How will climate change affect physiology and structure of dominant shrubs in water-limited ecosystems?

Leaf- to community-scale evidence from long-term, experimental manipulations

Keith Reinhardt

Tato akce se koná v rámci projektu:
Vybudování vědeckého týmu environmentální metabolomiky a ekofyziologie a jeho zapojení do mezinárodních sítí (ENVIMET; r.č. **CZ.1.07/2.3.00/20.0246**) realizovaného v rámci Operačního programu Vzdělávání pro konkurenceschopnost.

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UNITED STATES
CANADA
1. MAINE
2. NEW HAMPSHIRE
3. VERMONT
4. MASSACHUSETTS
5. RHODE ISLAND
6. CONNECTICUT
7. NEW JERSEY
8. DELAWARE
9. MARYLAND
Acadia National Park
Bangor
Manchester
Boston
Springfield
Albany
Niagara Falls
NEW YORK
Statue of Liberty
New York
Philadelphia
Dover
Annapolis
White House
NASA Headquarters
Richmond
Raleigh
WASHINGTON DC
Olympic National Park
Olympia
Mt. Rainier 4394 m
Salem
WASHINGTON
OREGON
IDAHO
Boise
MONTANA
Helena
WYOMING
Yellow Stone National Park
NORTH DAKOTA
Bismarck
SOUTH DAKOTA
Pierre
MINNESOTA
St. Paul
WISCONSIN
Madison
MICHIGAN
Lansing
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IOWA
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Topeka
NEBRASKA
Lincoln
OKLAHOMA
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TEXAS
Dallas
Austin
Houston
San Antonio
Houston space centre
COLORADO
Denver
Mt. Elbert 4401 m
Dinosaur National Monument
Cheyenne
UTAH
Salt Lake City
NEVADA
Carson City
Redwood National Forest
CALIFORNIA
Sacramento
San Francisco
Golden Gate Bridge
Yosemite National Park
Mt. Whitney 4421 m
Zion N.P.
Las Vegas
The Hoover Dam
Death Valley National Park
Los Angeles
San Diego
ARIZONA
Phoenix
Tucson
Copper Canyon
NEW MEXICO
Santa Fe
Albuquerque
MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
Gulf of Mexico
THE BAHAMAS
CUBA
ROCKY MOUNTAINS
GREAT PLAINS
CASCADE RANGE
Blue Mountains
Coast Ranges
SIERRA NEVADA
Appalachian Mountains
Lake Superior
Lake Michigan
Lake Huron
Missouri
Mississippi
Snake
Colorado
Arkansas
Ohio
Tennessee
Brazos
Gila
Rio Grande
RUSSIA
ALASKA
Bering Sea
Yucon
Mt. Mckinley 6194 m
Anchorage
Gulf of Alaska
HAWAII
Honolulu
Hilo
LEGEND
Country Boundary
State Boundary
Major Road
River
Major City
Sea Port
Country Capital
Airport
Point of Interest
120°W
110°W
100°W
90°W
80°W
70°W
50°N
40°N
30°N
0 100 200 300 400 KM
0 50 100 150 200 250 300 Miles
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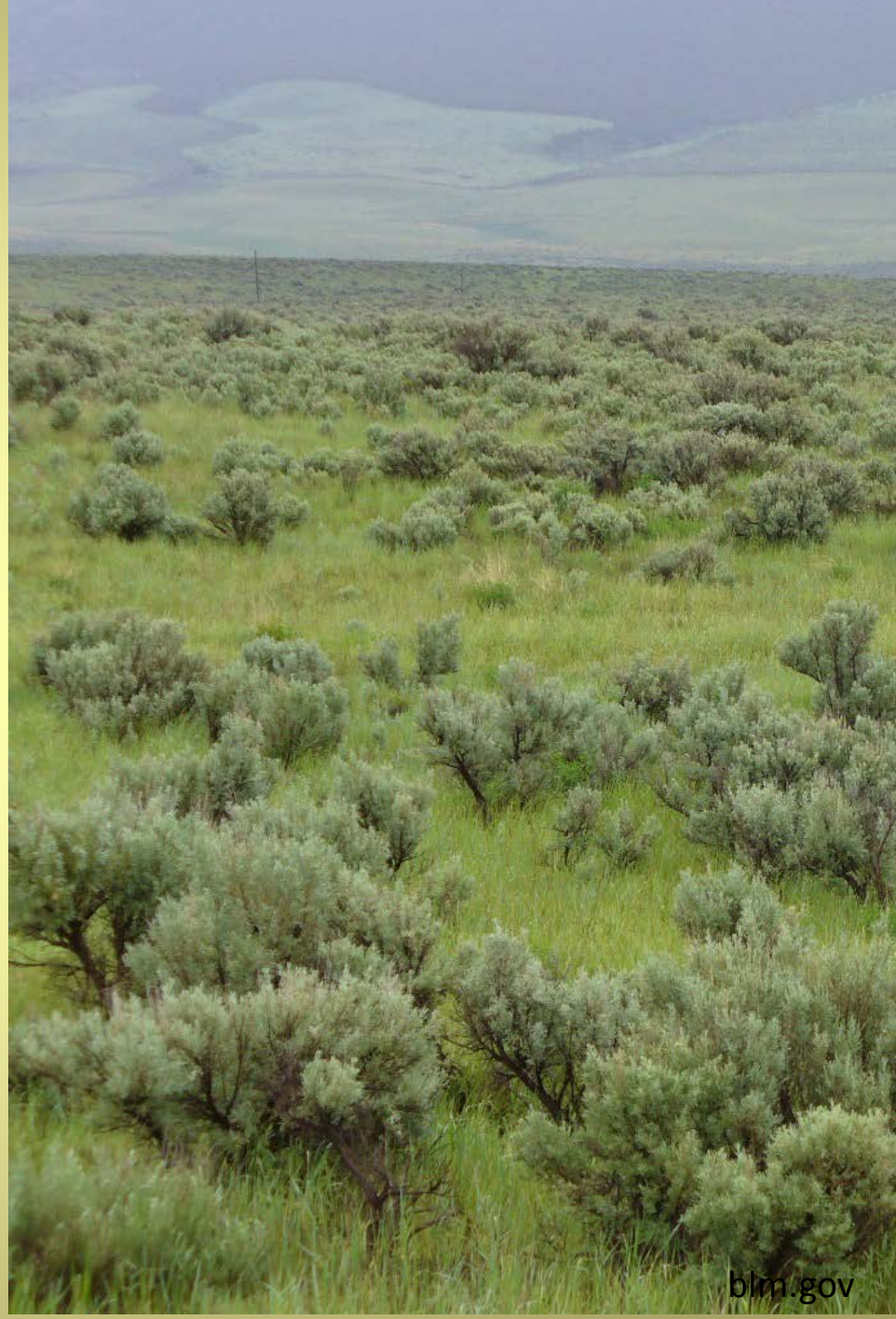
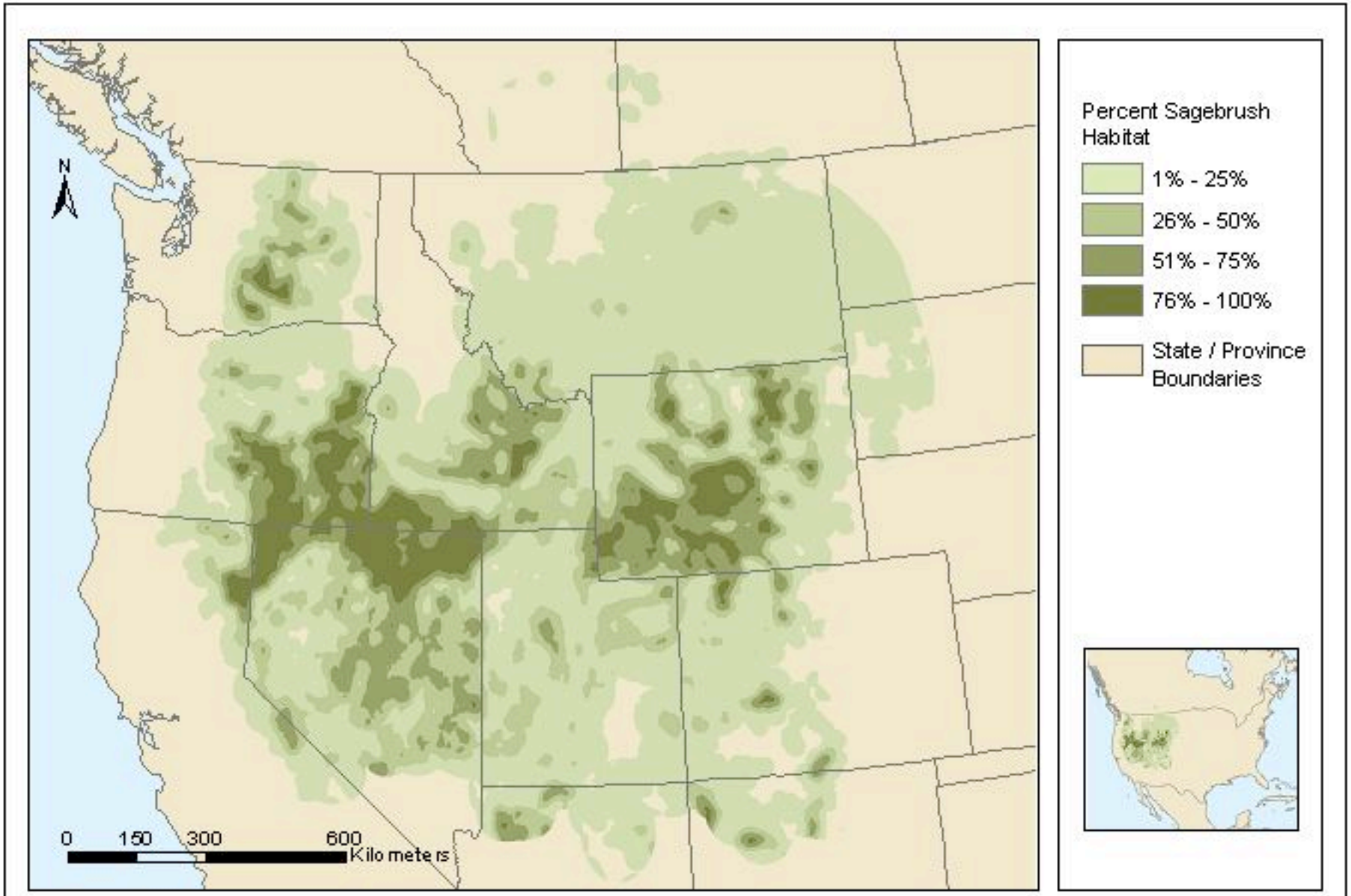
Shrublands

