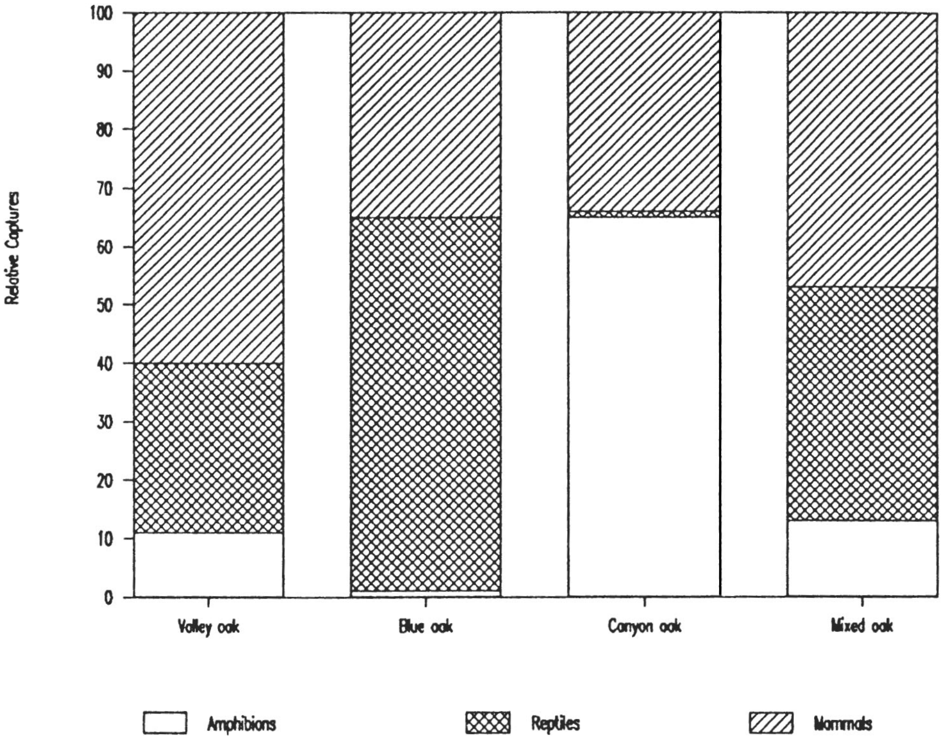

Figure 1.—Relative numbers of captures using pitfall traps within four oak woodland types at Tejon Ranch, Kern County, California from 5 December 1987 to 20 June 1988.

tive **method** or combination of methods to use for the species under study.

We evaluated our data in two different ways: comparisons of capture numbers and comparisons of trap success. Results from both analyses were generally consistent, although in some cases we found differences in comparisons of trap success, but failed to do so in comparisons of capture numbers. The discrepancies between these results may be attributable to both statistical and biological factors.

Statistical factors stem from the fact that continuous data were recorded for capture numbers whereas categorical data were recorded for trap success. Consequently, different statistical tests were required to analyze the different types of data. The lack of concordance between results may be the result of different assumptions of the different tests and of different powers of the associated statistics.

For example, in comparisons of capture numbers, our use of all captures from a trap for a given species may have violated assumptions of independence of samples; assumptions underlying most parametric and nonparametric statistical tests (e.g., see Sokal and Rohlf 1969, Maraxuilo and McSweeny 1977). Conversely, using presence-absence data as we did in analyses of trap success avoids the problem of dependency. A shortcoming of using only presence-absence data, however, is that information of the numbers and hence relative abundance of animals captured might be lost.

Table 2.—Capture numbers of amphibians, reptiles, and small mammals at three California oak woodlands: Tejon Ranch, Kern County; San Joaquin Experimental Range, Madera County; and Sierra Foothill Range Field Station, Yuba County, from mid-January through mid-March 1988.

Species	Tejon Ranch (n=8828)[1]	San Joaquin Exp. Range (n=8828)	Sierra Foothill Range Field Stn. (n=6912)
Batrachoseps attenuatus[2]		8	1
Batrachoseps nigriventris[2]	19		
Ensatina eschscholtzii[2]	3		
Taricha torosa		1	
Rana boylii	1		
Scaphiopus hammondii		3	
Sceloporus occidentalis[2]	20	31	96
Eumeces gilberti[2]	9	46	
Eumeces skiltonianus[2]			8
Gerrhonotus multicarinatus	1		1
Peromyscus maniculatus	6	7	3
P. boylii	13	6	5
P. truei	5	9	4
Perognathus californicus	1		
P. inornatus		1	
Microtus californicus	1		6
Thomomys bottae	1	4	1
Scapanus latimanus	1		
Sorex ornatus			3
Total captures	82	113	128
Species richness	13	10	9

[1]*Number of trap nights.*
[2]*Significant difference ($P < 0.10$) of captures among study areas.*

