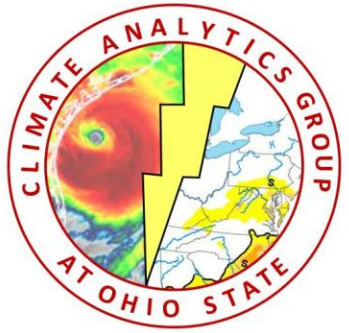
Evaluation of Drought Indices and Indicators for Ecological Drought in Ohio

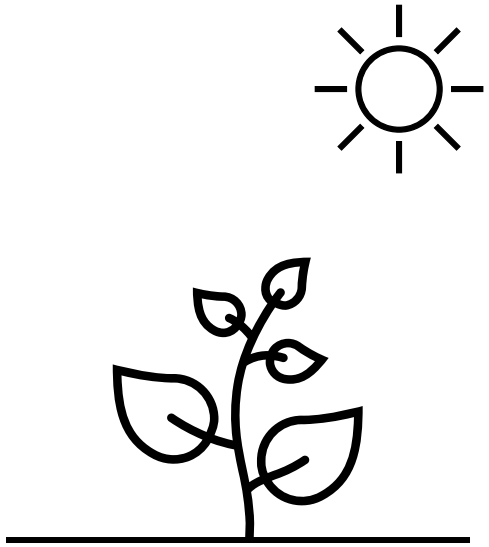
Jacklynn K. Beck
Doctoral Candidate
Atmospheric Sciences Program



Background

What is ecological drought?

Deficit in water availability that impacts ecosystem services, feedbacks in natural and human systems.



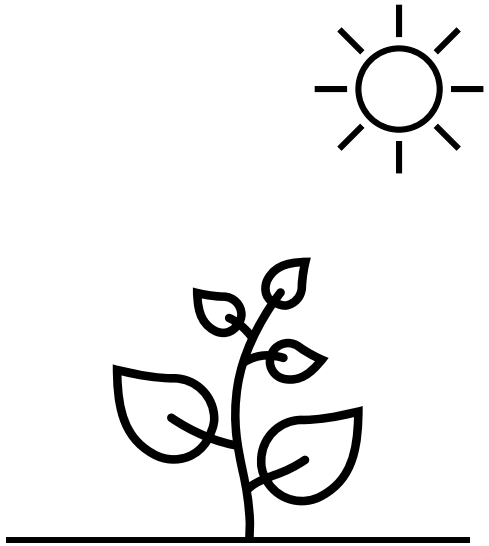
Current research (Slette, 2019)

- 50% were conducted during normal climate variability
- 30% of studies drought = dry conditions
- 13% occurred during periods of above normal precipitation
- 32% of papers defined what they considered drought to be

Background

Examples of Ecological Drought Impacts

- Changes in tree ring size
- Shifts in migration season and patterns
- Mortality
- Increased competition between species
- Increased pollution in streams and rivers



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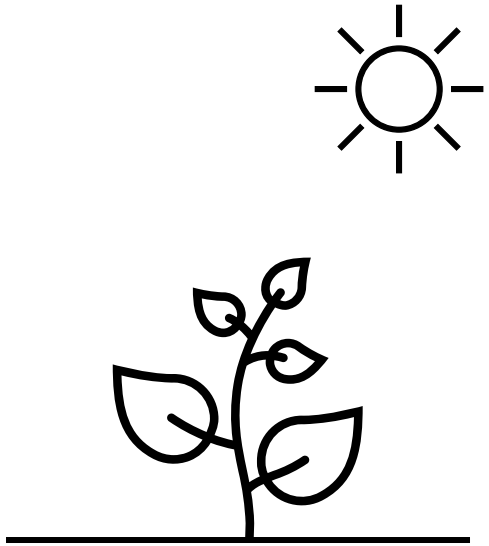
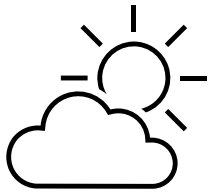


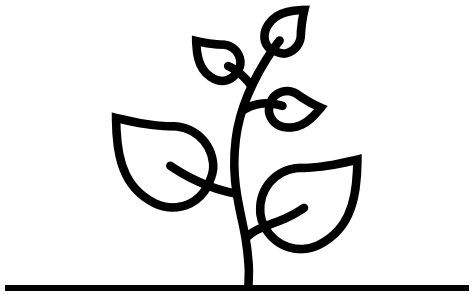
How are wildlife in Ohio impacted by drought?