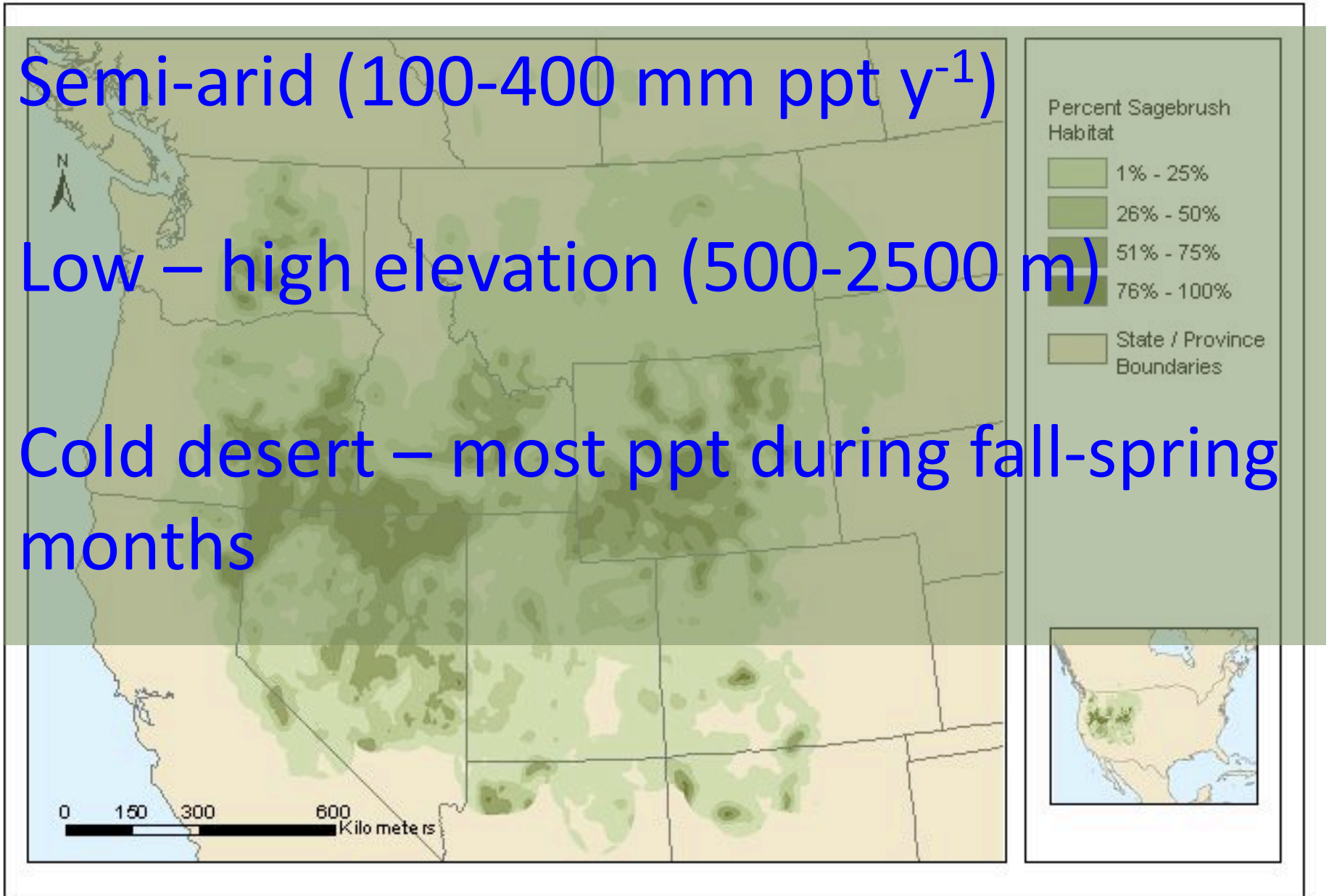
- Cover 31 – 51% of the Earth's surface; 42% of the U.S.
- Ecosystem services:
  - Soil stabilization and retention
  - Water capture, storage, and release
  - Habitat maintenance
  - Carbon Storage



Shrublands of Intermountain West



Shrublands of Intermountain West



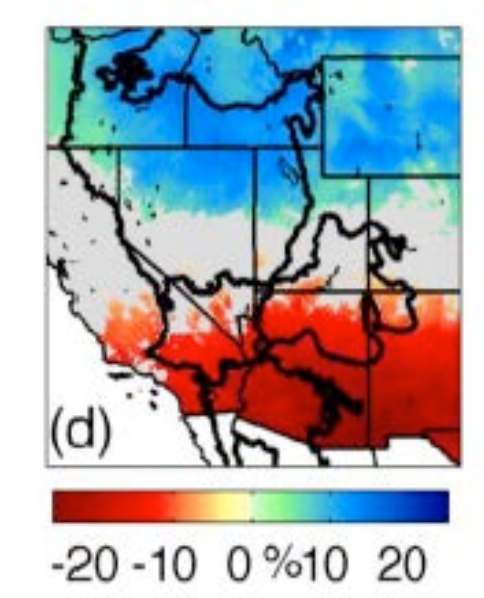
Semi-arid (100-400 mm ppt y^{-1})

Low – high elevation (500-2500 m)

Cold desert – most ppt during fall-spring months

Climate Change in western North America

- Temperature ↑ ~2-5 ^{o}C (mean annual)
- Precipitation
  - Annual amount ~same
  - Increased variability (stochastically, annually, seasonality)
  - Some evidence for changes in seasonality
  - Decreased snowpack (amount, duration, rain vs snow) mid-elevations

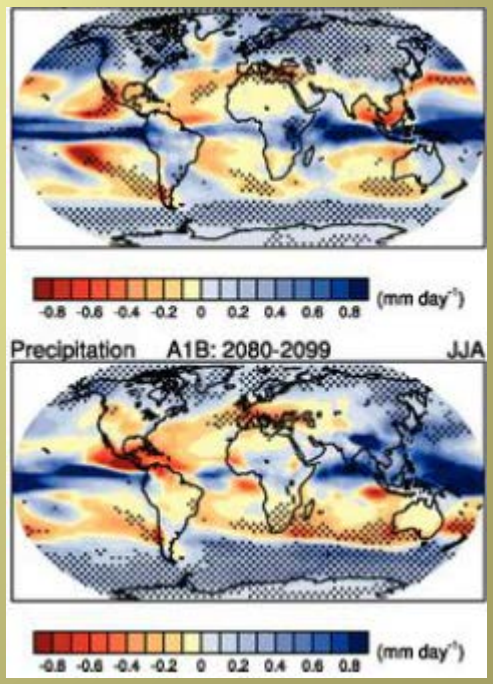


Nov-Mar

courtesy of John Abatzoglou

DJF

JJA



How will plants and ecosystems respond to these changes in climate?

- As a reference…the three **A**'s of plant response
  - **A**cclimation (short term, physiological response)
  - **A**daptation (long-term, genetic response)
  - **A**ssembly changes (short- to long-term changes in structure and community assembly)

- Different time scales + studied in isolation

- Using this approach as a model to understand plant responses to changing climate, let's look at two manipulative experiments…

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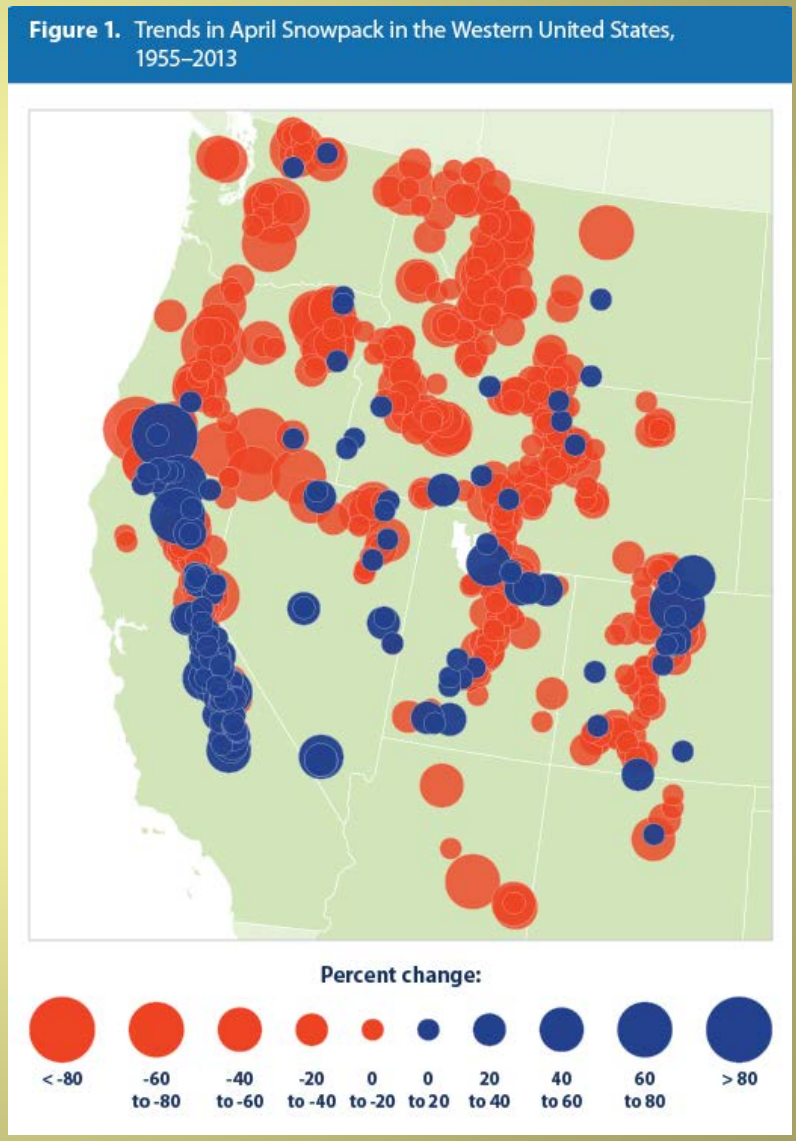
Experiment 1: Experimental warming and snowpack removal in a subalpine meadow

Climate Change in western N.A.

