Section 3:
Mechanisms of influence: Basic ecology

Learning outcomes

- mechanisms by which temperature and moisture influence plants and animals
- adaptations of plants and animals that allow them to live in suboptimal environments

Environmental Gradients

Different plants have different climate factors

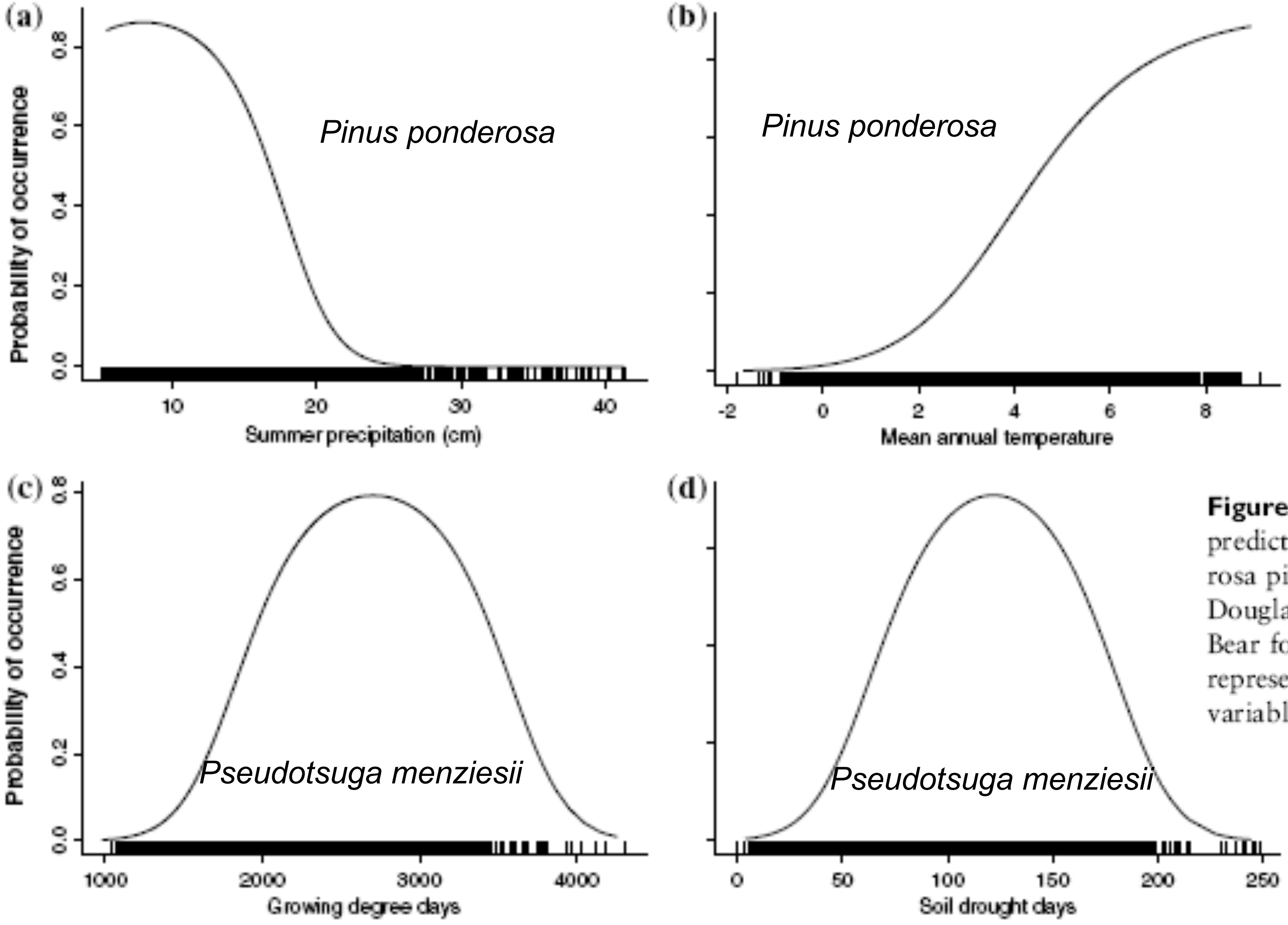


Figure 2 Unimodal/Gaussian responses are predicted by the models. (a) and (b) ponderosa pine on the Wenatchee NF. (c) and (d) Douglas-fir on the Wenatchee and Grizzly Bear forests. Density bands along the *X*-axis represent individual values of the predictor variables.

McKenzie et al., 2003

Environmental Gradients

Range and density

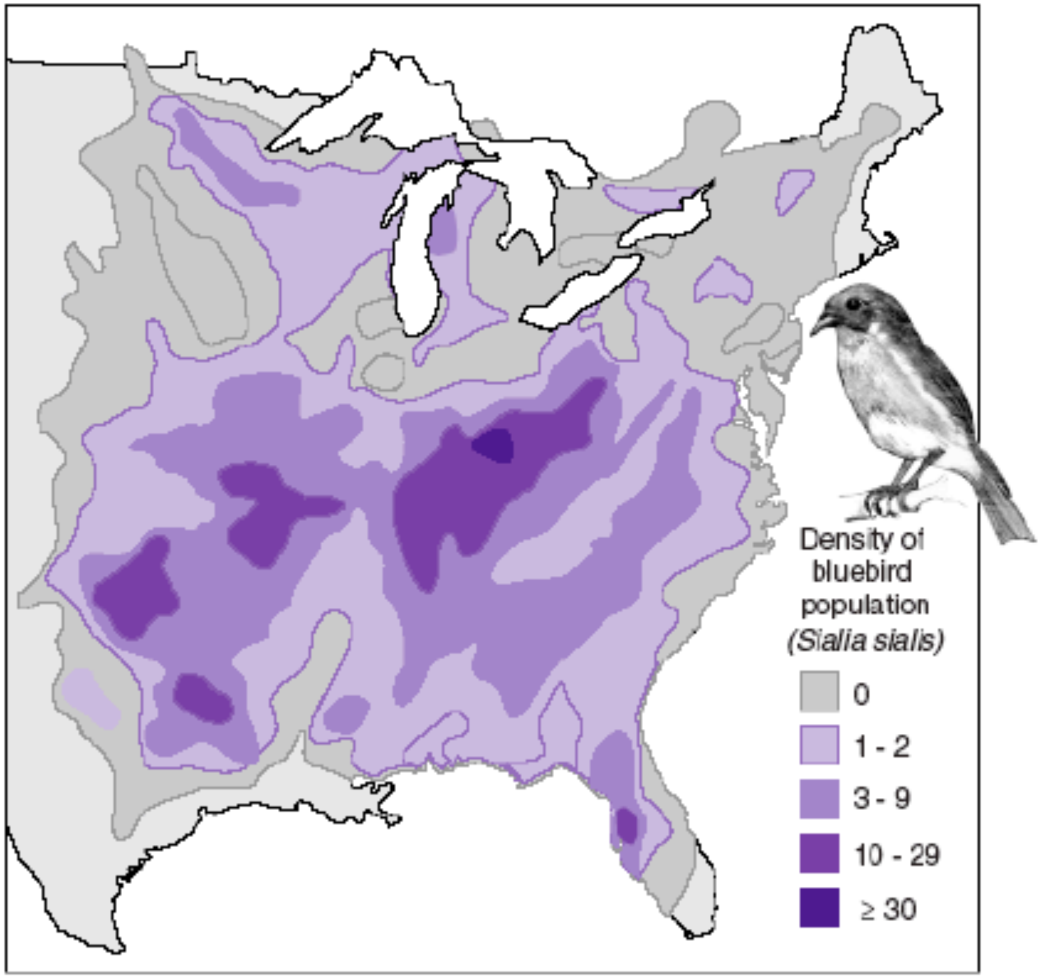
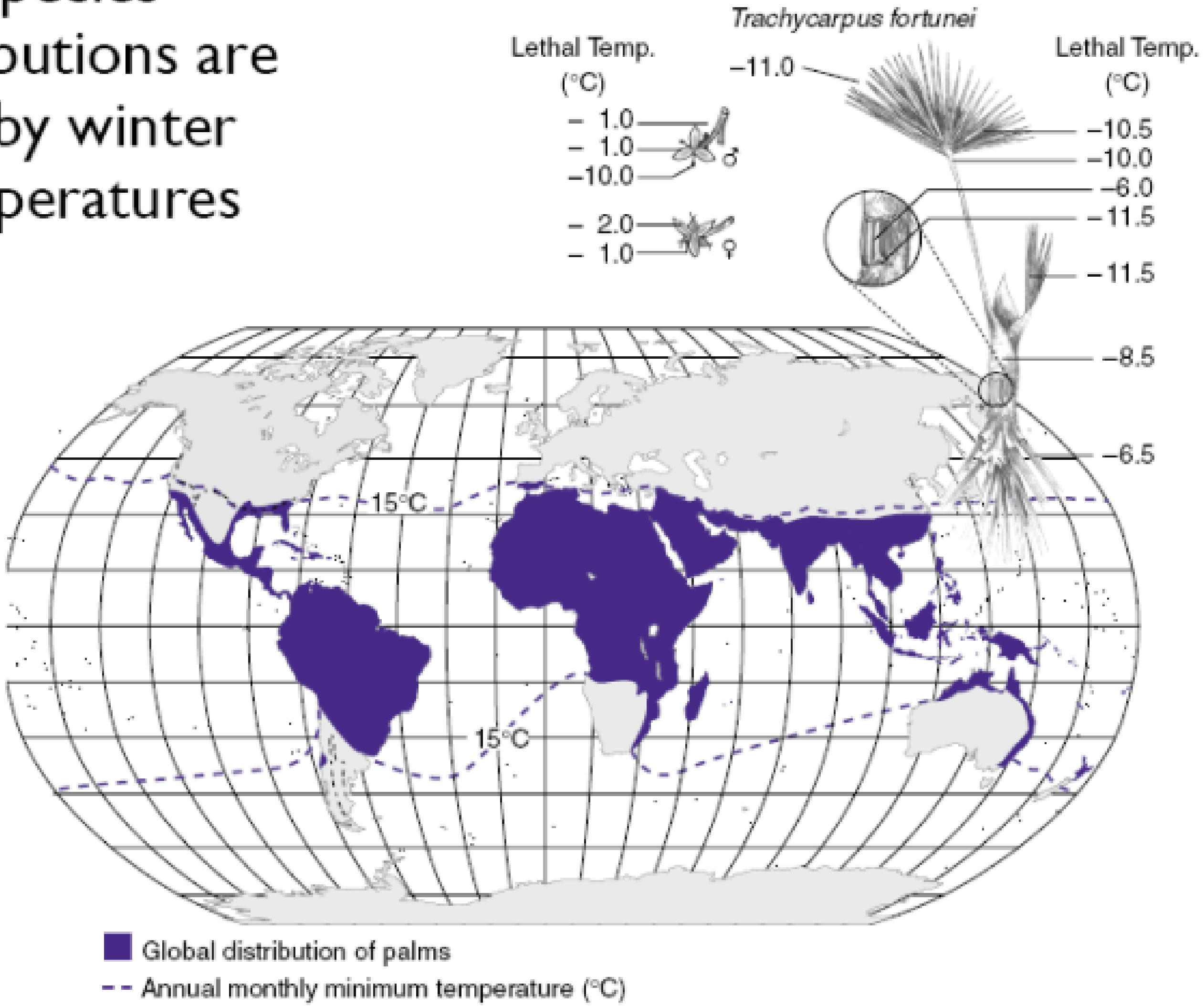


FIGURE 3.12 The range and population density of eastern Bluebird *(Sialia sialis)* in North America. Notice how population density is greatest in patches near the center of the geographic range (after Bystrak, 1979 and Brown and Gibson, 1983).