Data

Climatological Data

- Drought Indices
  - SPI at 1,3,6, and 9-month timescales
  - SPEI at 1,3,6, and 9-month timescales
  - Palmer Z-Index
  - EDDI





Ecological Data

- Terrestrial Mammal Data – ODNR
- Aquatic Data – OSU Biological Museum
- Avian Data – USGS Breeding Bird Survey

Methods

Correlation Analysis

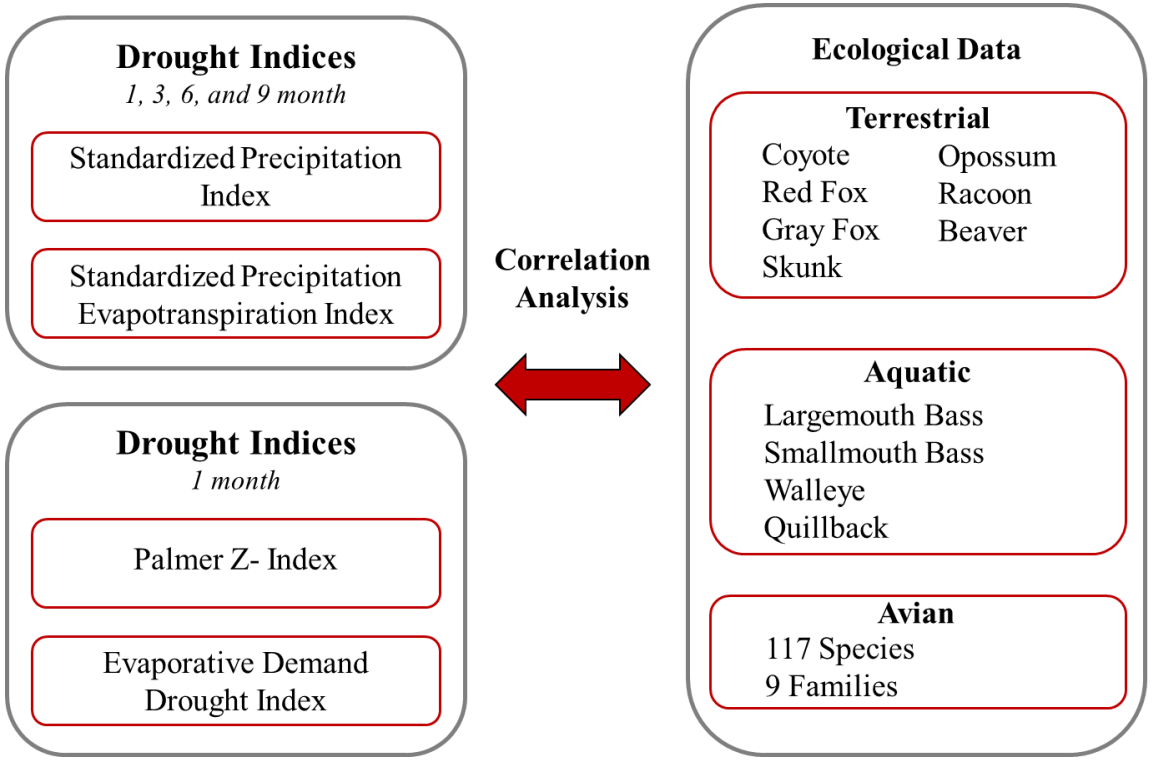
Pearson (r) – Pearson correlation

Delta (Δ) – $\Delta = (X_2 - X_1)$

Relative Change (RC) - $RC = \frac{X_2 - X_1}{X_2}$

Key Drought Years Analysis

2003, 2007, 2012-2013, 2016



Terrestrial Mammal

	Pearson Correlation 2000 - 2019							1 Year Lag Correlation 2000 - 2019							Relative Change Correlation 2000 - 2019							Delta Correlation 2000 - 2019						
	Coyote	Red Fox	Gray Fox	Skunk	Opossum	Raccoon	Beaver	Coyote	Red Fox	Gray Fox	Skunk	Opossum	Raccoon	Beaver	Coyote	Red Fox	Gray Fox	Skunk	Opossum	Raccoon	Beaver	Coyote	Red Fox	Gray Fox	Skunk	Opossum	Raccoon	Beaver
EDDI	-0.16	-0.39	**-0.53**	**-0.58**	**-0.50**	**-0.53**	0.20	-0.38	-0.35	-0.35	**-0.48**	**-0.44**	-0.42	0.20	-0.23	-0.03	0.18	0.06	0.02	0.19	0.24	-0.15	0.04	0.20	0.09	0.04	0.10	0.24
Z-Index	**-0.45**	-0.22	0.01	-0.06	-0.06	-0.01	-0.12	0.10	-0.05	-0.28	-0.09	0.02	-0.15	-0.12	0.37	0.28	**-0.55**	-0.02	-0.01	-0.28	**-0.46**	0.39	0.18	-0.33	-0.04	0.07	-0.12	**-0.46**
SPI 1 Month	**-0.55**	-0.33	-0.08	-0.29	-0.22	-0.18	-0.03	-0.06	-0.25	-0.41	-0.24	-0.14	-0.26	-0.03	0.33	0.09	**-0.59**	0.12	-0.01	-0.18	**-0.51**	0.35	0.08	-0.37	0.05	0.07	-0.06	**-0.51**
