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Amphibia-Reptilia

The ecology of the island-lizard *Podarcis sicula salfii*: Correlation of microdistribution with vegetation coverage, thermal environment and food-size.

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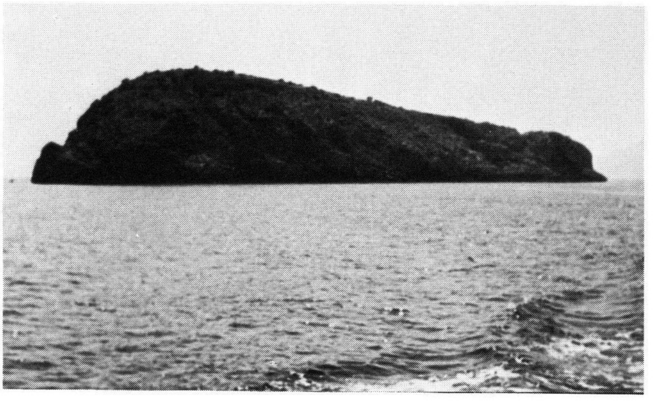
Abstract. In the summers of 1974 till 1979 microdistribution of *Podarcis sicula salfii* was examined. Areas without much vegetation and areas with dense vegetation have low densities. Horizontal space, predators, parasites, interspecific competition, shelter and dew appear to be non important factors in the microdistribution of *P. s. salfii*. From 9 a. m. until 6 p. m. temperature in the sun is above PBT (preferred-body-temperature) in all zones. Shade temperature is different from one zone to another. In the most rocky zone without much vegetation, shade is provided by crevices. Shade temperature is under PBT. Food is mainly available outside crevices, in vegetation of *Statice sinuatum*. Food-size is small, so excursion-time will be long. Lizards are able to collect sufficient food if *Statice*-plants are close to crevices. The zone with vegetation of *Erica arborea*, on top of the island, is shaded all day. Shade temperature is under PBT. Only clearings are inhabited by lizards. All other zones have bushes and open areas. During the hot hours bushes provide shade, with shade temperature close to PBT. Food is mainly available in these bushes.

Introduction

The research was started within the framework of the "Studygroup Island-Melanism". The members of this studygroup intended to check several hypotheses which try to explain island-melanism (e. g. Eimer, 1881; Mertens, 1915, 1934; Parker, 1935; Eisentraut, 1949; Kramer, 1949). For this research we selected the melanistic lizard *Podarcis sicula salfii* (Lanza, 1954).

The existence of this lizard, which lives on a small island, Vivaro di Nerano (or Scoglia Vetara) (fig. 1) in the Gulf of Salerno (province of Naples, Italy), was shown for the first time by Kramer in 1949. However a description of it was not given before 1954 by Lanza. Until now its name has only been mentioned 3 times, twice only casually by La Greca and Sacchi (1957) and by Bruno (1976). Mertens (1961) payed some more attention to this lizard and compared it with *Podarcis sicula gallensis* (Eimer, 1881) of the Galli-islands, situated 3 km farther east.

Visiting the island we noted that some areas were inhabited by more lizards than others and that densities seemed to be correlated with quantities of vegetation. A further analysis of this lizard's microdistribution became our main research project.



Figures 1.
Vivaro di Nerano, seen from the northeast.

Materials and Methods

The island was visited most summers (July–August) between 1974 and 1979 (not in 1976). Visits lasted from 3 to 21 days. The island was mapped with compass and measuring-tape and was divided into various zones on the basis of the occurrence of certain plant species (fig. 2). The northern and the southern zones (Bn, Bp, An, Bs and As) were mostly not involved in the research because of their inaccessibility.

First activity-pattern was determined by counting the lizards seen in a certain area. To reduce the influence of the observer on the lizard activity, we used cameras in 1978 and 1979. Every 15 minutes photographs of 2 open sunny plots, in zone A and zone D, were taken by remote control. After development, lizards present in the plots could be counted.

Lizard-densities on the island and in the various zones were determined by capture-recapture analysis. Lizards were captured by noosing (1974) or by using pitfall-traps (all other years). Because 25% of the lizards already missed 1 to 5 toes, marking them by toe-clipping was impossible. So, they were marked with quick-drying paint on 6 different headshields. To be able to observe migration easily, different colours were used for different zones. Population size (P) was calculated from:

$$P = \frac{a \cdot n\,(1 - q/s)}{r}$$

a is the number of lizards marked during the first census.
n is the number of lizards in the second census.
r is the number of marked lizards recaptured.
q is the mean number of days between the first and the second census.
s is the mean number of days between two sloughings.

