The key role of timing of weather events in the survival of the Karner blue butterfly

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Summary

- Subtle ways in which climate change can endanger species
- Timing of weather events was a key component of local extinction of an endangered butterfly in a national park due to phenological mismatching
- Microclimate – variation in variables such as temperature and soil moisture over small spatial and topographic scales can greatly affect survival
- Caveat - Although we posit a role for topographic soil moisture gradients in this extinction event, we did not specifically measure soil moisture as part of this study.

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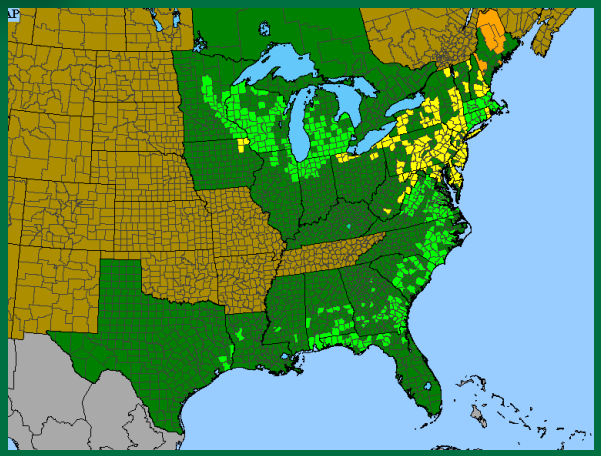
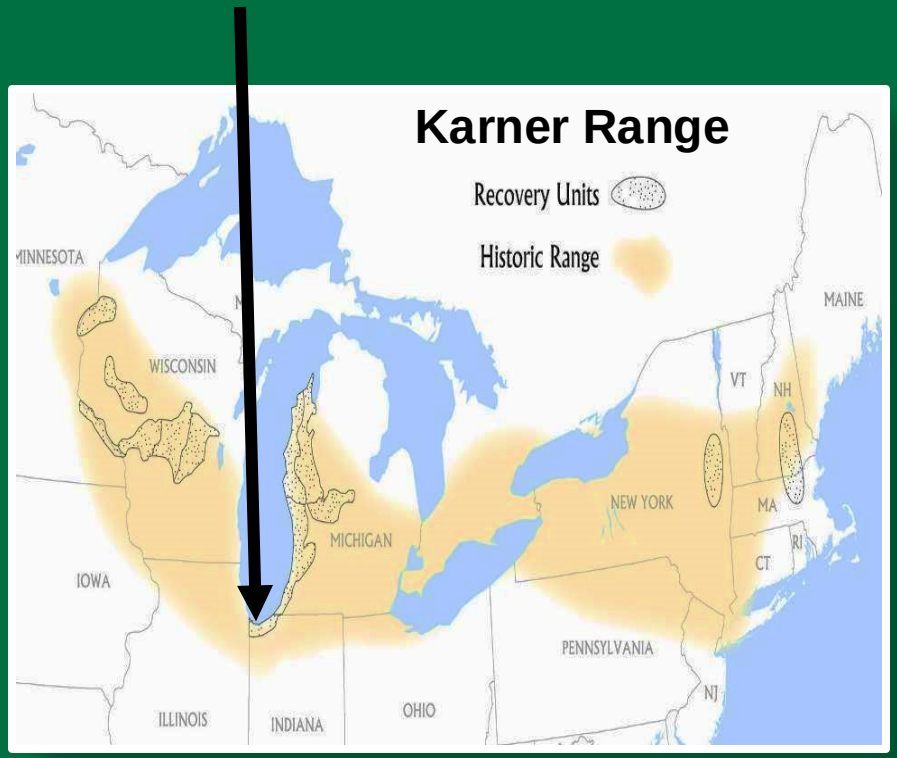
Karner blue butterfly

Lycaeides (Plebejus) melissa samuelis

- Federally Endangered 1992
- Lupine Specialist (*Lupinus perennis*)
- Indiana Dunes National Park



Lupine Range
(Green/Yellow)



Karner blue: 2+ yearly cycles; Lupine: 1/ year

April
Eggs hatch & larvae feed on lupine

Mid-May
Larvae pupate, mature into butterflies, emerge & mate

Early June
Females lay eggs near lupine plants

June
Eggs hatch & larvae feed on lupine

July
Larvae pupate, mature into adults, emerge & mate

Late July- Early August
Females lay eggs near lupine plants

What we learned about Karner blue habitat use

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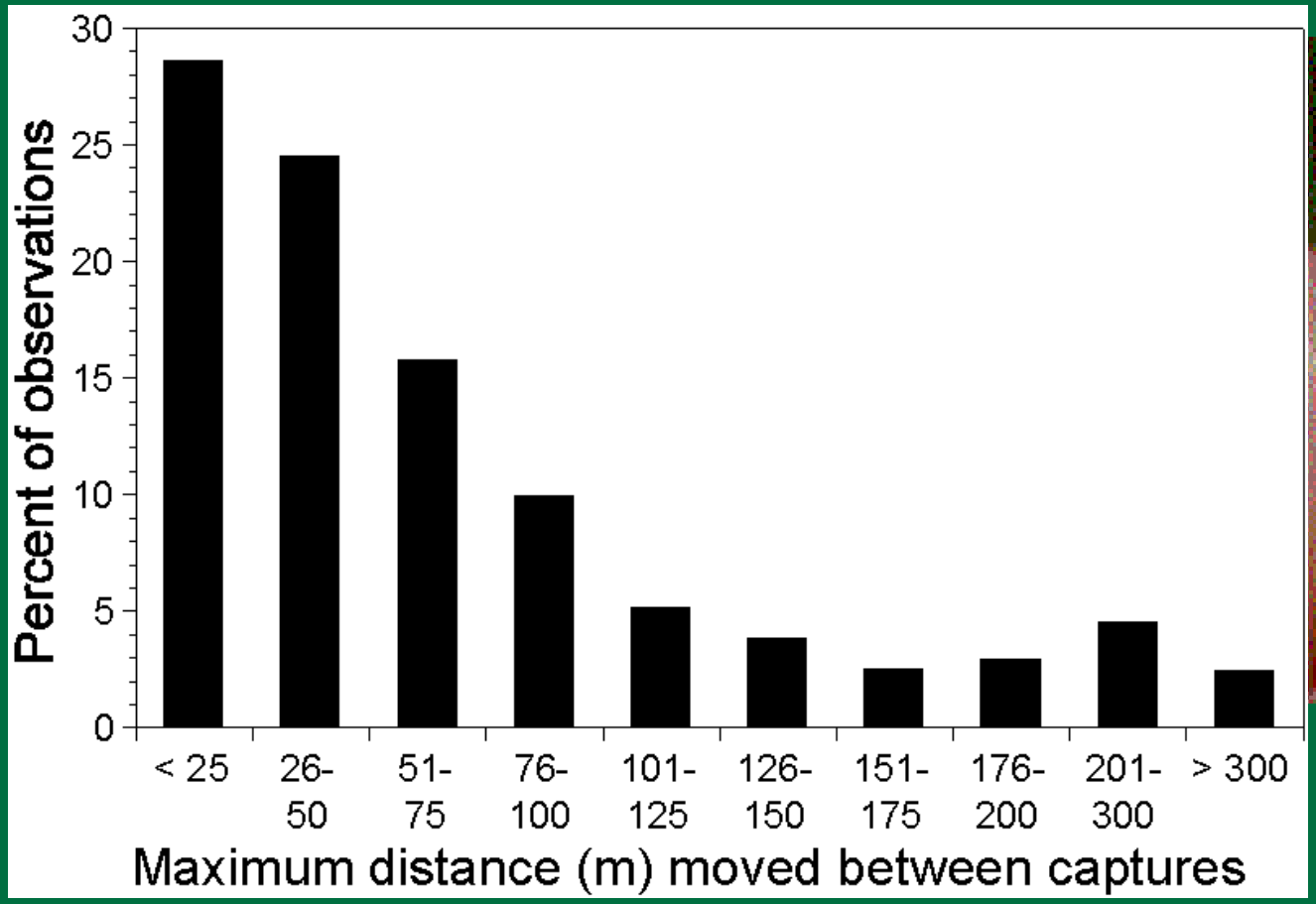
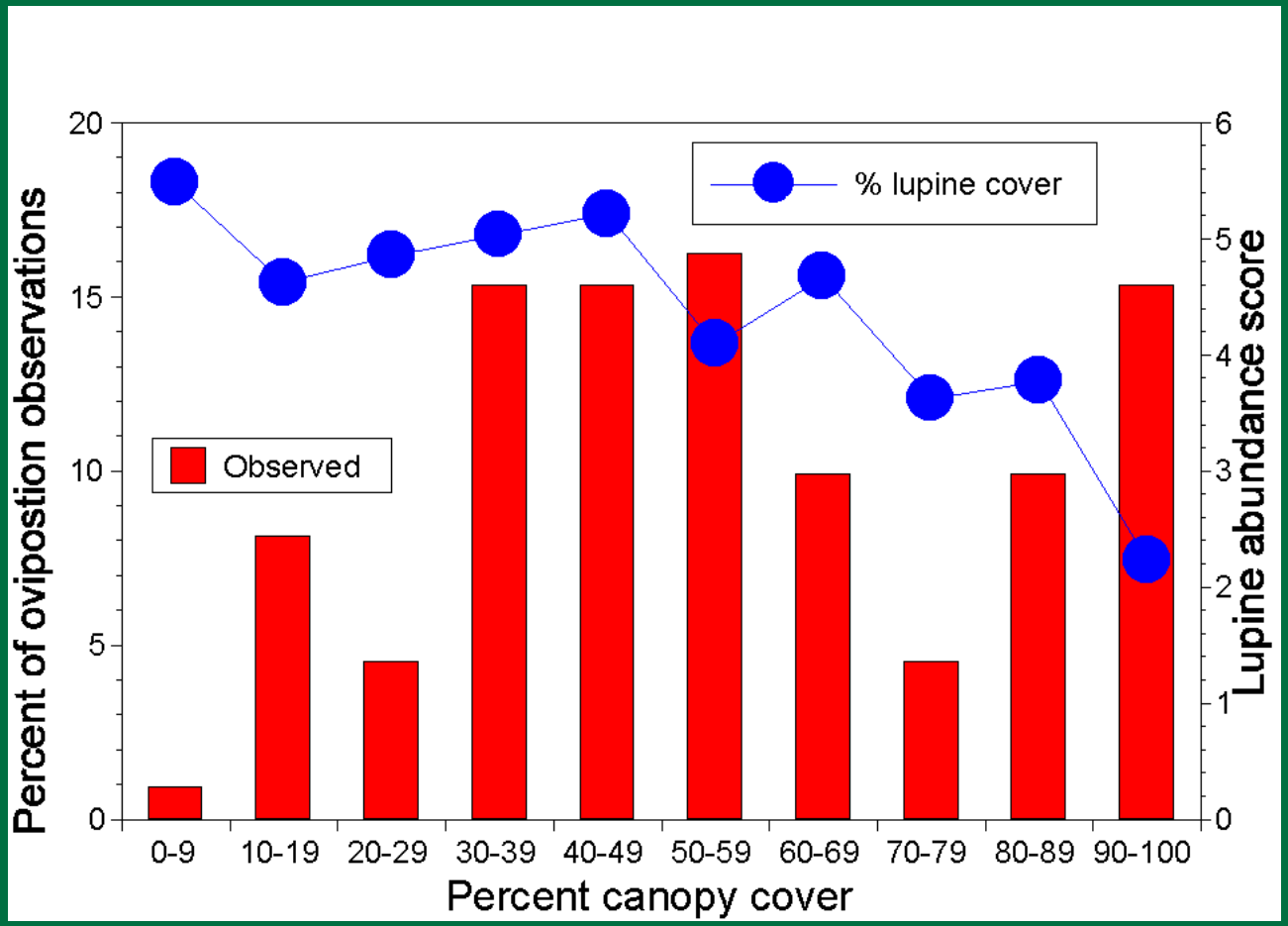
Limited Dispersal; Importance of local topography and shade heterogeneity



