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Dietary Overview of *Hemidactylus turcicus* with Possible Implications of Food Partitioning

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ABSTRACT.- **A stomach content analysis was conducted on *Hemidactylus turcicus*, the Mediterranean gecko, from 19 April 1990 to 15 October 1990, on the campus of Stephen F. Austin State University, Nacogdoches, Texas. Geckos (N = 167) were placed into four size groups based on snout-vent-length (≤ 29 mm, 30-39 mm, 40-49 mm, and ≥ 50 mm) and three microhabitat groups based on perch height (those occupying perch sites < 1.52 m, ≥ 1.52 m to ≤ 3.05 m, and > 3.05 m). Stomach contents were analyzed and sex, size, and microhabitat groups were compared using Schoener's percent overlap index. Volumetrically, the most important prey items taken were Orthoptera, Lepidoptera, and Isopoda. Geckos of different size groups showed some differences in diet. The greatest difference occurred between the smallest and largest size groups. A significant positive correlation was found between gecko size and prey size (r = 0.24, *P* = 0.0008). Differences in the diets of geckos inhabiting different microhabitats were very evident. Geckos occupying high perch sites ate more flying prey while geckos at lower perch sites ate more ground-dwelling prey.**

The Mediterranean gecko *(Hemidactylus turcicus)*, is an Old World Gekkonid lizard native to the Middle East and the Mediterranean region. This gecko was introduced inadvertently to the New World on ships and is now established in the Gulf coastal states of the U.S. (Conant and Collins, 1991). The first report of *H. turcicus* in the United States was made by Stejneger (1922) in Key West, Florida. This species quickly expanded its range in Florida and continued across the South (Barbour, 1936; Ethridge, 1952) into Texas (Brown, 1950; Conant, 1955; Davis, 1974).

Although the Mediterranean gecko has been colonizing the U.S. for more than 70 yr, food resource use has not been well documented. Carey (1988) identified prey items in the stomachs of 62 geckos and Rose and Barbour (1968) identified and determined relative frequencies of prey items in 59 stomachs.

Since the Mediterranean gecko has been introduced into a previously unoccupied niche in the United States, there appears to be no interspecific competition for food resources with native species (Selcer, 1982, 1986). However, *H. turcicus* appears to be competing with another introduced gecko *(Cyrtopodion scabrum)* in the port of Galveston, Texas (Vaughan, 1991; Klawinski et al., 1994). Therefore, outside of Galveston, it is probable that only intraspecific competition exists.

This paper reports differences existing in diet between geckos of different sizes, different sexes, and geckos occupying different microhabitats.

MATERIALS AND METHODS

This study was conducted on the campus of Stephen F. Austin State University (SFASU) in Nacogdoches, Nacogdoches Co. Texas (94°W longitude and 31°N latitude), one of the more northern locations for geckos in the U.S. (Conant and Collins, 1991; Dixon, 1987). The SFASU campus provides ample vertical habitat on many brick buildings, many of which have ornamental vegetation, such as shrubs or trees close to the walls which provide a retreat for the geckos. Grass and other ground cover at the base of the buildings are also used as retreats.

The sampling was confined to the campus buildings so that the captured animals could be taken back to the lab to be frozen within minutes after capture to minimize any further digestion (Rose, 1976). The first 15 geckos encountered during each sampling session were collected. All geckos were taken after sunset between 1844 and 0045 hrs from 19 April to 15 October 1990.

The geckos were thawed before snout-vent-length (SLV) and total length were measured. Individuals ≥ 44 mm SVL were considered adults (Selcer, 1986). Sex was determined using the presence of preanal pores to identify males. After thawing, geckos were fixed in 10% buf-

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TABLE 1. Total prey items taken from 167 Mediterranean geckos from Nacogdoches, Texas. Prey taxa are listed in phylogenetic order.