- Reduced snowpack totals
- Earlier snowmelt in the spring



Study Site

- 2,120 m
- Established 2009
- ~630 mm precipitation
- *Artemisia arbuscula*, flowering forbs, bare soil

Climate Treatments

n = 3

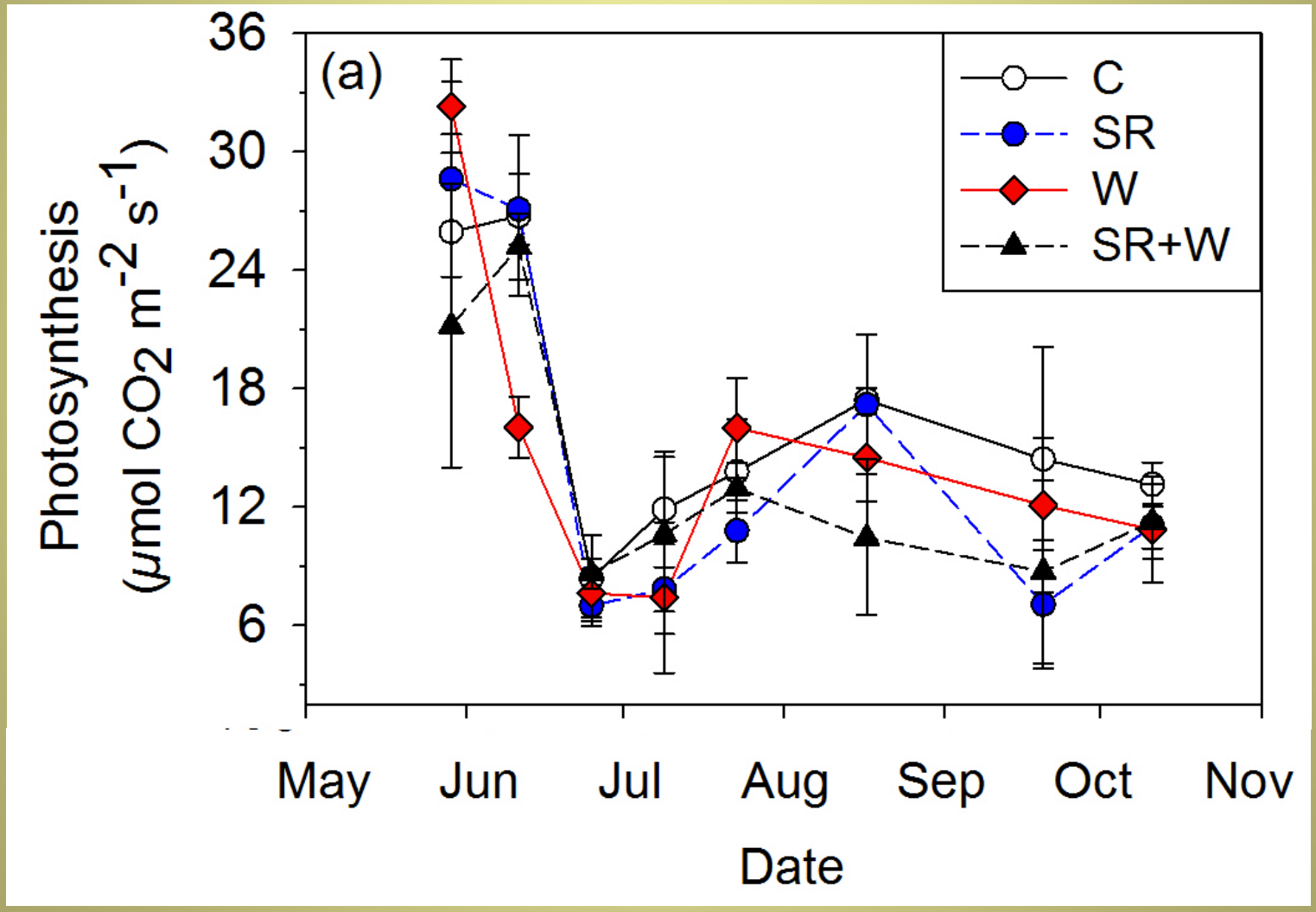
CONTROL

SNOWPACK REMOVAL
(~15% of 2014-2015 SWE)

WARMING (+1-3 ^{0}C)