The term $(1 - q/s)$ is added because marks are lost by sloughing. In summer, when sufficient food was available, an adult *P. sicula* sloughed every 33 ± 8 days (in captivity). So, every day 3% of the marks is lost. Standard error was estimated according to Begon (1979).

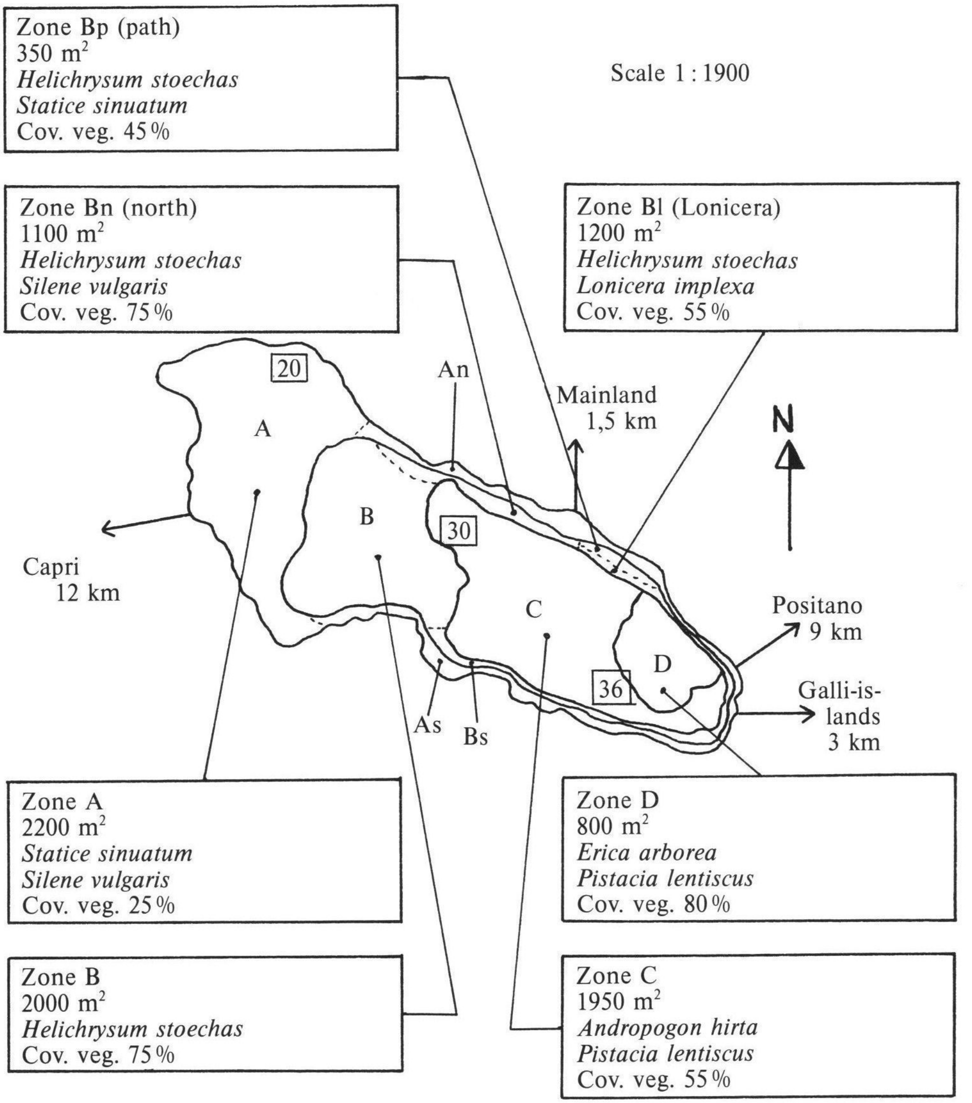


Figure 2. Map of Vivaro di Nerano with the various zones and their specific plant(s). The first mentioned plant species covers more than 50% of the total coverage of vegetation. Coverage of vegetation is indicated in percents of the ground surface. [30]: elevation in m.

The following factors, that may determine density, have been examined:

1. Horizontal space.
2. Food. Stomach-intestine-contents (SIC) of 2 lizards (1 male and 1 female) for every zone have been examined. At the same day we collected these lizards, insects were sampled with nets and pitfall-traps and by hand. This was done in every zone during some hours.