MacDonald, 2008

Temperature

some plant species distributions are set by winter temperatures



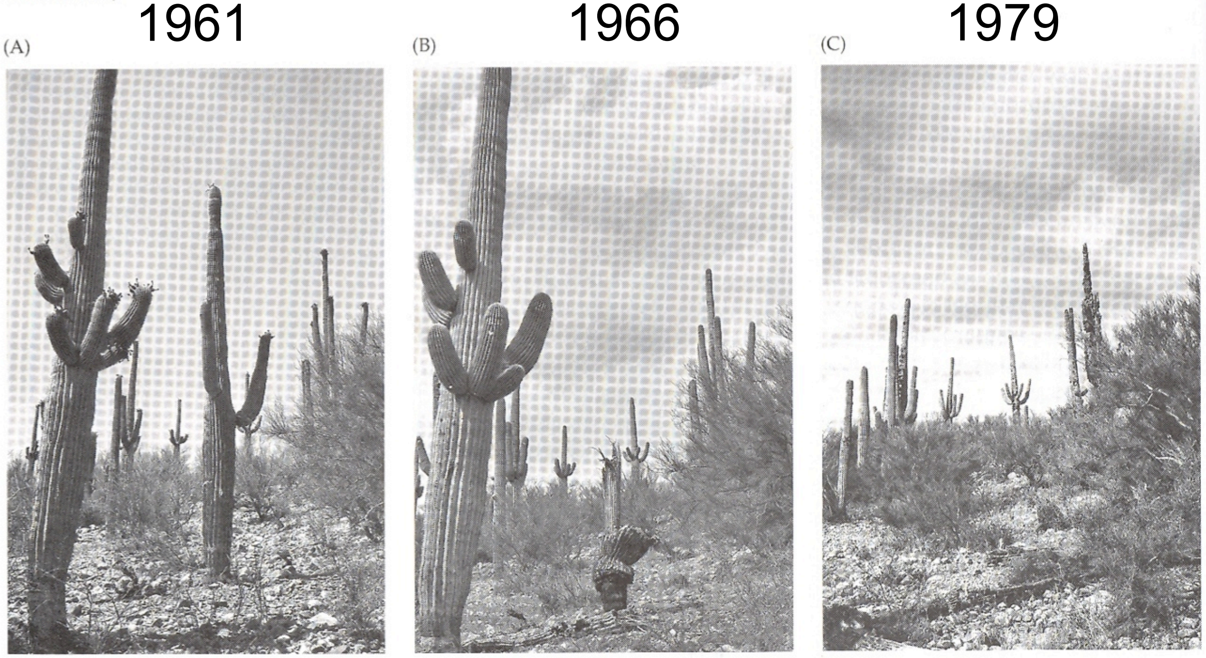
Slide courtesy of C. Still

Temperature

Temperature and the saguaro cactus (*Carnegiea gigantea*)

FIGURE 4.19 Matched photographs of a stand of saguaro cacti near Redington, Arizona, near the upper elevational and northern edge of the species' range. (A) In 1961. (B) In 1966, showing the loss of one large individual (center foreground) and scars (white patches near tips of arms) on several other cacti as a result of severe frost in 1962. (C) In 1979, showing much additional mortality due to severe frosts in 1971 and 1978; several of the individual cacti still standing are dead or dying. (A and B courtesy of J. R. Hastings; C courtesy of R. M. Turner.)

Frost damage in 1962:



Lomolino et al., 2006

0 deg C for >24 hours

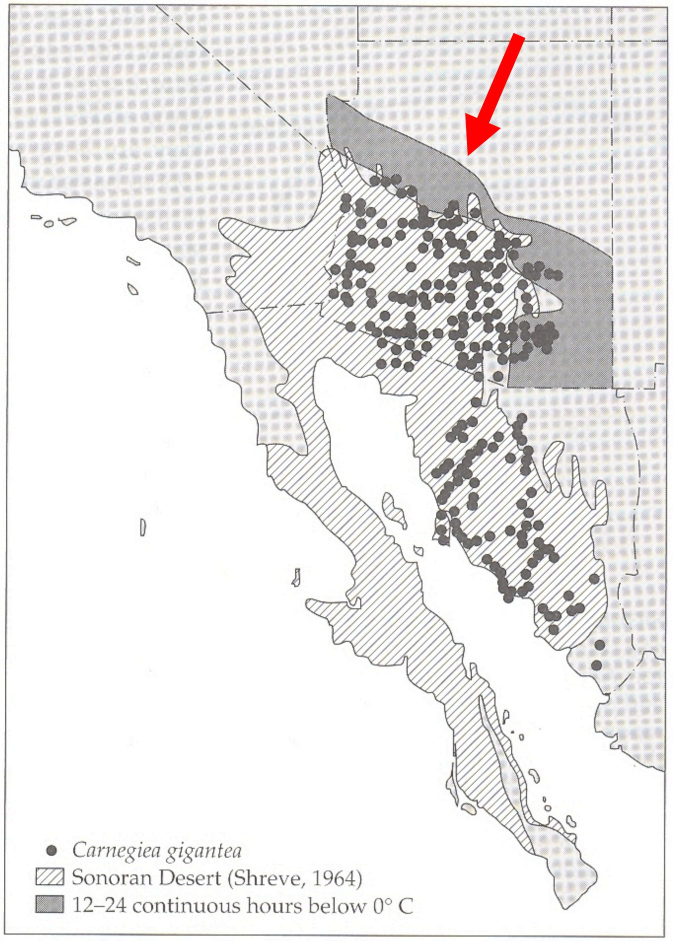


FIGURE 4.18 Distribution of the saguaro cactus (*Carnegiea gigantea*) in relation to winter temperature regime. This cactus, like many other Sonoran Desert plants, is intolerant of prolonged freezing. Note the close correspondence between the northern limit of the saguaro, the northern boundary of the Sonoran Desert, and the region where temperatures remain below 0° C for more than 12 hours. (Data from Hastings and Turner 1965; Hastings et al. 1972).

Temperature

other plant species distributions are set by summer temperatures and the length of the growing season

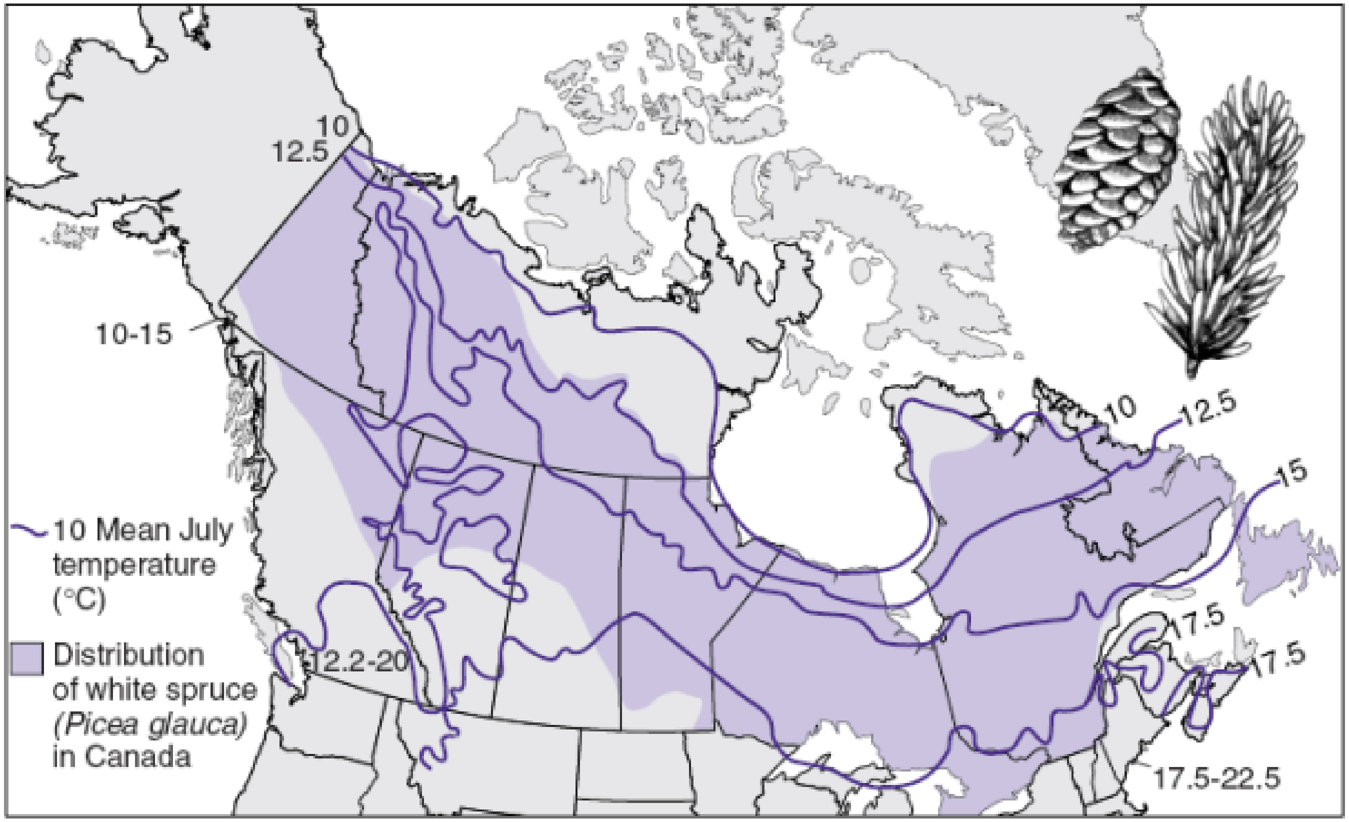


FIGURE 3.4 The relationship between the northern limits of spruce and July temperatures in Canada.

