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Birds, Bees—and Cookies? Great Plains Bioclimatology Observations during the Total Solar Eclipse of 21 August 2017

Neil C. Heywood, Pat Zellmer, and Ray Reser
University of Wisconsin – Stevens Point, Stevens Point, WI 54481

Abstract. Our overall field team dedicated five personnel to observing meteorological and biotic aberrations during the August 2017 total solar eclipse on the high plains of Nebraska and Wyoming. We regularly recorded both visual and audio data between pre- and post-onset event times. The teams also encountered and spontaneously improvised corrections for unanticipated environmental and technological obstacles at four observation sites. At each, we indeed observed abnormal bioclimatic phenomena.

1. Overview

Five members of a sixteen-person team from the University of Wisconsin—Stevens Point (UWSP) observed biotic and weather responses to the total solar eclipse of 21 August 2017 on the western Great Plains. We chose this primary observation area for multiple reasons; high probability of clear viewing conditions (low-stature vegetation and few clouds), lesser traffic congestion, and greater availability of public lands access. We also established observer partnerships with National Park Service personnel, and were accompanied by non-university citizen groups for additional assistance.

After four advance reconnaissance excursions, and in consultation with local residents and officials, UWSP observed at four Great Plains umbral path sites ("UWSP" on Figure 1): **Harrison,** Nebraska (54 kilometers from path center, 26 second totality within the Bailey's Beads zone); **Moore Springs,** Wyoming (0 meters from path center, 2 minute 29 second totality); **Fort Laramie National Historic Site,** Wyoming (25 kilometers from path center, 2 minute 22 second totality); and **Stegall,** Nebraska (52 kilometers from path center, 41 second totality within the Bailey's Beads zone). For some biotic measures, we also employed collaborators stationed at a private home in Pelzer**,** South Carolina ("SC" on Figure 1; 2 minute 36 second totality), four kilometers northward from the umbral path center. Peak totality darkness was at 11:48 AM MDT for the Great Plains sites, and at 2:49 PM EDT in Pelzer.

Some 35 UWSP and contributing local citizens, ranging in age from seven to seventy, participated in this venture. Sixteen were UWSP students, alumni, staff, and faculty (eleven were astronomical observers). All participated as collaborative observers; we had no idle sightseers. The grant-funded UWSP personnel acquired much valuable data and guidance from the many extracurricular assistants. Eight academic disciplines, three federal agencies, five local governments, two non-government offices, and numerous private citizens cooperated for this project; the overall endeavor was a societal collaboration among all.

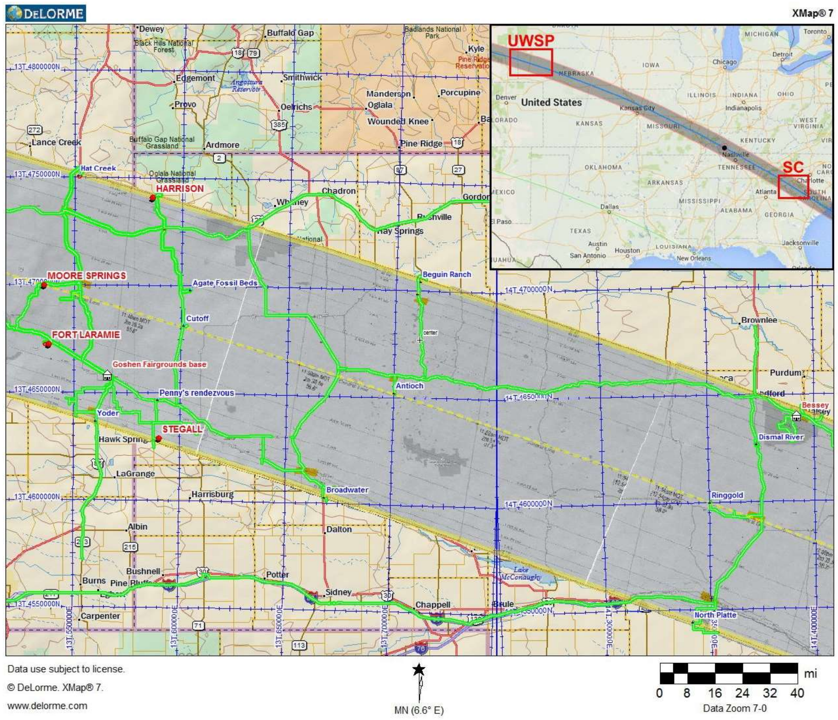

Figure 1. UWSP Great Plains observation sites (upper-case red sites; logistics bases are at the red lower-case sites). Contingency observation sites appear in blue; reconnaissance routes appear in green. Umbral (shadow) path appears in gray; graze zones (Bailey's Beads) and path center appear in yellow.