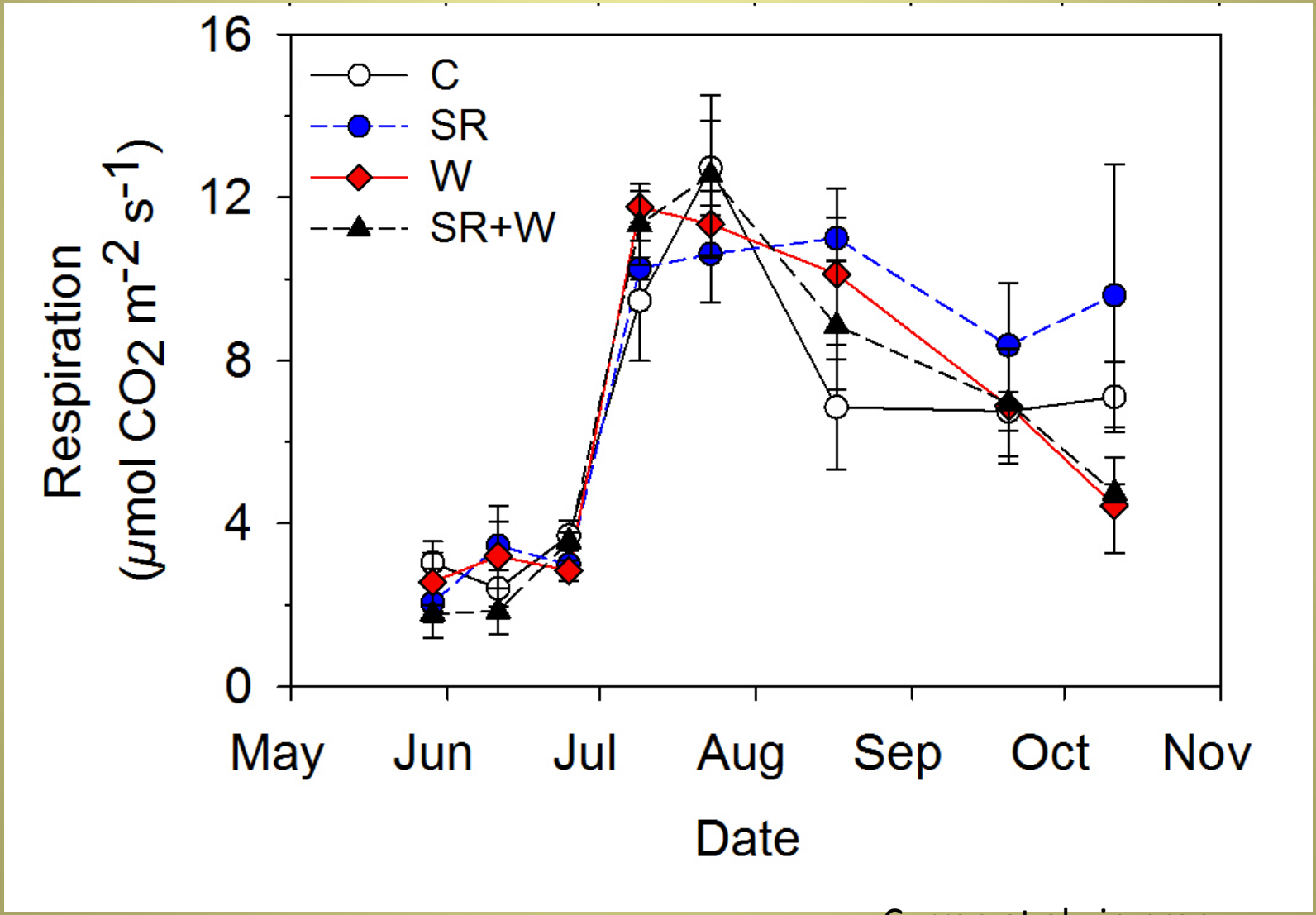
SNOWPACK REMOVAL + WARMING

Acclimation: gas exchange



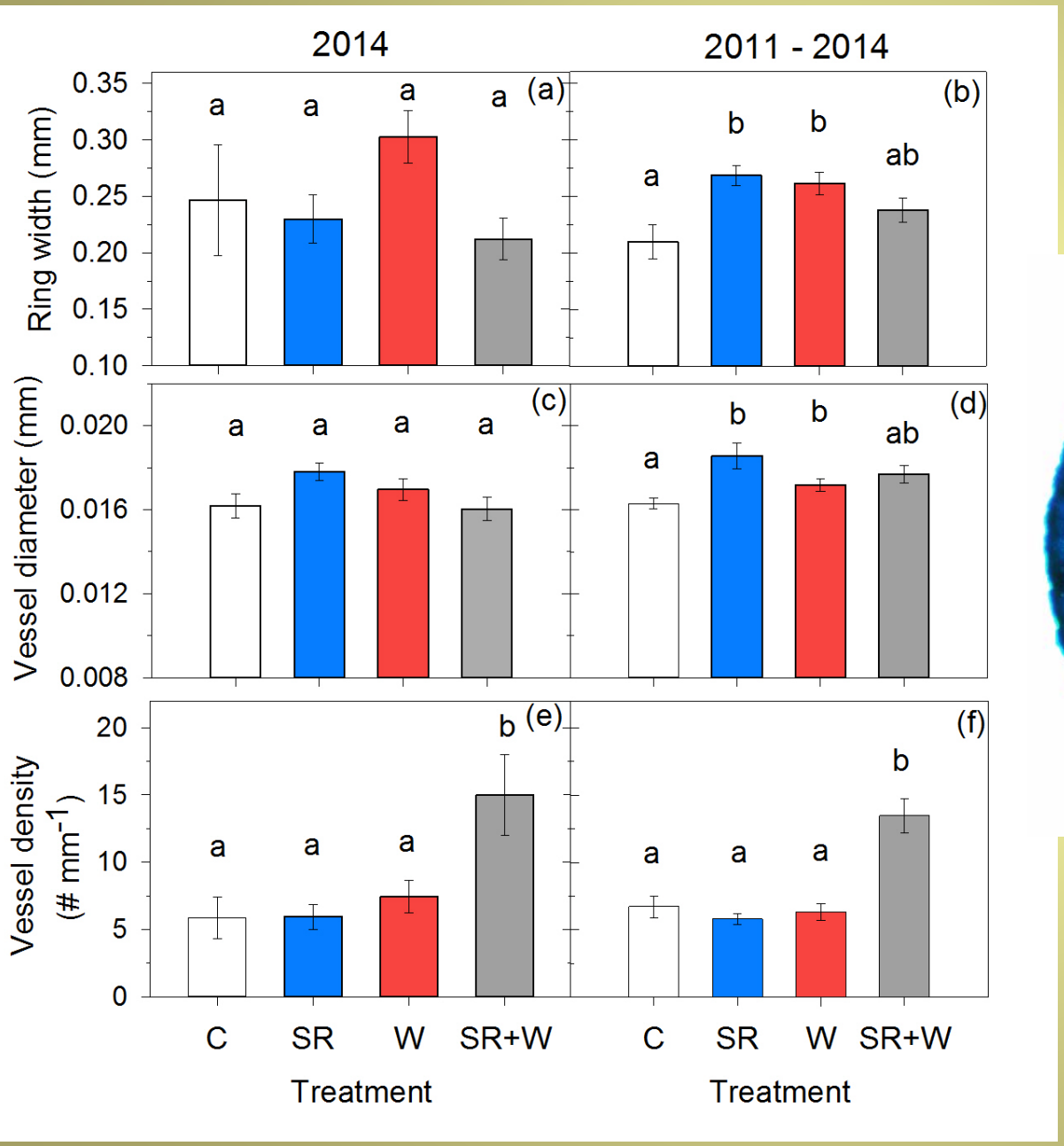
Curran et al., in prep

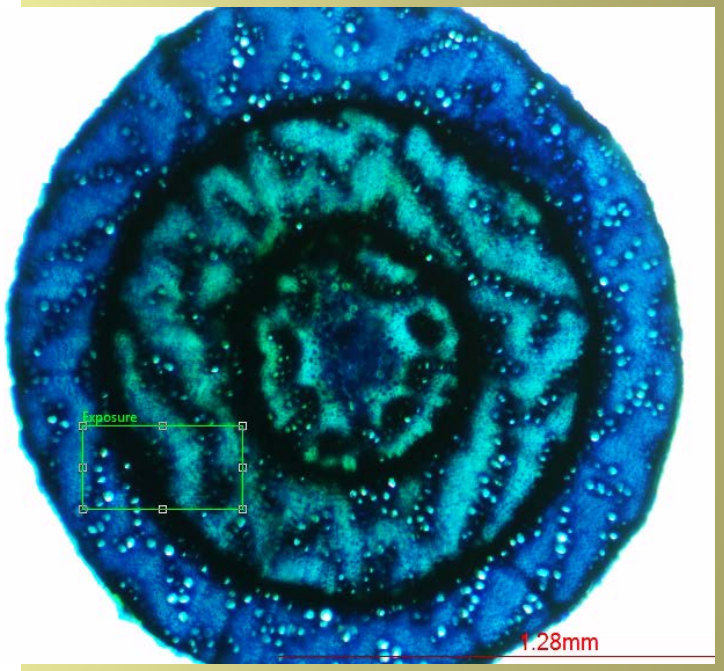
Gas exchange



Curran et al., in prep

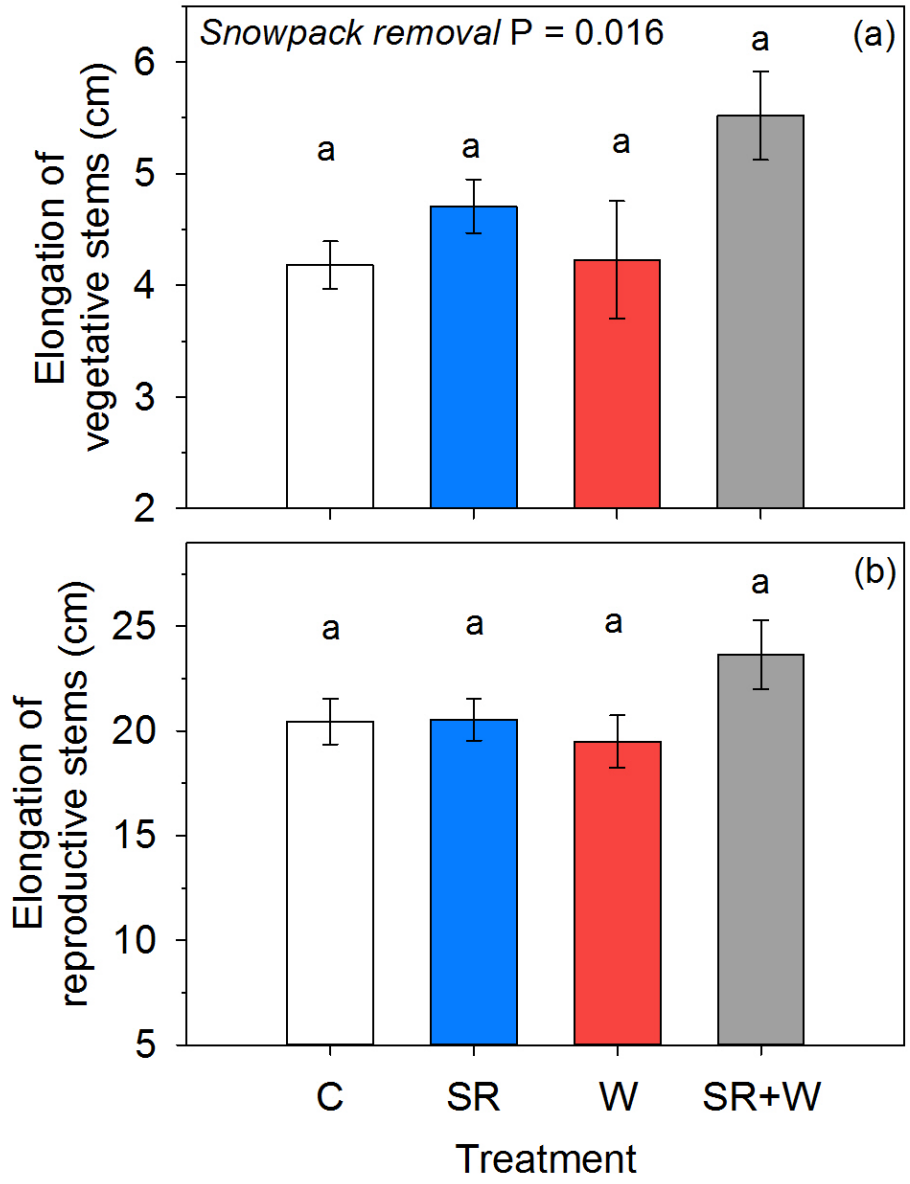
Assembly: xylem architecture





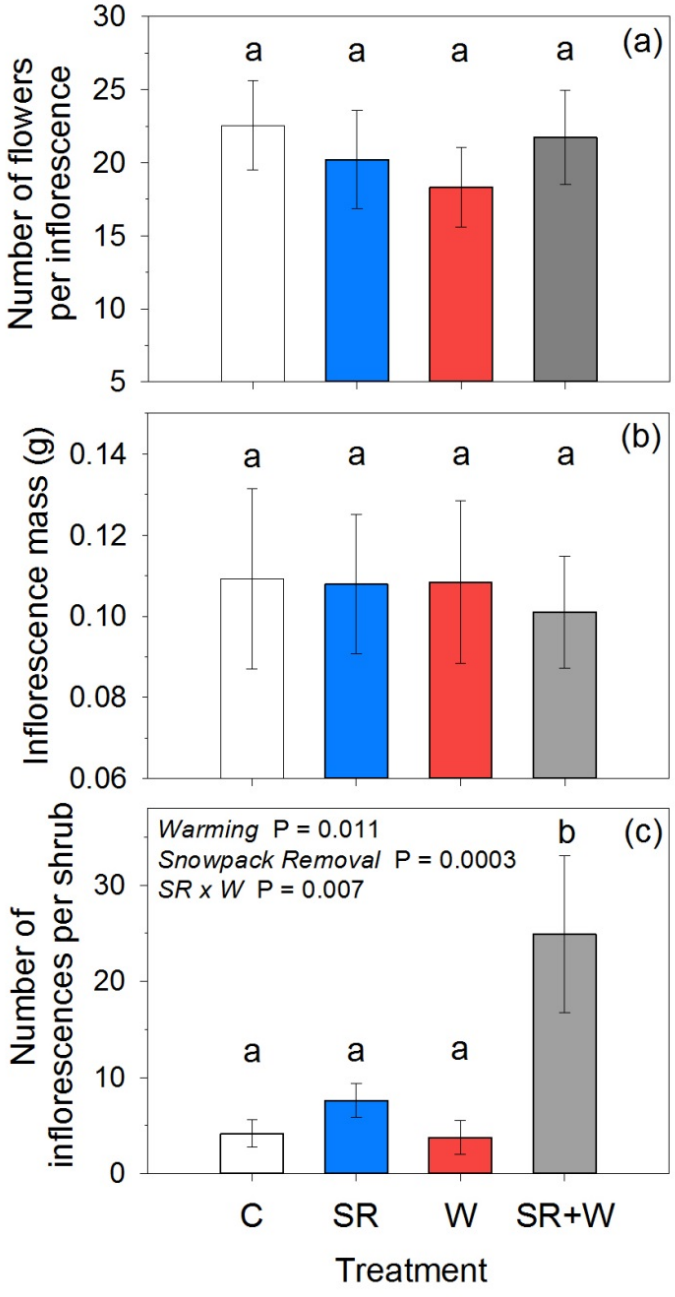
Curran et al., in prep

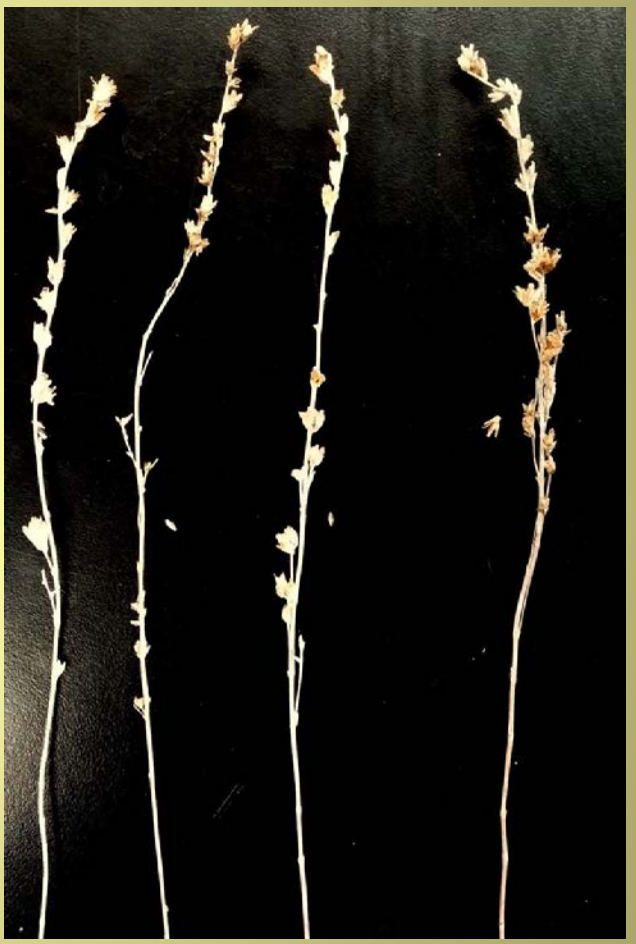
Stem Elongation



Curran et al., in prep

Inflorescences





Curran et al., in prep

Experiment #2: Desert Ecohydrological Experiment

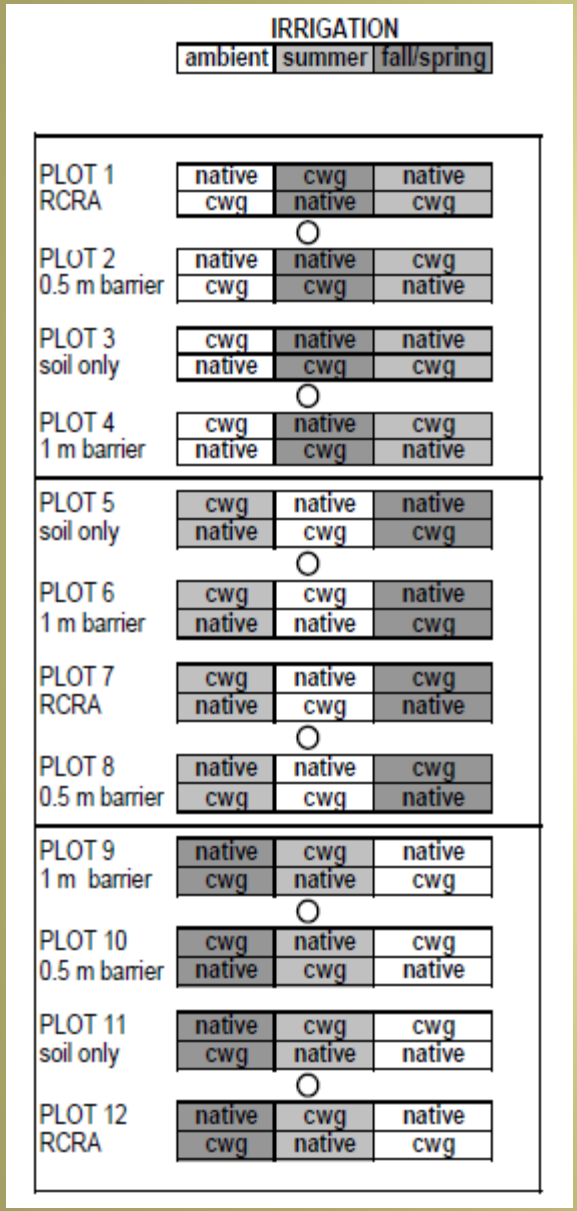
- Started in 1993
