SUPPLEMENTAL INFORMATION

RAINS FROM SUCCESSIVE HURRICANES REDUCE NESTING SUCCESS OF THE MARBLED SALAMANDER (*AMBYSTOMA OPACUM*)

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TABLE S1. Nest temperatures of Marbled Salamanders (*Ambystoma opacum*) from Tuskegee National Forest, Alabama, USA. Nest number 5 was never inundated with water. Some nests are not shown because they were under the same log as another nest.

NestID	DateFound	Mean	SD	Min	Max	StartDate	EndDate	FloodDate	DaysB4Flood	WaterRecede	DaysUnderWater	MeanTempB4Flood
1	10/20/2020	15	4.6	5.5	23.5	10/21/2020	12/10/2020	10/24/2020	4	10/27/2020	3	20.7
2	10/20/2020	14.8	4.4	5.5	23	10/21/2020	12/10/2020	10/24/2020	4	11/3/2020	10	20.2
3	10/20/2020	14.6	4.9	3.5	24.5	10/21/2020	12/10/2020	10/24/2020	4	11/10/2020	17	20.7
5	10/20/2020	14.8	4.6	6	23	10/21/2020	12/10/2020	N/A		N/A		
6	10/20/2020	14.4	4.8	5.5	23.5	10/21/2020	12/10/2020	10/24/2020	4	11/10/2020	17	20.5
7	10/20/2020	14.5	4.7	4	23	10/21/2020	12/10/2020	10/24/2020	4	11/17/2020	24	20.4
8	10/20/2020	14.8	4.5	6	23	10/21/2020	12/10/2020	10/24/2020	4	11/10/2020	17	20.5
9	10/20/2020	20.7	1.2	16.5	23	10/21/2020	10/30/2020	10/24/2020	4	11/17/2020	24	20.3
10	10/21/2020	14.5	4.8	4.5	23	10/21/2020	12/10/2020	10/24/2020	3	11/10/2020	17	20.5
11	10/21/2020	15.1	4.4	6	23	10/21/2020	12/10/2020	10/24/2020	3	11/10/2020	17	21.2
16	10/21/2020	14.7	4.7	5	23.5	10/21/2020	12/10/2020	10/24/2020	3	11/3/2020	10	20.4
19	10/22/2020	14.9	4.1	7	23.5	10/22/2020	12/10/2020	10/24/2020	2	11/17/2020	24	20.4
20	10/22/2020	20.7	0.9	18	22.5	10/22/2020	10/30/2020	10/24/2020	2	11/17/2020	24	20.6
21	10/22/2020	14	5	3.5	23.5	10/22/2020	12/10/2020	10/24/2020	2	11/3/2020	10	20.3
23	10/22/2020	15.2	4.2	5	23	10/22/2020	12/10/2020	10/24/2020	2	11/3/2020	10	20.5

25	10/30/2020	14.3	3.5	8	21.5	11/3/2020	12/10/2020	11/30/2020	31	12/10/2020	10	15.89
28	11/13/2020	12	2.8	7.5	17	11/17/2020	12/10/2020	11/30/2020	17	12/10/2020	10	13.9

DateFound: day the nest was discovered; Mean: average nest temperature; SD: standard deviation of nest temperatures; Min: minimum nest temperature; Max: maximum nest temperature; StartDate: first day nest temperatures were recorded; EndDate: last day nest temperatures were recorded; FloodDate: day the nest was inundated by water; DaysB4Flood: number of days between oviposition and nest inundation; WaterRecede: Date that the nest was no longer under water; DaysUnderWater: total number of days each nest was submerged; MeanTempB4Flood: average nest temperature during the days before the nest was inundated with water.

TABLE S2. List of studies concerning the effects of hurricanes and cyclones on amphibians. Studies are in alphabetical order by the last name of the first author. Full citations are given at the end of the supplement.

First author	PubYear	Storm	Group	Species	Focus	Type	Method	Result	Effect
Dorcas	2006	Frances, Ivan	Anura; Caudata	Multiple	Rainfall/flooding	Opportunistic	Sampled ponds for 3 to 6 days per month from March through June 2004 and for two days in September 2004. Sampled for two days during the spring of 2005 to determine effects of the two hurricanes which passed through during fall of 2004.	In the year prior to the hurricane, many anuran egg masses were found at the site along with *Ambystoma opacum* larvae. After the hurricanes, very few anuran egg masses were found and no *A. opacum* larvae.	Negative
Enge	2005	Georges	Anura; Caudata	Multiple	Rainfall/flooding	Opportunistic	Sampled 7 steephead stream sites for all reptiles and amphibians with drift-fences on 165 total days from Sept 1998 to July 1999. Hurricane George struck at the beginning of the study (27-28 Sept); thus, no pre-hurricane data was available for comparison to post-hurricane data.	A relatively large number of amphibians were trapped following the hurricane; indicating that hurricane rainfall stimulated the emergence of amphibians. Aquatic salamanders were particularly more likely to be trapped after the	Ambiguous

