ASSESSING IMPACTS OF DROUGHT ON HERPETOFAUNA THROUGH REPEATED SURVEYS AND MORPHOMETRIC COMPARISONS

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ASSESSING IMPACTS OF DROUGHT ON HERPETOFAUNA THROUGH REPEATED SURVEYS AND MORPHOMETRIC COMPARISONS

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To my parents for their unending support of my education.

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ASSESSING IMPACTS OF DROUGHT ON HERPETOFAUNA THROUGH REPEATED SURVEYS AND MORPHOMETRIC COMPARISONS

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Decreases in overall abundance, diversity and body condition of amphibians and reptiles have been linked to global climate change. One manifestation of climate change is more extreme weather patterns. Extended droughts and intense drought conditions are cyclical events for Texas and the Southwest. A recent exceptional drought in central Texas not only directly diminished aquatic and semi-aquatic habitats but also exacerbated other biotic stressors. I repeated relative abundance and diversity surveys conducted in

2004 at a 9-ha ranch in Guadalupe County, Texas, in spring 2009 coincidently with an intense drought. My relative abundance and diversity analyses sought to determine if the drought reduced abundance and diversity of herpetofauna. Additionally, data from the Bastrop County Houston toad (*Bufo houstonensis*) database combined with Houston toad captures from Griffith League Ranch (GLR) in Bastrop County in 2009 were analyzed for changes in body condition. The results provide new information for the assessment of drought impacts in this group of vertebrates and analytical issues associated with categorizing drought conditions and discriminating among years for drought effects.

CHAPTER 1

INTRODUCTION

Statement of the problem

More than one-third of amphibian species are considered globally threatened and more than 120 species have become extinct since 1980 (Whitfield et al. 2007). Reptiles inhabit similar habitats and are affected by changes in habitats (Gibbons et al. 2000). Herpetofauna are reliable indicators of ecosystem integrity due to limited emigration, recolonization, and adaptions to sudden habitat changes (Grant and Tingle 2002). The herpetofaunal abundance, diversity, and health of an area provide information on water and air quality and available nutrients (McCallum 2007).

State natural resources agencies are promoting increased amphibian and reptile surveys as a method to monitor population trends and supplement limited information on population declines in these vertebrate groups. The timing of such surveys is important, because ectothermic species hibernate during cooler seasons (Ruthven et al. 2002). A perceived shortcoming of population monitoring of herpetofaunal populations is the inefficiency of short-term studies. To understand ecological trends for ecosystems, there is an expectation of continuous monitoring for years. This would necessitate a significant change in policy, long-term planning, and funding from organizations and agencies (Gibbons et al. 1997).

Climate change has negatively impacted herpetofaunal populations, but controversy still surrounds the specific causes of declines (Carey and Alexander 2003). Increased temperatures could decrease temporal duration of hibernation, which might disrupt the normal life cycle and result in health issues and decreased growth rates (Reading 2007). Furthermore, herpetofauna may respond to temperature increases with decreased body size, potentially resulting in lower reproductive rates, higher mortality, and a reduced ability to build energy reserves (Reading 2007). Warmer temperatures might result in earlier and longer breeding seasons. Another possibility may relate to near-surface winds dispersing disease (Alexander and Eischeid 2001). After all individual causative factors are identified; many combinations and synergistic effects of those listed are possible impacts on herpetofauna (Carey et al. 2001). There are many additional concerns about the indirect effects of climate change, including overall biodiversity of the ecosystem and abiotic factors (Ibanez et al. 2006).

There are several types of droughts: meteorological, agricultural, and hydrological. A drought is defined meteorologically as an extended period with less than average precipitation, which applies to my research (NDMC 2009, Neilsen-Gammon and McRoberts 2009). Meteorological drought is determined by the degree and duration of dryness of a region. Agricultural drought deals with crop production but can also result from poor soils and tillage planning rather than precipitation. Hydrological drought occurs when reservoir levels fall below average but is not necessarily due to lack of precipitation (NDMC 2009). Wildlife can be impacted by drought in two ways: direct drought involves a lack of consumable water and indirect drought causes a decrease in food, habitat, and increased stress on organisms. Central Texas experienced a severe drought between 1950 and 1957 and again recently between fall 2007 and fall 2009 (Griffiths and Ainsworth 1981).