- Sagebrush steppe; cold desert
- 72 8m X 8m plots

Two vegetation covers

Crested wheatgrass (*Agropyron cristatum*) monocultures

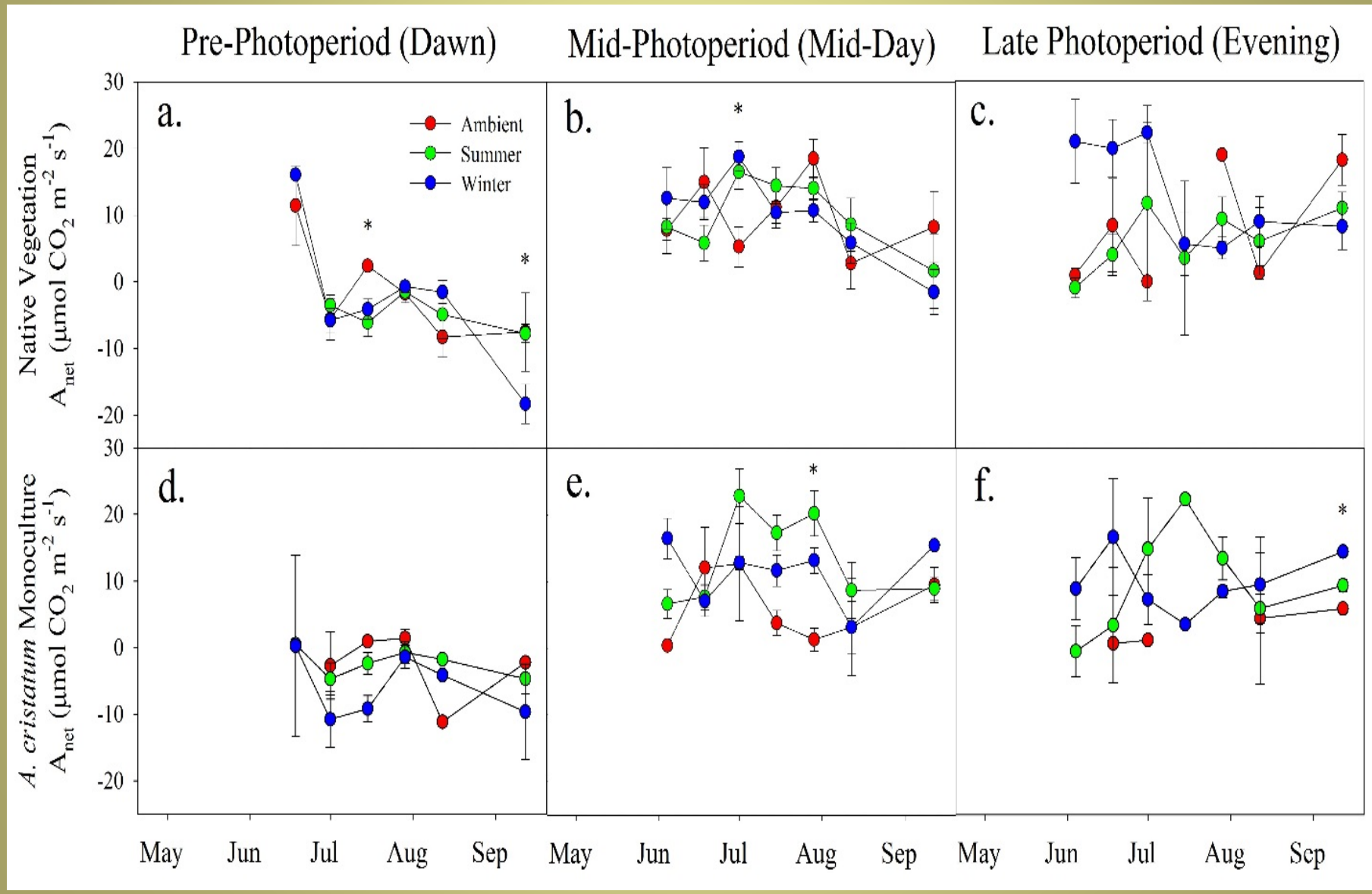
Native sagebrush-steppe mix (*Artemisia tridentata* dominant)

Three Precipitation Treatments



- **AMB**ient (ave ~200 mm/yr)
- **WIN**ter (+200 mm in plant dormancy)
- **SUM**mer (+200 mm in 4 applications in June-July)

Results after 20+ years of manipulation… leaf-level photosynthesis



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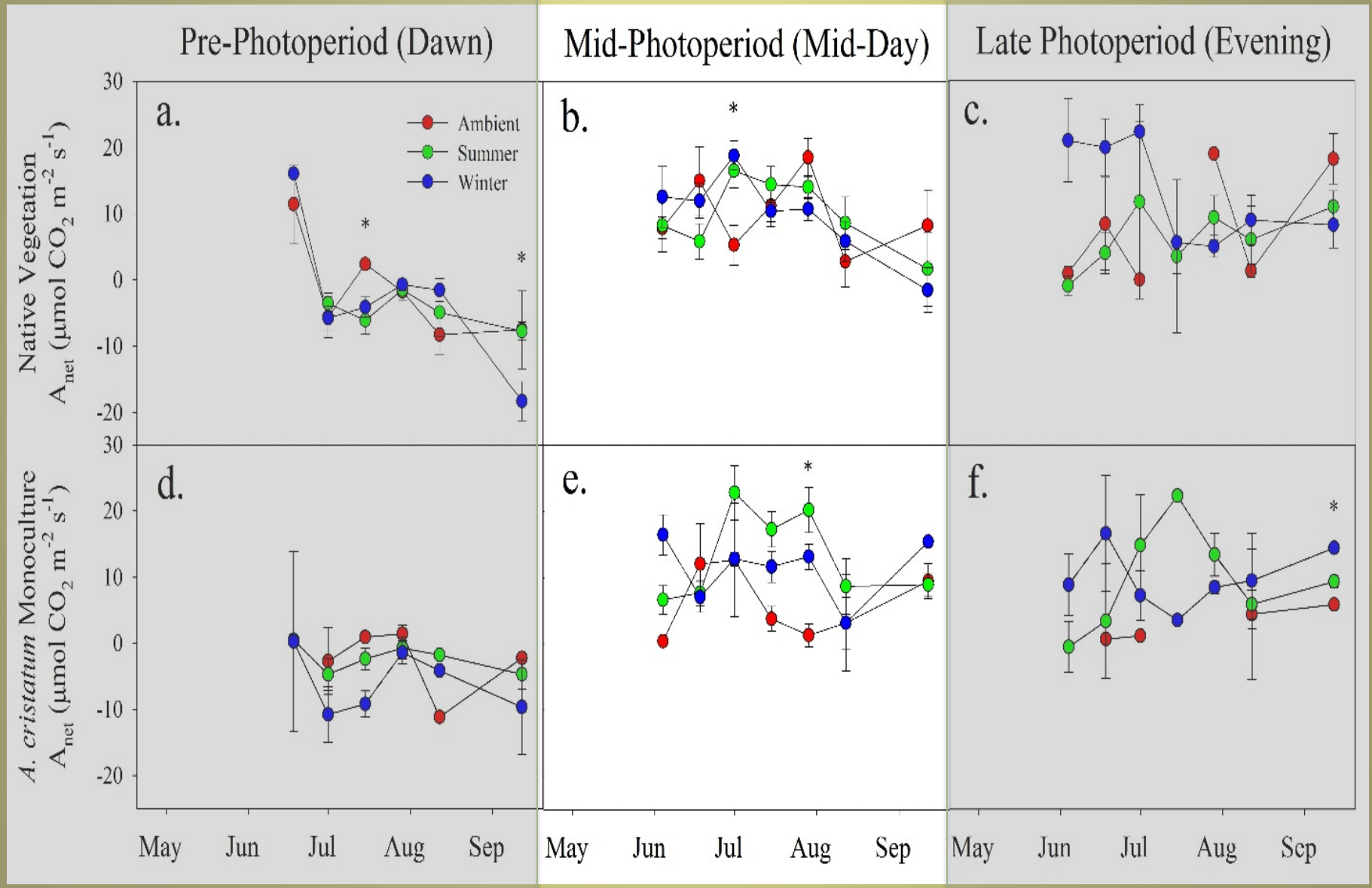
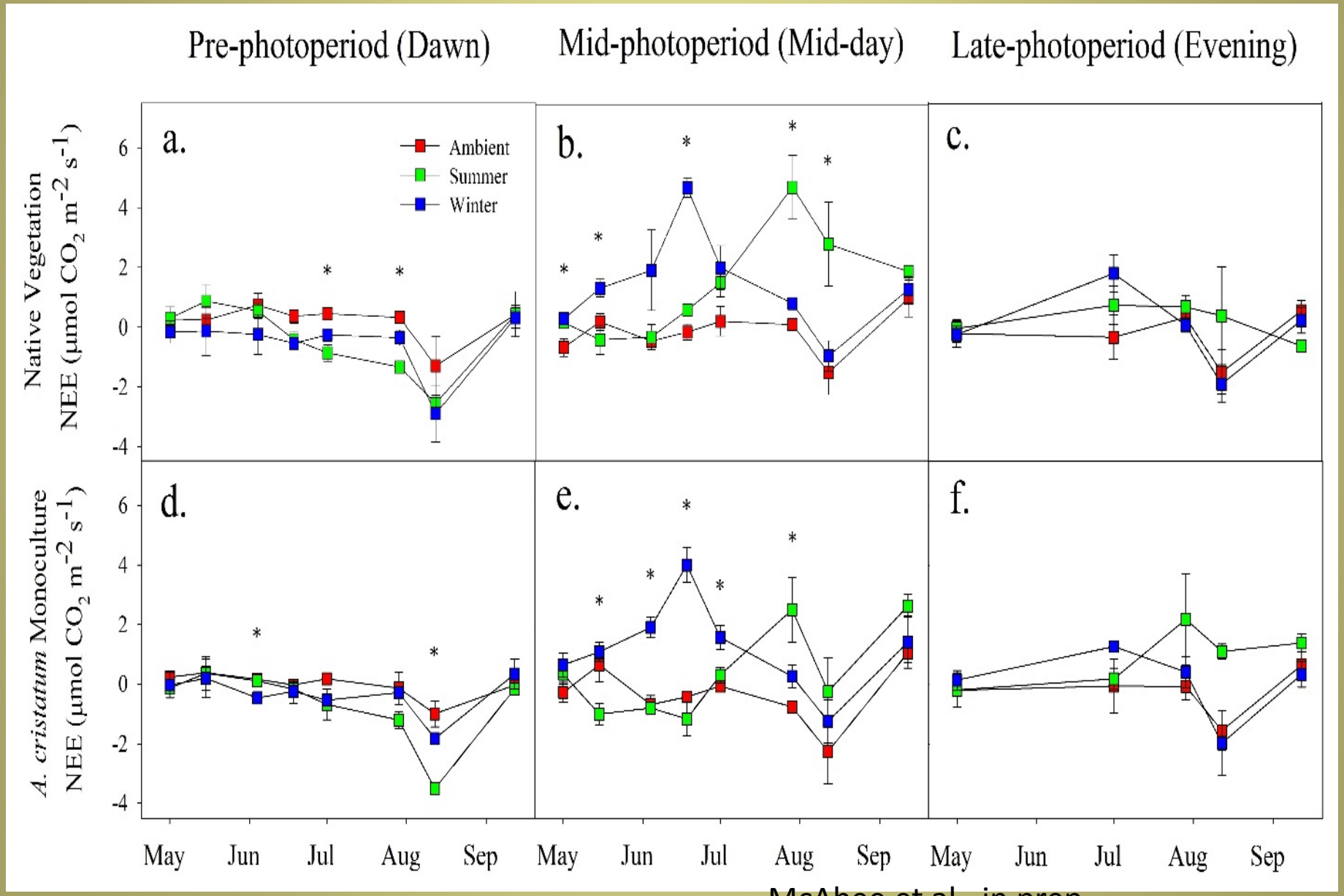
Acclimation: leaf-level photosynthesis