								hurricane.	
Gray	2017	Earl	Anura; Caudata	Multiple	No particular focus	Opportunistic	Sampled 4 habitat types for herpetofauna using drift fences during the rainy season of 2016 (8 total weeks). Assessed microhabitat at each site before and after the hurricane.	Despite significant changes to habitat (e.g., canopy cover) there were no differences in capture rates, species richness, or species diversity before vs after the hurricane.	Neutral
Greenberg	2001	Opal	Anura; Caudata	Multiple	Canopy disturbance	Opportunistic	Hurricane Opal resulted in multiple tree fall gaps. Some gaps were salvage logged. The aim of the study was to compare reptile and amphibian communities in windfall gaps, salvaged gaps, and control (intact forest).	No significant difference in relative abundance of amphibians across the study sites.	Neutral
Gunzburger	2010	Dennis	Anura; Caudata	Multiple	Storm surge; wetland salinity	Opportunistic	Sampled wetlands over a 45-month period to assess amphibian species richness and water chemistry. Seven wetlands were overwashed by storm surge from Hurricane Dennis. Compared these wetlands to nonoverwashed	Very little effect on the amphibian populations; salt-water concentration (chloride concentration) increased in wetlands overwashed by storm surge. Amphibian species richness was higher before	Neutral

							wetlands and compared populations before and after the hurricane.	the storm than after, but did not differ between overwashed and non-overwashed wetlands. The overwashed wetlands remained at a higher salinity for over a year after the storm; however, there were no major changes in the amphibian assemblage.	
Hawley	2006	Iris	Anura	Multiple	No particular focus	Opportunistic	Monitored species richness, composition, and abundance before and after the hurricane (20 months of monitoring before).	Canopy cover was greatly reduced by the hurricane. Species richness increased at every study site after the hurricane but the hurricane had no obvious effect on the abundance of frogs.	Neutral/ ambiguous
Klawinski	2014	N/A	Anura	*Eleutherodactylus coqui*	Leaf drop and canopy disturbance	Experimental	Experimentally simulated hurricane effects of canopy disturbance and debris deposition onto the ground in a factorial design; tried to mimic conditions created by Hurricane	Additional debris on the ground did not influence frog density but opening the canopy reduced frog density.	Negative

							Hugo (1989).		
Lorrain-Soligon	2021	Xynthia	Anura; Caudata	Multiple	Storm surge; wetland salinity	Opportunistic	Sampled amphibian communities in wetlands several years before they were submerged by the cyclone and for multiple years after.	The coastal topography influenced the storm's effect on the amphibian community: one site was protected from storm surge and experienced no change in species richness; the other site experienced a decline in richness after the storm. This site did, however, recover 4 years after the storm; however, salinity levels did not return to normal even after 7 years. The post-storm recovery at the site most affected by the storm was species-dependent.	Species-dependent
Luja	2010	Henriette, Julio, Lowell	Anura	*Pseudacris hypochondriaca curta; Lithobates catesbeianus*	No particular focus	Opportunistic	Monitored a population of native treefrog and invasive bullfrog over two years by searching transects, measuring, marking, and releasing all	Cyclones had no apparent long-term effect on native treefrog abundance; however, 3 of 4 marked, invasive bullfrogs were	Species-dependent

							individuals. Cyclones occurred in each year.	found dead or severely injured hundreds of meters downstream of the study site. Treefrogs exhibit the potentially adaptive behavior of climbing into rock crevice refugia during storms.	
Marroquin-Paramo	2021	Jova, Patricia	Anura	Multiple	No particular focus	Opportunistic	Conducted a long-term survey of frog and reptile populations (from 2009-2018) across various successional stages of forest. Analyze data from before and after the hurricanes with a focus on cumulative effects.	Abundance of frogs decreased due to hurricanes. Anuran species richness was reduced in old-growth forests. Declines were somewhat species-dependent.	Species-dependent
Meshaka	1993	Andrew	Anura	Multiple	No particular focus	Opportunistic	Monitored local populations of 3 species of frogs in an urban area after hurricane Andrew struck Florida.	All 3 species responded to the hurricane by breeding. Each species benefited via an increase in breeding sites created by the hurricane.	Positive
Nicoletto	2013	Rita	Anura; Caudata	Multiple	No particular focus	Opportunistic	Performed diversity surveys during 2001-2004 (before the	No major effect on the total number of species	Species-dependent

							hurricane) and in 2007-2008 (after the hurricane).	present; however, some species were much more abundant after the hurricane while others were less abundant.	
Roznik	2015	Yasi	Anura	*Litoria rheocola*	Canopy disturbance	Opportunistic	Sampled six sites to understand disease dynamics of *Batrachochytrium dendrobatidison* this frog species. Opportunistically studied the effects of cyclone Yasi after it damaged some, but not all of the canopy cover at the six study sites.	Areas with reduced canopy cover due to the cyclone resulted in lower infection rates of *Bd* than areas that did not sustain canopy damage. This is likely due to increased temperatures and evaporative water loss.	Positive
Schriever	2009	Ivan, Katrina, Rita	Anura; Caudata	Multiple	No particular focus	Opportunistic	Monitored abundance and diversity of reptiles and amphibians at multiple sites of three habitat types (marsh, swamp, levee) before and after several hurricanes.	Reptile and amphibian diversity decreased and evenness increased in each habitat type following hurricanes. Drastic reductions occurred for overall amphibian abundance. Authors note that increase in canopy openness after hurricanes	Species-dependent