SPI 3 Month	**-0.53**	-0.35	-0.10	-0.29	-0.23	-0.18	-0.05	-0.11	-0.31	**-0.44**	-0.28	-0.18	-0.32	-0.05	0.30	0.08	**-0.60**	0.08	-0.02	-0.22	**-0.49**	0.30	0.04	-0.39	0.00	0.04	-0.11	**-0.49**
SPI 6 Month	**-0.52**	-0.32	-0.05	-0.25	-0.20	-0.13	-0.05	-0.09	-0.25	-0.39	-0.24	-0.14	-0.27	-0.05	0.28	0.11	**-0.59**	0.09	-0.01	-0.23	**-0.53**	0.31	0.07	-0.39	0.00	0.05	-0.11	**-0.53**
SPI 9 Month	**-0.47**	**-0.48**	-0.30	**-0.50**	-0.37	-0.36	0.14	-0.27	-0.41	**-0.43**	-0.33	-0.34	-0.30	0.15	0.12	0.06	-0.27	0.13	-0.16	0.01	-0.42	0.14	0.07	-0.16	0.15	0.02	0.05	-0.42
SPEI 1 Month	**-0.49**	-0.21	-0.01	-0.09	-0.10	-0.05	-0.11	0.04	-0.15	-0.33	-0.06	-0.02	-0.16	-0.11	0.36	0.09	**-0.61**	0.14	0.03	-0.23	-0.39	0.37	0.06	-0.36	0.02	0.07	-0.09	-0.39
SPEI 3 Month	**-0.45**	-0.22	0.02	-0.15	-0.09	-0.04	-0.09	0.00	-0.13	-0.28	-0.14	-0.02	-0.15	-0.09	0.30	0.15	**-0.55**	0.09	0.01	-0.21	**-0.53**	0.32	0.09	-0.34	0.01	0.06	-0.08	**-0.53**
SPEI 6 Month	-0.41	-0.15	0.10	-0.07	-0.02	0.05	-0.09	0.06	-0.03	-0.17	-0.05	0.07	-0.05	-0.09	0.30	0.20	**-0.51**	0.09	0.00	-0.23	**-0.56**	0.33	0.13	-0.31	0.02	0.08	-0.09	**-0.56**
SPEI 9 Month	-0.36	-0.30	-0.10	-0.29	-0.17	-0.11	0.06	-0.28	-0.28	-0.27	-0.22	-0.23	-0.20	0.06	0.05	0.07	-0.29	0.10	-0.21	-0.11	**-0.45**	0.06	0.02	-0.19	0.07	-0.06	-0.07	**-0.45**

- Increased sightings with drought conditions
- Longer timescales strengthens the relationship
- Coyotes show strongest consistent relationship
- State level beaver analysis does not show strong relationship

Aquatic Species

Overall decrease in aquatic species with drought indices.

