August 2005

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Stephanie Place

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Stephanie Place
College of Agricultural and Life Sciences, University of Wisconsin – Madison

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ABSTRACT

There is evidence of a drastic world-wide decline in herpetofauna populations. This trend has been documented in disappearing *N. altae* and *N. tropidolepis* populations in the highland cloud forests of Monteverde (Pounds 2000). Ultraviolet radiation, atmospheric pollution, epidemic disease, and unusual weather patterns have been suggested as possible causes of the decline (Pounds and Crump, 1994), but not enough long-term data has been collected to pinpoint a single cause. This study sought to census the current *Norops* spp. populations in two sites in the Monteverde area and compare those findings to previous censuses conducted by Pounds (2000) and Martin (2004). Thirty total daytime hours were spent searching a two-hectare study site at 1540 m elevation located just west of the entrance road to the Monteverde Cloud Forest Preserve (the original Pounds 2000 study site), and 30 total daytime hours were spent searching a two hectare study site at 1540 m elevation surrounding the Monteverde Biological Research Station (MBRS). No *N. tropidolepis* or *N. altae* were found at either site. Eight *N. intermedius* and two *N. humilis* were observed within the original Pounds 2000 study site. Four *N. intermedius* and 12 *N. humilis* were observed in the MBRS study site. This represents a significant decline in total anole populations for both study sites as compared to Martin 2004 (X^2 , $p < .001$). These results suggest that the declining *N. tropidolepis* and *N. altae* populations have not recovered, and though *N. intermedius* and *N. humilis* have replaced them as the most abundant anole in the Monteverde region, these species may also be experiencing a population decline. Continued research is necessary to understand the forces behind herpetofauna decline and to prevent further loss.

RESUMEN

Hay evidencia de un declive drástico mundial de poblaciones de herpetofauna. Esta tendencia se ha documentado en poblaciones de *N. altae* and *N. tropidolepis* que están disminuyendo en el bosque nuboso de Monteverde (Pounds 2000). La radiación ultravioleta, la contaminación atmosférica, las enfermedades epidemicas, y los patrones de clima local extraños han sido sugeridos como algunas causas posibles del declive (Pounds and Crump 1994), pero no se han colectado suficientes datos a largo plazo para determinar una causa exacta. Esta investigación censó the población actual de *Norops* spp. en dos lugares en la zona de Monteverde y comparó esos resultados con censos hechos por Pounds (2000) y Martin (2004). Treinta horas se emplearon buscando en un sitio de dos hectáreas, a una elevación de 1540 m, localizado al lado del camino de entrada a la Reserva Bosque Nuboso Monteverde (el sitio de investigación original de Pounds). También, se emplearon treinta horas buscando en un sitio de dos hectáres, a una elevación de 1540 m y alrededor de la Estación Biológica Monteverde (MBRS). No se encontró ningún *N. tropidolepis* ni *N. altae* en ninguno de los sitios de investigación. Ocho *N. intermedius* y dos *N. humilis* se observaron en el sitio de investigación original de Pounds. Cuatro *N. intermedius* y doce *N. humilis* se observaron en el sitio MBRS. Ésto representa un declive significativo en las poblaciones totales de anoles en ambos sitios de investigación en comparación con Martin (X^2 , $p < 0.001$). Estos resultados sugieren que las poblaciones de *N. tropidolepis* y *N. altae* no se han recuperado. *N. intermedius* y *N. humilis* han sustituido a *N. tropidolepis* y *N. altae* como las especies de anoles más comúnes, pero es posible que sus poblaciones estén disminuyendo también. Investigaciones continuous son necesarias para entender las causas del declive de herpetofaunas y para impedir más pérdidas.

INTRODUCTION

Research conducted over the past 25 years indicates a general loss in species richness in amphibians and reptiles, especially in areas such as highland wet forest (Sarker 1996; Wake and Morowitz 1991). Ultraviolet radiation, atmospheric pollution, epidemic disease, and unusual weather (Pounds and Crump, 1994) have been suggested as possible causes of these trends, but there is not yet enough long-term data to pinpoint a single cause or determine if this decline is part of a larger global pattern (Pechmann and Wilbur, 1994).

Norops spp. are among the organisms in which crashing populations have been documented (Pounds 1988). A study conducted by Pounds between 1983 and 1997 surveyed the populations of *N. altae* and *N. tropidolepis* in a 30-hectare site located at 1540 m elevation, just west of the Monteverde Cloud Forest Preserve entrance road. He recorded a dramatic decline in numbers for both species during the course of his study. In 1983, Pounds encountered 3.01 *N. tropidolepis* individuals per hour of daytime search; by 1990 that number had dropped to 0.90 individuals per hour of daytime search and 0.02 in 1995. A similar trend was observed in *N. altae*: 1.8 individuals were encountered per hour of daytime search in 1983, 0.90 individuals per hour of daytime search in 1990, and 0.03 individuals per hour of daytime search in 1995. Neither species was encountered in 1996 or 1997 (Pounds, 2000). Conversely, casual observations suggest that the *Norops* spp. population is increasing in the area immediately surrounding the Monteverde Biological Research Station, which is located at the same elevation as the original Pounds site (Guindon, pers. com). The exact species or number of those individuals was not recorded.