3. Predators.
4. Parasites. In 1974 and 1975 faeces pellets were sampled (4 for each zone) and checked on parasites and their eggs. Also the lizards used for SIC-analysis were checked on parasites.
5. Interspecific competition. Food and interspecific relations of all animals (including insects) living on the island were traced from literature and if possible also in nature.
6. Shelter against enemies.
7. Dew. Dew was looked for every morning before sunrise. Humidity was measured by 2 Lambrecht thermo-hygrographs.
8. Temperature in the sun. Mostly one measures temperature at a sunny spot, under a shade that is put up for a short time. To approximate more or less the temperature sensed by a lizard we also made "lizard-skin-thermometers", constructed of a lizard-skin stretched over a piece of polystyrene-foam. An ordinary laboratory-thermometer was put inside a hole in the polystyrene-foam. The probe touched the lizard-skin from the inside. Measurements were made 80 cm above the soil, to reduce the influence of soil temperature. Differences between the first method and measurements made by a "lizard-skin-thermometer" are shown in fig. 3.

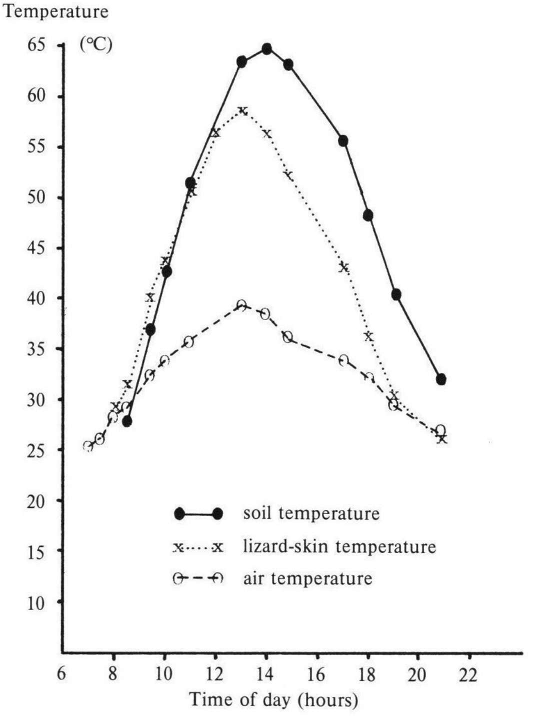


Figure 3. Difference between air-temperature (and soil-temperature) measured in the shade at a sunny spot and temperature measured by a „lizard-skin-thermometer" in the sun. Measurements made in zone A on August 1st of 1979 (a normal sunny day).

9. Shade.
10. Temperature in shaded areas. This was measured by Lambrecht thermo-hygrographs and by max-min thermometers at 4 kinds of shaded areas: 40 cm inside a crevice which had its opening facing northwest; 40 cm inside a rabbit-burrow also facing northwest (most rabbit-burrows were facing northwest); in the shade of *Pistacia*-bush, about 60 cm underneath the foliage; in the shade of *Erica arborea*-bush, about 250 cm underneath the foliage. All measurements were made about 10 cm above the soil.

Results

The island and the zones with their specific plant(s) are shown in fig. 2. Vegetation coverage (for 1974 and 1975) is also indicated.

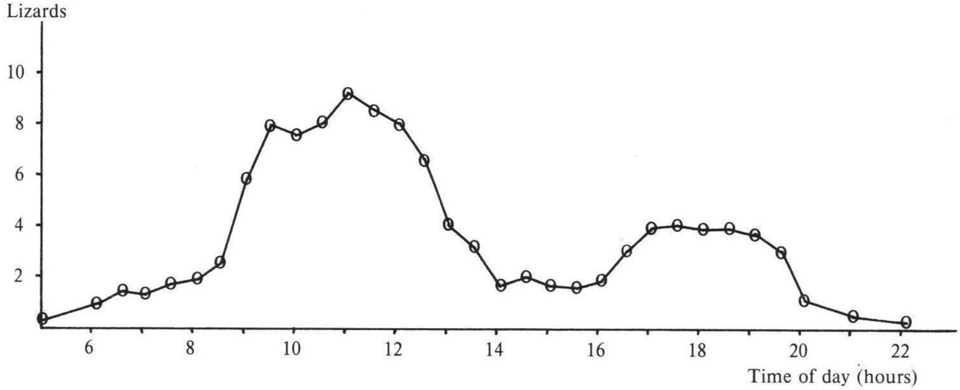


Figure 4. Lizard activity, measured as mean number of lizards seen in an area of 4 m^2.