Slide courtesy of C. Still

Temperature

Animals: Temperature effects on distributions

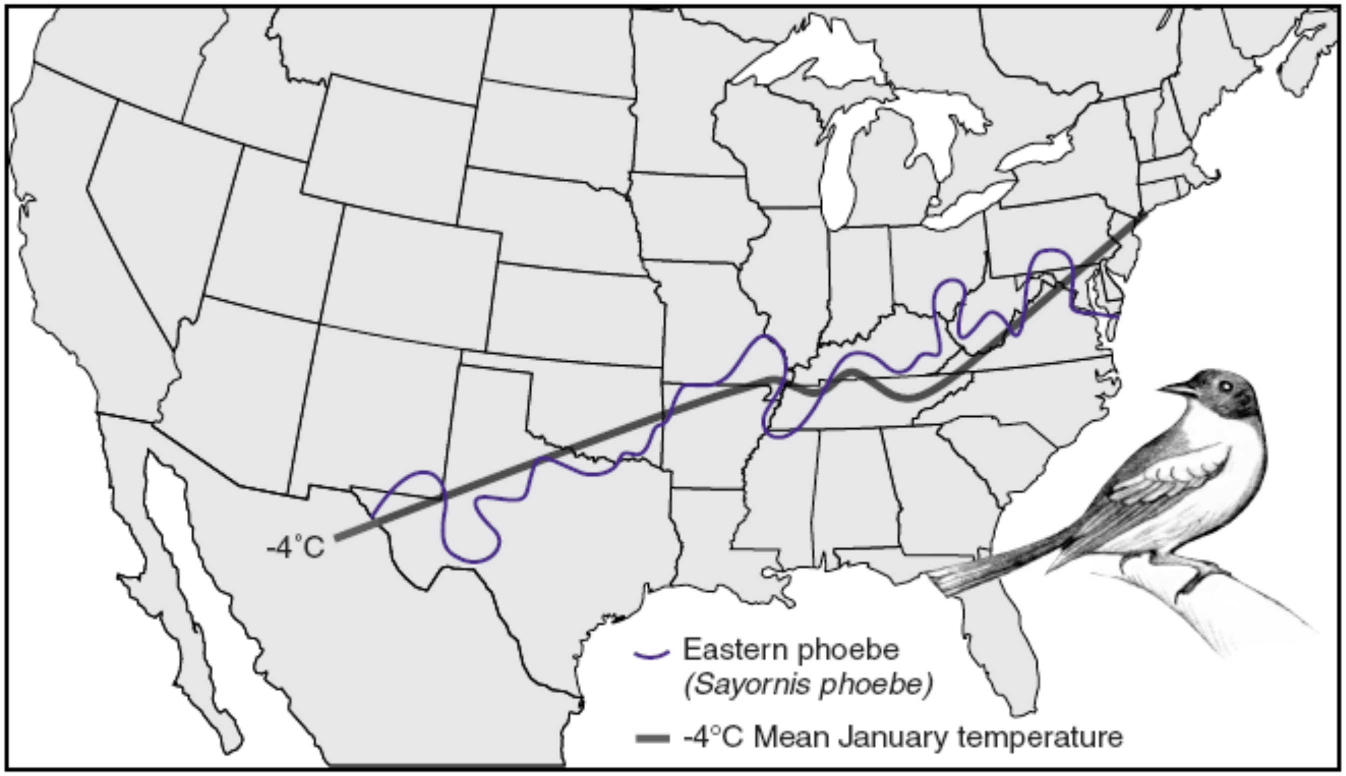


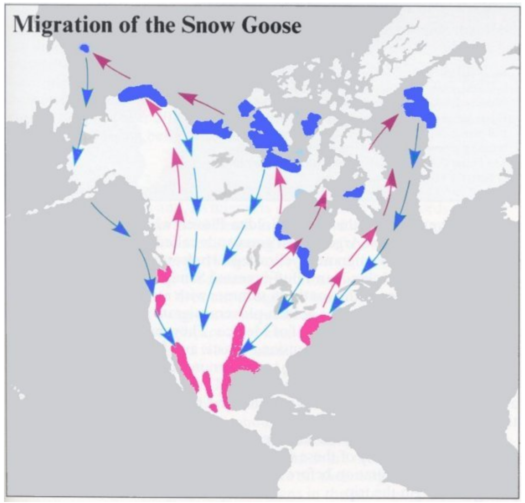
FIGURE 3.8 The relation between January temperature and the northern limits of the eastern phoebe *(Sayornis phoebe)*. North of the –4° C January isotherm, the birds cannot obtain food in sufficient quantities to support the metabolic activity required to maintain their body temperature above lethal levels (after Root, 1993).

Temperature

Animals: Temperature adaptations to cold

Migration

North-south



www.paulnoll.com/Oregon/Birds/Avian-migration.html

Higher-lower

www.oregonzoo.org/Cards/Cascades/elk.roosevelt.htm

Temperature

Animals: Temperature adaptations to cold

Physiology

Cold hardening of mountain pine beetle

Decrease of supercooling point as winter progresses

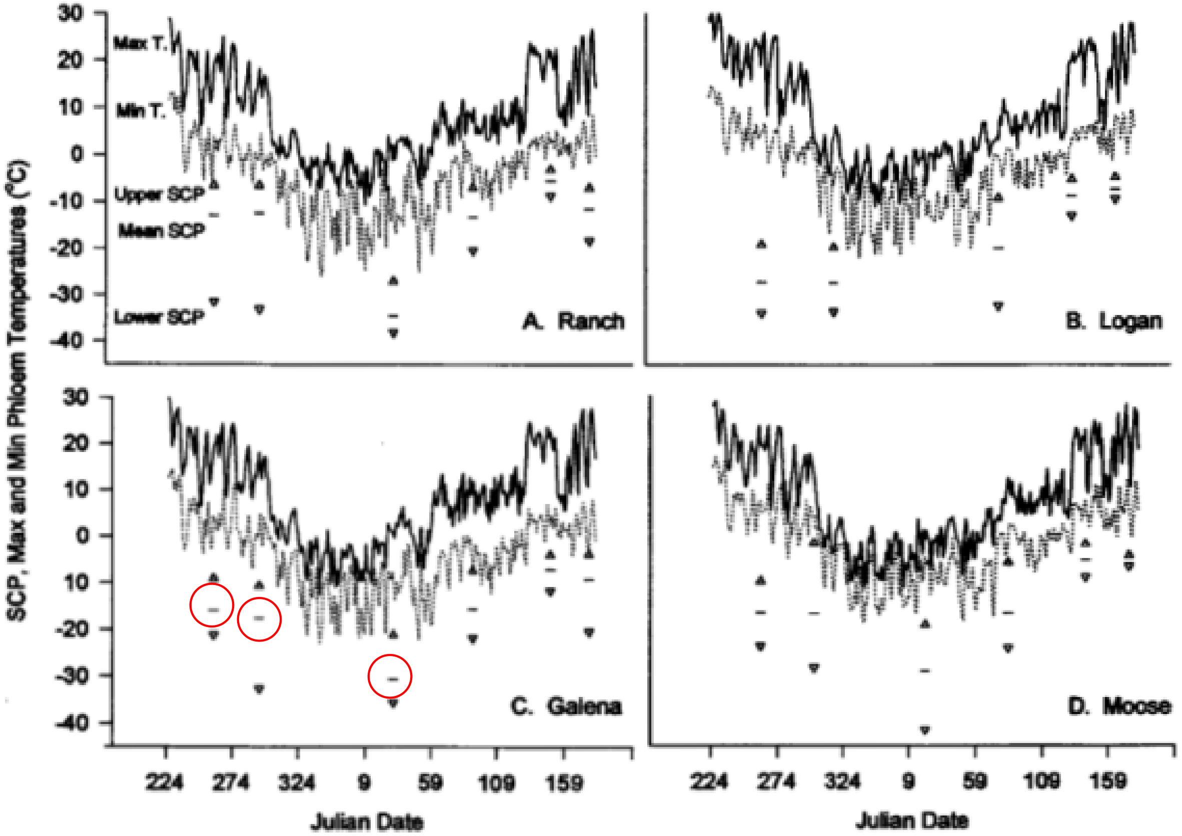


Fig. 1. Maximum and minimum phloem temperatures (T, °C) at 4 sites (A–D) in 1992–1993 with the mean (—) and range (△, ▽) of associated larval supercooling points (SCP) (°C).

Bentz and Mullins, 1999

Temperature

Animals: Temperature adaptations to heat

Shelter

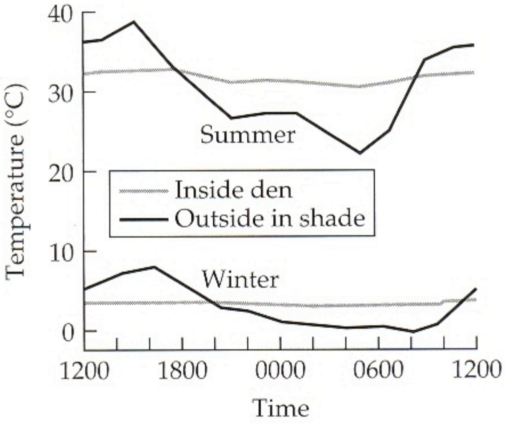


FIGURE 3.18 Temperatures inside and outside the den of a bushy-tailed woodrat (*Neotoma cinerea*) and a deep crack between large boulders in the high desert of southeastern Utah during midsummer and midwinter. Because the den (where the animal spends most of its time) experiences much less variation than the macroclimate outside, it affords vital protection from stressfully high and low temperatures in summer and winter, respectively. (After Brown 1968.)