Stronger relationships
- Largemouth Bass
- Walleye

Resilience beyond 1 year
- Largemouth bass
- Smallmouth bass

	Pearson Correlation				1 Year Lag				Relative Change				Delta Change			
	Largemouth Bass	Smallmouth Bass	Walleye	Quillback	Largemouth Bass	Smallmouth Bass	Walleye	Quillback	Largemouth Bass	Smallmouth Bass	Walleye	Quillback	Largemouth Bass	Smallmouth Bass	Walleye	Quillback
EDDI	0.18	-0.02	**-0.47**	-0.22	0.16	-0.13	**-0.54**	-0.39	0.09	-0.29	-0.34	-0.17	0.13	-0.26	-0.33	-0.13
Z-Index	0.11	-0.15	0.15	-0.06	-0.14	0.01	0.17	0.23	0.21	0.11	0.32	0.01	0.16	0.23	0.41	0.03
SPI 1 Month	0.06	-0.17	0.09	-0.09	-0.11	-0.21	0.01	0.16	0.28	0.09	0.33	0.13	0.24	0.20	0.38	0.19
SPI 3 Month	0.09	-0.06	0.11	-0.04	-0.08	-0.09	0.05	0.20	0.29	0.09	0.34	0.18	0.24	0.18	0.38	0.22
SPI 6 Month	0.07	-0.14	0.11	-0.11	-0.11	-0.20	0.06	0.20	0.30	0.11	0.35	0.12	0.26	0.22	0.41	0.16
SPI 9 Month	0.22	-0.08	0.15	0.06	-0.05	-0.11	0.19	0.20	**0.46**	0.22	0.16	0.02	0.42	0.32	0.20	0.01
SPEI 1 Month	-0.01	-0.19	0.21	0.06	-0.02	-0.21	0.12	0.24	0.14	0.13	0.39	0.20	0.10	0.24	0.40	0.25
SPEI 3 Month	0.06	-0.15	0.25	0.05	-0.05	-0.11	0.20	0.36	0.24	0.24	0.39	0.19	0.21	0.33	**0.44**	0.23
SPEI 6 Month	0.03	0.07	0.24	-0.05	-0.10	-0.05	0.21	0.34	0.25	0.01	0.38	0.10	0.21	0.03	**0.45**	0.13
SPEI 9 Month	0.18	0.08	0.33	0.11	0.00	-0.03	0.37	0.40	**0.46**	0.17	0.34	0.08	0.43	0.17	0.38	0.06