	Number of individual prey items	Percent of individual prey items
Mollusca		
Gastropoda		
Pulmonata	9	1.6%
Arthropoda		
Crustacea		
Isopoda	84	14.9%
Myriapoda		
Chilopoda	2	0.4%
Arachnida		
Acarina	2	0.4%
Aranea	42	7.4%
Insecta		
Collembola	20	3.5%
Orthoptera	65	11.5%
Blattoidea	7	1.2%
Dermaptera	9	1.6%
Psocoptera	93	16.5%
Hemiptera	10	1.8%
Homoptera	69	12.2%
Neuroptera	3	0.5%
Coleoptera	20	3.5%
Trichoptera	2	0.4%
Lepidoptera	44	7.8%
Diptera	64	11.3%
Hymenoptera	19	3.4%
Total	564	100%

fered formalin, tagged with an identification number and stored in 70% ethanol. Stomach contents were removed and identified to taxonomic Order (Borror and White, 1970). Entire gastrointestinal (GI) tracts were not analyzed because of potential bias against soft-bodied prey items in the lower GI tract (Floyd, 1982). The volume of each prey item was computed by multiplying its length, width and depth. Prey body dimensions were obtained by placing each food item on a 0.5 mm grid and viewing it with a 30× dissecting microscope. Once measured, the prey items were placed in labeled vials containing 70% ethanol for future reference. Total number and volume of prey types and their relative occurrence (percent of stomachs that contained a given prey taxon) were used as a measure of food preference. Pearson's correlation was used to relate gecko and prey sizes.

Food preferences were compared across gecko microhabitat, sex, and size groups to examine partitioning of food resources. The geckos were divided into four size groups based on SVL ($\leq$ 29 mm, 30-39 mm, 40-49 mm, and $\geq$ 50 mm, for groups 1, 2, 3, and 4, respectively) and three microhabitat groups based on perch height (perch sites $<$ 1.52 m, $\geq$ 1.52 m to $\leq$ 3.05 m, and $>$ 3.05 m were in the "low group", "middle group" and "high group", respectively). The microhabitat groupings were possible because *H. turcicus* is a sit-and-wait predator with a small home range (Rose and Barbour, 1968; Selcer, 1982; Klawinski, 1991). Therefore, it is not likely to move long distances in search of prey on a regular basis.

Relative occurrence of the seven most frequently occurring prey taxa were compared by sex, SVL class, and microhabitat groups. Food resource overlap of geckos was compared among different height zones, gecko size classes, and sexes following Schoener (1970).

RESULTS

Two-hundred geckos were captured during the sampling period. Three stomachs were lost to dehydration due to faulty seals on the storage vials and 26 had no prey items present in their stomachs, of which four had completely empty digestive tracts. The 167 geckos containing food items (564 items) in their stomachs were analyzed.

The prey items represented two Phyla, five Classes, and 18 Orders of invertebrates. Arthropoda and Mollusca were the two phyla present, with Arthropoda making up 98.4% of all prey items by occurrence. The four Arthropod Classes included Crustacea, Myriapoda, Arachnida, and Insecta. Insecta comprised 76.83% of all arthropod prey items. The most abundant insect prey taxa in order were Psocoptera (bark lice), Homoptera (leafhoppers), Orthoptera (grasshoppers and crickets), and Diptera (true flies) (Table 1). Besides invertebrates, three shed gecko skins (intentionally ingested), pebbles and pieces of vegetation (probably accidently ingested) were found in the stomachs.

Three Orders were responsible for 78.9% of the total volume of identifiable prey items [Orthoptera, Lepidoptera (moths) and Isopoda (pill bugs)] (Table 2). Volumetrically, only 1.0% of the prey items were not identifiable to Order.

Using relative occurrence of the prey taxa, six prey Orders most frequently occurred in gecko stomachs [Homoptera 23.4%, Isopoda 22.8%, Orthoptera 21.6%, Diptera 21.0%, Lepidoptera 20.4% and Aranea (spiders) 19.2%]. The next most frequently occurring prey Order was Coleoptera (beetles) (10.3%), which was an important prey taxon when food resource partitioning was examined.

Fifty-three male and 44 female adult geckos contained food items in their stomachs. Volumetrically the most important food taken by males was Orthoptera (33.4%) followed by Lepidoptera (14.0%). When relative occurrence is considered, the most important prey taxa for

TABLE 2. Total prey volume taken from 167 Mediterranean geckos from Nacogdoches, Texas. Prey taxa are listed in phylogenetic order.