Lomolino et al. 2006

homepages.gac.edu/~cjgroh/classes/TZPictures.html

Temperature

Animals: Temperature adaptations to heat

Morphology

“Cool” adaptations to hot conditions

Elephant (*Loxodonta africana*)

Chameleons (*Chamaeleo*)

fohn.net/elephant-pictures-facts

www.african-safari-journals.com/chameleon-pictures.html

Temperature

Temperature affects sex ratio of turtle hatchlings

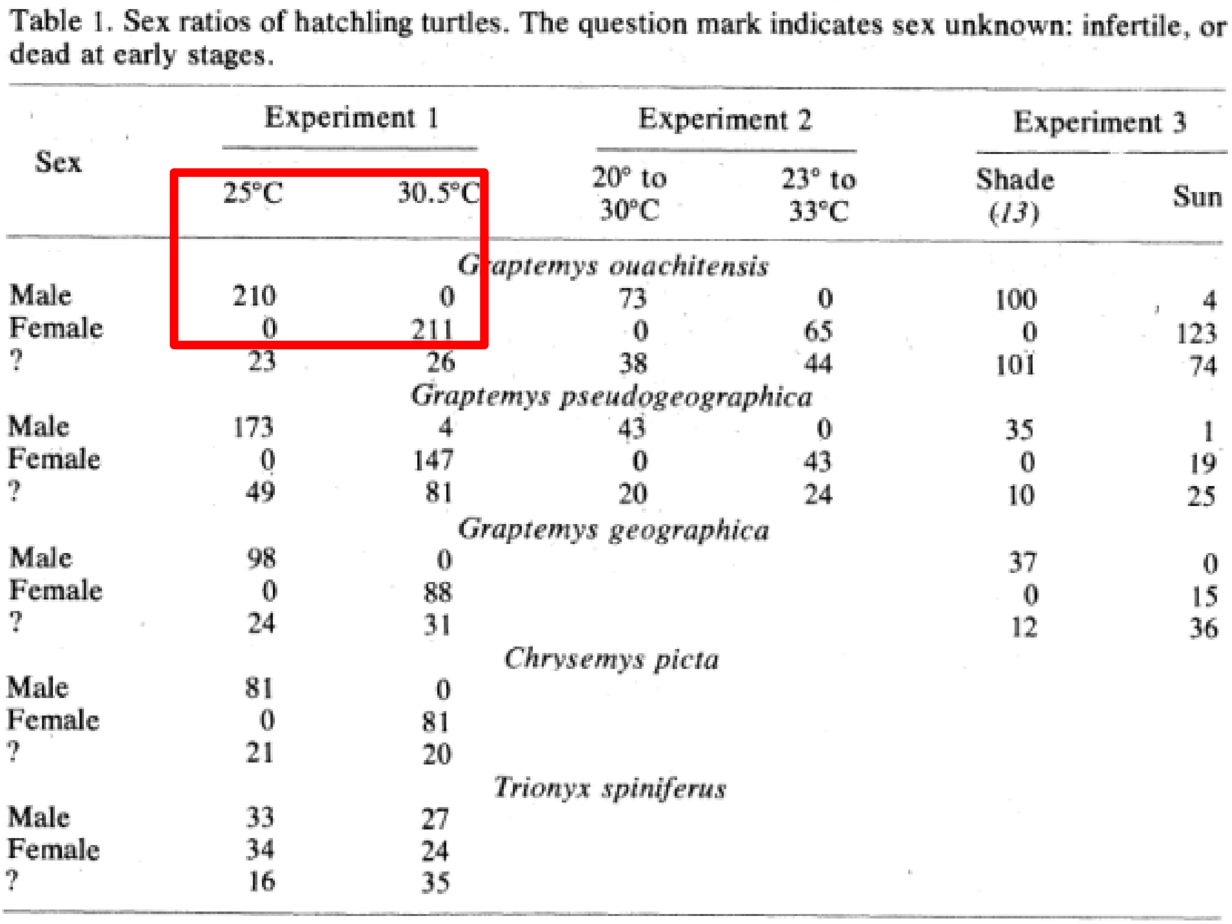


Table 1. Sex ratios of hatchling turtles. The question mark indicates sex unknown: infertile, or dead at early stages.

Sex	Experiment 1		Experiment 2		Experiment 3	
	25°C	30.5°C	20° to 30°C	23° to 33°C	Shade (*13*)	Sun
			Graptemys ouachitensis			
Male	210	0	73	0	100	4
Female	0	211	0	65	0	123
?	23	26	38	44	101	74
			Graptemys pseudogeographica			
Male	173	4	43	0	35	1
Female	0	147	0	43	0	19
?	49	81	20	24	10	25
			Graptemys geographica			
Male	98	0			37	0
Female	0	88			0	15
?	24	31			12	36
			Chrysemys picta			
Male	81	0				
Female	0	81				
?	21	20				
			Trionyx spiniferus			
Male	33	27				
Female	34	24				
?	16	35				

Implications of global warming?

Bull and Vogt, 1979

Moisture

Soil moisture controls on woody plants in desert Southwest

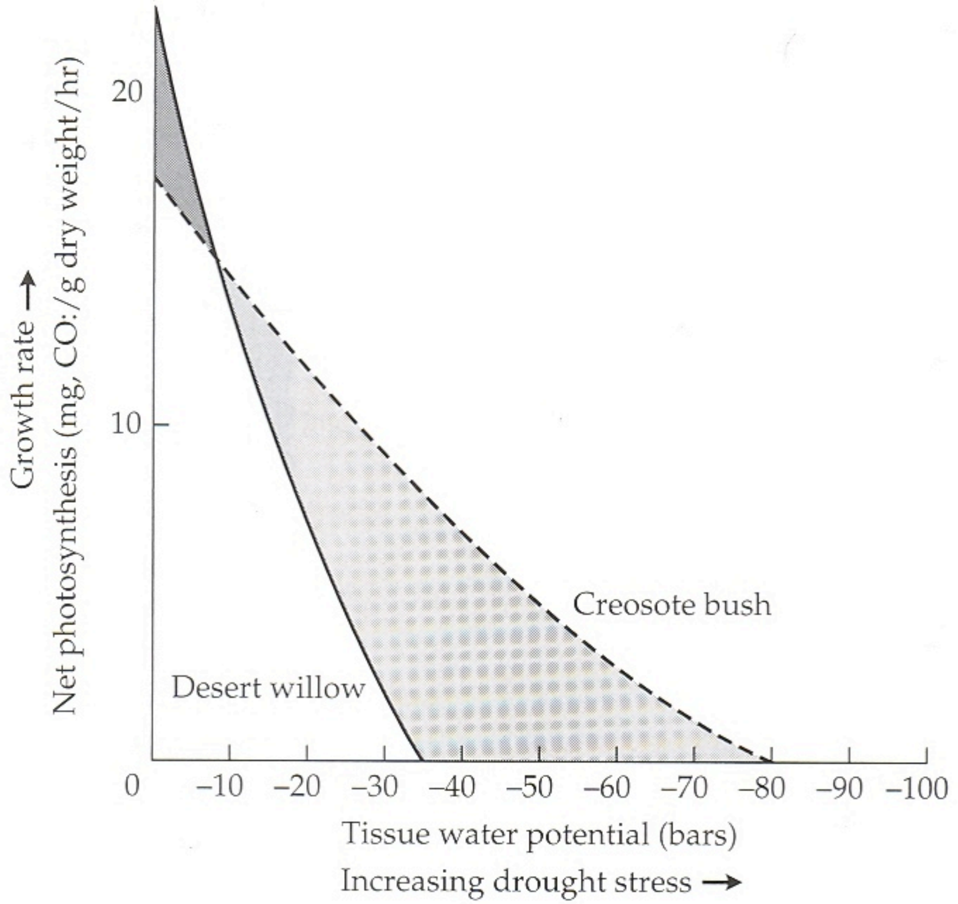


FIGURE 4.23 Trade-offs between growth rate and drought tolerance in two species of desert shrubs: creosote bush (*Larrea tridentate*), which grows in some of the driest North American deserts; and desert willow (*Chilopsis linearis*), which has an overlapping geographic range, but is more mesophytic, occurring in microhabitats along watercourses where the soil is permanently moist. Note that under relatively high drought stress (light gray region) creosote bush has the higher net photosynthetic rate and is able to grow faster, shade, and competitively exclude desert willow. (After Odening et al. 1974.)

Lomolino et al. 2006

Moisture

Moisture stress on plants: mortality

Croplands

http://soilcrop.tamu.edu/photogallery/cornsorghum+/images/drought%20stress%203.jpg

Pinyon pine in SW

Photo by Craig Allen - USGS

Moisture

Soil moisture controls on tree species distribution in PNW

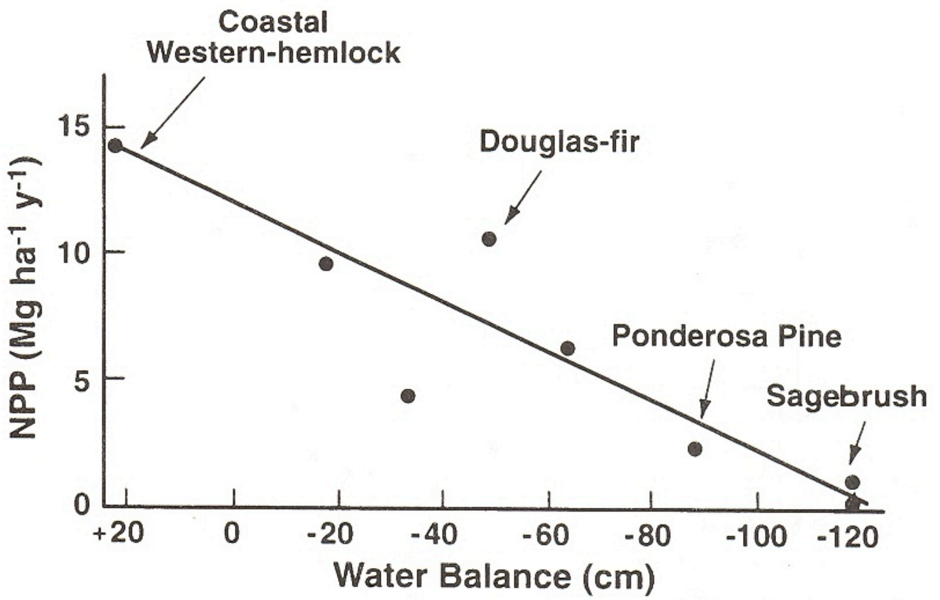


Figure 18.15. The water balance and aboveground net primary productivity (ANPP) of ecosystems in the Pacific Northwest. The relationship between water balance and ANPP emphasizes the idea that increases in water availability along climatic gradients in mountainous regions relate to an increase in net primary productivity. (After Gholz, 1982. Reprinted with permission of the Ecological Society of America.)