In summer activity-pattern is bimodal as shown in fig. 4. This bimodal pattern is caused by the tremendous heat during midday (cf fig. 7), which the lizards seek to avoid. Such patterns are also reported from other heliothermic lizards (e. g. AVERY, 1976). Some lizards awaked before sunrise (5–6 a. m.), when temperature was lowest, probably in order to drink dewdrops. There was no difference in activity between the chosen sunny areas in zone A and zone D.

Table 1 shows the density and the number of lizards in the various zones from 1974 till 1979. Although standard error is rather high in the first two years, it is clear that population size changes very rapidly from one year to another. Most dramatic changes were also obvious when just walking on the island. But in spite of these annual changes, the differences in density between the various zones remain. Also migration appeared to have no significant influence upon population microdistribution, although a lot of lizards were not very sedentary. During the total time of research 13 lizards, mostly males, were seen to migrate more than 15 m, with a maximum of 55 m. Males nor

Table 1. Number of lizards (n) and lizard densities (d, given as lizards/m^2) on the island and its most important zones between 1974 and 1979. In order to calculate the total number of lizards on the island in each year, we extrapolated the number of lizards in zones in which we didn't catch them the year concerned, from the mean density of lizards in that zone and its area.

Year	Zone										Total	
	A		B		C		D		D/Bl			
	n	d	n	d	n	d	n	d	n	d	n	d
1974					472 ± 262	(0,242)			129 ± 172	(0,065)	837 ± 315	(0,089)
1975			81 ± 34	(0,041)	203 ± 44	(0,104)	38 ± 23	(0,048)			406 ± 56	(0,043)
1976												
1977	36 ± 16	(0,016)	258 ± 110	(0,129)	773 ± 182	(0,396)			185 ± 50	(0,093)	1298 ± 204	(0,138)
1978			149 ± 21	(0,075)	595 ± 49	(0,305)	36 ± 11	(0,045)			1035 ± 54	(0,110)
1979	104 ± 27	(0,047)	194 ± 25	(0,097)	266 ± 24	(0,136)	71 ± 19	(0,089)			820 ± 38	(0,087)
Mean		0,032		0,085		0,237		0,060		0,079		0,098

females defended territoria. Dominant males and females always chased away every lizard in sight, especially near food, even when placed in a totally different spot of the island.

Total population density is very high: mean number of lizards per hectare is 980. This is much higher than densities of all terrestial lizards (except *Scincella lateralis*) listed by TURNER (1977). The density is highest in zone C and is relatively low in zone A and zone D. LANZA (1954) and MERTENS (1961) also mentioned that population density is high on this island, though they gave no figures.

Analysing the factors that possibly have some influence on the number of lizards in the different zones, we came to the following results:

1. Horizontal space. According to BUTZ and KUENZER (1956) horizontal space is an important factor in the distribution of *Podarcis sicula coerulea* on the Faraglioni-rocks. Lizards were only found on the flat top of the rocks and on horizontal ridges. During visits to the Galli-islands and the Monacone-rock (situated near the Faraglioni-rocks) we found the same to be true for *P. s. gallensis* and *P. s. monaconensis.* Vivaro di Nerano is much flatter than the above mentioned islands. We haven't got exact figures on the amount of horizontal space, because we believe horizontal space is not a limiting factor on this island. Relatively seen there is no difference in horizontal space between zone C and zone D. In zone A horizontal space is less, because of slanting rocks sticking out of the soil. However between these rocks there is still a lot of horizontal space, mostly not occupied by lizards.

Table 2. Food found in the SIC (stomach-intestine-contents) of 2 lizards per zone and food sampled by ourselves in 1979.
\+ observed number between 10 and 100.
++ observed number more than 100.

	zone A			zone B			zone C			zone D		
	SIC	%	Sample	SIC	%	Sample	SIC	%	Sample	SIC	%	Sample
Formicidae	49	52	++	27	66	+	15	75	+	4	12	+
other Hymenoptera	2	2	3	3	7	+	1	5	+	2	6	+
Gymnocerata	8	9	–	1	2	4	–	–	–	5	15	++
Aphidoidea	22	23	++	–	–	+	–	–	+	1	3	+
Diptera	1	1	+	1	2	3	–	–	–	1	3	–
Coleoptera	–	–	–	2	5	–	1	5	–	2	6	–
Microlepidoptera	–	–	2	–	–	+	–	–	–	–	–	–
Odonata	–	–	–	–	–	1	–	–	–	–	–	1
Mecoptera	1	1	–	–	–	–	–	–	–	–	–	–
Insect larva	1	1	–	3	7	–	–	–	–	–	–	–
Arachnida	3	3	–	1	2	–	–	–	2	1	3	1
Isopoda	–	+	–	1	2	–	1	5	1	–	–	–
Lizard-skin	1	1	+	1	2	+	1	5	+	–	–	+
Parts of plants	6	7	++	1	2	++	1	5	++	18	53	++