USGS

Knutson, R. L., J. R. Kwilosz, and R. Grundel. Natural Areas Journal **19**:109-120.

Canopy heterogeneity is an important component of habitat quality – "Bet hedging"



USGS

Grundel, R., N. B. Pavlovic, and C. L. Sulzman. Biological Conservation **85**:47-53.

- So, we had a prescription for Karner habitat – maintain canopy heterogeneity at a scale of ~100 m to account for Kbb dispersal ability.
- Greatly influenced recovery plan
- NPS implemented this prescription mainly using prescribed fire.
- How did it work at INDU?

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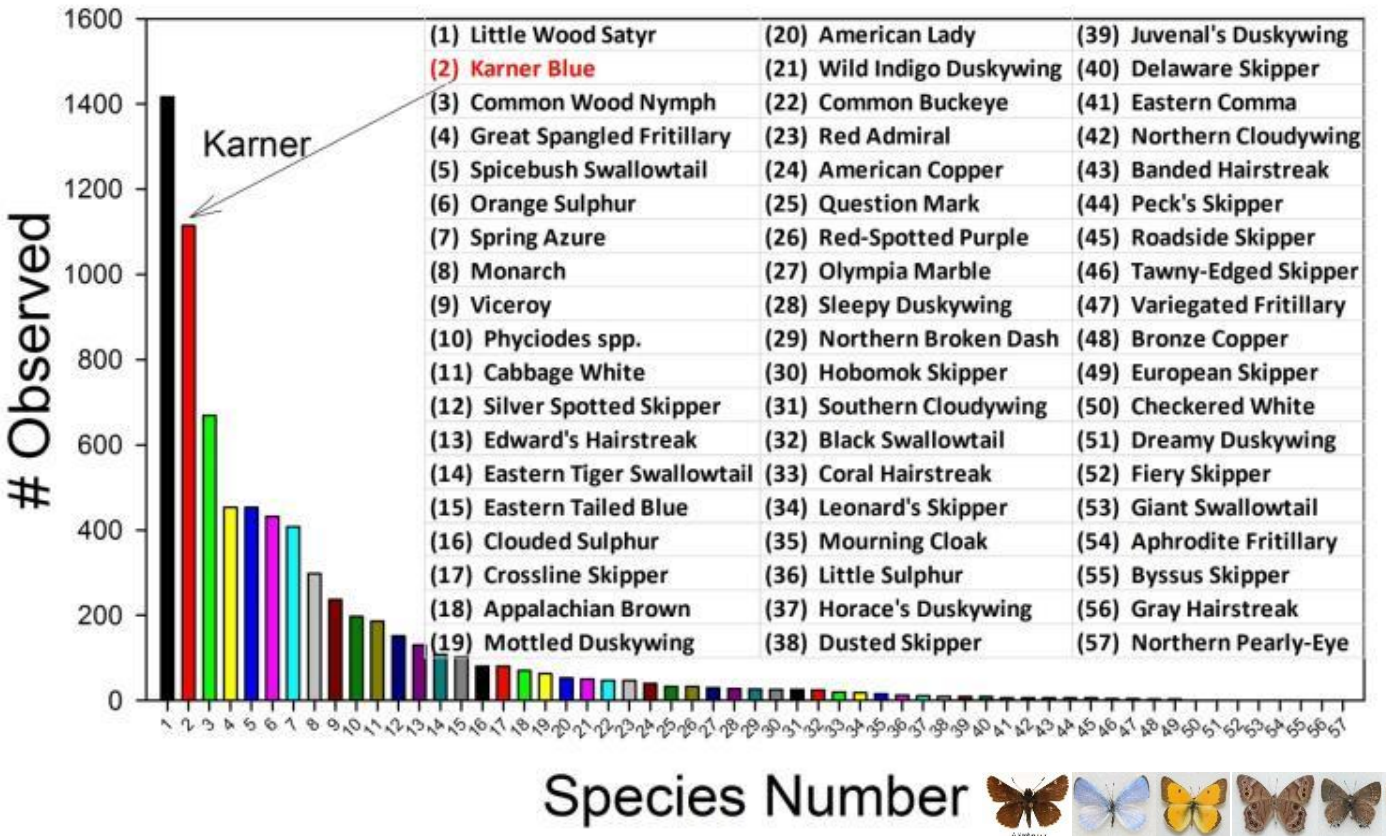
Butterflies of INDU 1999