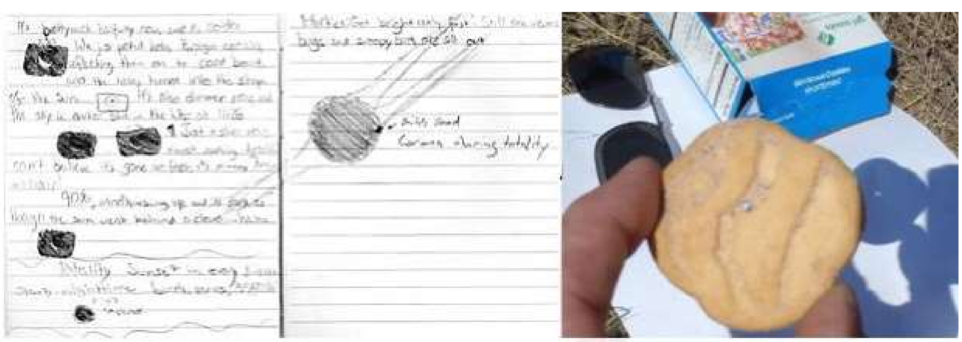

Figure 2. Participants included members of a Girl Scout Troop from Madison Wisconsin. Here a 13-year-old shared her valuable notes and a pin-hole improvisation, at Fort Laramie National Historic Site.

2. Methodology

The fundamental question that our bioclimatic team addressed was, "Will nocturnal or crepuscular conditions and organisms temporarily replace diurnal elements during the brief mid-day eclipse darkening?" Team members recorded measurements of local ground meteorological conditions, and of biotic behavioral aberrations, between 10:10 AM and 1:30 PM (MDT) at Fort Laramie and Stegall. Associates at Pelzer also recorded audible observations for comparison with eastern United States biota, between 1:00 and 4:00 PM (EDT).

We recorded atmospheric variables at five-minute intervals, including light levels, temperature, wind speed and direction, and relative humidity. Direct observations, video cameras, audible recorders, and ultrasonic recorders continuously captured biotic data from before until after the partial eclipse phases.

Devices for recording bioclimatic data had to be compact, durable, and effective; all pre-tested adequately on-site during the days before the eclipse. The field instrument arrays (Figure 3) included:

- pocket weather station, for temperature, relative humidity, wind speed, and light level;
- magnetic compass, for wind direction;
- shortwave radio, for shortwave world time signal (WWV) synchronization;
- GPS receiver, for positioning and backup time signals;
- binoculars, for distant organism and weather identifications;
- digital camera, for still and video images;
- video camera and tripod, for continuous site monitoring;
- voice recorder, for audible sound frequencies;
- ultrasonic recorder, for inaudible sound frequencies;
- compact studio recorder, for storing ultrasonic data.

3. Results

We harbored concerns about atmospheric viewing conditions, and so had contingency sites either east or west of our primary locations. Both the Great Plains and the South Carolina sites were forecast for clear skies (Figure 4), but late-summer aridity and ongoing west coast wildfires (Figure 5) risked dust and smoke viewing impairment for our teams. Neither materialized, but we only knew for sure on the morning of deployment. At our Goshen County Fairgrounds base, the early riverside fog had quickly burned off by 7:00 AM MDT. However, the Great Plains sites experienced the passage of a complex frontal system, which may have confounded some of our on-site atmospheric observations later during that day.

At Fort Laramie and Stegall during the eclipse our instruments recorded a 15 to 20°(F) drop in temperature, a minor and short-lived increase in relative humidity, and a pronounced directional and velocity shift of wind vectors; it became nearly dead calm shortly after totality (Figure 6).

Figure 3. Field Instrument Array.

Every one of our teams experienced unexpected technology lapses. All shortwave radio signals vanished at the time of the eclipse. We suspect that this might have involved the coincidental surge of solar flares during the days preceding and including the eclipse (Figure 7), but we also think that the eclipse did not demonstrably cause this. Effect: no radio time signal.