2. Food. Results of the stomach-intestine-contents (SIC) analysis are given in tab. 2. Ants are the lizards' most important food in nearly all zones. In zone D bugs are an important part of the diet as well. They are numerous in *Erica arborea*. Here the different vegetation structure will probably also be the cause of the availability of larger prey (fig. 5). The large amount of vegetable matter in the SIC of zone D is coming from one twig only.

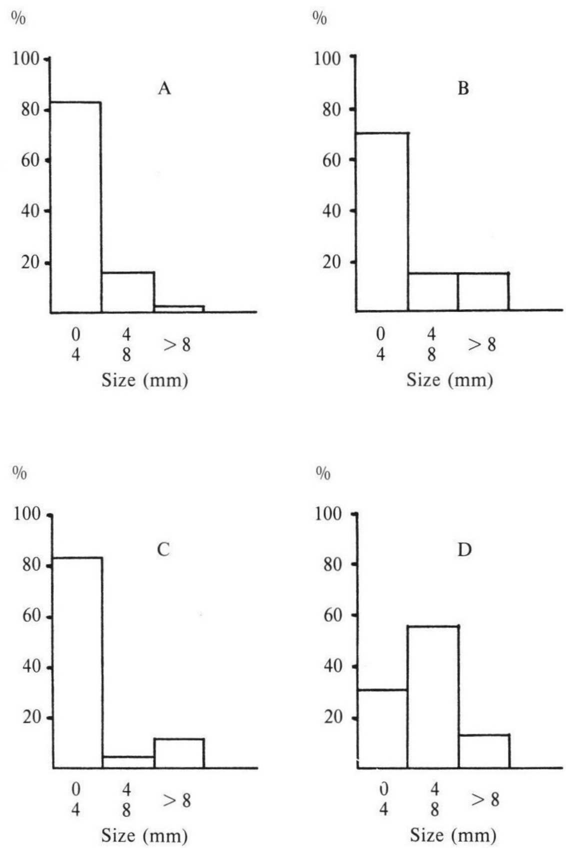


Figure 5. Distribution of the food items found in the SIC (stomach-intestine-contents) into 3 size-classes.

In 1975 and 1977 observations on eating lizards in zone B and C revealed that most insects were caught in plants. On *Helichrysum stoechas* in zone B mainly aphids and other little insects were caught. In zone C moths. None of these were found in the SIC of the lizards from the above mentioned zones. In 1979 aphids were mainly eaten in zone A. Moths were not found in any SIC, but are probably too soft to remain recognizable. The reason for the apparent contradictions in observed aphids eating, while none were found in the SIC, is that the island was infested with aphids from 1975 until 1977. In 1979 aphids were mainly confined to *Statice sinuatum* and so to zone A.

3. Predators. The island is inhabited by various invertebrate animals and by 2 reptile species, apart from *P. s. salfii* also *Tarentola mauritanica*. Birds are represented by 2 or 3 species, the long-tailed tit *(Aegithalos caudatus)* and a very shy singing bird (not identified). Sea-gulls were numerous near the mainland (1,5 km to the north). According to MERTENS (1961) the island is used as a resting-place by herring gulls. As EIMER (1881), we only observed black-backed gulls *(Larus fuscus)* and we never saw them on the island. EIMER (1881) was of the opinion that sea-gulls are important enemies of lizards, because experiments showed that captive sea-gulls could learn to eat them. The results of these experiments led us to believe that sea-gulls will not eat lizards easily. Even if they would eat them, they probably would not be able to catch them. KRAMER (1946) expresses the same opinion.

The only mammal on the island is the rabbit *(Oryctolagus caniculus)*. In 1975 there were hundreds of burrows and the rabbits became very tame within a couple of weeks. In later years the number of rabbits decreased, probably because of increased hunting. During all the weeks we have been on the island we never saw or heard a mouse or shrew and never caught one in our traps. The island is not inhabited by men.

In most lizards the main death-cause probably is predation (e. g. TURNER, 1977). Since this factor is absent here, it could be expected to find another important death-cause or a decreased fecundity to keep the population relatively stable. Probably both exist. KRAMER (1946) found that females of island-lizards produced about 11 eggs each year against 24 eggs in mainland-lizards, because of decreased clutch-size and number of clutches. In captivity one of our female lizards produced 2 clutches, of 2 and 3 eggs resp., in one year time.