Avian

	Accipitridae	Hirundinidae	Corvidae	Icteriidae	Cardinalidae	Vireonidae	Columbidae	Parulidae	Sturnidae	Turdidae	Accipitridae	Hirundinidae	Corvidae	Icteriidae	Cardinalidae	Vireonidae	Columbidae	Parulidae	Sturnidae	Turdidae	Accipitridae	Hirundinidae	Corvidae	Icteriidae	Cardinalidae	Vireonidae	Columbidae	Parulidae	Sturnidae	Turdidae	Accipitridae	Hirundinidae	Corvidae	Icteriidae	Cardinalidae	Vireonidae	Columbidae	Parulidae	Sturnidae	Turdidae
	Pearson Correlation 2000 - 2019										1 Year Lag Correlation 2000 - 2019										Relative Change Correlation 2000 - 2019										Delta Correlation 2000 - 2019									
EDDI	0.49	0.75	-0.02	-0.53	-0.43	-0.44	-0.02	-0.27	-0.23	-0.13	0.52	0.40	-0.22	-0.60	-0.50	-0.45	-0.06	-0.57	-0.35	-0.17	-0.33	-0.37	-0.26	-0.21	-0.14	0.02	-0.18	-0.07	-0.06	-0.17	-0.03	0.26	0.21	0.04	0.08	0.03	0.03	0.06	0.14	0.02
Z-Index	-0.30	-0.31	-0.35	-0.16	-0.10	0.11	-0.32	0.17	-0.22	-0.18	-0.06	0.09	-0.05	-0.11	-0.09	0.09	-0.06	0.03	-0.01	0.04	0.42	0.48	0.29	0.11	0.14	-0.14	0.30	0.27	0.29	0.04	-0.16	-0.30	-0.32	-0.08	-0.02	0.01	-0.14	0.14	-0.18	-0.17
SPI 1 Month	-0.23	-0.28	-0.55	-0.46	-0.38	-0.02	-0.46	0.16	-0.38	-0.47	0.08	0.19	-0.21	-0.24	-0.23	-0.11	-0.06	-0.09	-0.20	-0.02	0.29	0.53	0.31	0.21	0.31	0.03	0.25	0.38	0.37	-0.02	-0.21	-0.35	-0.36	-0.32	-0.18	0.08	-0.21	0.20	-0.13	-0.37
SPI 3 Month	-0.16	-0.26	-0.56	-0.47	-0.38	-0.04	-0.42	0.13	-0.42	-0.45	0.07	0.17	-0.24	-0.25	-0.26	-0.12	-0.11	-0.09	-0.25	-0.06	0.25	0.51	0.30	0.19	0.30	0.05	0.20	0.39	0.40	-0.06	-0.16	-0.31	-0.34	-0.32	-0.15	0.08	-0.17	0.17	-0.12	-0.33
SPI 6 Month	-0.23	-0.29	-0.55	-0.42	-0.36	-0.02	-0.43	0.15	-0.39	-0.44	0.04	0.16	-0.20	-0.22	-0.23	-0.10	-0.09	-0.08	-0.18	-0.03	0.30	0.51	0.29	0.17	0.29	0.03	0.22	0.38	0.35	-0.03	-0.18	-0.33	-0.37	-0.30	-0.16	0.07	-0.18	0.19	-0.16	-0.34
SPI 9 Month	-0.19	-0.14	-0.69	-0.68	-0.62	-0.31	-0.71	0.09	-0.45	-0.75	0.19	0.29	-0.32	-0.33	-0.27	-0.18	0.09	-0.20	-0.22	-0.02	0.28	0.54	0.53	0.40	0.47	0.45	0.47	0.49	0.60	-0.02	-0.27	-0.32	-0.40	-0.50	-0.41	-0.11	-0.44	0.20	-0.18	-0.61
SPEI 1 Month	-0.29	-0.39	-0.36	-0.16	-0.13	0.18	-0.27	0.20	-0.21	-0.24	0.00	0.06	-0.10	0.00	-0.01	0.02	-0.05	0.10	-0.09	0.11	0.33	0.52	0.28	0.19	0.24	-0.16	0.18	0.20	0.30	0.11	-0.20	-0.33	-0.28	-0.23	-0.14	0.14	-0.12	0.14	-0.10	-0.28
SPEI 3 Month	-0.28	-0.37	-0.48	-0.29	-0.23	0.07	-0.37	0.20	-0.32	-0.37	-0.06	0.06	-0.18	-0.11	-0.12	0.01	-0.10	0.04	-0.10	0.01	0.30	0.50	0.28	0.13	0.24	0.00	0.22	0.38	0.34	0.01	-0.15	-0.32	-0.32	-0.26	-0.13	0.05	-0.14	0.17	-0.17	-0.31
SPEI 6 Month	-0.37	-0.43	-0.43	-0.21	-0.18	0.11	-0.37	0.23	-0.26	-0.34	-0.11	0.04	-0.12	-0.06	-0.08	0.04	-0.07	0.06	-0.01	0.01	0.39	0.50	0.29	0.13	0.23	-0.03	0.27	0.35	0.29	0.01	-0.17	-0.35	-0.33	-0.21	-0.12	0.06	-0.16	0.19	-0.22	-0.29
SPEI 9 Month	-0.37	-0.26	-0.64	-0.49	-0.49	-0.21	-0.60	0.20	-0.41	-0.68	0.06	0.17	-0.22	-0.17	-0.14	-0.09	0.05	-0.07	-0.05	0.07	0.42	0.48	0.48	0.27	0.36	0.36	0.39	0.46	0.54	0.07	-0.29	-0.32	-0.45	-0.45	-0.41	-0.10	-0.36	0.23	-0.30	-0.62