(1) Little Wood Satyr	(20) American Lady	(39) Juvenal's Duskywing
(2) Karner Blue	(21) Wild Indigo Duskywing	(40) Delaware Skipper
(3) Common Wood Nymph	(22) Common Buckeye	(41) Eastern Comma
(4) Great Spangled Fritillary	(23) Red Admiral	(42) Northern Cloudywing
(5) Spicebush Swallowtail	(24) American Copper	(43) Banded Hairstreak
(6) Orange Sulphur	(25) Question Mark	(44) Peck's Skipper
(7) Spring Azure	(26) Red-Spotted Purple	(45) Roadside Skipper
(8) Monarch	(27) Olympia Marble	(46) Tawny-Edged Skipper
(9) Viceroy	(28) Sleepy Duskywing	(47) Variegated Fritillary
(10) Phyciodes spp.	(29) Northern Broken Dash	(48) Bronze Copper
(11) Cabbage White	(30) Hobomok Skipper	(49) European Skipper
(12) Silver Spotted Skipper	(31) Southern Cloudywing	(50) Checkered White
(13) Edward's Hairstreak	(32) Black Swallowtail	(51) Dreamy Duskywing
(14) Eastern Tiger Swallowtail	(33) Coral Hairstreak	(52) Fiery Skipper
(15) Eastern Tailed Blue	(34) Leonard's Skipper	(53) Giant Swallowtail
(16) Clouded Sulphur	(35) Mourning Cloak	(54) Aphrodite Fritillary
(17) Crossline Skipper	(36) Little Sulphur	(55) Byssus Skipper
(18) Appalachian Brown	(37) Horace's Duskywing	(56) Gray Hairstreak
(19) Mottled Duskywing	(38) Dusted Skipper	(57) Northern Pearly-Eye

Grundel, R., G. S. Dulin, and N. B. Pavlovic.
PLoS ONE **15**:e0234139

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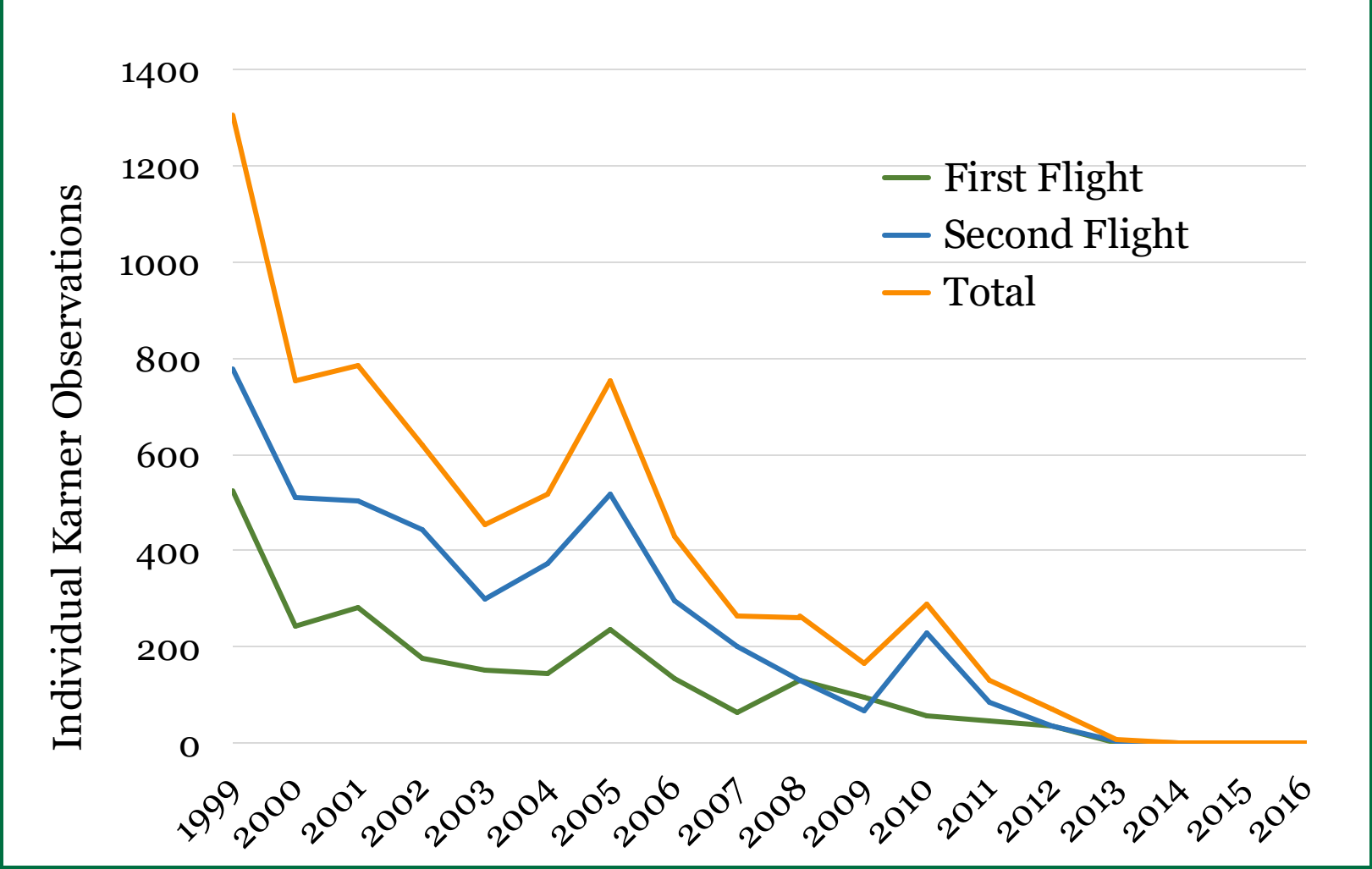
Extirpation of an endangered species in a national park
Indiana Dunes Kbb surveys – none found after 2013



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Source: Randy Knutson, NPS, Indiana Dunes NP

What went wrong?
We have good insight into the final year of decline

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Spring 2012 – earliest/warmest on record
Summer 2012 – hot and very dry

Eos, Vol. 94, No. 20, 14 May 2013

EOS

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 94 NUMBER 20
14 MAY 2013
PAGES 181–188

The False Spring of 2012, Earliest in North American Record

PAGES 181–182

Phenology—the study of recurring plant and animal life cycle stages, especially their timing and relationships with weather and climate—is becoming an essential tool for documenting, communicating, and anticipating the consequences of climate variability and change. For example, March 2012 broke numerous records for warm temperatures and early flowering in the United States [*Karl et al.*, 2012; *Elwood et al.*, 2013]. Many regions experienced a "false spring," a period of weather in late winter or early spring sufficiently mild and long to bring vegetation out of dormancy prematurely, rendering it vulnerable to late frost and drought.

As global climate warms, increasingly warmer springs may combine with the random climatological occurrence of advective freezes, which result from cold air moving from one region to another, to dramatically increase the future risk of false springs, with profound ecological and economic consequences [e.g., *Gu et al.*, 2008; *Marino et al.*, 2011; *Augspurger*, 2013]. For example, in the false spring of 2012, an event embedded in long-term trends toward earlier spring [e.g., *Schwartz et al.*, 2006], the frost damage to fruit trees totaled half a billion dollars in Michigan alone, prompting the federal government to declare the state a disaster area [*Knudson*, 2012].

Phenological Forecasting: Predicting False Springs a Season or Two in Advance?