CONCLUSIONS

Using pitfall traps to sample amphibian, reptile, and small mammal populations, we found pronounced variation within and among study areas, and within and between years in capture rates of all taxa and of many of the species studies. Implications of these results apply both to the design of studies for these animals as well as for their management. First, we recognize biases by using only pitfall traps to sample populations of free-ranging vertebrates, and we suggest that researchers evaluate all possible methods to determine the best one or combination of methods for the study of a particular organism(s). Second, within-year variation in capture rates suggests that researchers should design a study to sample seasonal variations in activities and in habitat use. Similarly, spatial variation, both within and among stand types and among distinct geographic locations, should be studied to better identify distributional limits of the species studied and to determine how specific habitats contribute to the survival and reproduction of the species. From a management perspective, understanding temporal and spatial variability in habitat use is critical when trying to provide suitable conditions for the animal to survive and reproduce. All oak woodlands cannot be managed in the same way for all species. Each oak-woodland type contains a unique set of factors that predispose species to use the area for some aspect of their life histories. Management for a species should be based on information that considers the spatial and temporal variability in habitat use to provide for all life requisites.

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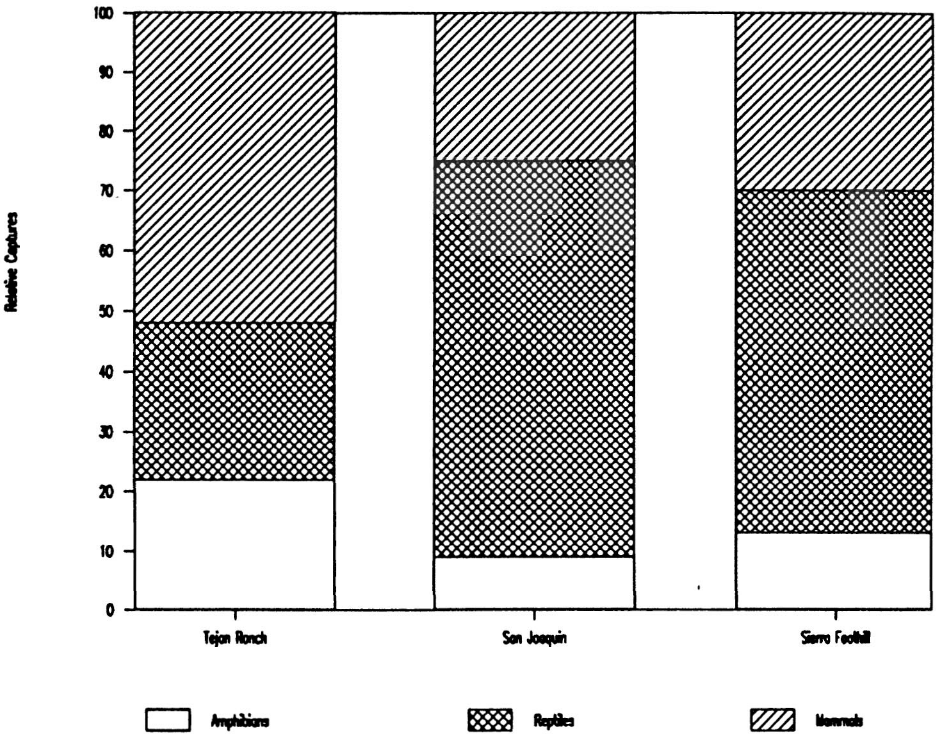

Figure 2.—Relative numbers of captures using pitfall haps **within** three oak woodland **study** areas **in California: Tejon** Ranch, **Kern** County, **San Joaquin Experimental** Range. **Madera** County; and Sierra **Foothill** Range Experimental Field **Station**, Yuba County. **Trapping** occurred from 5 December 1987 to 20 March 1988.

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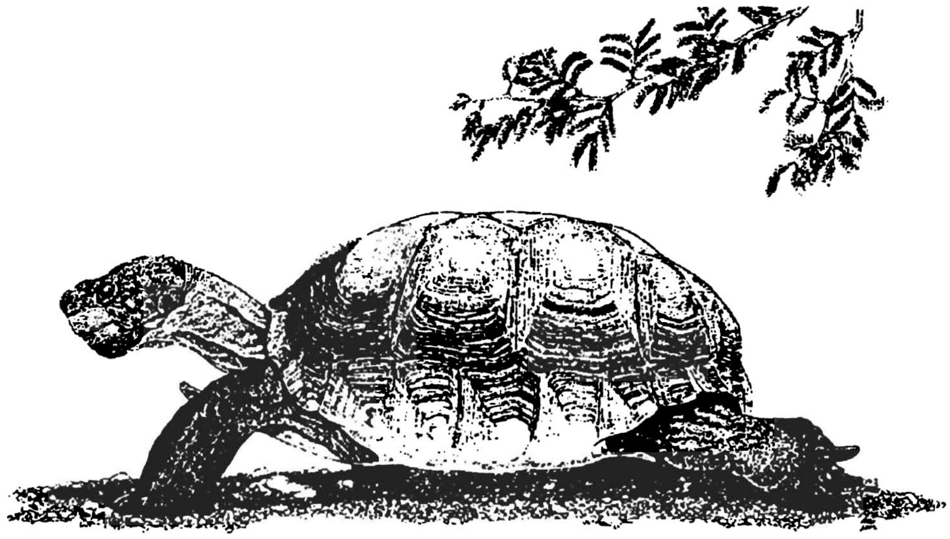

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