Texas is divided into at least 11 ecologically distinct regions based on physiography and variations in climate. These are the Piney Woods, Oak Woods and Prairies, Blackland Prairies, Gulf Coast Prairies and Marshes, Coastal Sand Plain, South Texas Brush Country, Edwards Plateau, Llano Uplift, Rolling Plains, High Plains, and Trans-Pecos (TPWD 2009). With this extensive diversity in habitat, there is a complementary diversity of wildlife. Texas ranks as the second most biodiverse state in the United States (Stein 2002).

Baseline data from previous studies provide a unique opportunity to examine changes in herpetofauna abundance, richness, and body condition at two locations in the most severely impacted areas of a recent drought. Thus, using replication of baseline surveys and contrasting the extent of variation in rainfall over a relatively long time, my study does not only provide snapshots and comparisons of abundance, diversity, and body condition of Texas herpetofauna but allows continued future comparative measurements. This is only the beginning of what could become a very long-term, low-expense, and informative look into the effects of drought on Texas wildlife.

Comparative Research

It became apparent in the early 1980s that amphibians were experiencing worldwide population declines and extinctions (Wake 2007). Amphibians are considered globally threatened with 32.5% of species in jeopardy (Stuart et al. 2004). Many hypotheses have been presented to explain the decline of herpetofauna including habitat destruction and alteration, introduced invasive predators and competitive species, acid rain, chemical pollution, increased UV-B radiation, climate change, and disease (Reading 2007, Wake 2007).

Major die-offs of amphibian populations have been ascribed to chytrid fungus (*Batrachochytrium dendrobatidis)* since its discovery in the early 1990s (Berger et al. 1998). Many herpetologists have hypothesized this fungus is responsible for the majority of rapid amphibian declines, but a more recent series of publications describes several issues with this initial assumption. For example, increased temperature actually inhibits the growth and spread of chytrid fungus (Wake 2007). Whitfield et al. (2007) observed a 75% decrease in leaf-litter amphibians (4.1% per year) and reptiles (4.5% per year) in a primary forest during a 35-year study in Costa Rica. Rainfall did not increase overall, but there was a 50% decrease in the number of dry days and an increase in the average minimum temperature. Because of a similar, concurrent reptile decline, Whitfield et al. (2007) concluded the decrease in amphibians resulted from the decline in leaf litter and not chytrid fungus. Daszak et al. (2005) found only a 2.18% chytrid fungus infection rate in anurans between 1978 and 1981 in South Carolina. However, based on further observations, the decrease in frogs was attributed to an increase in the frequency of drought conditions between 1978 and 2004 (Daszak et al. 2005).

Seigel et al. (1995) evaluated presence and absence of snakes before, during, and after a severe drought between 1985 and 1987 which resulted in an overall decrease in the abundance of *Nerodia fasciata* (Banded water snake) and *Seminatrix pygaea* (Black swamp snake) in South Carolina. Seigel et al. (1995) concluded *Nerodia fasciata* declined from an absence of water; whereas, *Seminatrix pygaea* declined due to an absence of suitable prey. Shine (1991) associated a decrease in larger snakes, the Eastern brownsnake (*Pseudonaja textilis*) and the Common blacksnake (*Pseudechis porphyriacus*), in Australia with a lack of suitable prey.

Two studies on desert tortoise (*Gopherus agassizii*) populations in the Mojave Desert demonstrated the detrimental effects of drought. The first study analyzed feeding rates and metabolic rates of two populations over 18 months. Tortoise populations were affected not only directly by a lack of consumable water but also indirectly by a reduced availability and quality of food (Peterson 1996). The second study noted survival rates at two locations over a nine-year period. During a short-term drought a substantial decline in survival was observed. The lack of directly consumable water coupled with limited food was hypothesized as the cause for this population decline (Longshore et al. 2003).

It is important to document the effects of short-term and long-term impacts of drought on herpetofaunal populations. A long-term study analyzing abundance, diversity and body condition during periods of average rainfall compared to periods of drought could support the idea that drought and, more generally, global climate change has a detrimental impact on the biosphere as a whole. Central Texas has just experienced the second of two historic droughts. The first occurred in the 1950s with 40% of average total rainfall and lasted seven years (Griffith and Ainsworth 1981). The availability of long-term data from previous studies and different environmental conditions due to the current drought created the prime opportunity to conduct my study.