Robust phenological forecasts at seasonal

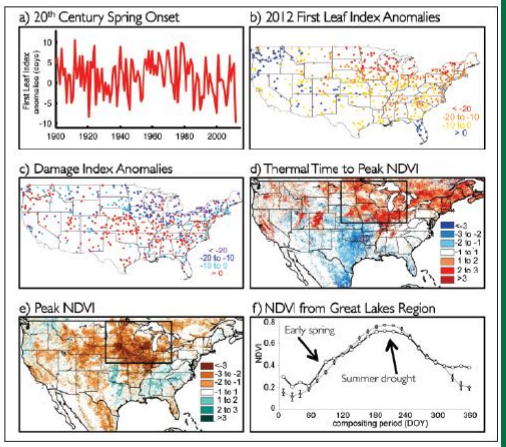
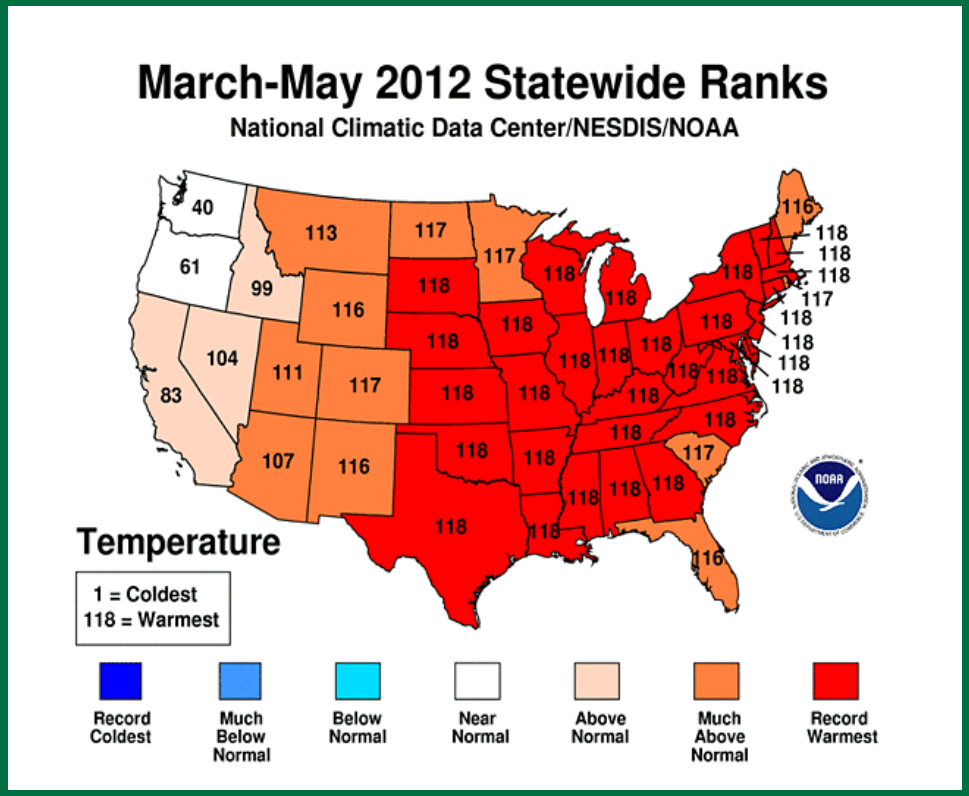


Fig. 1. Metrics of phenology during the spring and summer of 2012. (a) Time series of station-based extended spring index anomalies with respect to the 1981–2010 climatology from 1900 through 2012 and averaged over the conterminous United States (the first leaf index described in Schwartz et al. *[2006] and* Schwartz et al. *[2013]). (b) Map of first leaf index anomalies (in days) with respect to the 1981–2010 climatology. (c) Values of the damage index with respect to the 1981–2010 climatology (also described in* Schwartz et al. *[2006]), which measures the anomalous*



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2012 Weather in comparison to 1990-2023 mean

- March Max Temp – Mean: 7.6 °C (± 2.8 sd); 2012: 16.3 °C
- April – July Max Temp (°C) compared to historic monthly mean: April: -0.6, May: 2.7, June 0.9, July: 3.5
- Precipitation Ratio (2012:1990-2023 Mean): March: 80%, April: 38%, May: 54%, June: 58%, July: 148%
- Snow depth during coldest months: December 2012 - Feb 2013: 9%, 19%, 81% of long-term mean
- CONCLUSION: Very early spring, hot spring/summer, low precipitation spring/early summer, low snow cover next winter

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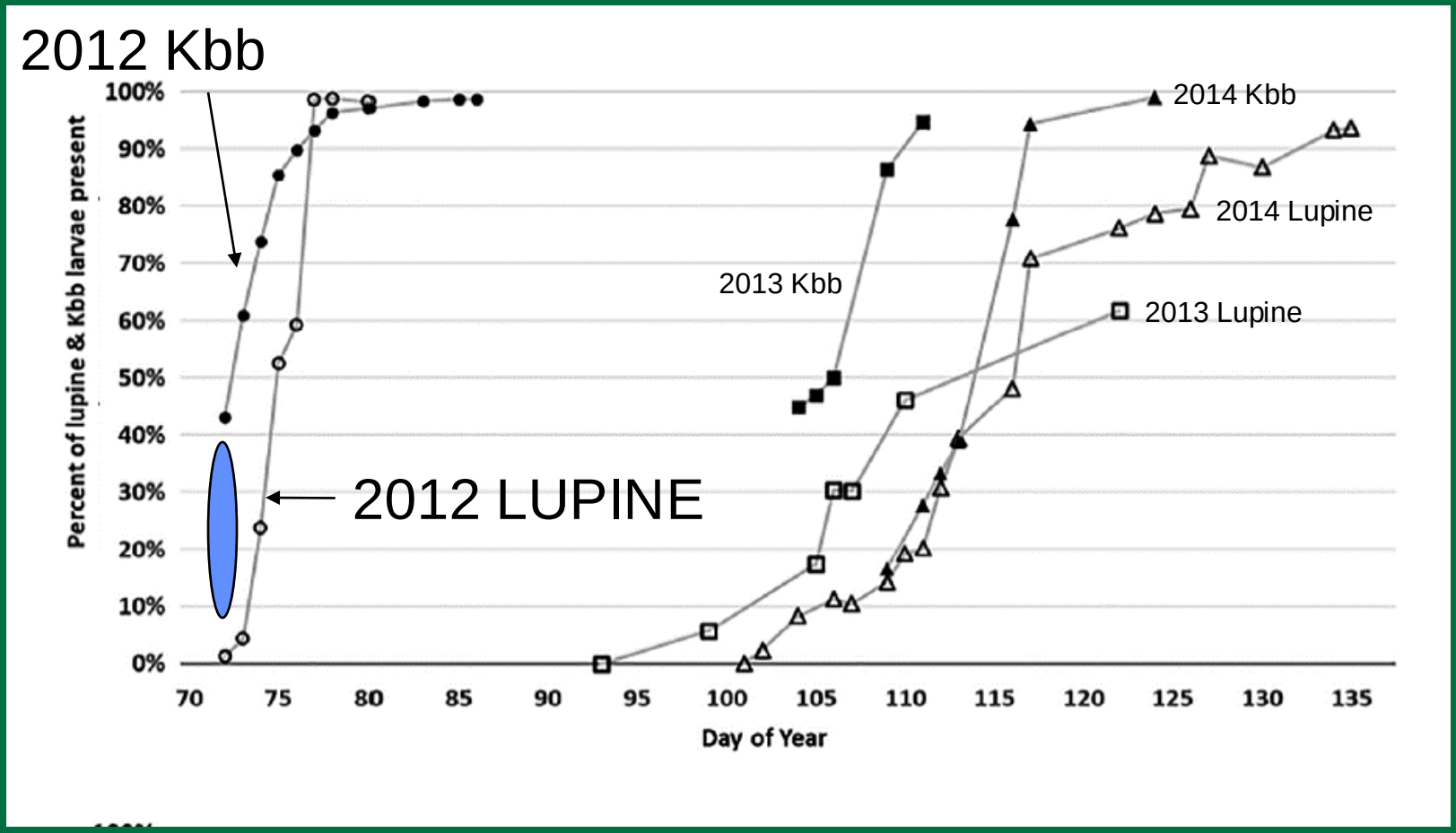
Spring 2012 – earliest/warmest on record in US
Phenological Mismatch

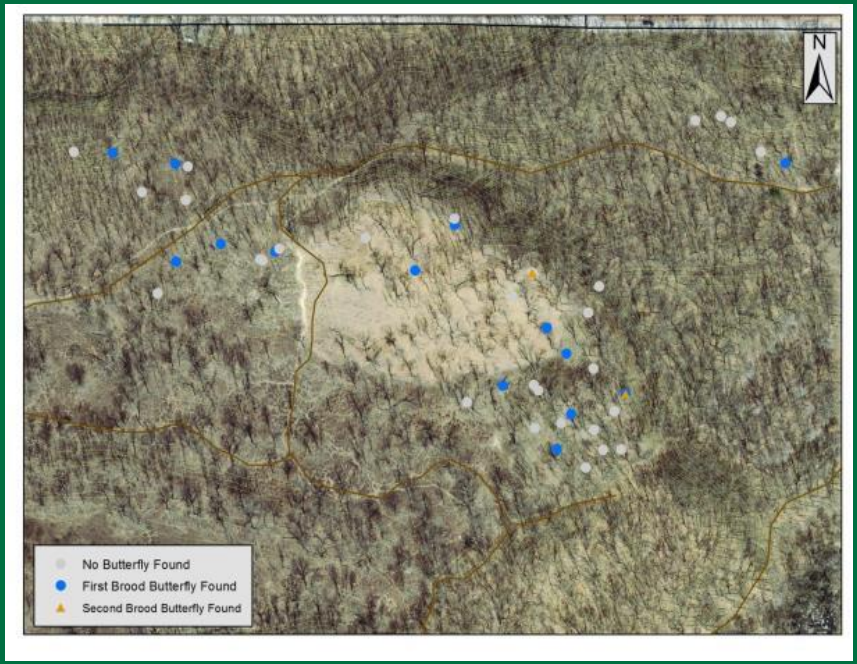


USGS

Patterson, T. A., R. Grundel, J. D. K. Dzurisin, R. L. Knutson, and J. J. Hellmann. 2020. Conservation Science and Practice **2**:e147.