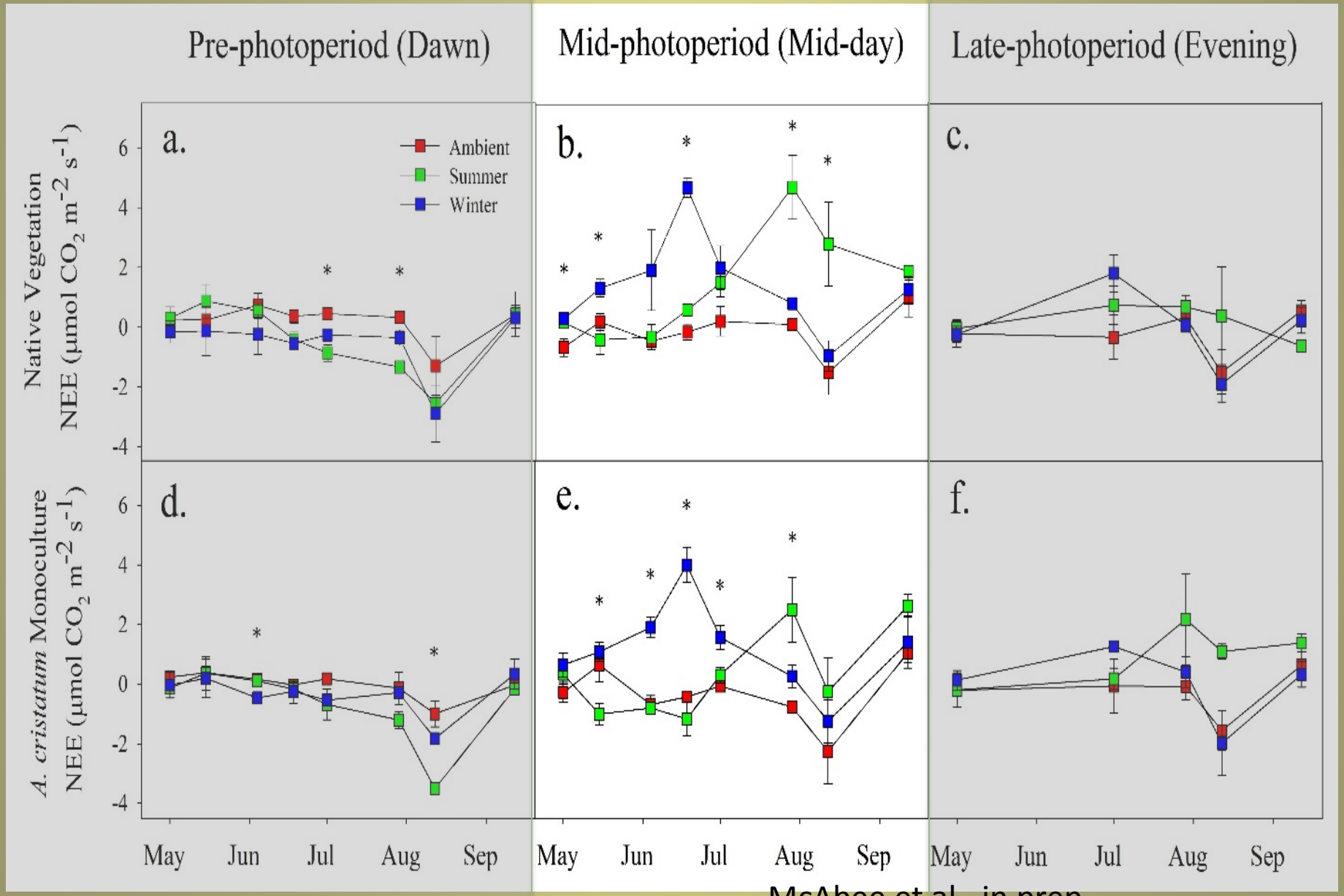
McAbee et al., in prep

NEE (Net Ecosystem Exchange)



McAbee et al., in prep

NEE (Net Ecosystem Exchange)