The Great Plains teams also lost all cell phone communication, but perhaps this resulted from system overload (despite new transponder installments) rather than solar flare signal disruption. We cannot determine the cause. Ancillary cell phone functions (e.g., photography and videos) continued to function. Effect: no reliable cell phone time signal, nor communication between our dispersed observers.

Global Positioning System (GPS) receivers did continue to function, perhaps because these signals have security designs to avoid natural or human disruptions. Effect: these (and wristwatches, for teammates still using them) reliably continued to provide our time synchronizations.

Our teams also confronted and spontaneously corrected for additional technology lapses, such as mundane power losses and device operation procedural errors. Lessons learned: *Know your equipment proficiently* to adjust upon short notice; only poor "carpenters" blame their tools. *Have multiple contingency plans.* We did; each of our teams effectively adjusted, and so they all still returned with valuable data despite their unanticipated obstacles.

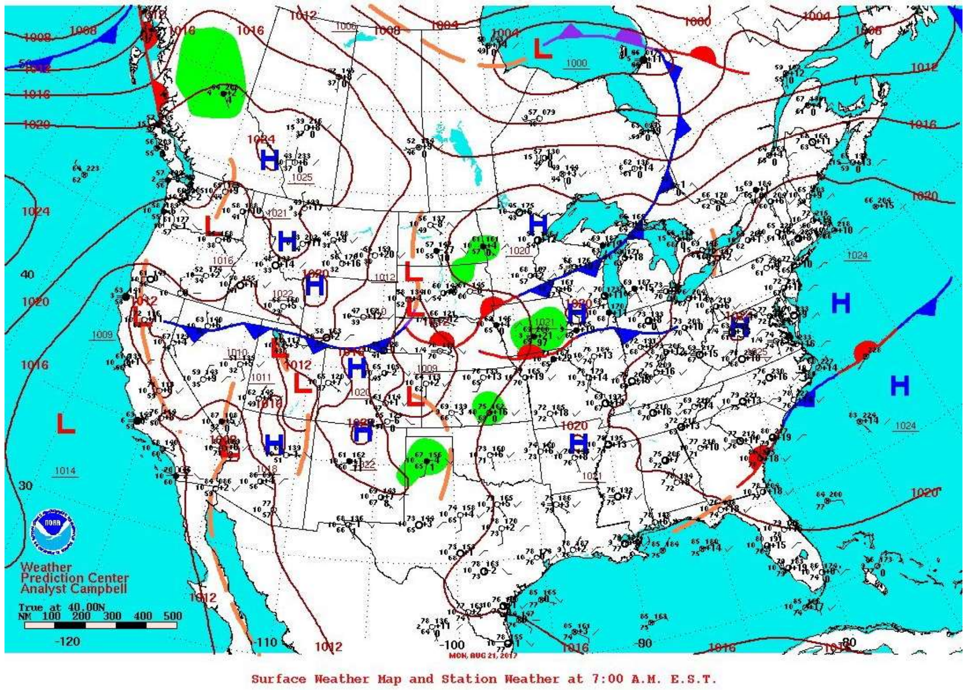

Figure 4. Synoptic weather, 2017 August 21 5:00 AM MDT (from *NOAA*)