Poor survival second brood as well

- In the second generation, only 5.7% of eggs led to adults. Only eggs on northern slopes, at the limit of where lupine occurred, reached the adult stage. 27% of test sites on south faces completely lost all lupine leaves during early larval instars. We suspect that low soil moisture was responsible for the relatively early demise of lupine and the only environmental buffering was from the relatively shaded northern slopes.



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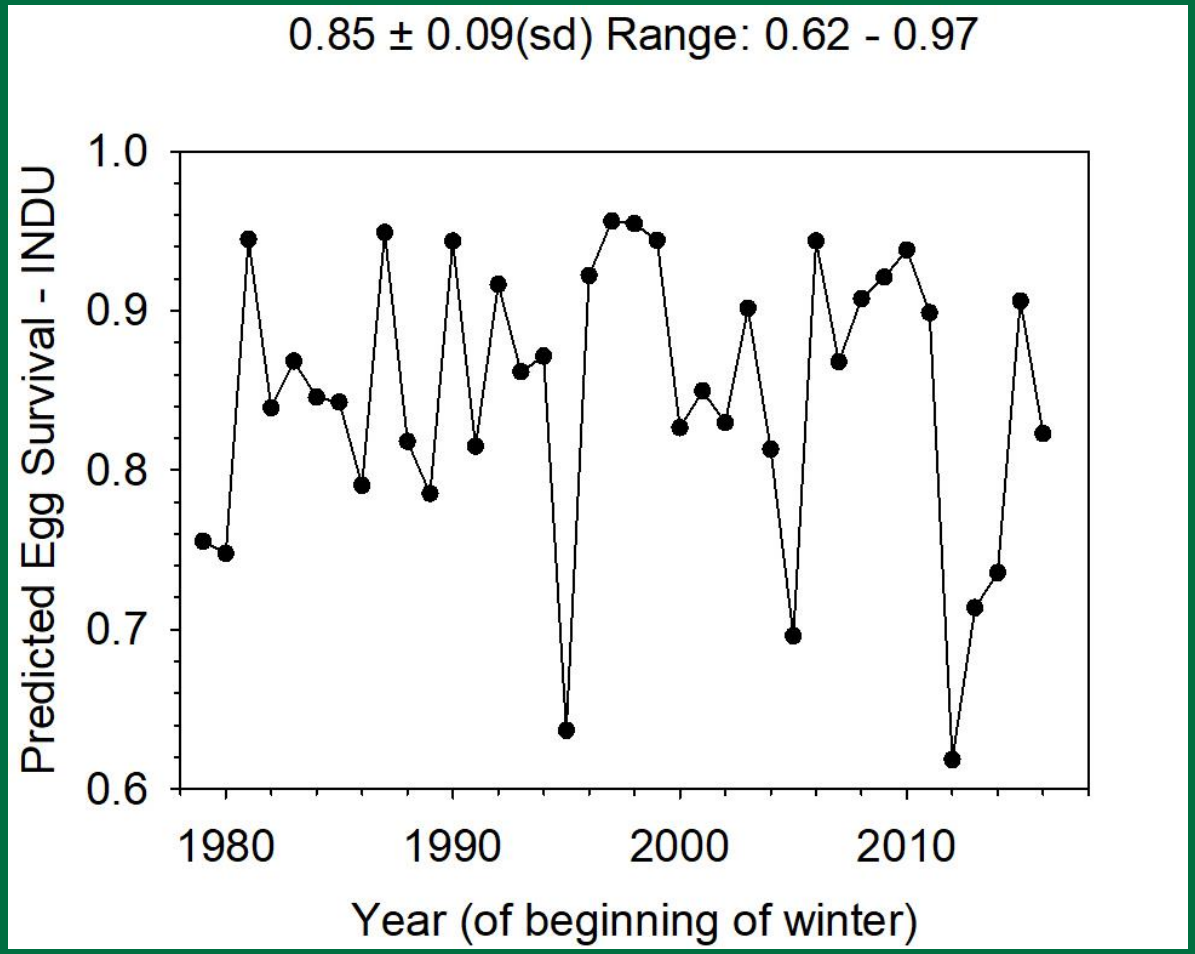
Egg survival was lowest Winter 2012-13 @ Indiana Dunes – low snow cover couldn't buffer cold temperatures



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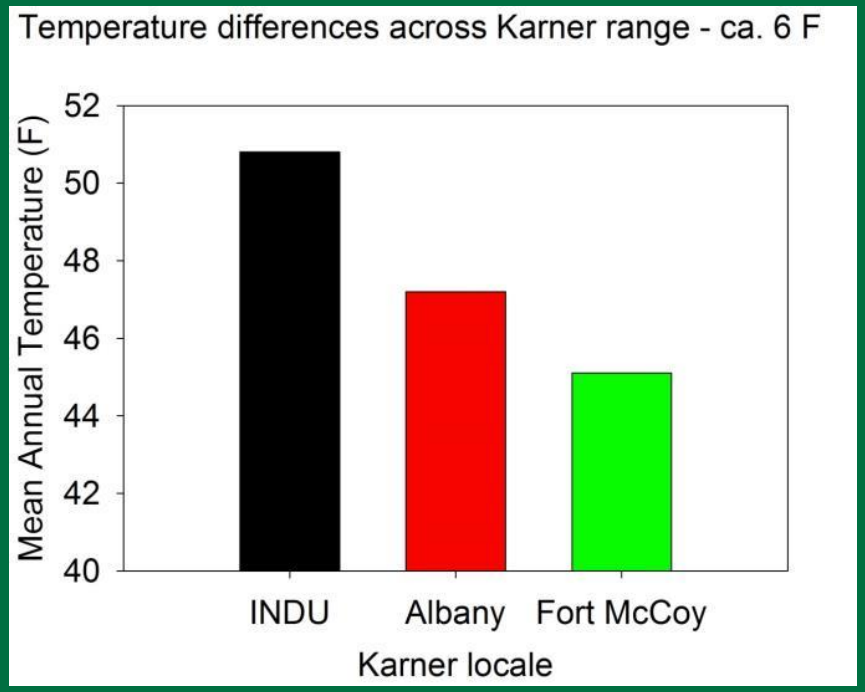
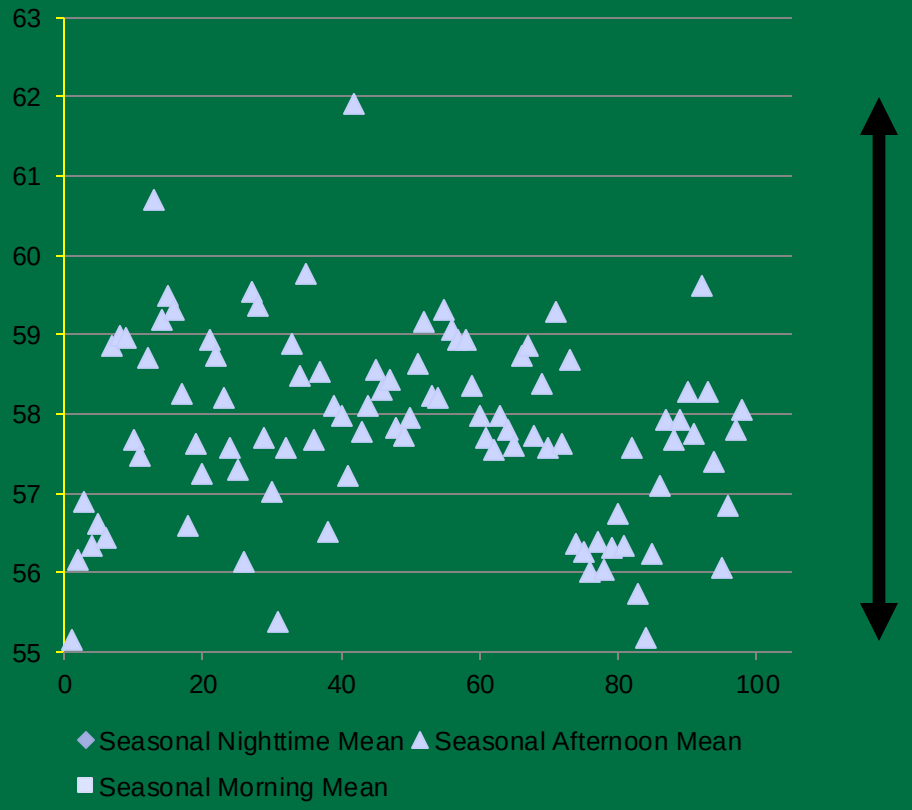
Small scale differences in temperature and soil moisture could be important.
Mean temp difference across Kbb range = temp difference across dune aspects

