

Comparative water-loss rates of *Hemidactylus mabouia* and *Sphaerodactylus notatus* on Eleuthera Island, Commonwealth of the Bahamas

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Abstract. In June 2012 on Eleuthera, Commonwealth of the Bahamas, we examined water-loss rates of *Hemidactylus mabouia* and *Sphaerodactylus notatus* to test the prediction that the larger, nocturnally active *H. mabouia* will experience comparatively lower mass-specific water-loss rates and percentage mass lost than the diminutive, diurnally active *S. notatus*. During the first hour, *S. notatus* experienced a faster rate of water loss than *H. mabouia*, and juvenile *H. mabouia* lost proportionately more water than adults. After the first hour, water-loss rates did not differ significantly between the two species or between adult and juvenile *H. mabouia*. In terms of percentage loss of original mass, *S. notatus* was indistinguishable from adult and juvenile *H. mabouia*. Desiccation rates were near the lower limits reported for congeners of both species, which might be attributable to the relatively xeric conditions on Eleuthera. In general, these data supported our prediction that *H. mabouia* will experience lower mass-specific water loss rates than *S. notatus*.

Keywords. Bahamas, Desiccation, Geckos, *Hemidactylus mabouia*, *Sphaerodactylus notatus*, Water-loss rates

Introduction

Because terrestrial environments present water-conservation challenges to vertebrates that must maintain a consistent water content at around three quarters of total body weight (Khalil and Abdel-Messeih, 1954) and to better understand adaptations to habitats and the effects of alterations to those habitats, investigations of water-loss rates are essential. Geckos in the genera *Hemidactylus* (Gekkonidae) and *Sphaerodactylus* (Sphaerodactylidae) typically seek shelter in microhabitats that provide protection from desiccation as well as predators (e.g., Heatwole and Veron, 1977; Hensley et al., 2004). However, they must leave shelters to forage, seek mates, or escape

from an intruding predator. When away from refugia, these lizards are vulnerable to detrimental effects of dehydration, including reductions in endurance that can affect overall fitness (Wilson and Havel, 1989).

In June 2012, we examined water-loss rates of *Hemidactylus mabouia*, an introduced species with origins in Africa and an increasingly broad distribution in the West Indies (Powell et al., 1998, 2011), and *Sphaerodactylus notatus*, native to several island banks in the Bahamas and the Cuban Archipelago (Schwartz, 1970; Henderson and Powell, 2009), to test the prediction that the larger, nocturnally active *H. mabouia* will experience comparatively lower mass-specific water-loss rates and percentage mass lost than the diminutive, diurnally active *S. notatus*, because of either lower surface-area-to-volume ratios for cutaneous water loss (e.g., Heatwole and Veron, 1977; Turk et al., 2010) or higher levels of physiological plasticity often associated with successful colonisers (e.g., Jeschke and Strayer, 2008; Chown et al., 2010).

Materials and Methods

We conducted our study on the grounds of the Island School and Cape Eleuthera Institute, Eleuthera Island, Commonwealth of the Bahamas (24°50'01"N, 76°19'33"W). This region has a tropical maritime climate, with the majority of precipitation occurring

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between May and October (Blume, 1974). We collected 13 *Hemidactylus mabouia* on 3–4 June 2012 and nine *Sphaerodactylus notatus* on 16–18 June. For each *H. mabouia*, we recorded ambient and microhabitat temperatures at time of capture using a digital thermometer with K-type thermocouples (Fluke® 51/52 Series II; Fluke Corporation, Everett, Washington, USA) and ambient and microhabitat humidity with an Extech Instruments® Humidity Alert II (Extech Instruments, Waltham, Massachusetts, USA). We did not collect these environmental data for *S. notatus*, mainly because lizards were under cover and microhabitat conditions were altered in searching for them. For *H. mabouia*, we measured snout-vent length (SVL), tail length (TL), and head length (HL) and width (HW) to the nearest 0.1 mm using digital calipers (Mitutoyo Digimatic Caliper CD-67 CSX; Mitutoyo USA, Aurora, Illinois, USA). For *S. notatus*, we photographed each individual on graph paper and determined morphological data to the nearest 0.01 mm using ImageJ version 1.46 (National Institutes of Health, Bethesda, Maryland, USA). For both species, we sexed each gecko by candling, recorded the number of eggs for gravid females, and noted any instances of tail autotomy. The smallest *H. mabouia* with discernible gonads was a male with SVL = 39 mm; smaller individuals were classified as juveniles. The smallest *S. notatus* was a gravid female with SVL = 21 mm, so all individuals were classified as adults.