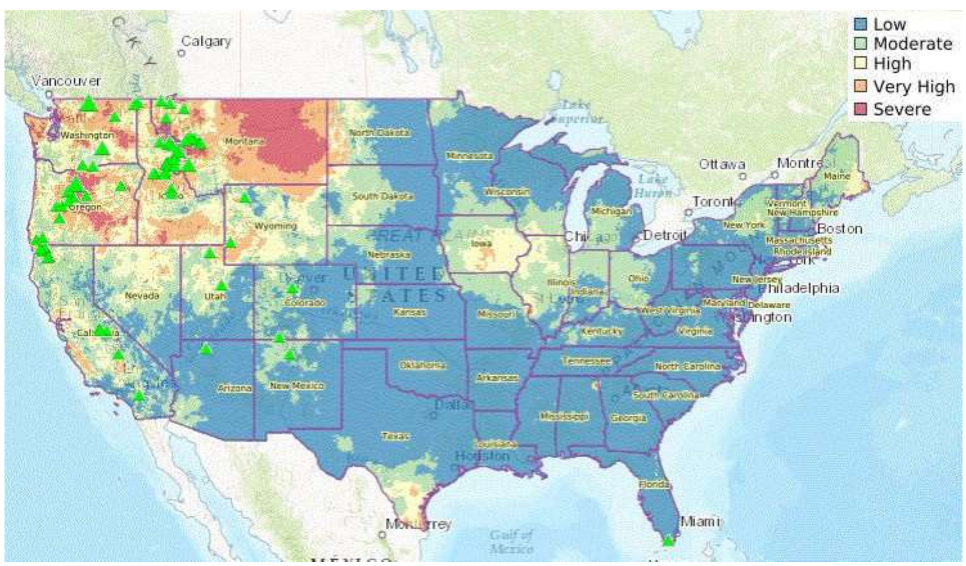

Figure 5. Wildfire and dust conditions, 2017 August 17. Green triangles indicate active wildfires. (*USDA*)

Our Fort Laramie, Stegall, and Pelzer teams observed ground variations. Table 1 and 2 encapsulates their combined observations. Some observations were truly unanticipated, and a few were unprecedented.

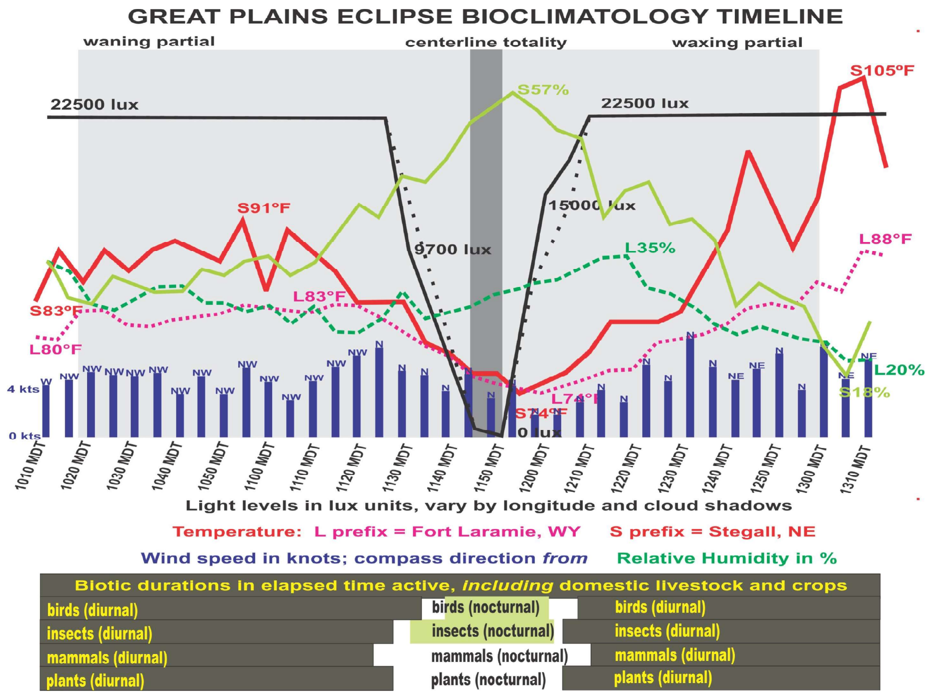

Figure 6. On-site Great Plains bioclimatic observations, 2017 August 21 1010-1310 MDT

In general, diurnal animals became inactive during totality, but most nocturnal creatures did not become active. It was unclear whether the nighttime creatures remained inactive due to the brevity of totality, or due to sudden temperature and other atmospheric changes.

Diurnal birds returned to roosting sites, or took shelter in vegetation, shortly before totality. They resumed normal behavior within thirty minutes of daylight resumption, although raptors initially soared at low altitude as they do to catch early morning thermals. Except for nighthawks, we detected no nocturnal birds such as owls, visually or audibly, during totality. Curiously, roosting diurnal swallows all faced eastward during the 360°twilight conditions at totality, and then behaved quite disoriented when full daylight re-emerged from the west.

Bats, moths, and nocturnal plants did not emerge. National Park Biologist Dan Licht activated an ultrasonic 17-station network that also detected no bat activity, corroborating our observations. Prairie dogs stood vertically before the eclipse, but lay prone afterwards; this perhaps was due to re-emerging raptors flying at low altitude awaiting redevelopment of rising convective warm air currents. Riparian mammals appeared uninfluenced, but nocturnal riverside insects and aquatic invertebrates did emerge, and game fish seemed to re-activate in response. Again curiously, cicadas and other diurnal insects in South Carolina progressed through calling from opposite sides of streets during the eclipse.