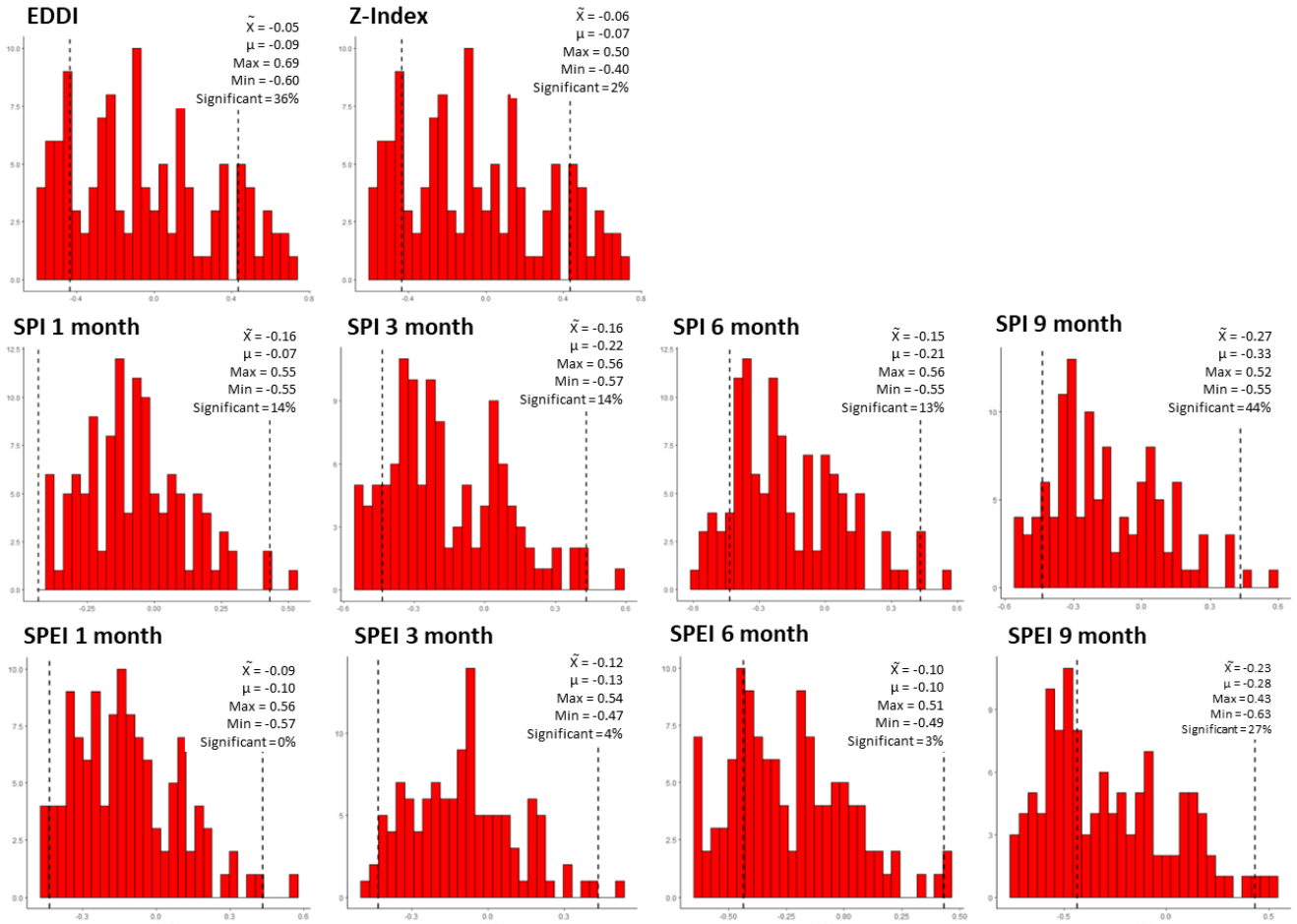
- Generally, SPEI and SPI show strongest relationship
- Stronger relationship with longer timescales
- Avian species do not see impacts beyond year one
- Inverse response with Parulidae

Avian

Top Performing Indices

- SPI 9 month (44%)
- EDDI (36%)
- SPEI 9 month (27%)

Overall increase in avian occurrences during drought periods



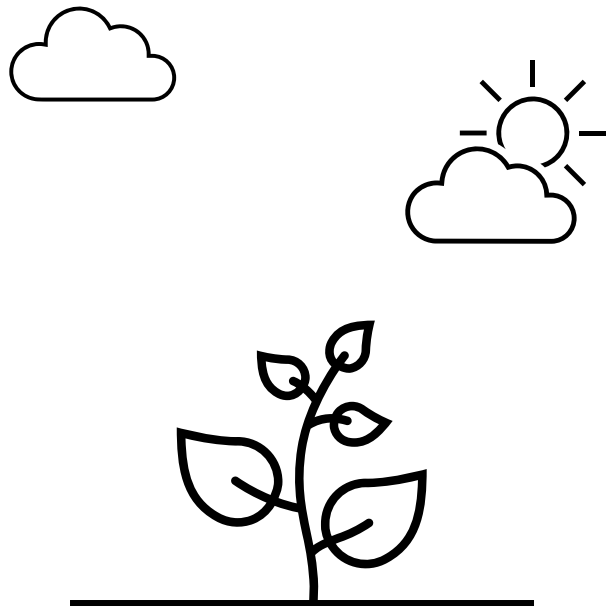
Key Drought Years % Changes

- Avian families overall show mild to moderate declines during drought years
- Mix of positive and negative impacts from Aquatic and Terrestrial species
- Red foxes have a high variability due to small sample size