Mortality-rate of juveniles (less than 1 year old) is very high. Only a very small number of juveniles was observed during summer and only 2 were caught in the pitfall-traps as far as we know. One of these two was swallowed halfway by an adult lizard, so this could have happened to more trapped juveniles. Probably kannibalism, which we observed on four other occasions, also outside the traps, is the main death-cause in juveniles. The occurrence of kannibalism among island-lizards is also mentioned by KAMMERER (1926), MERTENS (1934) and KRAMER (1946). Although kannibalism cannot be advantageous directly (it does not realy add food to the population), it can help (part of) the original population to survive bad seasons. When food is plentyful in summer, it can be eaten by more specimens. When food is scarce, reserve-food (juveniles) is walking around on the island.

Not only juveniles are eaten, but tails as well. About 36% of the lizards possessed regenerated tails. On several occasions we observed lizards eating the tail of others.

Mortality-rate of adults and subadults (more than 1 year old) is much lower, as can be calculated with a formula used by AVERY (1975) for *Lacerta vivipara,* and is $12 \pm 6\%$.

4. Parasites. In 1974 and 1975 we sampled faeces pellets to have them checked on parasites. In 4 pellets between 9 and 181 (mean 64,3) *Oxyuris*-eggs were found. In 1979 between 1 and 15 (mean 7,5) *Oxyuris*-worms were found in the SIC. Lizards in all zones were infected, but the differences between various years and between adjacent zones are too large to be able to tell much from the figures.

Apart from these internal infections very small mites are to be found on nearly all lizards (on 100% of 81 lizards). Some lizards were infected with hundreds of them, especially near the legs, but they cannot be considered dangerous for the host. In all zones severely infected animals were found as well as animals which were hardly infected.

5. Interspecific competition. If we regard *P. s. salfii* to be an insectivorous animal, it will not have very many competitors. In all the years we have been visiting the island we only saw 2 or 3 lacewings (*Chrysopa* spec.), some ladybirds (*Coccinella* spec.) and some dragonflies (*Anax* spec.), insects that can be considered insectivorous. Of course ants will eat a lot of insects as well, but they themselves are the main food-source of the lizards. In addition the ants of Vivaro di Nerano use aphids for their honeydew and protect them against small predators. The few birds that live on the island will not have very much influence on the number of insects, especially not on the insects that are mostly eaten by the lizards. *Tarentola mauritanica* is not numerous and is confined to rocky areas. Since these are the areas where *P. s. salfii* has a low density, one could easily think these lizards to be competitors. But on the mainland and in other Mediterranian countries *Podarcis* species and *T. mauritanica* are often found together, even in the same holes, apart from that *T. mauritanica* will mainly eat nocturnal insects, like mosquites, which are an inexhaustible food-source on the island.

6. Shelter against enemies. This is not necessary, because no enemies are present. Even if enemies should be present, the influence of shelter in different zones is negligible, since shelter is available everywhere. Most zones have sufficient vegetation. Zone A has less, but on the other hand it has rocks with a tangle of crevices and holes.

As already mentioned in the introduction, lizard density seemed to be correlated with vegetation coverage. This correlation is shown in fig. 6. While vegation is not an important part of the lizards' diet this cannot be a direct correlation.

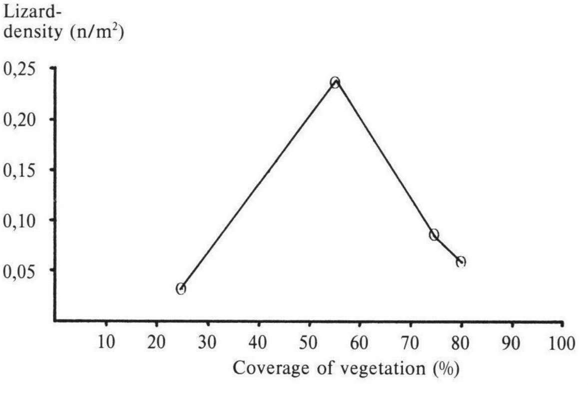


Figure 6. Correlation between lizard density and coverage of vegetation.

7. Dew. On a little island surrounded by the sea humidity is very high. Mornings without dew were rare. Dew was on all plants, especially near the ground, all over the island. Probably insect-juices are not sufficient for the lizards' water-needs, because they emerge to drink dew-drops at the coldest time of the day, just before sunrise.