A similar study conducted by Martin in 2004 found *N. altae* and *N. tropidolepis* in extremely low numbers and only in elevations above 1600 m. Martin found that *N. intermedius* and *N. humilis* had replaced *N. altae* and *N. tropidolepis* as the most abundant in the Pounds 2000 research site. Martin recorded a total of 25 *N. intermedius* individuals and 26 *N.humilis* individuals in his two study sites, one of which was located within the original Pounds study site. His data provides a reference population estimate for use in future studies of *N. intermedius* and *N. humilis.*

This study sought to determine whether or not the trend of declining *Norops* spp populations has continued since Pounds' study. This question was addressed using a focused census of *Norops* spp in two representative sites, one located within Pounds' original research site and one located around the Monteverde Biological Research Station. The size of the study sites was reduced from Pounds' orginal 30 hectares to two hectares to allow for an intensive, repeated survey of anoles in those areas. Monteverde Biological Research Station was included as a study site, an additional replicate, because random distribution may play a part in anole distribution. Five species of anoles have been previously documented in the Monteverde area and were considered when surveying: *N. altae*, *N. humilis*, *N. tropidolepis*, *N. intermedius*, and *N. woodi*.

The null hypothesis predicted that there would be no significant difference in population size or species diversity of *Norops* spp between the two study sites, and the population density (individuals per square meter) of *N. altae* and *N. tropidolepis* would not have changed since the census preformed by Pounds in 2000.

MATERIALS AND METHODS

Two study sites were considered: the Campbell site is a two-hectare patch at 1540 m elevation located just west of the entrance road to the Monteverde Cloud Forest Preserve. The Monteverde Biological Research Station (MBRS) site is a two- hectare patch at 1540 m elevation surrounding the Monteverde Biological Research Station (Fig 1). Both sites have approximately equal amounts of open pastured area and forest.

A total of 60 hours (30 total hours per site) was spent searching for anoles between July 16 and August 3rd, 2005. The 30 hours spent at each site were divided into 15 hours before noon, and 15 hours after noon. Time at each site was further divided equally between open and forested areas. The species, gender, and snout-vent length (if the individual could be captured) was recorded for each individual encountered. Individuals were marked with a drop of green non-toxic fingernail polish on the tip of the tail to avoid recounting the same individual. Photographs, keys, and species accounts from The Amphibians and Reptiles of Costa Rica (Savage 2002) were used to identify anoles to species. Chi square tests were preformed to determine if any significant differences existed between population sizes at the two study sites. A chi square test was also used to determine if a significant difference existed between hourly rate of encounter between this study and the Pounds 2000 study.

Students working near either study site were asked to report the species and location of any anoles they chanced to observe within either study site during the time period of this study. All observations gathered in this way were recorded as anecdotal data.

RESULTS

No *N. altae, N. tropidolepis*, or *N. woodii* were found in either study site (Table 1). This is identical to the findings of the Pounds (2000) study. A total of 12 *N. intermedius* were found, eight within the Campbell site and four within the Monteverde Biological Research Station site. *N. intermedius* individuals were distributed evenly between the two sites. (X^2 , $p = 0.35$). *N. humilis* were found in significantly greater numbers at the MBRS site (X^2, $p = 0.001$). A total of 14 *N. humilis* were found, two within the Campbell site and 12 within the Monteverde Biological Research Station site. No anoles were recaptured in either site.

Twelve additional anoles were encountered by other students outside of recorded searching time (Table 2). Six *N. humilis* and three *N. intermedius* were found outside of recorded searching time in the Monteverde Biological Research Station site, and three *N. intermedius* were found outside of searching time at the Campbell site.

DISCUSSION

The results of this study failed to reject the null hypothesis that the population density of *N. altae* and *N. tropidolepis* would not have changed since the census preformed by Pounds (2000). This study found no *N. altae* or *N. tropidolepis* within the original Pounds study site, which matches the findings for the final two years of the Pounds study.

Therefore, *N. altae* and *N. tropidolepis* populations have not recovered in the eight years since Pounds' study. This could be because local environmental conditions have not yet reverted to ranges suitable for those species. Lack of recovery could also indicate a lack of nearby source populations to recolonize the area.

Populations of *N. humilis* and *N. intermedius* found by this study are significantly lower in each study site than those recorded by Martin (2004). This may be in part because of the different seasons in which the two studies were conducted, but it may also indicate that *N. humilis* and *N. intermedius* populations are in sharp decline. Continual monitoring of these and other anole species will be required to determine if this drop in numbers is a significant trend or just a yearly fluctuation.