	Volume mm³ of prey items	Percent volume of prey items
Mollusca		
Gastropoda		
Pulmonata	56.00	0.40%
Arthropoda		
Crustacea		
Isopoda	3119.33	22.17%
Myriapoda		
Chilopoda	5.13	0.04%
Arachnida		
Acarina	0.26	>0.01%
Aranea	407.00	2.89%
Insecta		
Collembola	8.47	0.06%
Orthoptera	4778.40	33.96%
Blattoidea	4.50	0.03%
Dermaptera	100.51	0.71%
Psocoptera	276.21	1.96%
Hemiptera	216.38	1.54%
Homoptera	571.26	4.06%
Neuroptera	55.63	0.40%
Coleoptera	469.13	3.33%
Trichoptera	19.00	0.14%
Lepidoptera	3198.48	22.73%
Diptera	235.19	1.67%
Hymenoptera	233.39	1.65%
Unidentified	135.50	0.96%
Total	14,069.52 mm³	100%

the males were Lepidoptera (28.6%), Orthoptera (25.0%), and Homoptera (23.1%). By volume, the most important prey taxa for females were Isopoda (38.5%) and Orthoptera (30.4%). The most frequently occurring prey taxa in female gecko stomachs were Isopoda (36.4%), Aranea (25.0%), and Lepidoptera (22.7%). Male and female gecko diet overlapped 67.7% by volume using Schoener's (1970) method. Orthoptera (37.7%), Lepidoptera (19.3%), and Isopoda (14.3%) made up the major portion of the diet of the juveniles by volume. The most frequently occurring prey taxa were Homoptera (27.1%), Diptera (25.7%), and Aranea (24.3%). The juveniles' diet overlapped 65.7% with adult females and 77.6% with adult males.

A significant correlation was detected between gecko SVL and prey size ($r = 0.24$, $P = 0.0008$). These geckos were divided into four size groups. Group 1, the smallest juveniles, contained fewer prey items per lizard than did the other three groups (Table 3). Prey volume consumed per gecko increased from the smallest group, Group 1, to the largest size group, Group 4 (Table 3). Relative occurrence of the most common prey items was calculated for each of the size groups. These data show that the larger prey items (Isopoda, Lepidoptera, and Orthoptera) were eaten more frequently by larger geckos while the smaller prey items (Homoptera, Aranea, and Diptera) were eaten more often by the smaller geckos (Fig. 1). Schoener's (1970) percent overlap index was used to compare the four size groups. The amount of overlap decreased as the difference in size of the lizards increased (Table 4a).

Geckos were placed in three groups according to microhabitat association by height above ground. The "low group" fed heavily on Isopoda (42.0%) and Lepidoptera (27.4%) by volume. Isopoda (32.0%) and Aranea (23.0%) were the most frequently occurring prey taxa in the "low group."

Volumetrically, the major prey taxa consumed by the "middle group" were Orthoptera (36.6%) and Lepidoptera (25.3%). Several prey groups had a high relative occurrence. Five taxa of flying prey had a greater relative occurrence in the "middle group" than they had in the "low group" [Homoptera (37.2%), Orthoptera (23.3%), Diptera (23.3%), Lepidoptera (23.3%), and Coleoptera (13.9%)], whereas the typically ground-dwelling taxa [Aranea (20.9%) and Isopoda (11.6%)] showed a decrease in relative occurrence in the stomachs of the "middle group" (Fig. 2).

Orthoptera (70.8%) contributed the most volume to the "high group", with Lepidoptera (10.0%) contributing the next greatest amount. The relative occurrence trends observed in the "low" and "middle groups" continued into the "high group." The "high group" exhibited an increased use of flying taxa with decreased use in the more typically ground-dwelling forms. (Fig. 2).

Schoener's (1970) percent overlap index comparing dietary overlap, calculated from prey

TABLE 3. Mean number of prey items and volume consumed by gecko size groups.