Objectives and Goals

The purpose of my study was to determine impacts of drought on amphibians and reptiles. Specifically, I collected data to quantify abundance, diversity, and body condition during drought and non-drought conditions. Previous studies identical in methodology, but preceding the current drought provided data for long-term and short-term comparative analyses. I used comparative abundance/capture-rate and diversity data from a site originally trapped prior to drought and then affected by drought, and body condition comparisons using an adjusted ratio of weight by length ((weight/length)^3*100,000) for comparative data sets (Anderson and Neumann 1996).

Hypotheses

The following are null hypotheses.

1. There is no difference in overall abundance of herpetofauna trapped during the drought compared to those collected prior to the drought at both test sites.
2. There is no difference in overall diversity of herpetofauna trapped during the drought compared to those collected prior to the drought at both test sites.
3. There is no difference in overall body condition of herpetofauna trapped during the drought compared to those collected prior to the drought at both test sites.

The following are alternate hypotheses.

1. There is a decrease in overall abundance of herpetofauna trapped during the drought compared to those collected prior to the drought at both test sites.
2. There is a decrease in overall diversity of herpetofauna trapped during the drought compared to those collected prior to the drought at both test sites.

3. There is a decrease in overall body condition of herpetofauna trapped during the drought compared to those collected prior to the drought at both test sites.

CHAPTER 2

METHODS AND MATERIALS

Overall Plan

I conducted my study at a site in Guadalupe County in the Blackland Prairie ecoregion and another site in Bastrop County in the Post Oak Savannah ecoregion. Both sites had pre-drought monitoring of herpetofaunal diversity, abundance, and measurements of all specimens. Pre-drought data were collected during 2004 at the end of a period with above average precipitation. Post-drought data were gathered during 2009 at the end of a severe drought that began in 2007 (Neilsen-Gammon and McRoberts 2009).

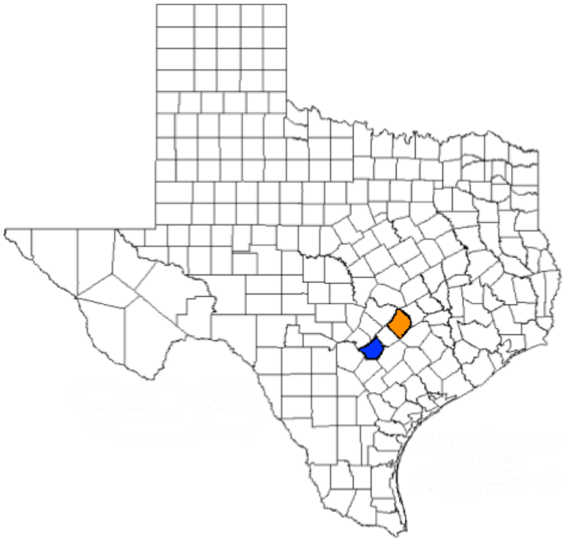

Figure 1. Map of Texas counties showing locations of study sites. Guadalupe County is highlighted in blue and Bastrop County in orange.

Abundance and Diversity Study

Diversity and abundance information were collected in Guadalupe County using six drift fences with a pitfall trap and predator exclusion device (Ferguson 2005, Ferguson and Forstner 2006) at each end, and a nearby track-monitoring station. These drift fences were monitored for 84 consecutive nights (6 traps, 2 buckets each, total of 1,008 trap nights counting each bucket) during fall 2009 (8 August through 31 October). This is a replication of a previous study in the same location using identical materials and similar methods (23 June 2004-5 October 2004).

Evaluation of species diversity and richness at the Guadalupe site was performed by calculating Simpson's Index of Diversity (D) by the following formula:

$$D = [\sum_{i=1}^{S} n_i (n_i - 1)] / [N (N - 1)]$$

where:

S = number of species,

N = total number of captures, and

n = number of captures of each species.

This number gives a proportion of diversity with a value of 1 being least diverse and 0 being most diverse (Simpson 1949). Because Simpson's index of diversity decreases with increasing diversity the values herein are subtracted from 1 to allow for easier comparison with the following indices.