								favored some species over others. Some species increased in abundance after hurricanes while others decreased.	
Stewart	1995	Hugo	Anura	*Eleutherodactylus coqui*	No particular focus	Opportunistic	Studied a deme of frogs from 1979 to 1993 to understand seasonal variation in abundance and activity.	Major reduction in the number of juveniles and increase in number of adults post-hurricane Hugo. The canopy was opened and leaf drop increased due to the hurricane. Spider (i.e., frog predators) populations crashed which may have increased survival of adult frogs. *E. coqui* experienced increased adult density and decreased juvenile density; other species that are less tolerant of high temperatures and dry conditions nearly	Species-dependent

								disappeared after the hurricane.	
Suazo-Ortuño	2018a	Jova	Anura	Multiple	No particular focus	Opportunistic	Two years before the hurricane, authors started a study of the herpetofaunal communities in various successional stages of forest. Then opportunistically studied the effect of the hurricane on amphibian and reptile populations with respect to various successional stages of habitat ranging from early-forests to old-growth continuous forests.	Total number of frogs declined significantly after the hurricane in all successional stages; however, some species increased in number while others decreased. These differences were related to successional stage, habitat preference, functional traits, reproductive habit, and body size. Three species were only documented after the hurricane.	Species-dependent
Suazo-Ortuño	2018b	Jova	Anura	Multiple	No particular focus	Opportunistic	This study utilized the same data as Suazo-Ortuño et al. 2018a; however, analyses focused on sampling completeness, assemblage structure, assemblage evenness, and assemblage composition.	Total abundance of frogs declined significantly after the hurricane in all successional stages; however, 9 species decreased in abundance and 8 species increased.	Species-dependent

								Thus, the frog assemblage became more even at all successional stages after the hurricane. Species-specific changes in abundance differed among successional stages.	
Villela	2005	Georges	Anura	*Eleutherodactylus coqui*	No particular focus	Opportunistic	Estimated frog abundance and diversity from call counts along transects before and after Hurricane Georges.	Abundance of *E. coqui* increased after the hurricane while abundance decreased for 5 other species.	Species-dependent
Walls	2019	Michael	Caudata	*Ambystoma cingulatum*	Storm surge; wetland salinity	Opportunistic	Monitored salamander populations before and after the hurricane.	Juvenile recruitment appears to be much lower after the hurricane (though authors admit studying the overall effect of the storm will take additional time).	Negative
Wojnowski	2000	Floyd, Dennis	Caudata	*Ambystoma opacum*	Rainfall/flooding	Opportunistic	Monitored a breeding population during a year with excessive flooding due to Hurricanes Dennis and Floyd	Six clutches were found and all resulted in total egg mortality because the breeding site was flooded prematurely causing females to nest in areas	Negative

								that were never inundated by water (which is necessary for hatching in this species).	
Woolbright	1991	Hugo	Anura	*Eleutherodactylus coqui*	No particular focus	Opportunistic	Monitored populations with capture mark recapture before and after the hurricane.	Adult density increased sharply after the hurricane; however, body size decreased; juvenile survival, however, was greatly reduced by the hurricane. The smallest frogs were least likely to survive. Of non-target frog species, some increased and some decreased abundance due to the hurricane.	Species-dependent
Woolbright	1996	Hugo	Anura	*Eleutherodactylus coqui*	No particular focus	Opportunistic	Monitored populations from 1987 to 1995 and considered changes caused by hurricane Hugo in 1989.	Population size increased 6 fold after hurricane Hugo. Author suggests that the largest single impact on the frog populations in nine years was hurricane Hugo.	Positive

First author – the last name of the first author. *PubYear* – the year the study was published. *Storm* – the name of the hurricane or cyclone that is the focus of the study. *Group* – the major amphibian group that was studied. *Species* – the species name for the focal organism. Says "Multiple" if more than one species were studied. *Focus* – the particular aspect of the hurricane that was studied. *Type* – opportunistic studies are those that monitored the effects of hurricanes while conducting a study for another purpose. Experimental describe studies that manipulated habitat to understand effects of hurricanes. *Method* – a description of the study methods. *Result* – a description of the main findings of the study. *Effect* – the overall effect of the hurricane. "Neutral" – no real affect. "Ambiguous" – the overall affect is unknown, perhaps because a species was affected positively in some ways and negatively in others. "Positive" – the hurricane had a positive effect. "Negative" – the hurricane had a negative effect. "Species-dependent" – if multiple species were studied, some species exhibited positive responses to the storm and some exhibited negative responses.

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