Size group	No. prey items per gecko	Prey vol. mm³ per gecko
Group 1 (N = 26)	2.5 (SD = 3.2)	8.2 (SD = 7.9)
Group 2 (N = 41)	4.4 (SD = 4.4)	20.5 (SD = 49.5)
Group 3 (N = 37)	4.5 (SD = 10.4)	49.2 (SD = 93.1)
Group 4 (N = 63)	4.5 (SD = 15.2)	55.4 (SD = 85.2)

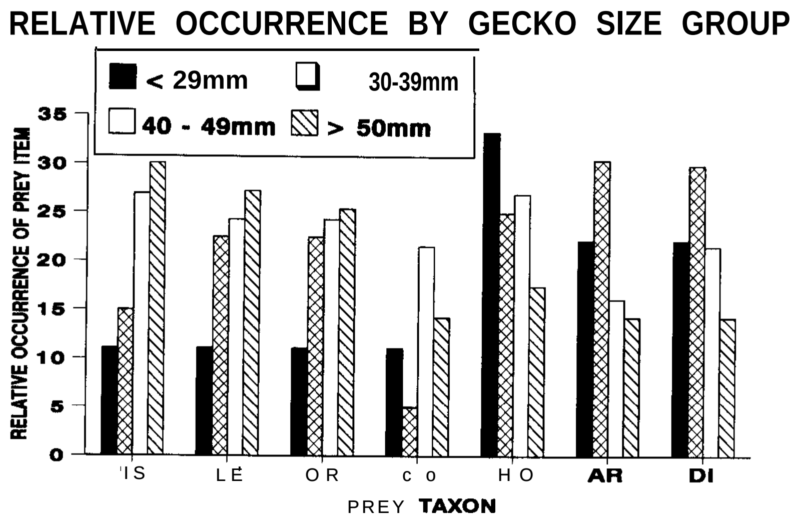

FIG. 1. Relative occurrence of prey Orders in gecko stomachs by gecko size group. Bars represent the percentage of gecko stomachs containing each prey Order in each gecko size group. Only the seven Orders found most frequently in all gecko stomachs are shown: (IS = Isopoda, LE = Lepidoptera, OR = Orthoptera, CO = Coleoptera, HO = Homoptera, AR = Aranea, and DI = Diptera).

volume, indicated that the "low group" overlapped minimally in diet with the "high group." The "middle group" appeared to be an intermediate between the "low" and the "high groups" (Table 4b).

DISCUSSION

Twenty-six geckos had no prey items present in their stomachs. This high number of empty stomachs is probably due to the time of capture of the lizards. It is likely that many geckos were captured immediately after they emerged from their diurnal retreat since most sampling was conducted soon after sunset. If sampling had been conducted later in the evening the lizards would have had more time to forage.

Psocoptera, a small soft-bodied type of flying insect were the most abundant prey item (16.5%) in the stomachs of the lizards. Their small size diminished their volumetric importance in the diet (2.0%). The relative occurrence (7.8%) of Psocoptera was also low in the diets of the geckos. Although they were the most abundant prey item, they were found in only a few lizards. By volume, the largest portion of the diet was composed of Orthoptera, Lepidoptera, and Isopoda. These three taxa were the larger prey items and were eaten frequently. Isopoda was not expected to be an important taxon due to its ground-dwelling habits.

In addition to Isopoda, Aranea and other non-flying taxa made up a major portion of the total diet. This may be evidence contrary to the assumption that Mediterranean geckos congregate around artificial lights to feed (Behler and King, 1979). This study suggests that the primary reason geckos are attracted to lights may not be for foraging, since the lizards readily capture prey far from any light source.

This gecko may be considered a generalist in its feeding habits, since no prey taxon constituted more than 25% of the diet. This is an effective strategy for a colonizer. Once this species has been introduced to a new area it has little trouble finding sufficient food, as it will take almost any available small invertebrate prey.

Food partitioning may be a contributing factor in the success of this species. By relative occurrence, female Mediterranean geckos tended to select more ground-dwelling prey (Aranea and Isopoda) than males. Males tended to eat higher frequencies of flying prey (Lepidoptera, Homoptera, and Orthoptera). Simon (1976) also found that *Sceloporus jarrovi*, as lizard em-

TABLE 4. Schoener's percent overlap between Mediterranean gecko size groups and microhabitat groups from Nacogdoches, Texas. The values represent the percent overlap in diet by volume between A) Mediterranean gecko size groups and B) Microhabitat groups.