Corresponding to respective activity periods (Fuenmayor *et al.*, 2005; Henderson and Powell, 2009), we subjected *H. mabouia* to desiccation at 2100–0300 h and *S. notatus* at 1100–1700 h. Animals were housed without food at ambient conditions in 50-ml centrifuge tubes with damp paper towels until they defecated. Following defecation, we moved animals to dry 400-ml plastic containers (Ziploc® Snap N' Seal; S. C. Johnson and Son, Racine, Wisconsin, USA) with screened tops in a closed room maintained at ambient temperature and humidity. Data for each animal were recorded at 20- or 30-min intervals. For the small number of recordings obtained every 20 min, we averaged the values for 20- and 40-min marks. These measurements included ambient temperature and humidity in addition to the mass of each lizard (measured to the nearest mg using a Denver Institute Co. Model S-110 electronic scale, Denver, Colorado, USA). After desiccation, animals were rehydrated and released at original sites of capture.

We used Minitab 16® (Minitab Inc., State College, Pennsylvania, USA) to conduct statistical analyses. We used unpaired t-tests to compare ambient and

microhabitat conditions and Mann-Whitney U pairwise comparisons to discern differences in morphological data between species. Due to small sample sizes, we did not compare sexes within species, but juvenile and adult *H. mabouia* were segregated for all analyses except regression of water-loss rate on morphological data. We used Wilcoxon signed-rank tests for small sample sizes to detect differences in the rates of water loss over time. One *H. mabouia* with an erroneously recorded initial mass was excluded from statistical analyses. All means are presented \pm one SE. For all tests, $\alpha = 0.05$.

Results

The mean temperature and relative humidity for microhabitats used by *Hemidactylus mabouia* at times of capture were $27.9 \pm 0.2^\circ\text{C}$ and $81.2 \pm 0.3\%$, respectively. Chosen shelter sites were significantly cooler ($t = -3.07$, $P = 0.01$, $df = 11$) and more humid ($t = 11.78$, $P < 0.001$, $df = 22$) than ambient conditions during desiccation ($28.6 \pm 0.04^\circ\text{C}$ and $76.0 \pm 0.2\%$).

Juvenile *H. mabouia* were smaller than adults and were significantly larger than *Sphaerodactylus notatus* (Table 1; all $P < 0.03$). Juvenile *H. mabouia* weighed significantly less than adults ($W = 63.0$, $P = 0.006$), but were indistinguishable from *S. notatus* ($W = 50.0$, $P = 0.11$). Clutch size was invariably two in *H. mabouia* ($n = 2$) and one in *S. notatus* ($n = 4$). All lizards of both species had complete, non-regenerated tails.

The rate of water loss by *H. mabouia* (Table 2; Fig. 1) did not significantly differ by hour (all $P > 0.05$). For *S. notatus* (Table 2; Fig. 1), the rate of water loss during the first hour of desiccation was significantly greater than the third and fifth hour rates ($P = 0.03$), approached significance for the fourth and sixth hour rates ($P = 0.06$), but was indistinguishable from the second hour rate ($P = 0.16$). Desiccation in all other hours did not differ significantly from one another (all $P > 0.05$).