The Shannon index of diversity (H) provides a relative number useful for comparative evaluations and was calculated to measure biodiversity between time periods by:

$$H = -\sum_{i=1}^{S} [(n_i/N)\ln(n_i/N)]$$

I calculated Pielou's species evenness index for captures to compare the relative abundance of each species at the Guadalupe site. Pielou's species evenness index ranges from 0 to 1. Pielou's species evenness index (J') was calculated by:

$$H' = H - [(S-1)/2N]$$

$$H'_{max} = -\sum_{i=1}^{S} (1/S)\ln(1/S) = \ln S$$

$$J' = H'/H'_{max}$$

Body Condition Study

Body condition comparisons were made using the Bastrop County Houston toad database (Forstner et. al. unpublished), as well as data I collected from the Griffith League Ranch (GLR) in Bastrop County. My Houston toad work required collection of body condition measurements for use in comparison with toads collected on site in the last 10 years. The same proxy for body condition (i.e., gender specific slope of length by mass) of Houston toads was compared to existing data prior to drought conditions to determine whether or not their growth deviated from the given norm.

I calculated weight by length adjusted ((mass/length)^3*100000) ratios, year-to-date cumulative precipitation for each capture, and used a two-sample *t*-test conducted to compare Houston toad body condition to data collected from the Bastrop County site over the last 10 years.

CHAPTER 3

RESULTS

Overall Results

There was an overall decrease in relative abundance, diversity, and body condition in herpetofauna trapped during the drought as compared to data collected prior to the drought at both test sites.

Abundance and Diversity Study

All three diversity indices indicated a decrease in value indicating a decrease in species diversity (Table 1). After excluding the Mediterranean gecko (*Hemidactylus turcicus), an invasive species*, from the results the same trend occurred with a greater difference in values (Table 2).

Table 1. Changes in diversity indices based on pre-drought (2004) and drought (2009) conditions at the Guadalupe County study site.

Index	2004	2009	Change
Simpson's index of diversity (1-D)	0.58612	0.54564	Decrease
Shannon index of diversity	1.32166	1.23955	Decrease
Pielou's species evenness index	0.47669	0.53833	Increase

Table 2. Changes in diversity indices excluding *Hemidactylus turcicus* based on pre-drought (2004) and drought (2009) conditions at the Guadalupe County study site.

Index	2004	2009	Change
Simpson's index of diversity (1-D)	0.58612	0.46429	Decrease
Shannon index of diversity	1.32166	1.02987	Decrease
Pielou's species evenness index	0.47669	0.23120	Decrease

Overall, there was an 81% decrease in total captures and a 38% decrease in number of species in the pre-drought and drought periods (Table 3). With the exclusion of *H. turcicus* there was an 82% decrease in total captures and a 44% decrease in number of species (Table 4).

Table 3. Change pre-drought (2004) and drought (2009) species abundance and species richness at the Guadalupe County study site.

Overall	2004	2009	Change
Total number individuals	546	95	Decreased by 81%
Species richness	20	11	Decreased by 38%

Table 4. Change pre-drought (2004) and drought (2009) species abundance and species richness at the Guadalupe County study site excluding *Hemidactylus turcicus*.

Variable	2004	2009	Change
Total number individuals	546	87	Decreased by 82%
Species richness	20	10	Decreased by 44%

Body Condition Study

The mean snout-urostyle length and mass for Houston toads captured at GLR pre-drought (2004, *n* = 33) and drought (2009, *n* = 45) were 61.8mm and 25.5g (SE =

0.0915749, range = 1.3-3.6) and 54.9mm and 18.1g (SE = 0.0723481, range = 1.9-4.2), respectively. Snout-urostyle length to body mass of Houston toads captured in pre-drought 2004 compared to 2009 were significantly larger and heavier in 2005 (t = -4.7578, *p* = 0.02462; Figure 2).