Barnes et al., 1998

Moisture

Rooting depth in arid landscape controls species distribution

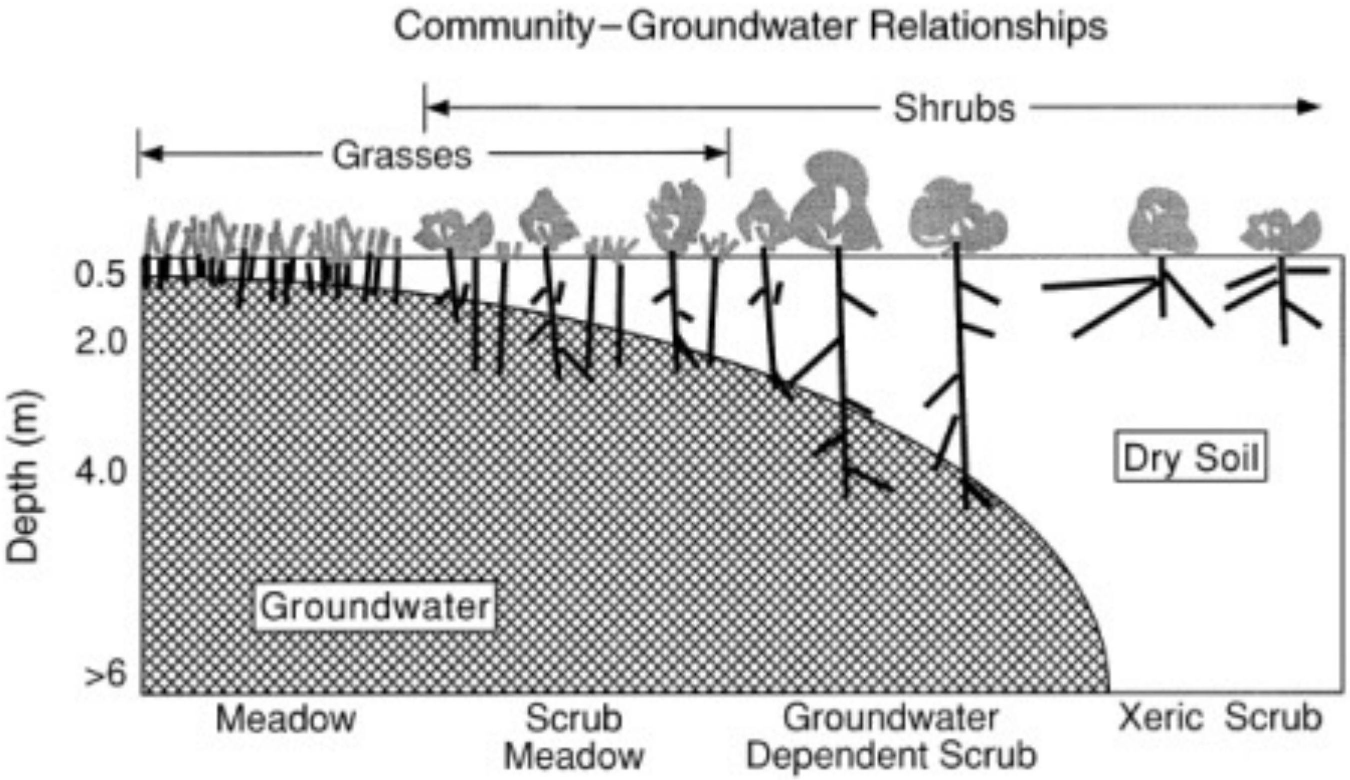
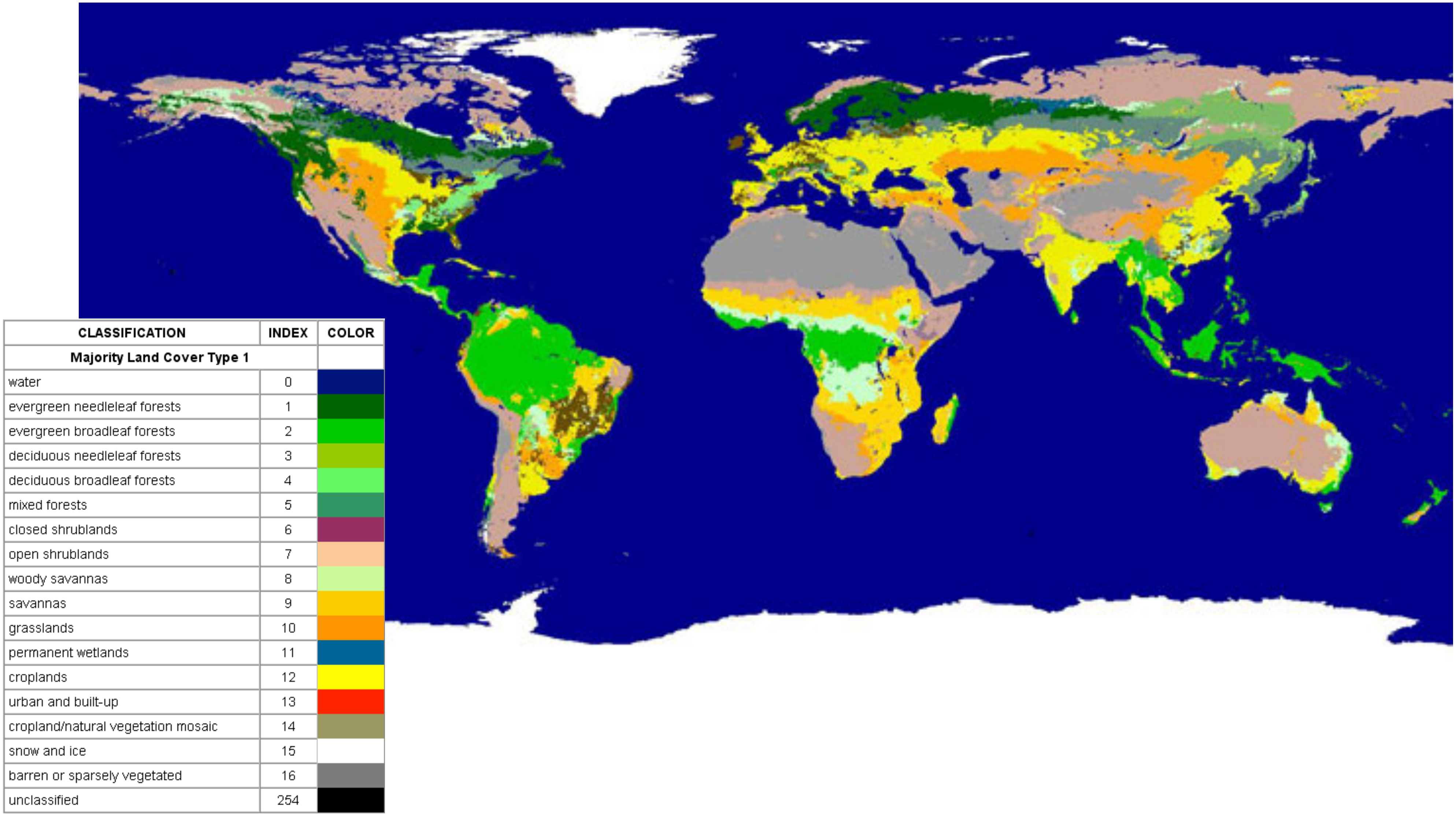


FIG. 2. Phreatophytic plant communities in Owens Valley are distributed on the landscape according to patterns of groundwater availability. Meadow communities require shallow water tables, a mixture of shrubs and grasses occur at intermediate water table depths, and shrubs dominate the deepest levels. Xeric shrub communities, as defined here, require no groundwater resources. Exotic annuals can compete with varying success at any point on this gradient.

Elmore et al., 2003

Moisture

Controls of soil moisture at larger scale

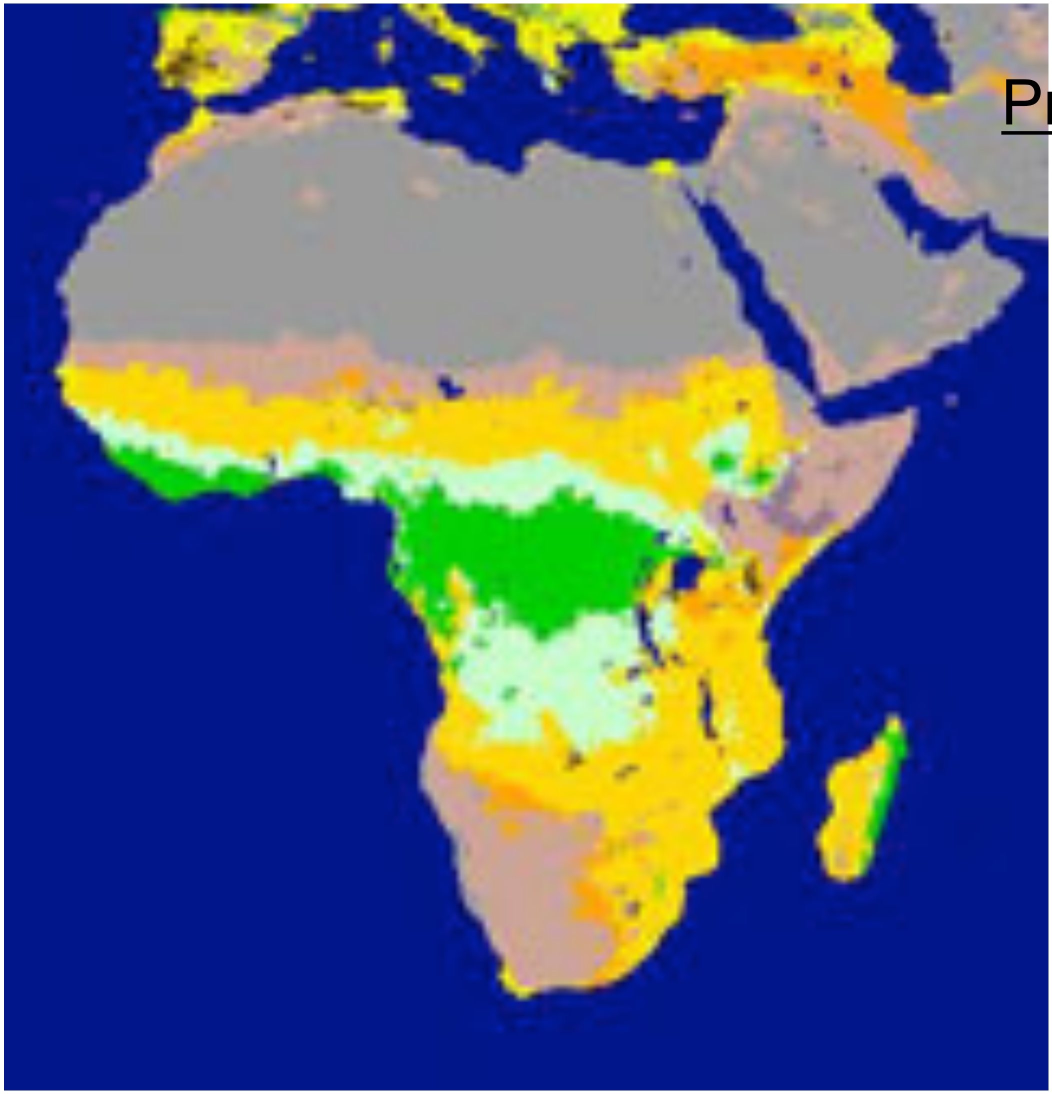


CLASSIFICATION	INDEX	COLOR
Majority Land Cover Type 1		
water	0	🟦
evergreen needleleaf forests	1	🟩
evergreen broadleaf forests	2	🟩
deciduous needleleaf forests	3	🟩
deciduous broadleaf forests	4	🟩
mixed forests	5	🟩
closed shrublands	6	🟪
open shrublands	7	🟧
woody savannas	8	🟩
savannas	9	🟨
grasslands	10	🟧
permanent wetlands	11	🟦
croplands	12	🟨
urban and built-up	13	🟥
cropland/natural vegetation mosaic	14	🟫
snow and ice	15	⬜
barren or sparsely vegetated	16	⬛
unclassified	254	⬛

Friedl et al.