Rangewide 6 F



Across INDU aspects 7 F



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Is the Kbb doomed by low Adaptive Capacity – limited mobility, diet specialization, small climatic niche breadth - in a time of rapid global change?

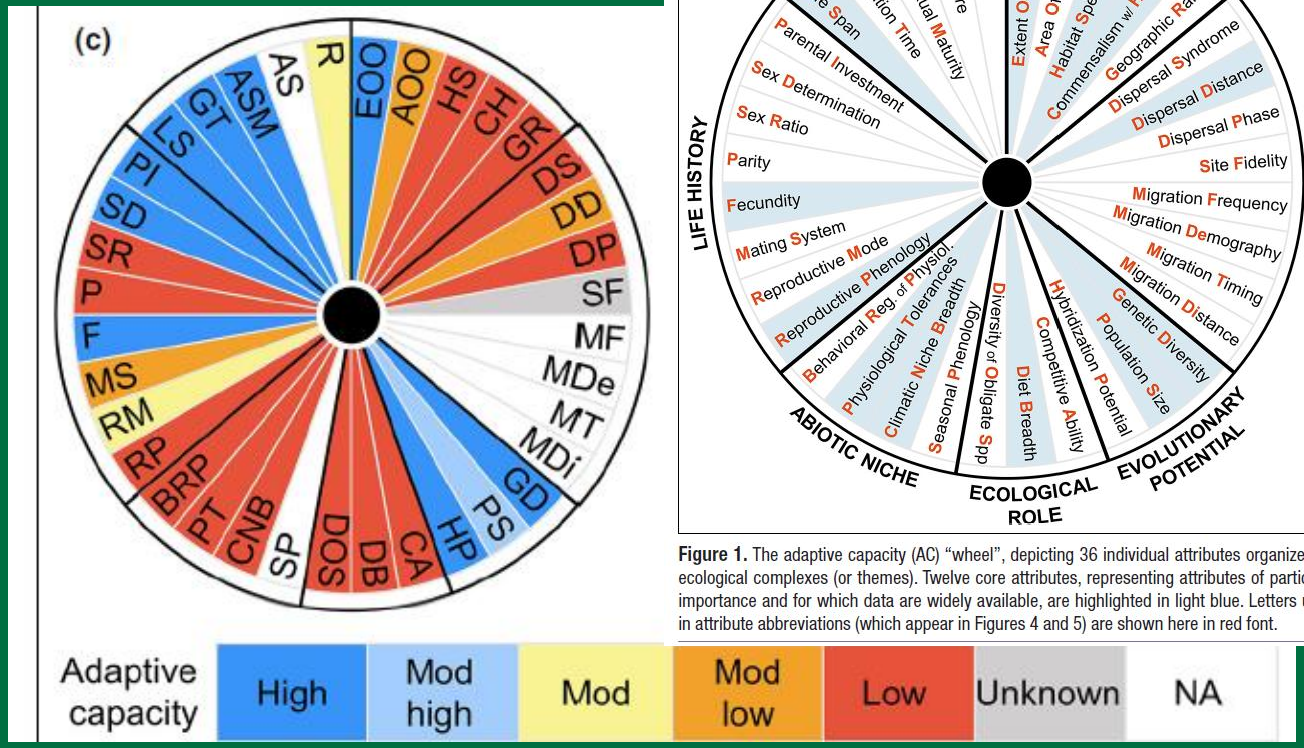


Figure 1. The adaptive capacity (AC) "wheel", depicting 36 individual attributes organized by ecological complexes (or themes). Twelve core attributes, representing attributes of particular importance and for which data are widely available, are highlighted in light blue. Letters used in attribute abbreviations (which appear in Figures 4 and 5) are shown here in red font.

USGS

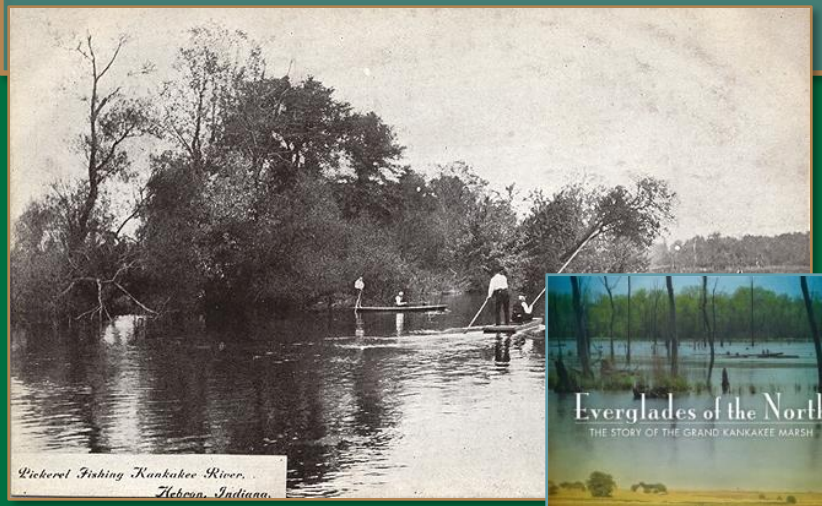
Thurman, L. L., et al. (2020). Frontiers in Ecology and the Environment **18(9): 520-528.**

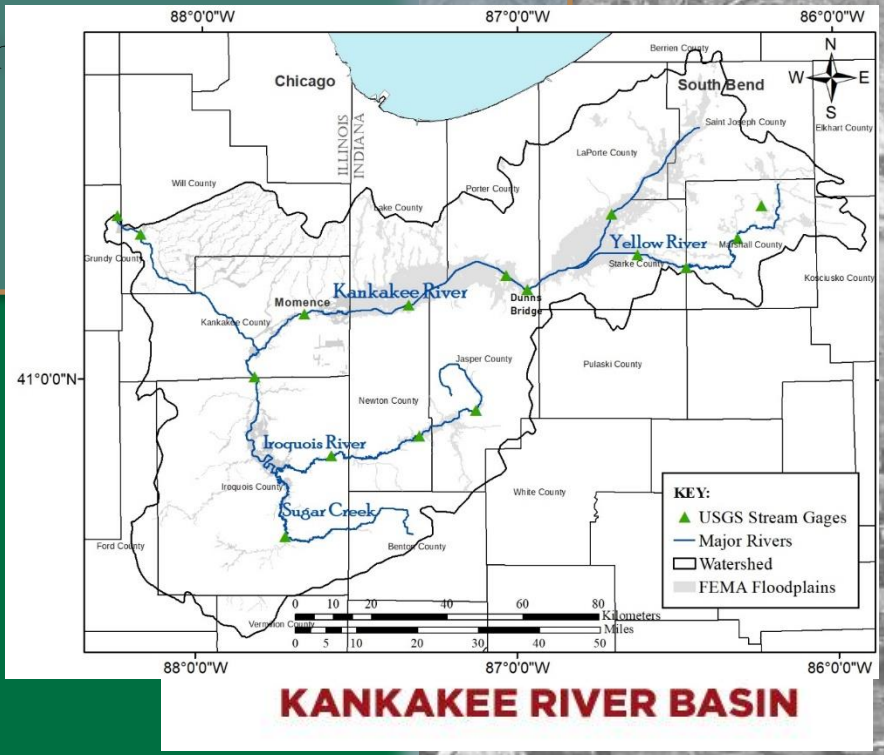
Are changes in precipitation (soil moisture) that negatively affected the Karner blue – decreased late spring/summer – likely to continue to occur?