A) Gecko SVL	30-39 mm	40-49 mm	≥50 mm
≤29 mm	74.71%	52.12%	41.68%
30-39 mm	—	68.46%	62.63%
40-49 mm	—	—	76.59%
B) Microhabitat Group		**Mid group**	**High group**
Low Group		59.5%	22.7%
Mid Group		—	59.6%

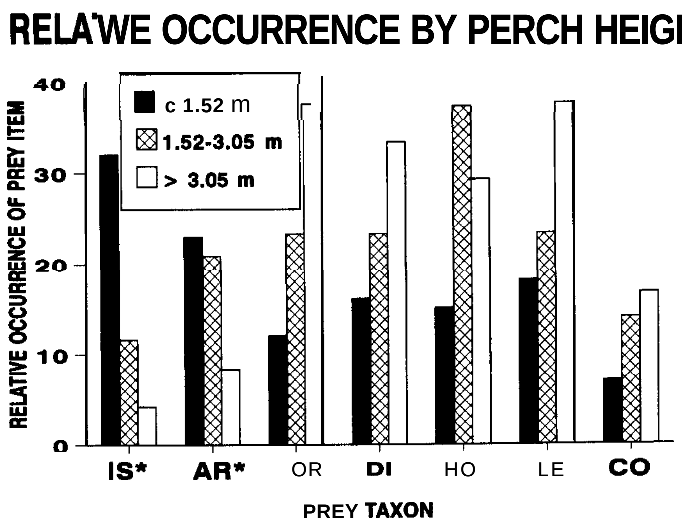

FIG. 2. Relative occurrence of prey Orders in gecko stomachs by perch heights. Bars represent the percentage of gecko stomachs containing each prey Order at each perch height. Only the seven Orders found most frequently in all gecko stomachs are shown: (IS = Isopoda, AR = Aranea, OR = Orthoptera, DI = Diptera, HO = Homoptera, LE = Lepidoptera, and CO = Coleoptera). * Denotes Orders that are typically ground-dwelling.

ploying a similar feeding strategy to that of *H. turcicus*, seemed to exhibit sexual differences in diet selection, which may reduce intraspecific competition and increase feeding efficiency in *S. jarrovi*, since male and female territories often overlap. Adult *H. turcicus* territories seldom overlap (Klawinski, 1991); however, differences in microhabitat preferences between sexes may decrease the amount of diet overlap. Schoener's overlap index indicated that overlap between the diets of male and female adult lizards was 67.7%. The differences found in the diet of the two groups may be more a function of microhabitat association than prey selection. However, sample sizes were too small to make any definite conclusions.

Diets of juvenile lizards were compared to those of adults. Relative occurrence showed that juveniles tended to choose prey items which were consistently smaller (Homoptera and Diptera). The differences in juvenile and adult diets are probably due to gecko size differences rather than a function of sexual maturity.

Gecko size groups were compared for differences in diet. Larger lizards fed on larger prey taxa (Orthoptera, Lepidoptera, and Isopoda) more frequently than did small lizards, and the smaller prey taxa, such as Homoptera, Aranea and Diptera, were taken more frequently by small lizards.

Schoener's (1970) overlap index showed that the greater the similarity in size between gecko groups the greater the amount of overlap in diet. The differences in the diets of the size groups are probably due to the physical inability of the small lizards to consume the larger prey items. Large lizards tend to take prey of all sizes, but seem to concentrate on large items for the bulk of their diet.

Microhabitat selection seems to be a major factor in determining this geckos' diet. If geckos in this population were sampled only above 3.05 m on a wall, they could be mistakenly considered to specialize in Orthopterans. If they were sampled from only below 1.52 m on the wall, the ground-dwelling prey taxa might be overestimated in the gecko diet. Failure to sample geckos across a range of height zones may result in an incorrect assessment of the species' diet.

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