Moisture

Controls of soil moisture at larger scale



Precip	Biomass	Veg type
dry	none	none
		shrublands
		savannas
wet	high	dense forest
dry	none	

Friedl et al.

Moisture

Plant strategies to deal with drought: 1. Escapees

- Perennials (dormancy)
- Annuals (“emphemerals”)

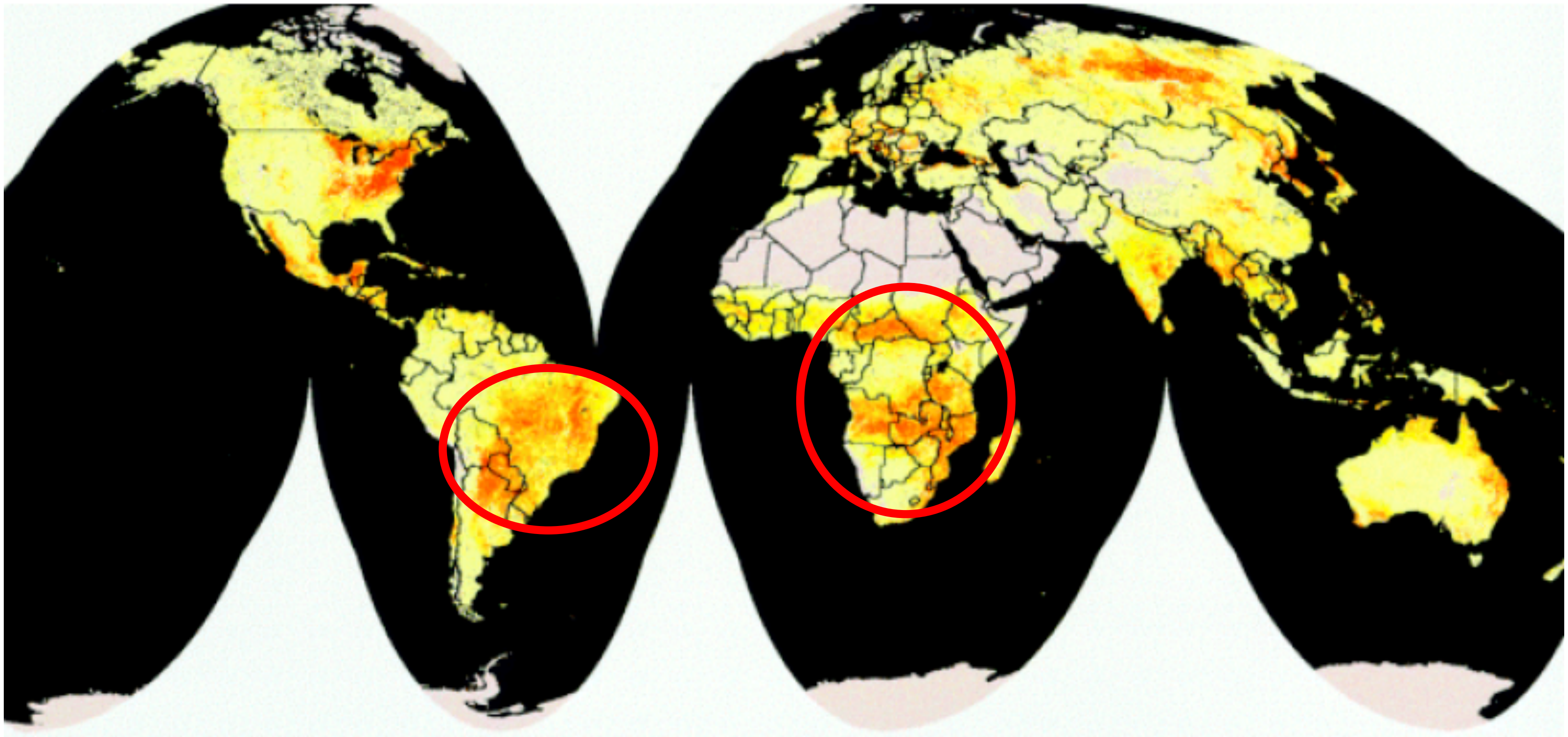
Still very dry and nothing is blooming yet, photo from Anza Borrego Desert State Park on Jan. 1, 2007

www.desertusa.com/wildflo/wildupdates.html

Moisture

Plant strategies to deal with drought: 2. Avoiders

another strategy: shed leaves (drought deciduous)
focus on subtropical forests with high % deciduous



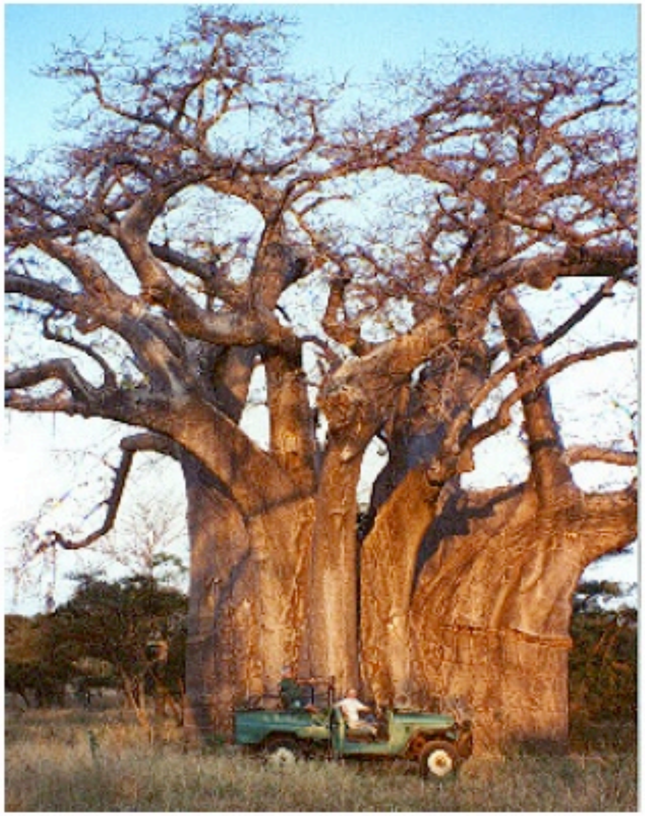
Slide courtesy C. Still

DeFries et al., 2000

Moisture

Plant strategies to deal with drought: 2. Avoiders

store water in the trunk (up to 120,000 liters!)



http://www.safari-tours.com/pgbs/images/lodges/baobab.jpg

have deep roots (*Larrea tridentata* roots measured to 53 m!)

Slide courtesy C. Still

Moisture

Adaptations to low water availability

Namib Desert beetle (*Onymacris unguicularis*)

morphology adaptations to capture fog:
- bumps on back
- channels to mouth
- head down behavior

can capture 40% of body weight in one morning

www.nacoma.org.na/Pictures/Photos/Beetle.jpg

http://www.biomechanics.bio.uci.edu/_html/nh_biomech/namib/beetle.htm

Multiple factors/interactions

What factors limit white spruce at its northern and southern extent?

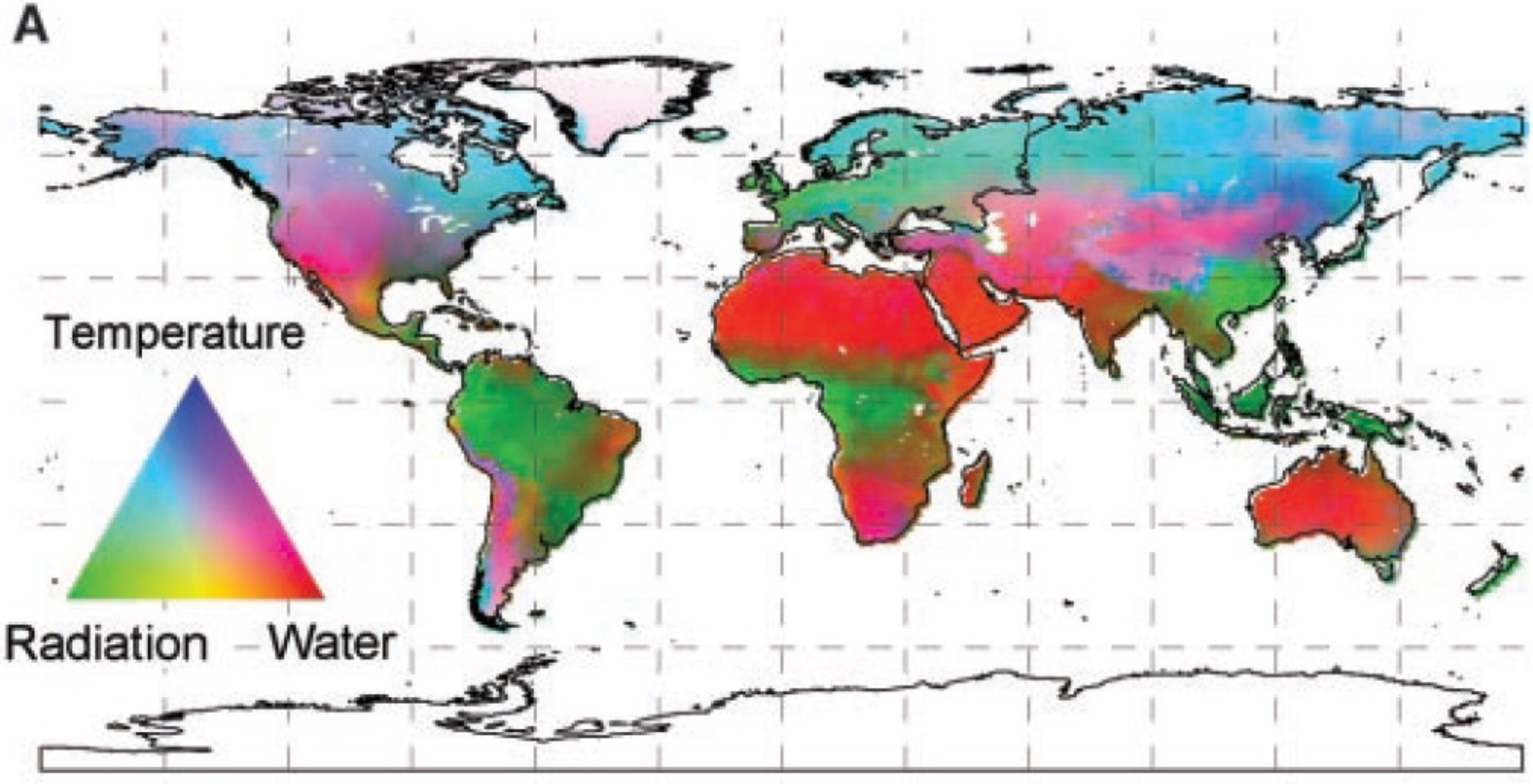
Summer temperatures

FIGURE 3.4 The relationship between the northern limits of spruce and July temperatures in Canada.