Reptiles became inactive, but there was a modest increase of crepuscular frog/toad calls at totality.

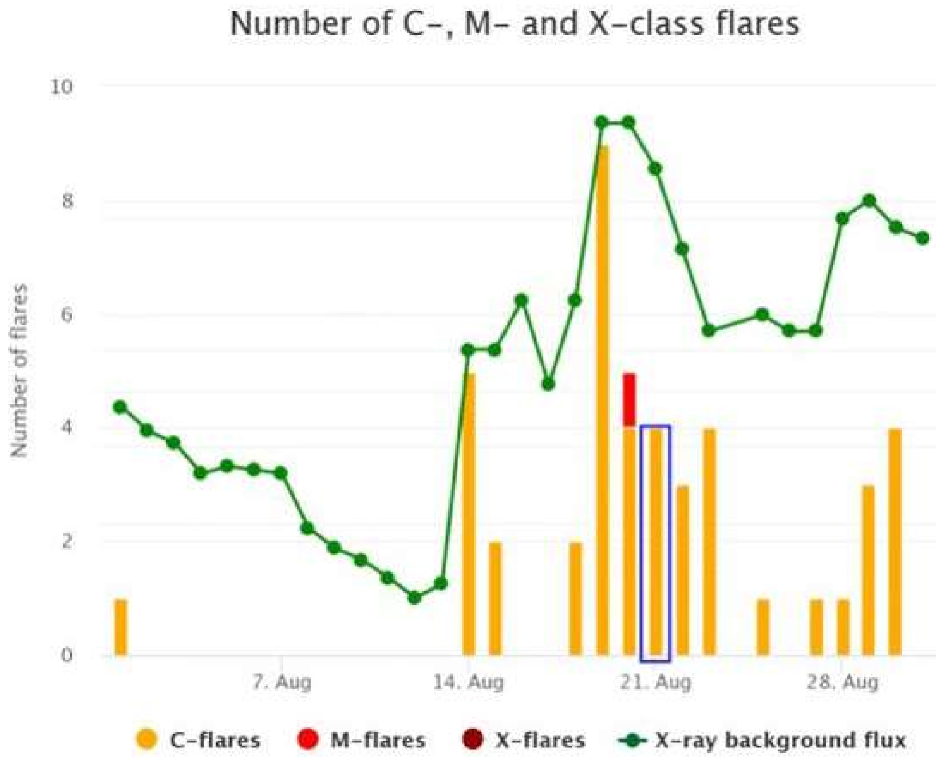

Figure 7. Observed solar flares, 2017 August. Blue enclosure indicates the 21 August eclipse day. C = cosmic, M = magnetic, X = x-ray. *Adapted courtesy from SpaceWeatherLive.com.*

Wild sunflower blossoms normally track the solar azimuth (hence the name), and did so up until the onset of the totality. Upon re-emergence of full sunlight, however, the blossoms faced towards different directions, despite the brevity of totality darkening and contrary to domestic crop sunflower response.

Domestic livestock and crops exhibited mixed responses. Cattle congregated as is typical at dusk, then promptly re-dispersed for daytime grazing. Roosters began crowing at re-emergence of full sunlight. Dogs began howling at totality onset, then became silent soon after resumption of full daylight. Domestic sunflower, alfalfa, and horses, however, showed little or no departure from usual daytime behaviors.

Observed biotic activity that we documented is summarized in Tables 1 and 2.

4. Interpretations

It appeared that mid-day darkening did not much affect most nocturnal and crepuscular organisms, but did force inactivity for some diurnal creatures. The underlying reasons for such disparities remain unclear, and perhaps warrant further investigation. The implications could be significant; if we further understand effects of unusual light level and atmospheric departures, then perhaps we might more sustainably adapt towards

Table 1. Biotic Activity. 24-hour ("military") *local* daylight savings times are of observation; **boldface** indicates Eastern time at Pelzer.