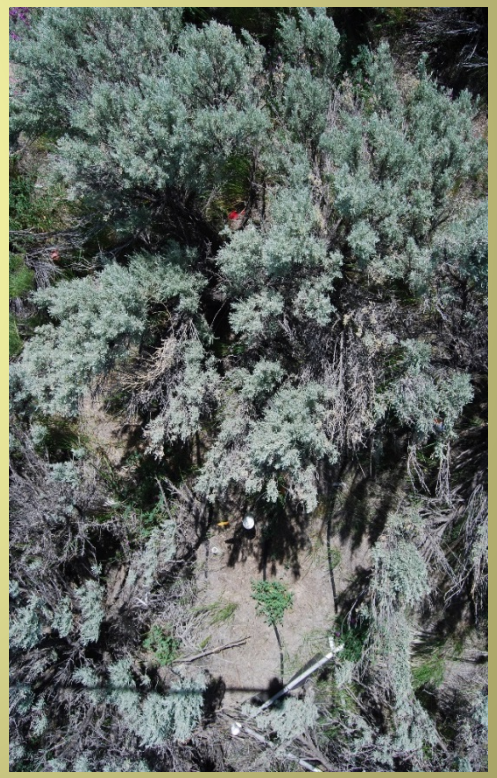
McAbee et al., in prep

Assembly: 20 years' effects on plant growth and ecosystem structure

Ambient

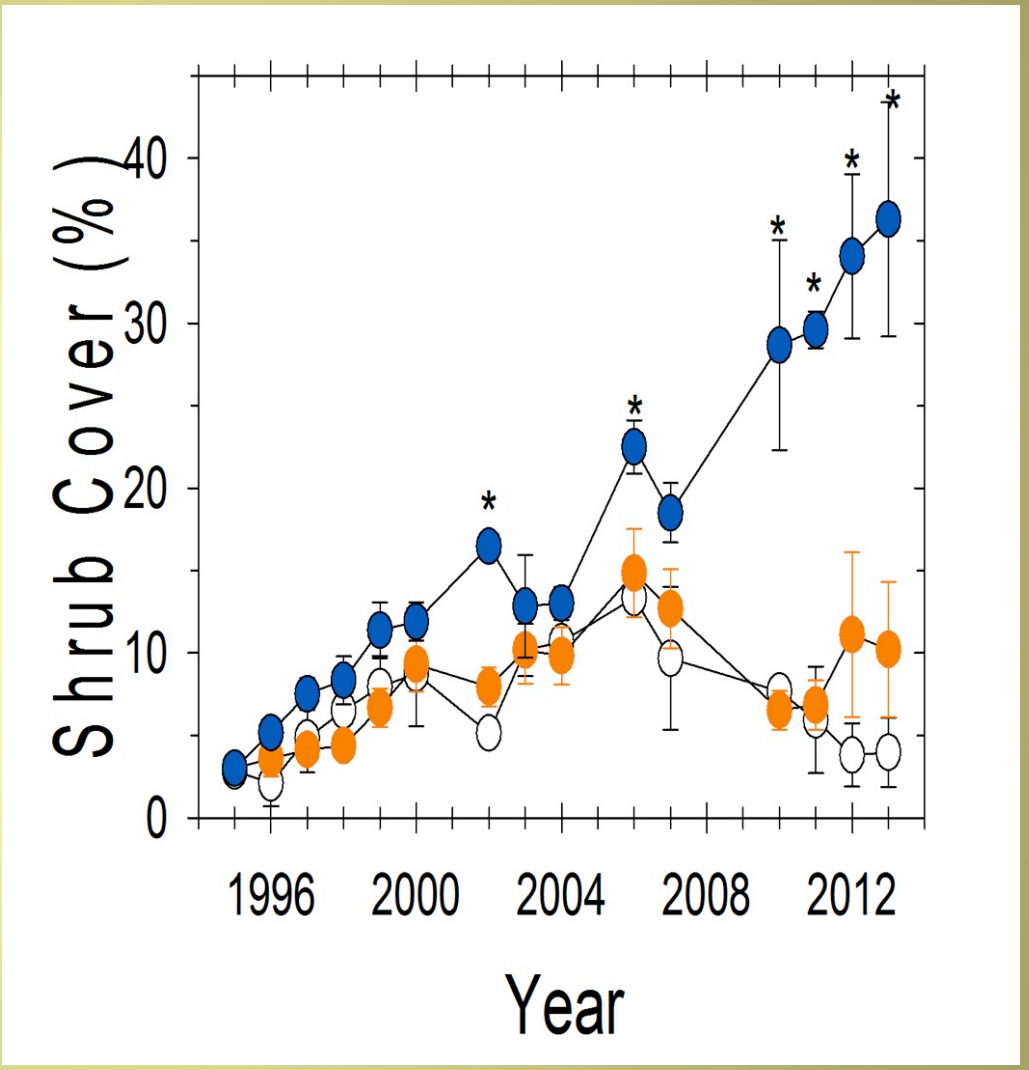
Summer

Winter

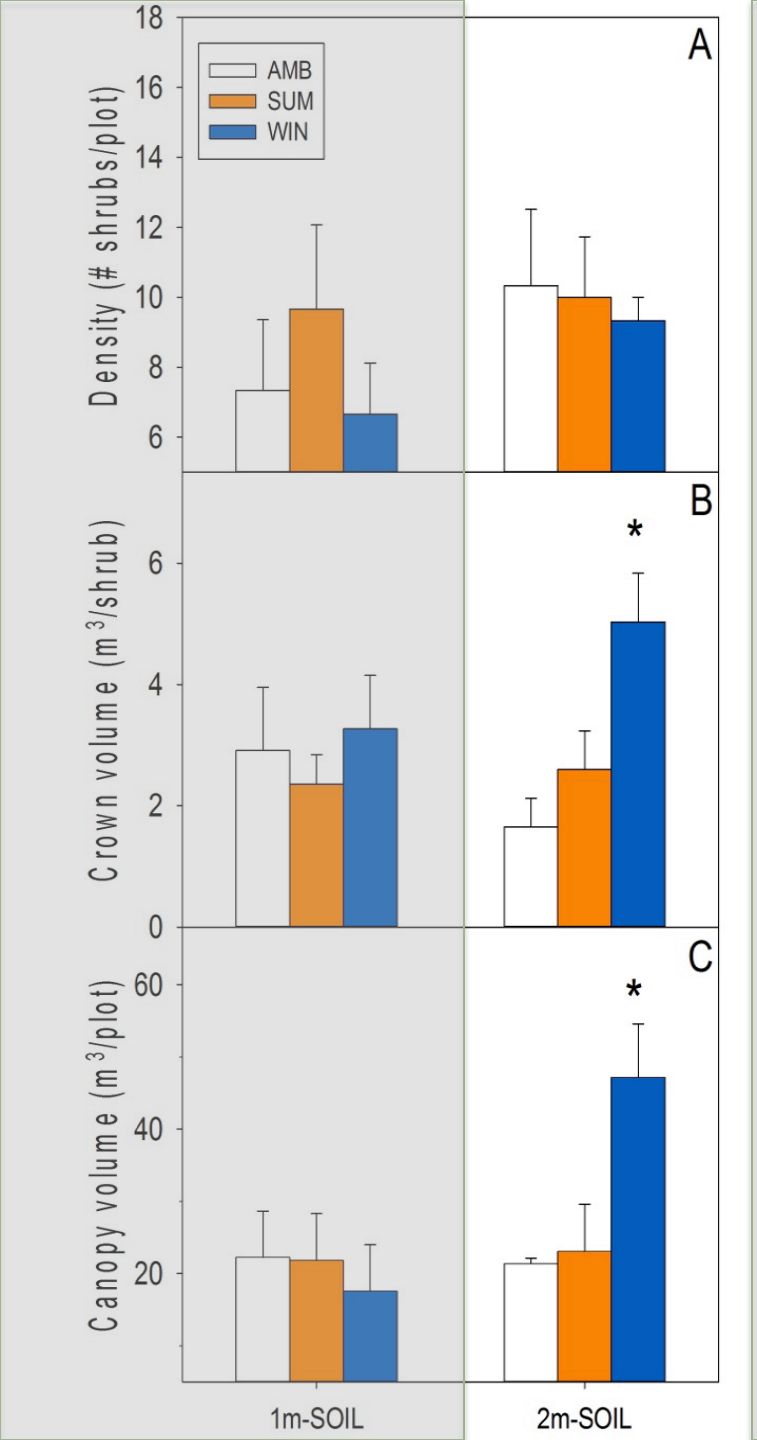


Greater shrub cover in WIN plots only

WIN



Germino and Reinhardt, J Ecol 2014



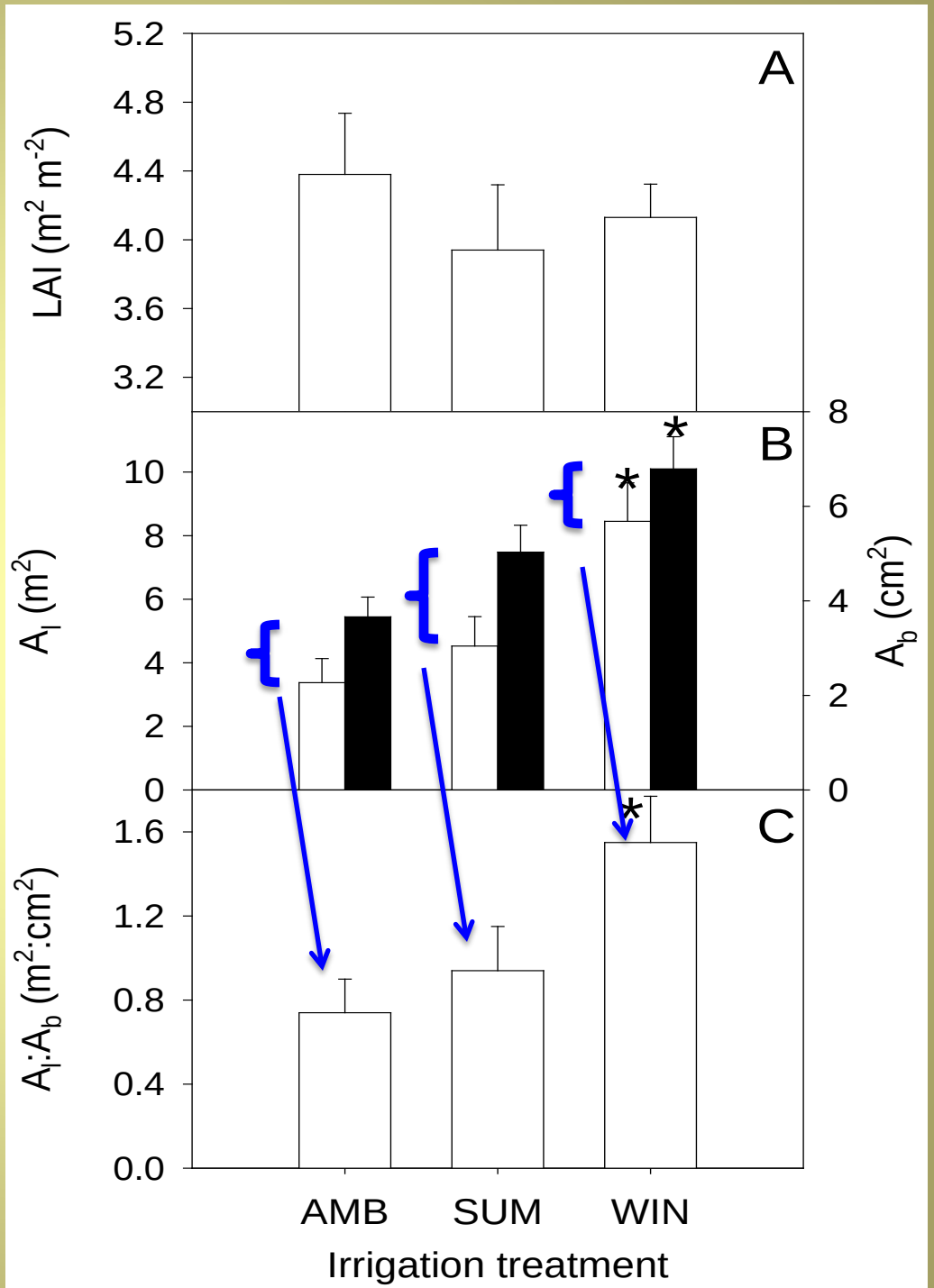
- No differences in shrub density (#shrubs/plot)
- WIN results in larger shrubs (except in shallow-soil plots)
  - @ individual scale
  - @ population scale

Germino and Reinhardt, J Ecol 2014

Hydraulic paramater adjustments

Adjustments in $Area_{crown}$:$Area_{basal}$

A_{water_loss}:A_{water_pipes}



Conclusions

Conclusions

1) (Well, there are LOTS of take-home messages)

Conclusions—focusing on the three **A**'s

1) For both modest and strong experimental treatments,
   a) Little evidence of physiological **A**cclimation
      a) No changes in leaf-level gas exchange (C gain) or respiration
   b) Relatively greater changes in **A**ssembly
      a) shrub morphology and tissue structure