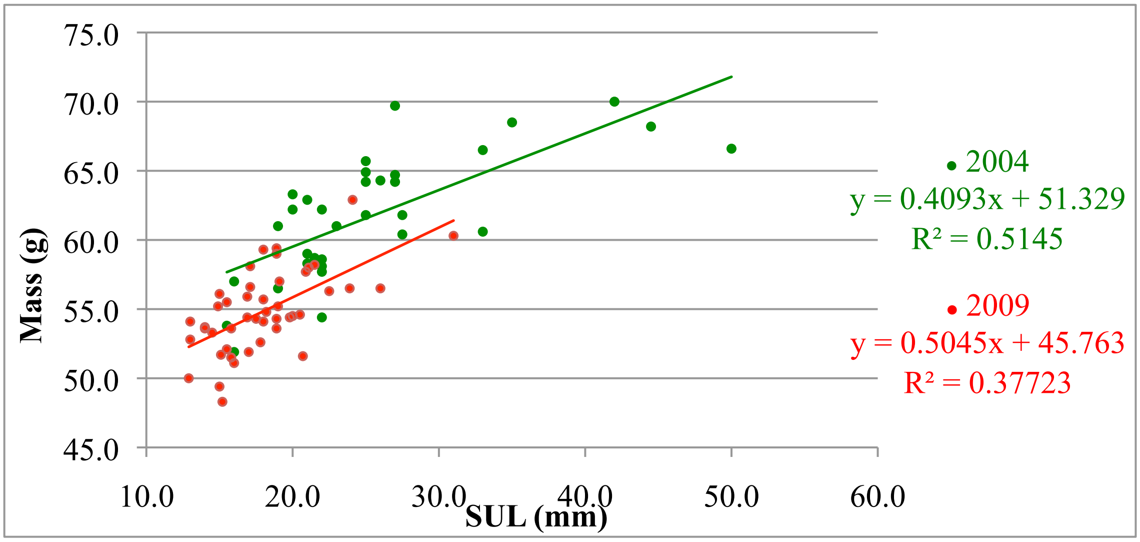

Figure 2. Length (snout-to-urostyle length) to mass ratios comparing body condition of Houston toads captured in pre-drought (2004) conditions to captures during drought (2009) conditions.

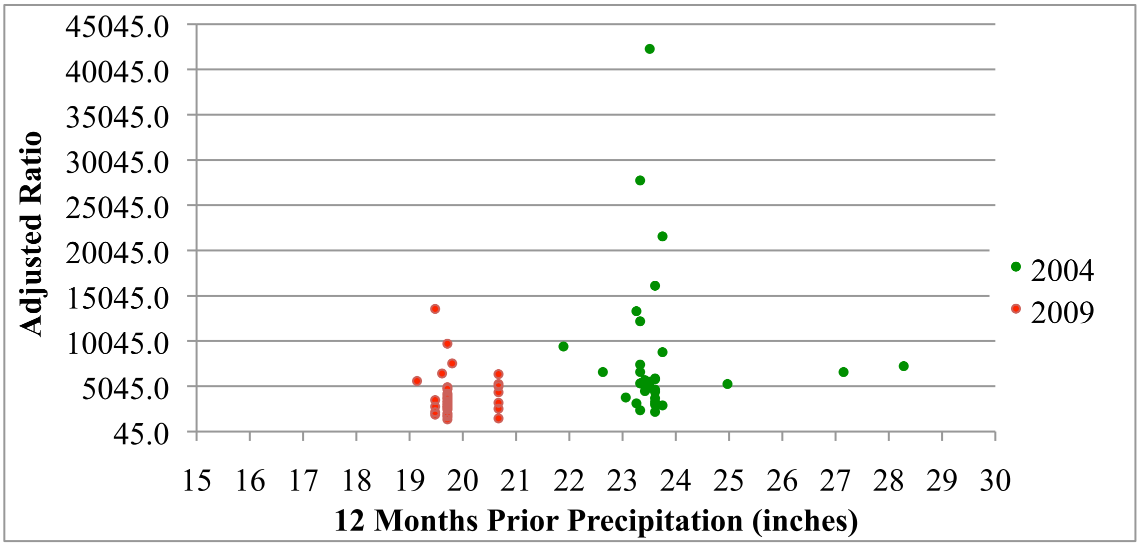

Figure 3. Weight by length adjusted ratios to year-to-date cumulative precipitation comparing body condition of Houston toads captured in pre-drought (2004) conditions to captures during drought (2009) conditions.