8. Temperature in the sun. Temperatures measured by "lizard-skin-thermometer" for zone A and zone D are shown in fig. 7. The much lower temperature in zone A is probably caused by wind. Zone D is much more sheltered against wind because it slants to the northeast, while wind is mainly coming from the southwest. The slower cooling of zone A in the late afternoon is also caused by the slope as well as by the position of the sun at that time.

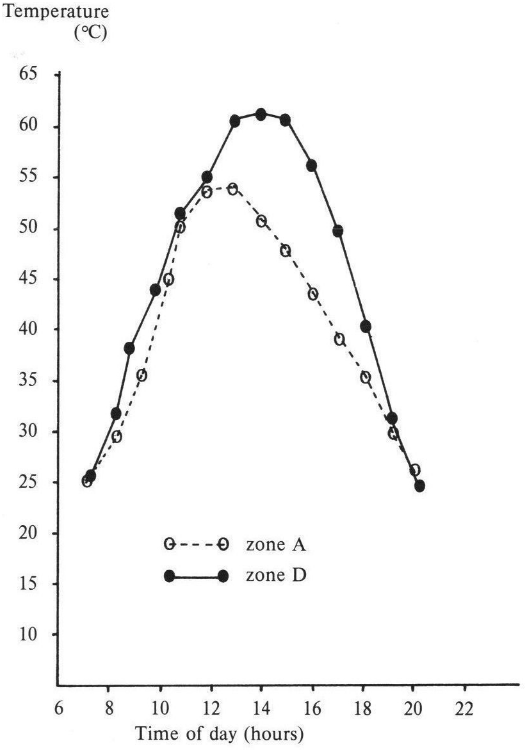


Figure 7. Temperature measured by „lizard-skin-thermometers" in the sun, 80 cm above the soil. Mean for measurements made on August 1st and August 2nd of 1979 and for 2 lizard-skins in each zone.

In all zones temperature is above PBT (as determined by Avery (1978) on *P. s. campestris:* 35,2 °C) between about 9 a. m. and 6 p. m. In zone D PBT is reached half an hour earlier than in zone A. Because maximum temperature is much higher in zone D lizards will not be able to stay in the sun as long as lizards living in zone A.

9. Shade. Shaded areas are the same as potential hiding-places against enemies and so there are plenty all over the island.

10. Temperature in shaded areas. The temperature of different shaded areas is measured. Results are shown in fig. 8. Temperature is lowest in a burrow. For a lizard the quickest way to cool would be in the shade of a burrow, but we actually never saw one voluntarily enter a burrow, except for catching an insect. It can be easily understood that the *Pistacia*-bush has the highest temperature, while the sun filters through the foliage. During part of the day this temperature is close to the assumed PBT. *Erica arborea* in zone D gives more shade and the influence of temperature-conduction from surrounding hot air will be less, while shade-providing plants are much taller. Temperature in the shade is far under PBT.

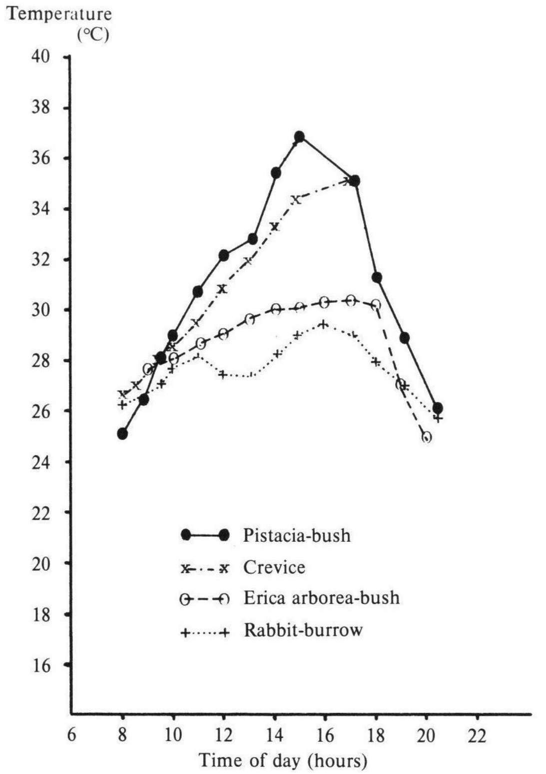


Figure 8. Temperature in different kinds of shaded areas, 10 cm above the soil. Measurements made on August 1st of 1979.