In the first hour, *S. notatus* experienced a faster rate of water loss than *H. mabouia* ($W = 98.0$, $P = 0.017$), and juvenile *H. mabouia* lost proportionately more water than adults ($W = 28.0$, $P = 0.006$). Otherwise, water-loss rates did not differ significantly between *H. mabouia* and *S. notatus* ($W = 118.0$, $P = 0.34$), between adult *H. mabouia* and *S. notatus* ($W = 43.0$, $P = 0.09$), or between juvenile *H. mabouia* and *S. notatus* ($W = 40.0$, $P = 0.79$), although the difference between adult and juvenile *H. mabouia* approached significance ($W = 34.0$, $P = 0.07$). In terms of percentage loss of original mass, *S. notatus* was indistinguishable from adult ($W = 43.0$, $P = 0.09$) and juvenile *H. mabouia* ($W = 40.0$, $P = 0.79$).

Table 1. Morphological data and percent mass lost during desiccation for *Hemidactylus mabouia* and *Sphaerodactylus notatus* at Cape Eleuthera, Commonwealth of the Bahamas.

Species	n	SVL	TL	HL	HW	Initial	Percent Mass
		(mm)	(mm)	(mm)	(mm)	Mass (mg)	Lost (%)
<i>Hemidactylus mabouia</i>							
Males	2	53.5 ± 10.3	55.0 ± 6.4	15.4 ± 2.7	10.2 ± 2.1	4853 ± 28	1.17 ± 0.55
Females	5	57.0 ± 1.7	61.6 ± 1.6	16.5 ± 0.4	10.3 ± 0.3	4811 ± 476	0.83 ± 0.40
Juveniles	5	30.2 ± 1.6	28.6 ± 3.6	9.3 ± 0.5	5.8 ± 0.3	518 ± 123	1.95 ± 0.34
All	12	45.3 ± 4.3	46.8 ± 5.0	13.3 ± 1.2	8.4 ± 0.8	3029 ± 806	1.35 ± 0.27
<i>Sphaerodactylus notatus</i>							
Males	3	23.29 ± 0.82	18.93 ± 1.75	6.99 ± 0.28	4.08 ± 0.31	371 ± 25	1.06 ± 0.53
Females	6	22.47 ± 0.36	18.80 ± 1.31	7.15 ± 0.35	3.75 ± 0.14	310 ± 21	2.26 ± 0.51
Gravid	4	22.64 ± 0.52	19.19 ± 1.18	6.95 ± 0.49	3.82 ± 0.20	323 ± 29	3.00 ± 0.43
Non-Gravid	2	22.14 ± 0.08	18.02 ± 3.08	7.54 ± 0.24	3.59 ± 0.06	284 ± 18	0.79 ± 0.01
All	9	22.74 ± 0.37	18.84 ± 1.06	7.09 ± 0.26	3.86 ± 0.14	330 ± 20	1.86 ± 0.44

For *H. mabouia*, all measures of body size were inversely correlated with the average rate of water loss (all $P < 0.005$), but morphological data for *S. notatus* were not significantly correlated with desiccation rate (all $P > 0.34$).

Discussion

Although limited by small sample sizes, our data nevertheless indicated that water-loss rates in these geckos are negligible when they are subjected to

desiccation for six hours under ambient conditions. Even the one *H. mabouia* that experienced the greatest water loss retained over 97% of its original hydrated body mass, and the most dehydrated *S. notatus* retained over 95% during the desiccation period. The water loss experienced by all individuals was well below the vital limits of water loss reported for *H. mabouia* (24.7%; Heatwole and Veron, 1977) and several species of *Sphaerodactylus* (average 23.7%; Leclair, 1978).

Although exact comparisons are impossible as methods varied by study, the average rate of water loss we observed for *S. notatus* was at the lower end of rates previously observed in *Sphaerodactylus* spp. (Steinberg et al., 2007), which ranged from 1.8 ± 0.14 (Snyder, 1979) to 16.1 mg/g/h (Heatwole and Veron, 1977), excluding very high first-hour-only rates determined by Nava (2004). Even when we included data from Bentz et al. (2011), the only study showing comparable desiccation rates was by Snyder (1979) on *S. beattyi*, which reported ranges of 1.8–2.0 mg/g/h at temperatures comparable to those in this study, albeit at much lower humidity (0%).