USGS

Waterfowl Habitat Restoration as an Adaptive Mechanism for Water Sustainability in the Kankakee River Watershed

- Once home to Grand Kankakee Marsh
- Hydrology is highly modified system
- Predominantly agricultural landscape
- Some quality remnant wetlands remain
- Wetland restorations completed in watersh
- National Wildlife Refuge





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UPPER MIDWEST & GREAT LAKES LANDSCAPE CONSERVATION COOPERATIVE

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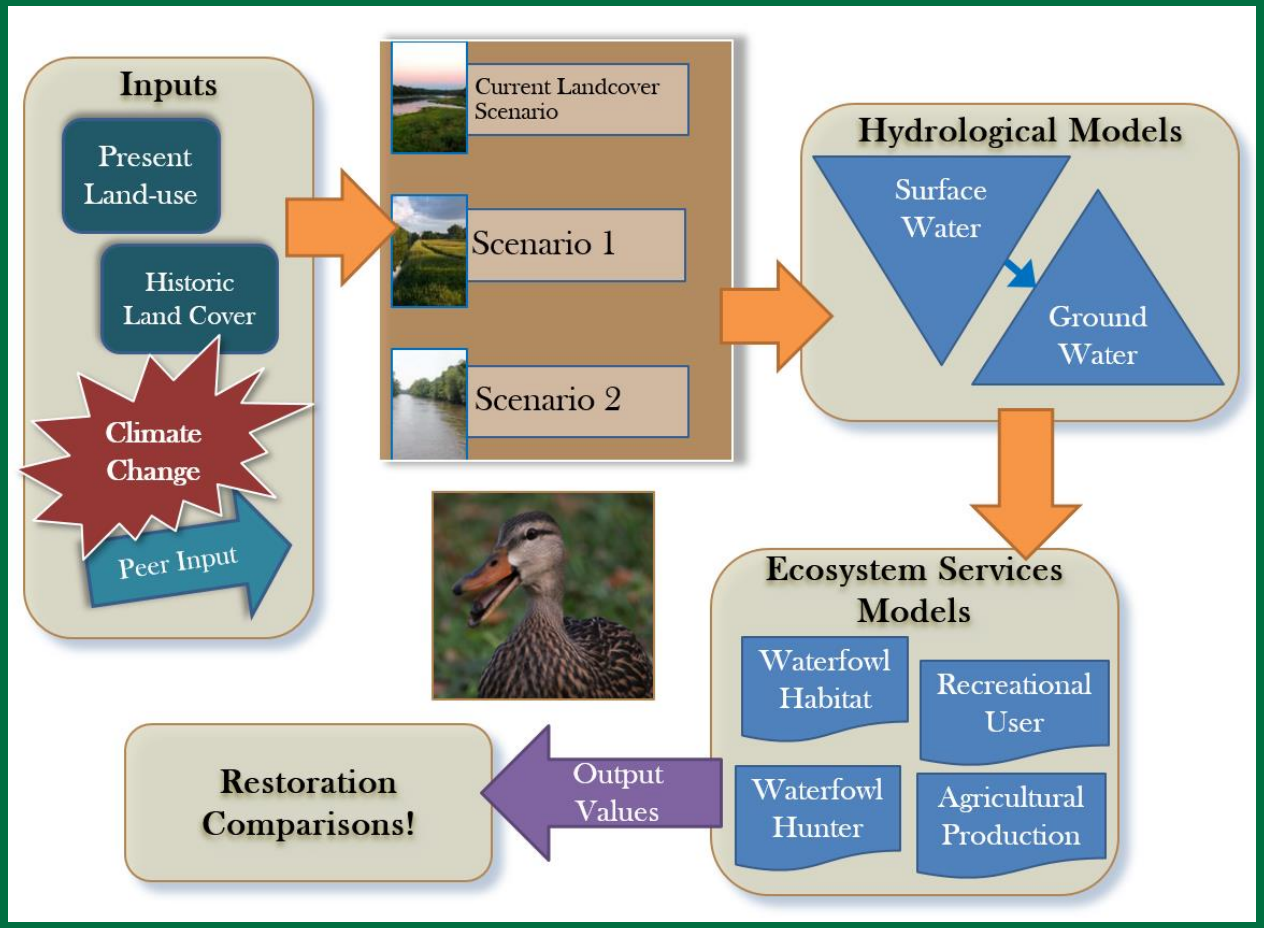
USGS science for a changing world

MODELING SCHEME: Waterfowl Habitat Restoration as an Adaptive Mechanism for Water Sustainability in the Kankakee River Watershed

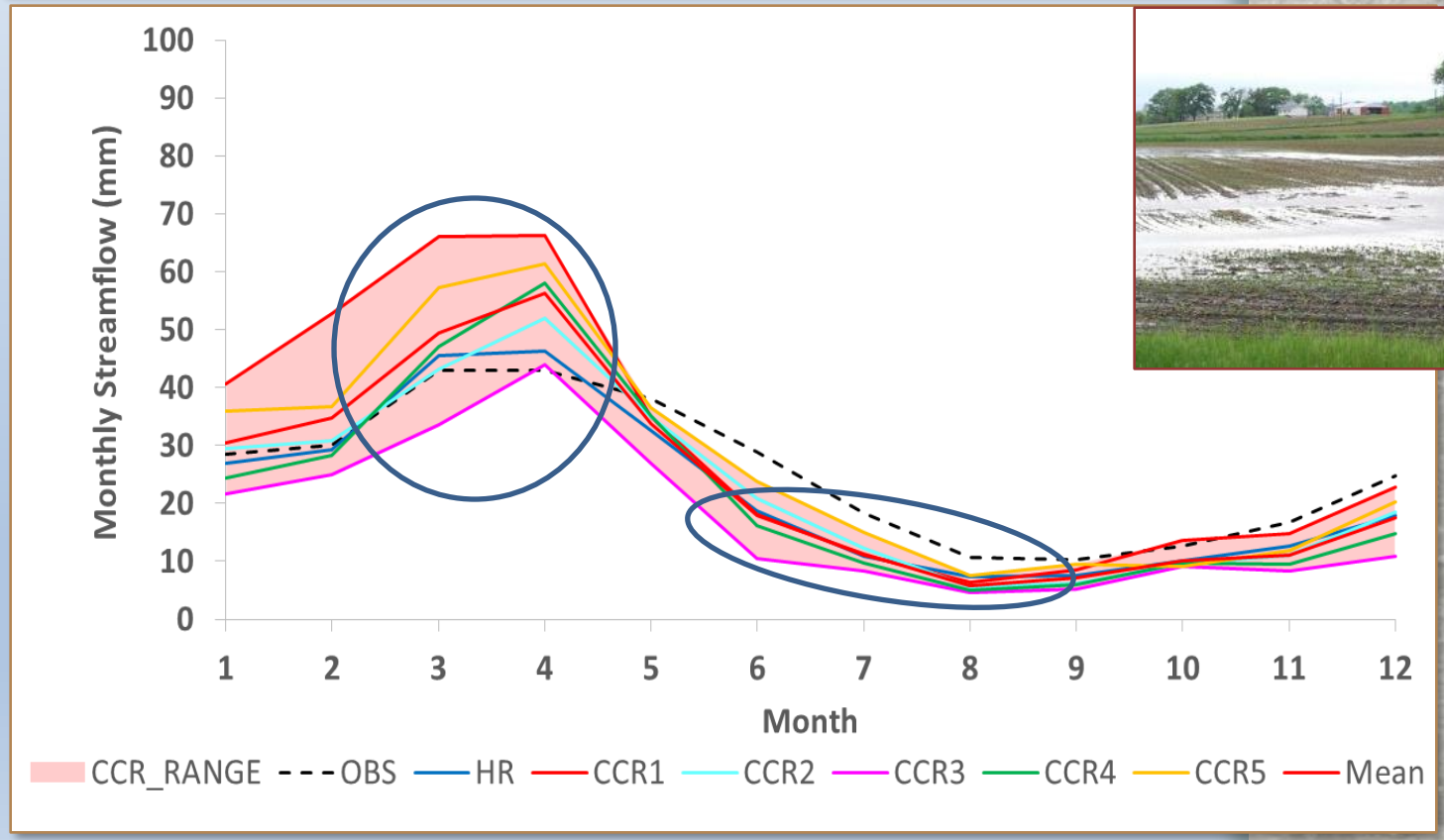
Variable Infiltration Capacity (VIC) for surface water modeling, MODFLOW for groundwater