		2002-2003	2007	2012-2013	2016
Terrestrial Mamals	Beavers	18%	33%	-24%	8%
	Coyote	-3%	-1%	14%	6%
	Red Fox	86%	-54%	-77%	214%
	Raccoon	-1%	-35%	-44%	33%
	Skunk	7%	-18%	-31%	24%
	Opossum	-22%	-37%	-32%	54%
Aquatic	Largemouth Bass	-17%	-11%	22%	-49%
	Walleye	26%	0%	-19%	-95%
	Quillback	-33%	18%	3%	-53%
	Smallmouth Bass	-23%	25%	15%	-59%
Avian Famlies	Accipitridae	-25%	-2%	-9%	-3%
	Hirundindae	-27%	33%	21%	-6%
	Corvidae	-17%	16%	3%	-15%
	Icteridae	-2%	-1%	-7%	-19%
	Cardinalidae	-12%	2%	0%	-5%
	Vireonidae	-6%	5%	-5%	2%
	Parulidae	-1%	-4%	2%	0%
	Sturnidae	-13%	29%	1%	-12%
	Turdidae	-6%	0%	9%	-13%
	Columbidae	-16%	7%	12%	-10%

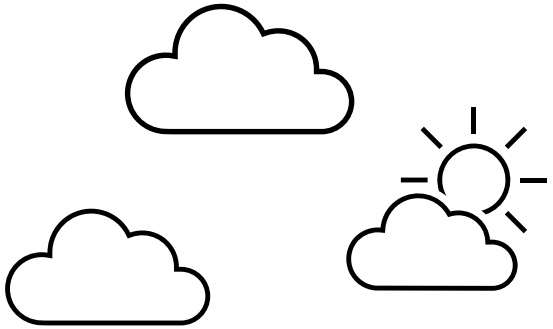
Conclusions

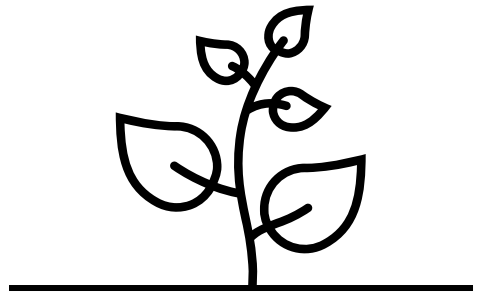
- None of the indices fit work well for all species
- Longer timescales tend to work better across all species
- 9 month SPI and SPEI performed the best across all indices
- Mix of impacts by drought and by species



Future Areas for Work

- Reducing the spatial resolution
- Impact based thresholds for ecological systems
- Evaluating predator and prey interactions between species
- Including ecologically based indices in the analysis





Acknowledgments

Collaborators
Dr. Steven M. Quiring

Dr. Aaron Wilson

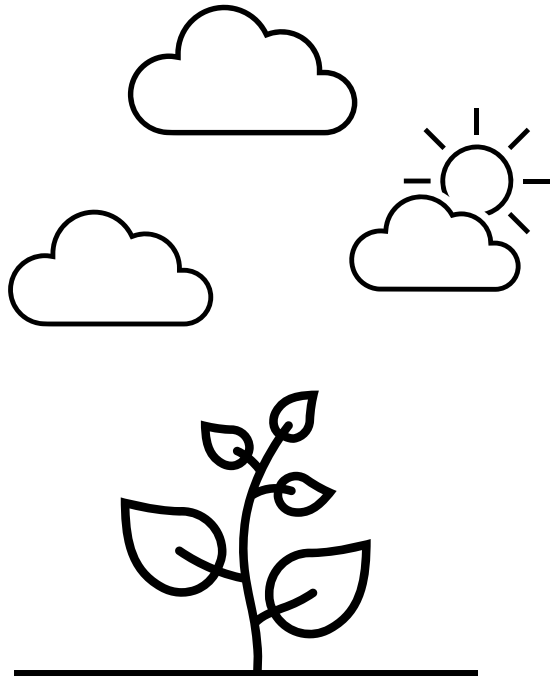
Dr. Zhiying Li

Dr. Zack Leasor

Data Providers:
Ms. Cathrine Dennison – ODNR

Mr. Mark Kibby – OSU Biological Museum

Project funders: NIDIS



Email: beck.746@osu.edu
Twitter: @jkbeck3087