For *H. mabouia*, our observed water-loss rate was much lower than that observed for *H. mabouia* in Puerto Rico, which lost 13.9 mg/g/h at 20°C and 55% humidity (Heatwole and Veron, 1977), but comparable to the 1.12 mg/g/h rate for *H. frenatus* from Brunei at 20.3°C

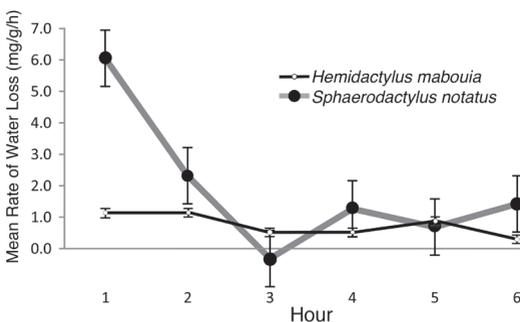


Figure 1. Rates of water loss (mg/g/h) by hour in *Hemidactylus mabouia* and *Sphaerodactylus notatus* at Cape Eleuthera, Commonwealth of the Bahamas.

Table 2. Mean rates of water loss (mg/g/h) for *Hemidactylus mabouia* and *Sphaerodactylus notatus* at Cape Eleuthera, Commonwealth of the Bahamas.

Species	n	Hour					
		1	2	3	4	5	6
<i>Hemidactylus mabouia</i>							
Males	2	0.85 ± 0.13	1.10 ± 0.51	1.17 ± 0.60	0.44 ± 0.13	0.78 ± 0.31	0.86 ± 0.39
Females	5	0.31 ± 0.15	0.43 ± 0.09	0.57 ± 0.13	0.29 ± 0.06	0.39 ± 0.05	0.37 ± 0.05
Gravid	2	0.58 ± 0.41	0.61 ± 0.43	0.87 ± 0.61	0.42 ± 0.30	0.46 ± 0.32	0.38 ± 0.27
Juveniles	5	2.07 ± 0.67	1.89 ± 0.92	0.25 ± 0.50	0.77 ± 0.54	1.38 ± 0.21	0.01 ± 0.39
All	12	1.14 ± 0.36	1.15 ± 0.42	0.53 ± 0.25	0.51 ± 0.22	0.87 ± 0.17	0.30 ± 0.19
<i>Sphaerodactylus notatus</i>							
Males	3	3.01 ± 0.77	2.07 ± 2.35	0.79 ± 0.79	0.40 ± 0.40	0.49 ± 0.49	0.89 ± 0.45
Females	6	7.56 ± 1.17	2.41 ± 2.10	-0.87 ± 0.62	1.70 ± 0.94	0.79 ± 0.86	1.69 ± 1.37
Gravid	4	8.88 ± 1.25	4.99 ± 2.03	-1.30 ± 0.88	1.10 ± 0.65	0.22 ± 0.95	2.12 ± 2.09
All	9	6.05 ± 1.09	2.30 ± 1.51	-0.32 ± 0.54	1.27 ± 0.65	0.69 ± 0.58	1.42 ± 0.90

and 0% humidity (Snyder and Weathers, 1976).

Several explanations could account for the relatively low desiccation rates we observed, but the most likely reason is that these animals occur on a drier island than those examined in most other studies (Blume, 1974). Reptiles in more xeric environments are generally more resistant to desiccation than even closely related forms from more mesic habitats (e.g., Warburg, 1966; Perry, Dmi'el and Lazell, 2000; Steinberg *et al.*, 2007). These adaptations can be anatomical, such as decreasing epidermal permeability to fluids (Cohen, 1975) or behavioural, such as seeking microhabitats that retain moisture (Maclean, 1985; Steinberg *et al.*, 2007) or limiting activity during warmer times of day (Nava *et al.*, 2001) or year (Dawson, Shoemaker and Licht, 1966).