Moisture stress (high summer temps, low precip)

Multiple factors/interactions

Controls on Net Primary Production



Nemani et al., 2003

Annual water balance and climatic water deficit

Sierra Nevada, CA: Coniferous

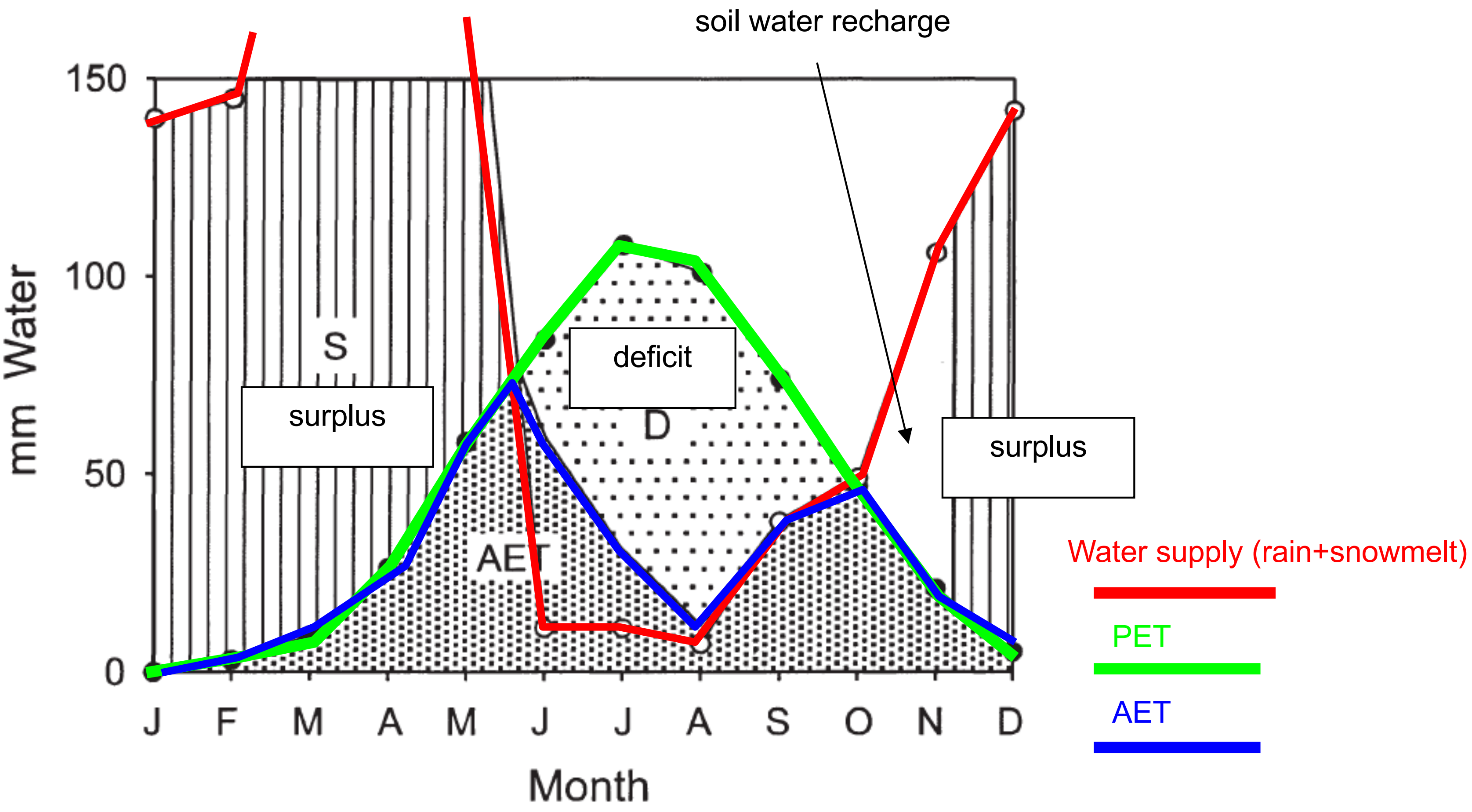
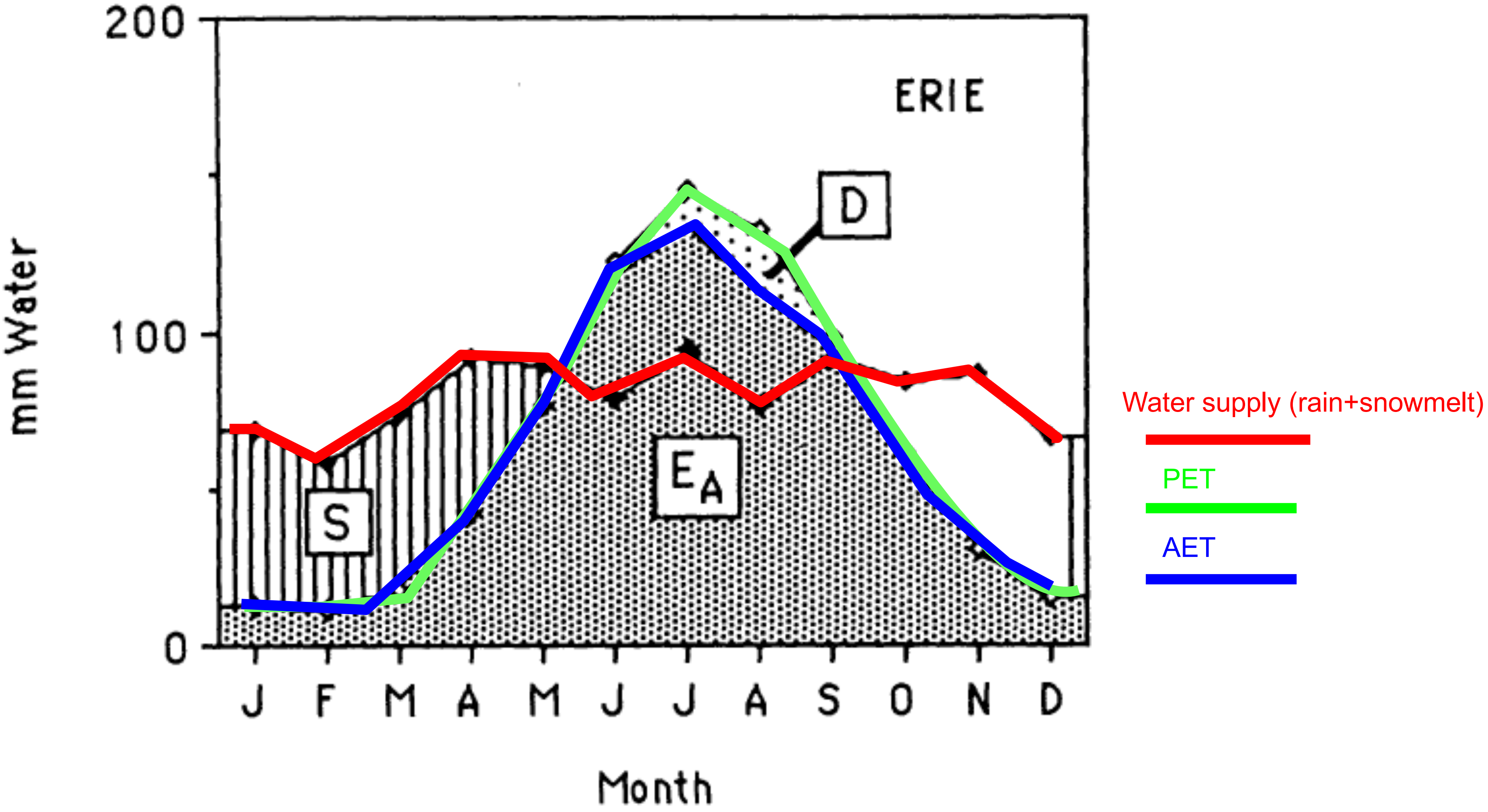


FIG. 1. The annual water balance of a site on level ground, soils of 0.5 m depth, at 2000 m elevation, and in the wet Kaweah watershed of the southern Sierra Nevada (data from Stephenson, 1988). From October through May, water supply (rain plus snowmelt, ○) exceeds evaporative demand (potential evapotranspiration or PET, ●); during this period, actual evapotranspiration (AET, *dense stippling*) equals PET. In October and November, excess water replaces soil water used during the summer; the white area between the water supply and PET curves represents soil–water recharge. From November through May, after soil water has been replenished, the difference between water supply and PET is surplus (S, *vertical stripes*). From June through September, PET exceeds water supply. During this period, AET equals water supply plus water extracted from the soil (which is shown as the curve between the water supply and PET curves). Deficit (D, *light stippling*) is the difference between PET and AET.