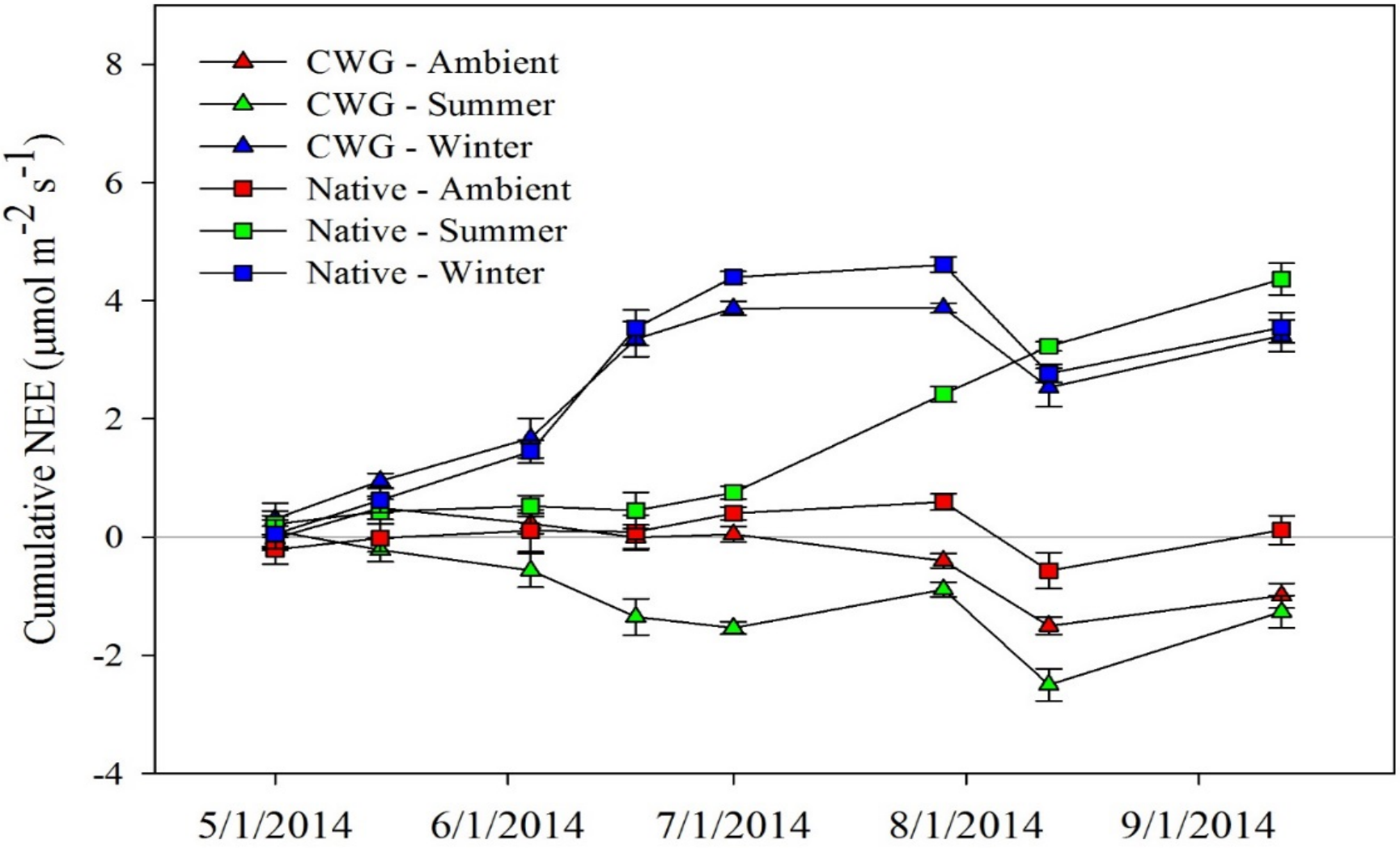
2) It's not just about photosynthesis!
   I) Handful of studies demonstrate that many plant processes compensate to maintain C flux (keep photosynthesis
   2) Remember the three A's when planning msts!

Acknowledgments

- Jay Anderson—experimental design
- Idaho National Lab/DOE
- NSF EPSCoR Idaho
- PNW Climate Science Center
- S.M. Stoller Corporation, Idaho Falls, ID
  - Amy Forman, Roger Blew
- Research Assistants
  - Sara Bachman, Jeremy Greth, Jackia Hafla, Brandy Janzen, Liam Junk, Ryann Mata, Jeff Morgan, Jeremias Pink

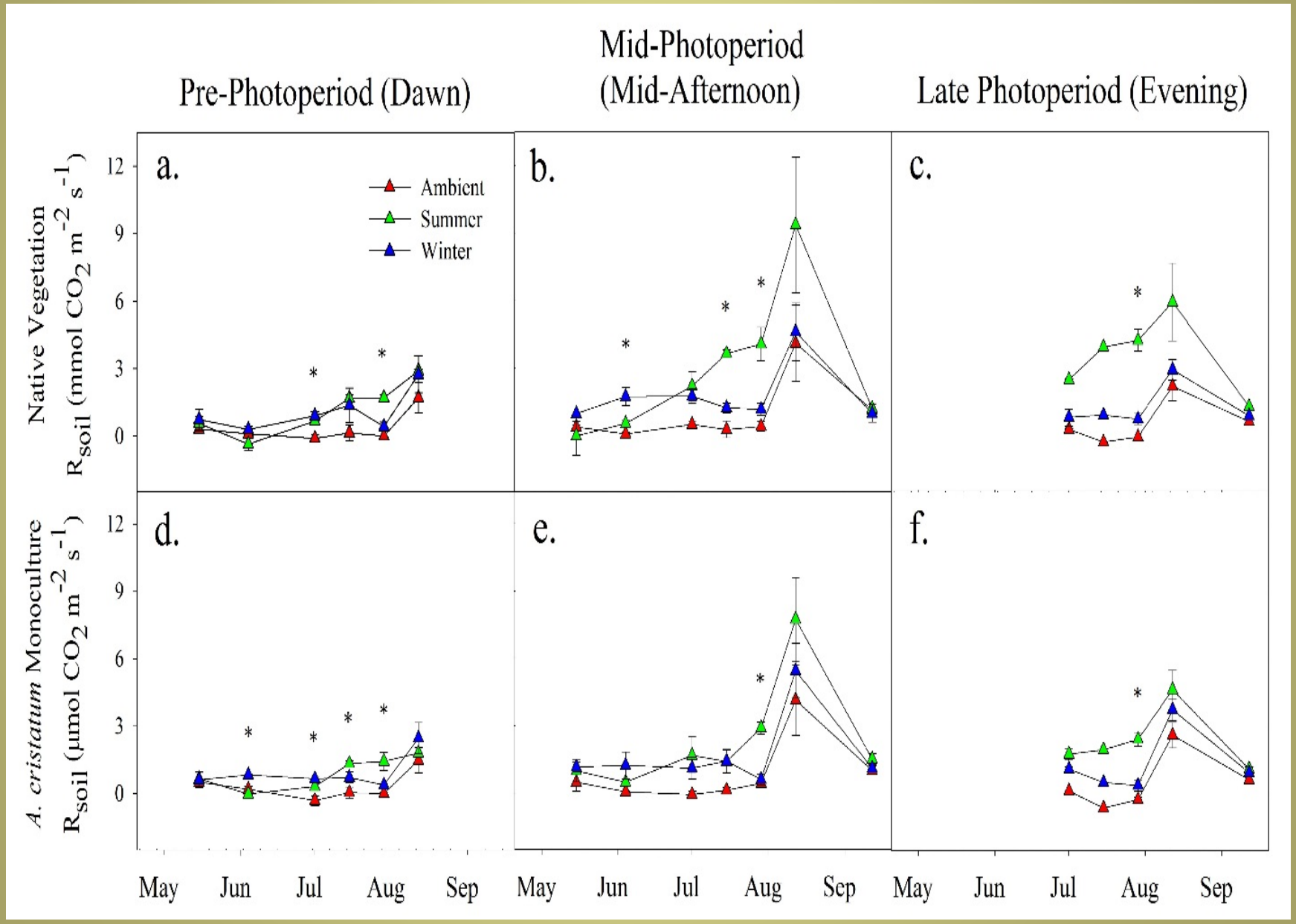
Děkuji

Cumulative NEE (across growing season)



McAbee et al., in prep

Soil respiration



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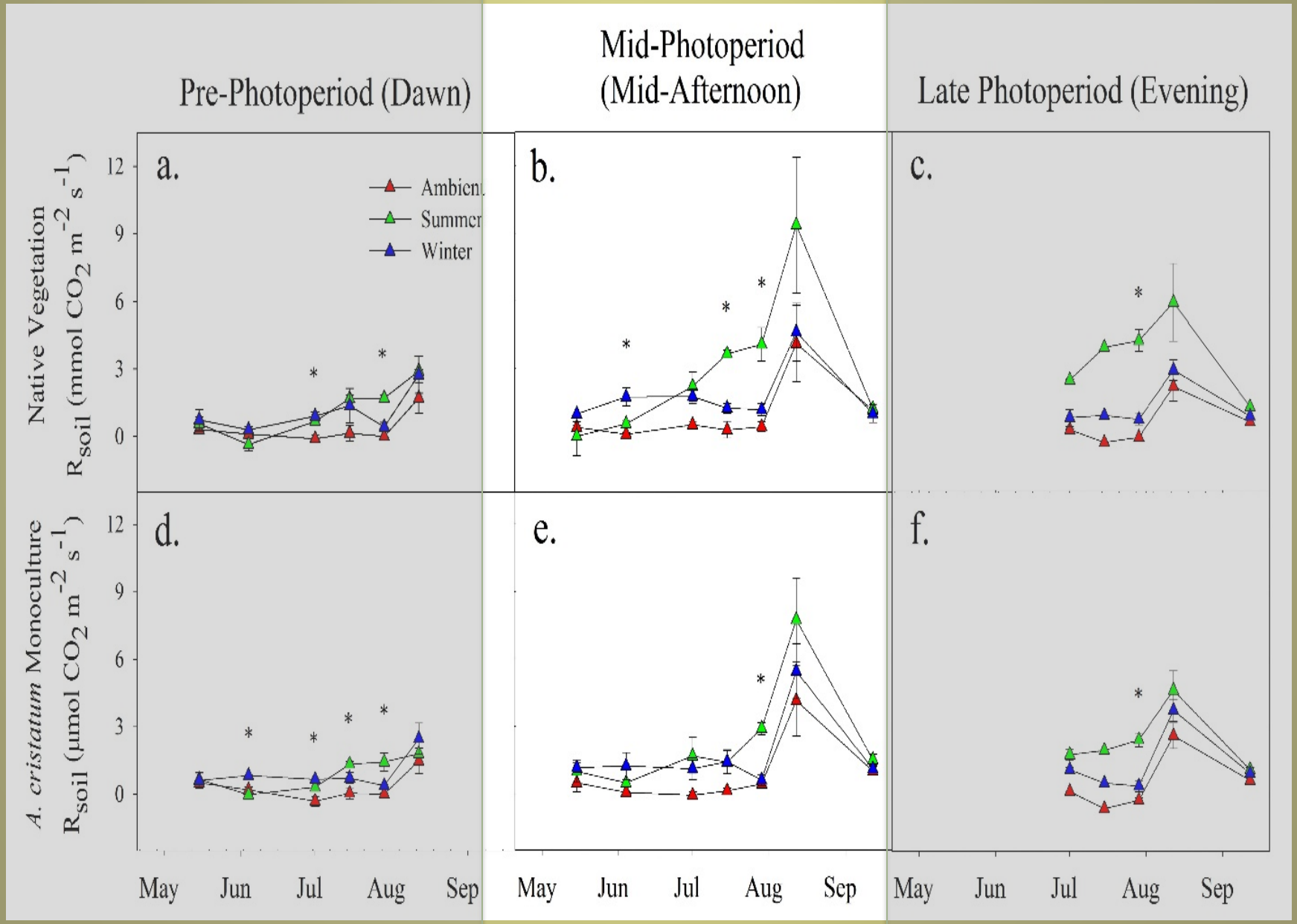
Soil respiration



McAbee et al., in prep

Nearly 3x as much carbon in winter plots!!