Discussion

From our results it appears that some factors are less important than others. We were not able to find any correlation with the factors 1, 3, 4, 5, 6 and 7 , though all these factors were studied closely. A factor that hasn't been given enough attention is food. Probably our sampling-time was much too short. Still our samples correspond reasonably well with SIC's of the lizards.

In future research a better material must be found instead of polystyrene-foam. Polystyrene-foam probably will be more insulating than lizard tissue, certainly when bloodcirculation is taken into account.

Unfortunately we had no instruments to measure lizard-body-temperatures at the time, so we assumed PBT to be the same as for *P. s. campestris:* 35,2 °C (Avery, 1978). Maybe PBT of *P. s. salfii* is somewhat higher, but this hardly influences our conclusions.

Distribution of lizard species is often studied, but mainly on a larger scale. Distribution-patterns, that were not easy to explain by historical or present-day barriers, have often been explained by environmental temperatures and the temperature-needs of the species involved (e.g. CLARK and KROLL, 1974; RAWLINSON, 1974; SPELLERBERG, 1976). Of course temperature will be important, but it is difficult to conclude something mainly on the basis of air- or soil-temperatures. PEARSON and BRADFORD (1976) and others have shown that lizard-body-temperatures can be much higher than air-temperature or even soil-temperature. A very important factor in the distribution of heliothermic lizards will probably appear to be solar radiation and sunshine hours per annum.

Herpetologists working on microdistribution have mainly restricted themselves to the structural organization of the habitat (SEXTON, 1958, 1959, 1960; HEATWOLE, 1961, 1962). SEXTON, HEATWOLE and KNIGHT (1964) have suggested that the correlation they found between the structure of the habitat and the microdistribution of certain species was not necessarily a direct cause-effect relationship and that the underlying cause could be temperature. Because we had to deal with just one species in a rather simple habitat we were able to find out the direct cause for the correlation between coverage of vegetation and the microdistribution of *P. s. salfii*: namely temperature and food-availability in the shade.

For lizards there are 3 different (temperature-)zones on the island:

I / Zone A. Mainly rocks with some small plants. From about 1 p. m. onwards the increasing heat makes it impossible for lizards to stay in the sun for more than a few minutes. This situation will continue until about 5 p. m. (fig. 4). Lizards will seek shade inside crevices. But inside these crevices are few insects and apart from this the temperature is too low to maintain PBT. So, activity in the shade will be low. If the lizards would stay in the shade, they would not be able to eat for 4 hours of the day. Because of the small prey (predominantly aphids and ants) this situation is unsuitable. They will have to go out into the sun for short excursions. This will only pay off if food can be found at a short distance. Since aphids and ants are particularly found on or near *Statice*-plants, the only places where lizards can live, will be places with sufficient shelter very near to *Statice*- plants. In 1979 we looked around in zone A, to see if this hypothesis could be near the truth and indeed lizards were only seen on such places.

The idea that lizards can have time problems in catching food is not new. AVERY (1971) mentioned it for *Lacerta vivipara* and MCGINNIS (1970) for *Sceloporus occidentalis* during cold summers.

II / Zone C. Vegetation of *Pistacia lentiscus, Andropogon hirta* and *Helichrysum stoechas*. Heat is tremendous for the same period, but inside bushes the temperature approaches PBT and lizards are able to remain active without actually exposing themselves to the sun. Bushes are also the best places to search for insects. So, between 1 p. m. and 5 p. m. activity is continued. Lizards living in this zone are able to hunt all day without much limitation.

III / Zone D. Vegetation of *Erica arborea*. The largest part of the area is shaded all day. The temperature in the shade is below PBT. Lizards will only live at the border of zone D or at small clearings. Keeping PBT, just by following patches of sunlight or by climbing up the bushes into the sun would cost too much time (cf HERTZ, 1974; HEUY, 1974). This is also the reason why temperate climatic zones are nearly devoid of shade-dwelling species of reptiles (RUIBAL, 1961). Although *P. s. salfii* is not territorial (in summer), aggression prevents extreme densities in favourable spots.

Although much work is done on behavioural thermoregulation since the classical paper of COWLES and BOGERT (1944) (e.g. SAINT GIRONS and SAINT GIRONS, 1956; BRADSHAW and MAIN, 1968; MCGINNIS, 1970; HEUY, 1974; AVERY, 1976, 1978), the hypothesis that in semi-arid habitats lizards prefer a shade temperature that is close to PBT, if food is available in the shade, is probably new. I think that a lot of heliothermic lizards that live in a heterogeneous semi-arid habitat will appear to have a microdistribution that depends on shade temperature and food availability in the shade.

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