Nevertheless, as we predicted based on the higher surface-to-volume ratios of smaller individuals (e.g., Heatwole and Veron, 1977; Turk *et al.*, 2010), *S. notatus* lost a greater percentage of body mass than *H. mabouia* and juvenile *H. mabouia* lost more than adults. Similar to results reported by Dunson and Bramham (1981), the higher mass-specific water-loss rate in the first hour of desiccation accounted for much of that difference. Largely because of that substantive difference during the first hour, these data generally supported our prediction that *H. mabouia* would experience lower mass-specific

water loss rates than *S. notatus*. However, we were unable to determine whether the insignificant differences in subsequent hours could be attributed to physiological plasticity in *H. mabouia*, rendering it more resistant to water loss than expected in a nocturnally active species, or to higher than expected resistance to water loss in diurnally active *S. notatus*. Because the latter is semifossorial and associated with moisture-retaining microhabitats such as leaf litter (Henderson and Powell, 2009), we tend to favour the initial hypothesis, although further research will be necessary before any definitive determination is possible.

Acknowledgements. Kevin J. Avilés-Rodríguez and Kaitlin E. Allen helped capture animals. Matthew E. Gifford provided helpful comments on an earlier draft of this manuscript. Sandra D. Buckner and Stacy Lubin-Gray facilitated our fieldwork in the Bahamas. Staff of the Cape Eleuthera Institute and the Island School generously shared space and resources. The permit to conduct research in the Commonwealth of the Bahamas was issued by Philip S. Weech, Director, The BEST Commission. Protocols were approved by the Avila University Animal Care and Use Committee (IACUC 2007-01). Fieldwork was funded by a grant from the National Science Foundation (USA) to Robert Powell (DBI-0851610).