CHAPTER 4

DISCUSSION

Drought is relative to location and point of view, therefore, it is difficult to define. Additionally, with drought conditions, regardless of intensity, occurring sporadically in time and across landscapes the completion of studies examining drought effects is difficult to execute without long-term intentions. A key asset to my comparison was the availability of pre-existing herpetofauna datasets from two central Texas locations.

The difference between detection and extirpation must be noted; some species are directly dependent on constant and nearby water sources while others have the ability to aestivate. It is entirely possible some species were present, just not active. In this case, captures in this study could be a combination of both aestivation and extirpation. It is also possible, and considered likely, the lack of activity was due to drought conditions.

My study was designed to assess changes in herpetofaunal abundance, diversity, and body condition influenced by a recent drought in central Texas to parameters collected prior to previous droughts. This is important on both a small and a large scale. Minimally, this study potentially demonstrates the link between a lack of rainfall and abundance, diversity, and body condition and sets the stage for additional studies in other geographic areas and with other species to see whether a similar trend is demonstrated. In the big picture, though, my study addresses issues that could have worldwide and long-term impacts. Currently, scientific opinion debates anthropogenically induced global climate change, but this study examines impacts from drought, which represents one of the projected impacts to large regions of the planet under warming models.

Climate changes over time from ice ages to broader continental drift induced ecological dynamics. Wildlife has been adapting to these changes both locally and globally during their evolutionary history. However, the planet today is vastly anthropogenically influenced potentially altering the potential for wildlife populations' historical successes in adapting to changes in climate. At the same time, many animal populations have less available habitat in more fragmented configurations acting as additional stressors on those populations. Adding drought impacts could potentially cause cascade effects as species less dependent on water availability, but relying on water-dependent species, lose their supporting fauna. By gathering more information and evaluating impacts of droughts on wildlife, a better understanding of the short-term impacts from droughts and a broader understanding of climatic changes over time can be realized.

I found fewer individuals, fewer species, and some evidence supporting the hypothesis that drought contributes to changes in how well animals respond to drought. All categories of measurement, from species diversity to body condition, caused me to reject of all null hypotheses; there was, in fact, a difference in overall abundance, diversity and body condition of herpetofauna trapped during the drought compared to data collected prior to the drought at both test sites.

When comparing captures by species between 2004 and 2009, the Mediterranean gecko, an introduced species, is an obvious anomaly. Their increase is possibly attributed to lack of natural predators, little competition, capitalization on human dwellings for shelter, and high survival rates (Davis 1974, Selcer 1986). When looking at the results as a whole the removal or retention of the gecko data matters not; the trend is present in all calculations.

The results of this study provide information on impacts of droughts on herpetofauna populations. With the lack of additional documentation locally, nation-wide, and even worldwide, there is little to compare and a limited understanding of impacts of drought on a large scale. A national drought impact database does not exist but efforts have been made to create one. The National Drought Mitigation Center (NDMC 2009) at the University of Nebraska-Lincoln has begun collecting data and documenting drought impacts across the country, but information can only be reported when provided by researchers. Studies like this one need to be conducted on a large scale and for an extended time to supplement that database or one similar to it. By expanding the range and test data, organizations like the NDMC can provide valuable information aiding in legislation, regulation, and preservation. The consequences of drought are well known but rarely studied. With additional research and documentation, we may determine the cause of global climate change and alter the effects or modify our actions to accommodate drought conditions.

APPENDIX

Total captures for abundance and diversity study in pre-drought conditions (2004, Ferguson 2005) and drought conditions (2009).

Species	**2004**	**2009**
Rana berlandieri	1	0
Rana catesbeiana	298	0
Rana sphenocephala	4	0
Acris crepitans	1	1
Gastrophryne olivacea	73	62
Bufo valliceps	66	7
Hemidactylus turcicus	0	8
Sceloporus olivaceus	7	10
Sceloporus undulatus	2	0
Crotalus atrox	1	1
Coluber coluber flaviventris	12	0
Elaphe guttata emoryi	0	1
Elaphe obsolete lindheimeri	3	0
Nerodia erythrogaster transversa	7	0
Nerodia rhombifer rhombifer	2	0
Thamnophis proximus rubrilineatus	9	2
Thamnophis marcianus marcianus	1	1
Virginia striatula	1	1

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