Birds	**Location**	***Local* Time**
Barn swallow (*Hirundo rustica*)	Fort Laramie, Stegall	0610, 1110
Cliff swallow (*Petrochelidon pyrrhonota*)	Fort Laramie	0610
Blue jay (*Cyanocitta cristata*)	Fort Laramie, Pelzer	0610, **1249**
Kingfisher (*Megaceryle alcyon*)	Fort Laramie	0610
Sparrow (*Emberizidae* spp.)	Fort Laramie, Pelzer	0610
Crow (*Corvus brachyrhynchos*)	Fort Laramie	0610
Duck (*Anatidae* spp.)	Fort Laramie	0610
Osprey (*Pandion haliaetus*)	Fort Laramie	0610
Golden eagle (*Aquila chrysaetos*)	Fort Laramie	1205
Nighthawk (*Chordeiles minor*)	Fort Laramie	0610, 1148
Owls (*Strigidae, Tytonidae* spp.)	Fort Laramie, Stegall	No sighting
Peregrine falcon (*Falco peregrinus*)	Fort Laramie	1200
Turkey vulture (*Cathartes aura*)	Fort Laramie	1120, 1215
Mourning dove (*Zenaida macroura*)	Stegall	1140
Swainson's hawk (*Buteo swainsoni*)	Stegall	1130, 1210
Chukar (*Alectoris chukar*)	Stegall, Harrison	1135
Pheasant (*Phasianus colchicus*)	Stegall	1135
Bluebird (*Sialia sialis*)	Pelzer	**1250**
Starling (*Sturnus vulgaris*)	Pelzer	**1245**
Mockingbird (*Mimus polyglottos*)	Pelzer	**1251**

Mammals	**Location**	***Local* Time**
Prairie dog (*Cynomys ludovicianus*)	Stegall	0700, 1235
Otter (*Lontra canadensis*)	Fort Laramie	Throughout
Bat (*Vespertilionidae* spp.)	Fort Laramie, Stegall	No sighting
Chipmunk (*Tamias striatus*)	Pelzer	**1331**

Fish	**Location**	***Local* Time**
Brown trout (*Salmo trutta*)	Fort Laramie	1140

Reptiles and Amphibians	**Location**	***Local* Time**
Rattlesnake (*Crotalus viridis*)	Stegall, Moore Springs	0700, 0930
Garter snake (*Thamnophis radix*)	Stegall	1020
Gecko (*Gekkonidae* spp.)	Stegall	1030
Frog (*Hylidae, Ranidae* spp.)	Stegall, Harrison	1150
Toad (*Scaphiopodidae, Bufonidae* spp.)	Stegall, Pelzer	0610

nurturing greater food system and ecosystem efficiencies within management and practice?

Table 2. Biotic Activity. 24-hour ("military") *local* daylight savings times are of observation; **boldface** indicates Eastern time at Pelzer.

Invertebrates	**Location**	***Local* Time**
Honeybee (*Apidae* spp.)	Stegall, Pelzer	1135
Grasshopper (*Acrididae* spp.)	Stegall, Harrison	1135
Cricket (*Gryllidae, Gryllotalpidae* spp.)	Fort Laramie, Stegall	1135, 1155
Katydid (*Scudderia furcate*)	Stegall	1150
Mosquito (*Aedes communis*)	Fort Laramie	1145
Butterfly (*Danaidae, Lycaenidae* spp.)	Fort Laramie, Stegall	1130
Moth (*Noctuidae, Sphingidae* spp.)	Fort Laramie, Stegall	No sighting
Midge (*Chironomidae* spp.)	Fort Laramie	0610, 1330
Cicada (*Cicadidae* spp.)	Pelzer	**1252**
unknown day insects	Pelzer	**1251, 1434**

Vegetation	**Location**	***Local* Time**
Sunflower (wild) (*Helianthus mollis*)	Stegall	1135, 1205
Night jasmine (*Cestrum nocturnum*)	Stegall	No sighting
Day jasmine (*Cestrum diurnum*)	Stegall	1130
Night catchfly (*Silene noctiflora*)	Stegall	No sighting
Day catchfly (*Silene laciniata*)	Stegall	1130

Domestic Livestock and Crops	**Location**	***Local* Time**
Cattle (*Bos taurus*)	Moore Springs	1140
Horses (*Equus caballus*)	Stegall, Moore Springs	Throughout
Chickens (*Gallus gallus domesticus*)	Stegall	1210
Dogs (*Canis lupus familiaris*)	Stegall	1145
Sunflower (domestic) (*Helianthus* annuus)	Stegall	1030, 1235
Alfalfa (*Medicago sativa*)	Stegall	Throughout

Our bioclimatic observation experience yielded evidence for two provoking general concepts warranting further development: refinement of instrumentation and investigative objectives during future eclipse and other light fluctuation events, and pursuit of practical applications. This expedition was not just about "Darkness at Noon"; there are broader implications.