Seasonal Flows:

Climate Change

- Projected Period: 2020s
  - More springtime rain events
  - Heavy springtime rain events
  - Decrease in summer/fall rain events



Seasonal Flows:

Climate Change

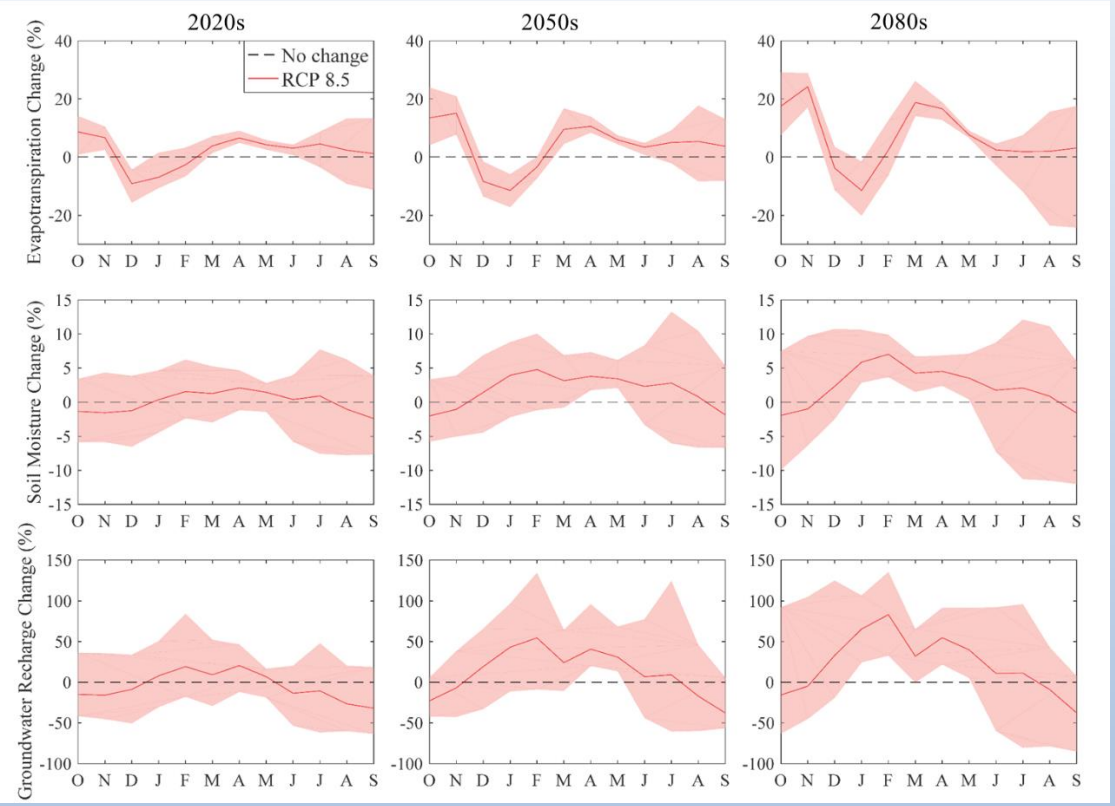
- Projected Period: 2050s
  - MORE spring rain events
  - HEAVIER springtime rain events
  - Decrease in summer/fall rain events

Seasonal Flows:

Climate Change

- Projected Period: 2080s
  - Doubling of springtime rain
  - WET, earlier winters
  - Dry summers

Predicted ET, Soil Moisture, and Groundwater Recharge for 5 climate change scenarios as % difference from 1971-2000 mean



Soil Moisture declined below long-term average July-August (later in the future). Above long-term mean in spring.

For 2020, 2050, 2080

- Decreased summer precipitation
- That was one of the factors that got the Karner blue in trouble
- The predicted patterns – increased spring flows and decreased summer flows could have negative effects on agricultural productivity and could negatively affect native species that depend on summer plant resources

Karner project team

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USGS – Grasslands Initiative
University of Minnesota, University of Notre Dame

USGS

Kankakee Project Team:

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Jessica Hellmann, Climate Change Ecologist, University of Minnesota
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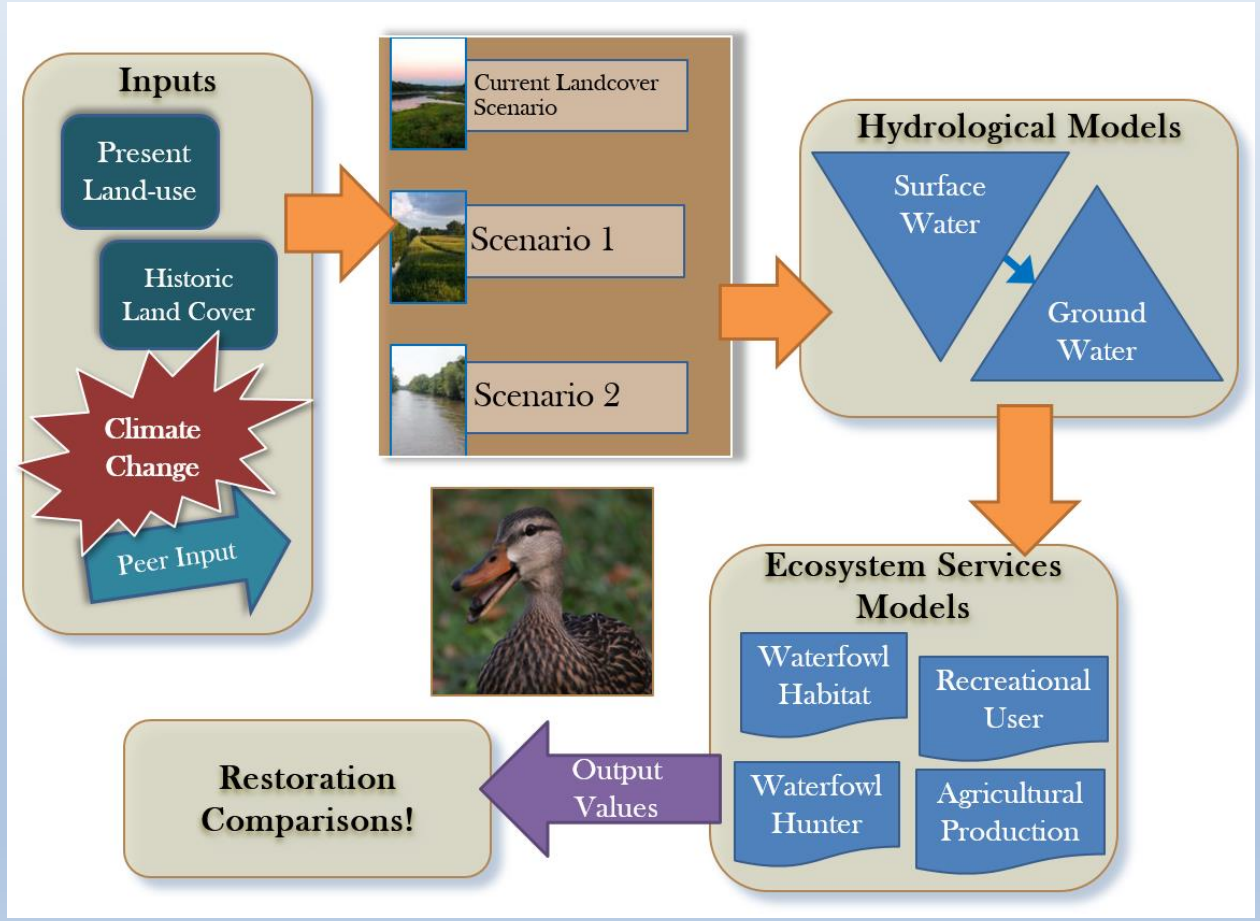
Inputs
Present Land-use
Historic Land Cover
Climate Change
Peer Input
Current Landcover Scenario
Scenario 1
Scenario 2
Hydrological Models
Surface Water
Ground Water
Ecosystem Services Models
Waterfowl Habitat
Recreational User
Waterfowl Hunter
Agricultural Production
Output Values
Restoration Comparisons!