References

- Bentz, E.J., Rivera Rodríguez, M.J., John, R.R., Henderson, R.W., Powell, R. (2011): Population densities, activity, microhabitats, and thermal biology of a unique crevice- and litter-dwelling assemblage of reptiles on Union Island, St. Vincent and The Grenadines. *Herpetological Conservation and Biology* **6**: 40–50.
- Blume, H. (1974): *The Caribbean Islands. Geographies for Advanced Study*. London, Longman.
- Chown, S.L., Hoffmann, A.A., Kristensen, T.N., Angilletta, M.J., Jr., Stenseth, N.C., Pertoldi, C. (2010): Adapting to climate change: a perspective from evolutionary physiology. *Climate Research* **43**: 3–15.
- Cohen, A.C. (1975): Some factors affecting water economy in snakes. *Comparative Biochemistry and Physiology* **51**: 361–368.
- Dawson, W.R., Shoemaker, V.H., Licht, P. (1966): Evaporative water losses of some small Australian lizards. *Ecology* **47**: 589–594.
- Dunson, W.A., Bramham, C.R. (1981): Evaporative water loss and oxygen consumption of three small lizards from the Florida Keys: *Sphaerodactylus cinereus*, *S. notatus*, and *Anolis sagrei*. *Physiological Zoology* **54**: 253–259.
- Fuenmayor, G.R., Ugueto, G.N., Bauer, A.M., Barros, T., Manzanilla, J. (2005): Expansion and natural history of a successful colonizing gecko in Venezuela (Reptilia: Gekkonidae: *Hemidactylus mabouia*) and the discovery of *H. frenatus* in Venezuela. *Herpetological Review* **36**: 121–125.
- Heatwole, H., Veron, J.E.N. (1977): Vital limit and evaporative water loss in lizards (Reptilia, Lacertilia): A critique and new data. *Journal of Herpetology* **11**: 341–348.
- Henderson, R.W., Powell, R. (2009): *Natural History of West Indian Reptiles and Amphibians*. Gainesville, University Press of Florida.
- Hensley, R.L., Wissmann, S.M., Powell, R., Parmerlee, J.S., Jr. (2004): Habitat preferences and abundance of dwarf geckos (*Sphaerodactylus*) on St. Eustatius, Netherlands Antilles. *Caribbean Journal of Science* **40**: 427–429.
- Jeschke, J.M., Strayer, D.L. (2008): Usefulness of bioclimatic models for studying climate change and invasive species. *Annals of the New York Academy of Sciences* **1134**: 1–24.
- Khalil, F., Abdel-Messeih, G. (1954): Water content of tissues of some desert reptiles and mammals. *Journal of Experimental Zoology* **125**: 407–414.
- Leclair, R., Jr. (1978): Water loss and microhabitats in three sympatric species of lizards (Reptilia, Lacertilia) from Martinique, West Indies. *Journal of Herpetology* **12**: 177–182.
- Maclean, W.P. (1985): Water-loss rates of *Sphaerodactylus parthenopion* (Reptilia: Gekkonidae), the smallest amniote vertebrate. *Comparative Biochemistry and Physiology* **82A**: 759–761.
- Nava, S.S. (2004): Microhabitat selection, resource partitioning, and evaporative water loss by dwarf geckos (*Sphaerodactylus*) on Puerto Rico. Unpublished MS Thesis, University of Texas at El Paso, El Paso, Texas, x + 48 pp.
- Nava, S.S., Lindsay, C.R., Henderson, R.W., Powell, R. (2001): Microhabitat, activity, and density of a dwarf gecko (*Sphaerodactylus parvus*) on Anguilla, West Indies. *Amphibia-Reptilia* **22**: 455–464.
- Perry, G., Dmi'el, R., Lazell, J. (2000): Evaporative water loss in insular populations of *Anolis cristatellus* (Reptilia: Sauria) in the British Virgin Islands. III. Response to the end of drought and a common garden experiment. *Biotropica* **32**: 722–728.
- Powell, R., Crombie, R.I., Boos, H.E.A. (1998): *Hemidactylus mabouia*. *Catalogue of American Amphibians and Reptiles* **674**: 1–11.
- Powell, R., Henderson, R.W., Farmer, M.C., Breuil, M., Echternacht, A.C., van Buurt, G., Romagosa, C.M., Perry, G. (2011): Introduced amphibians and reptiles in the Greater Caribbean: Patterns and conservation implications. In: *Conservation of Caribbean Island Herpetofaunas. Volume 1: Conservation Biology and the Wider Caribbean*, p. 63–143. Hailey, A., Wilson, B.S., Horrocks, J.A., Eds. Leiden, Brill.
- Schwartz, A. (1970): *Sphaerodactylus notatus*. *Catalogue of American Amphibians and Reptiles* **90**: 1–2.
- Snyder, G.K. (1979): Water loss and oxygen consumption in tropical *Sphaerodactylus*. *Oecologia* **38**: 107–110.
- Snyder, G.K., Weathers, W.W. (1976): Physiological responses to temperature in the tropical lizard, *Hemidactylus frenatus* (Sauria: Gekkonidae). *Herpetologica* **32**: 252–256.
- Steinberg, D.S., Powell, S.D., Powell, R., Parmerlee, J.S., Jr., Henderson, R.W. (2007): Population densities, water-loss rates, and diets of *Sphaerodactylus vincenti* on St. Vincent, West Indies. *Journal of Herpetology* **41**: 330–336.
- Turk, P.A., Wyszynski, N.N., Powell, R., Henderson, R.W. (2010): Population densities and water-loss rates of *Gymnophthalmus pleii*, *Gymnophthalmus underwoodi* (Gymnophthalmidae), and *Sphaerodactylus fantasticus fuga* (Sphaerodactylidae) on Dominica, West Indies. *Salamandra* **46**: 125–130.
- Warburg, M.R. (1966): On the water economy of several Australian geckos, agamids, and skinks. *Copeia* **1966**: 230–255.
- Wilson, B., Havel, P. (1989): Dehydration reduces the endurance running capacity of the lizard *Uta stansburiana*. *Copeia* **1989**: 1052–1056.