The observation that *N. intermedius* and *N. humilis* were the only species of anole encountered at 1540 m supports the theory that anole ranges are shifting upward in elevation in response to changing climactic pressures (Pounds et al.1999). Pounds (2000) tracked the gradual disappearance of *N. altae* and *N. tropidolepis* in his study site, which is within their previous range of greatest abundance. Then the 2004 study conducted by Martin broadened the elevational gradient and found populations of *N. tropidolepis* and *N. altae* only at or above 1600 meters (the highest portion of his research area), which is a higher elevation than that at which these two anoles were previously most abundant. *N. altae* and *N. tropidolepis* have now been replaced by *N. intermedius* and *N. humilis* as the most abundant in lower areas. This upward squeezing of the anole populations in the area comes in the midst of a 26-year trend toward more severe dry seasons, an increasing number of days with no precipitation, and a rising average altitude of cloud base. (Pounds et al, 1999).

Previous studies assert that tropical lizards are highly sensitive to natural fluctuations in precipitation and cloud cover (Andrews 1999), but the mechanism by which these fluctuations actually affect the anole populations is still unclear. Pounds (2000) suggests that the upward elevation shifts observed in *N. tropidolepis* (and their replacement by *N. intermedius* and *N. humilis*) are related to the thermoconforming metabolism of body-temperature regulation exhibited by *N. tropidolepis*. Thermoconformers allow their body temperatures to track ambient temperature, do not bask, and generally are found in cool, damp habitats (Savage 2002). As the cloud bank rises, the average local temperature rises and mist input decreases, creating an environment favorable for heliothermic organisms, such as *N. intermedius,* that rely on solar energy to regulate body temperature. This altered environment is unfavorable for thermoconforming organisms such as *N. tropidolepis*. A similar phenomenon may have occurred in the case of *N. altae*, but not enough is known about the thermoregulation in *N. altae* to draw conclusions. *N. humilis* is a thermoconformer like *N. tropidolepis*, but has a wider range of tolerance that likely buffered the effects of climactic change. This would explain the continued presence of *N. humilis* in the research areas.

N. intermedius were equally distributed between the Campbell study site and the MBRS site, but *N. humilis* was significantly more abundant in the MBRS site than in the Cambell site. The reasons for this are still unclear. Causes could include random chance, local microclimate differences, or any number of biotic factors. Future studies should be designed to compare population distribution to environmental factors such as local microclimates, prey species abundance, presence of competing species, and predator abundance. The absence of recaptures and the observance of *N. intermedius* and *N. humilis* individuals outside of daytime search hours implies that this population estimate

is a minimum. The number of anoles included in anecdotal data is likely skewed toward the Monteverde Biological Research Station because of the greater number of students working near the site during the time period of this project.

The primary fault in experimental design is the restriction on time. Time restriction forced long periods of searching to be conducted on days exhibiting unfavorable weather conditions. A more thorough approach would have been to divide searching time into daily one or two hour periods over multiple weeks. The density of anoles recorded by this study may have been influenced by the time of year because of more sedentary behaviors exhibited by anoles in the wet season and patterns in reproductive cycles that dip in the wet season (Savage 2002). An important future study would involve similar censusing throughout the year and for consecutive years to observe seasonal as well as yearly fluctuations.

In the Monteverde area, populations of *N. tropidolepis* and *N. altae* have disappeared from their original ranges and now only occur in small patches at high elevations. *N. humilis* and *N. intermedius* have replaced them as most abundant between 1500 m and 1600 m, but there is evidence that they too are experiencing a sharp decline in population density. These trends are only a snapshot of the alarming world-wide decline in anuran and reptilian populations, and there are still crucial gaps in our understanding of forces driving these declines. Continued research must be conducted in order to understand the environmental and anthropogenic causes of herpetofauna disappearance and prevent further loss.

ACKNOWLEDGEMENTS

Many thanks go out to Carlos Guindon and Javier Méndez, for their advice and patience in designing and carrying out this project, and to Maria and Nathanial for the random songs, stats expertise editing, and always keeping the snack box full. Thank you Señior and Señora Guindon, Martha Campbell, and the Monteverde Biological Research Station for allowing me to hunt lizards on your property. A special thanks is owed to Mark Wainwright for taking the time to review my proposal and pass on the wisdom of a lizard-hunting veteran. And of course, this project wouldn't have been possible without Squishy, who shall always be my Squishy.

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Figure 1**:** Location of Cambell study site (green highlighted region) and Montevede Biological Research Station study site (blue highlighted region). Monteverde, Puntarenas, Costa Rica, July 2005.

Table 1. Total number of *Norops* spp encountered in 30 daytime searching hours at the Cambell research area (site 1) and 30 daytime searching hours at the Monteverde Biological Research Station (site 2).

Norops spp.	Cambell Site	Monteverde Biological Research Station
N. woodii	0	0
N. altae	0	0
N. tropidolepis	0	0
N. intermedius	8	4
N. humilis	2	12

Table 2. Anecdotal data. *N. intermedius* and *N. humilis* encountered between July 16 and Aug. 3rd outside of research hours but within the Cambell research area (site 1) or the Monteverde Biological Research Station (site 2). No *N. tropodolepis*, *N. altae*, or *N. woodii* were encountered outside of research hours at either site.

Norops spp.	Monteverde Biological Research Station	Cambell Site
N. intermedius	3	3
N. humilis	6	0