For atmospheric observations, continuous (rather than hand-held) weather stations would improve by having firm mounting stands and continuous data recorders for light levels, temperatures, humidity, barometric pressure, and wind vectors. This would free human observers for other tasks, and provide a record of less disjointed (than our 5-minute) observation intervals. It would also eliminate reliance upon radio time signals, by using calibrated instrument clocks.

For biotic observations, continuous audible and ultrasonic data recorders would be a substantial improvement. Our experience suggests that such conceivable refinements of procedure might possibly enhance artificial management efficiencies of photo- and weather-sensitive wildlife, vegetation, crops, and livestock. Ideally, we would acquire longer baseline data, several days before and after the 2024 and other eclipse events. Our observations also suggest a lingering and pivotal question awaiting future field and laboratory address: *"Was it the environmental exposure departures (e.g., light levels, temperature shifts), internal "bioclocks" (circadian rhythms or migration cycles), or some combination of these that principally cued the biotic responses that we did (or did not) witness during the 2017 eclipse?"*

5. Conclusion: Adjustments for 2024

The next total solar eclipse crossing North America will occur on Monday, 08 April 2024, running from Mazatlán, Sinaloa to Gander, Newfoundland (Figure 8). Seeking optimal viewing conditions, we plan to station observation teams between Eagle Pass and Lampasas, Texas. Due to the wider and more oblique (to Earth's rotation) umbral path, we anticipate longer durations of totality, and solar re-emergence from the southwest.

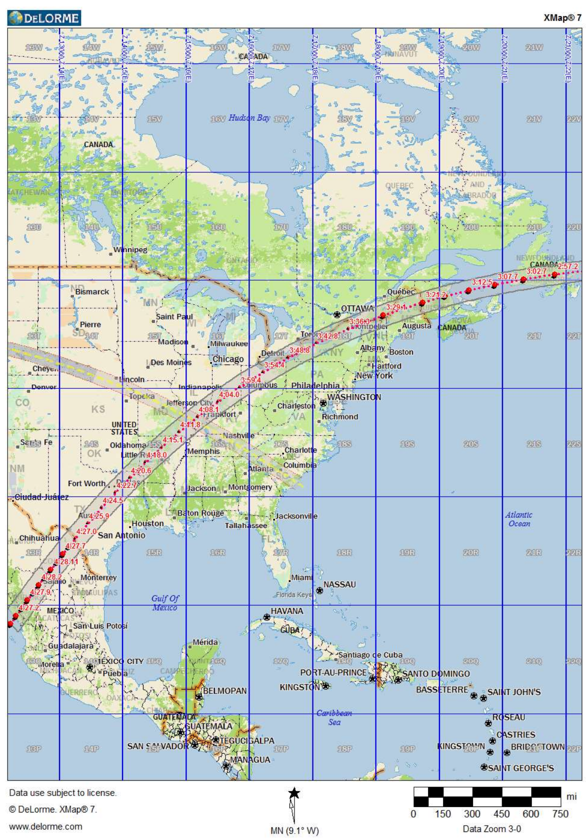

Figure 8. 2024 total solar eclipse path. Anticipated 2024 totality durations are in red; 2017 path is in yellow.

Beyond the data points that we obtained in 2017, our plan next is to obtain continuous automated records of all atmospheric variables, and add barometric pressure. Biotic observations also would repeat, but with acquisition of additional automated riverbed aquatic invertebrates, insects, fish, and domestic biota data.

To accomplish this, we desire to add continuous NIR/TIR ground-imaging monitors, fixed submersible acoustic and visual sensors, complete recording field weather stations, and all with continuous and synchronized internal timers. Most of all, however, we will need dedicated volunteers to collaborate in 2024.

Up to it?

Figure 9. The UWSP 2017 Eclipse Field Team. Standing: Joselyn, Sam, Liza, Sarah, Jesse J, Chedomir, Brayden, Allyssa, Nancy, Zach. Kneeling: Neil, Jesse W, Art. Absent on assignments: John, Ray, Pat.

Acknowledgments. To the many local citizens and organizations, local law enforcement, National Park Service, National Forest Service, UWSP students-alumni-employees, youth organizations, and sponsoring agencies: *Salúte!*