Stephenson, 1998

Annual water balance and climatic water deficit

Erie, PA: Deciduous



Multiple factors/interactions

Distribution of major N. America plant formations

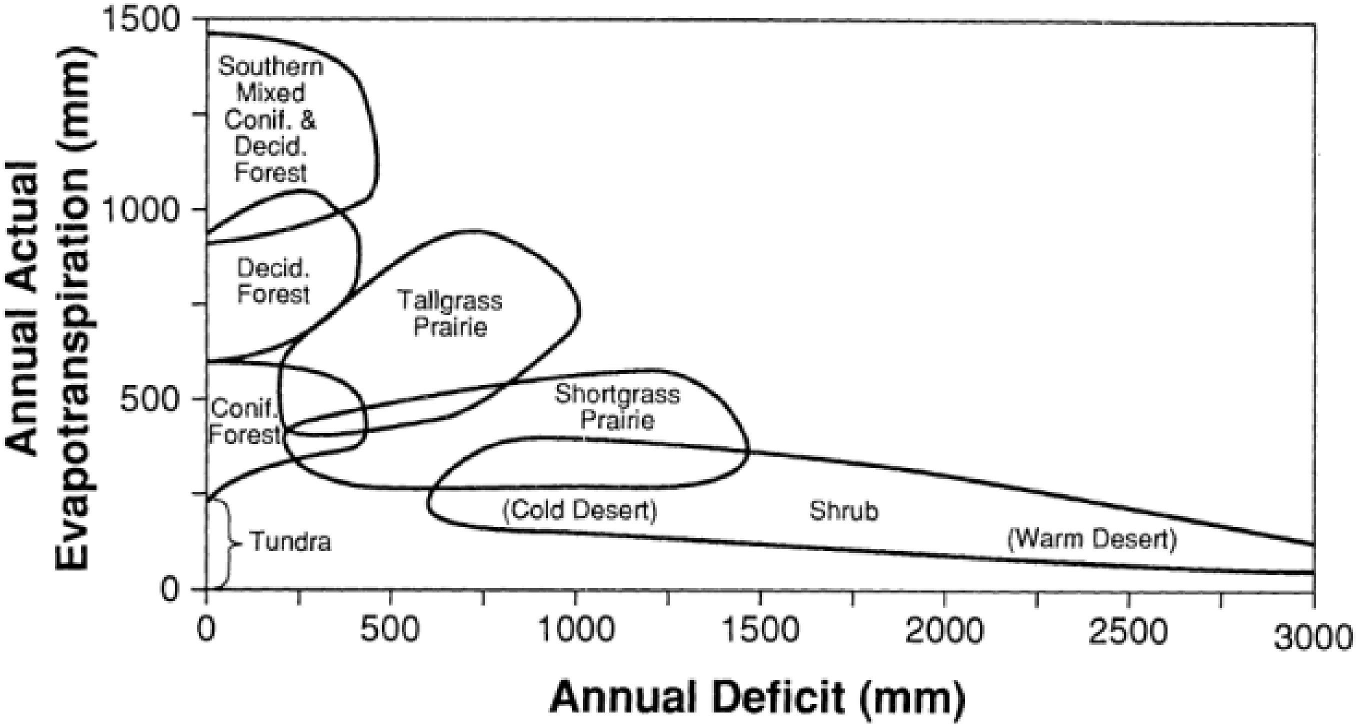


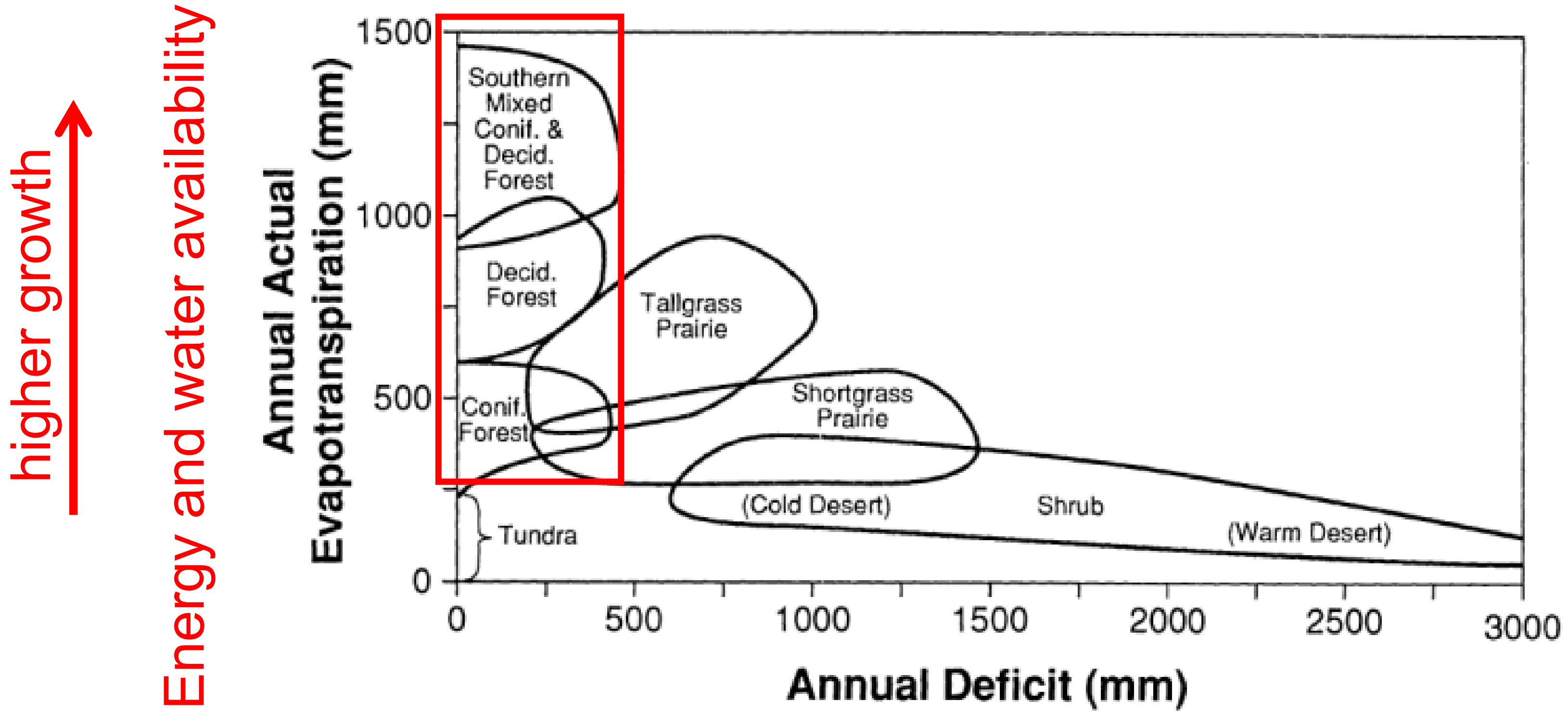
FIG. 3.—Mean annual actual evapotranspiration and deficit of the major North American plant formations. The denominator of the following fractions is the number of sites within each formation; the numerator is the number of the sites that fell within the boundary indicated for the formation. Southern mixed coniferous and deciduous forest, 34/34; deciduous forest, 60/62; coniferous forest, 28/29; tundra, 5/5; tallgrass prairie, 17/22 (17/18 when coastal prairie sites of Texas and Louisiana are eliminated; see the text); shortgrass prairie, 31/33; shrub 17/17. For clarity, the three transition formations (northern mixed forest, woodland and savanna, and shrub steppe) were not plotted. Values of actual evapotranspiration and deficit for the transition formations usually fell within the range of the formations that the transition formations physiognomically bridged (Stephenson 1988).

Stephenson, 1990

Multiple factors/interactions

Distribution of major N. America plant formations

AET: separation of different forest types



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Stephenson, 1990

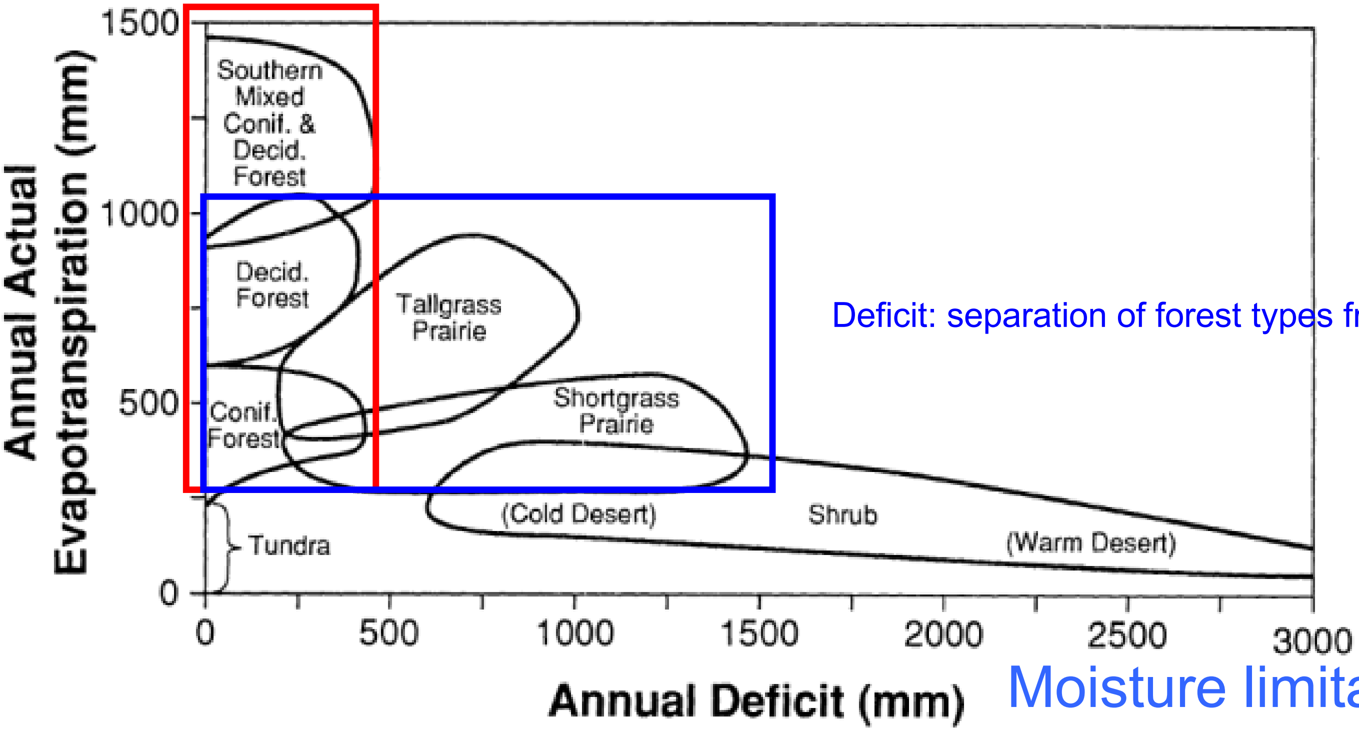
Multiple factors/interactions

Distribution of major N. America plant formations

AET: separation of different forest types

higher growth

Energy and water availability



Deficit: separation of forest types from prairie

Moisture limitation

higher growth

FIG. 3.—Mean annual actual evapotranspiration and deficit of the major North American plant formations. The denominator of the following fractions is the number of sites within each formation; the numerator is the number of the sites that fell within the boundary indicated for the formation. Southern mixed coniferous and deciduous forest, 34/34; deciduous forest, 60/62; coniferous forest, 28/29; tundra, 5/5; tallgrass prairie, 17/22 (17/18 when coastal prairie sites of Texas and Louisiana are eliminated; see the text); shortgrass prairie, 31/33; shrub 17/17. For clarity, the three transition formations (northern mixed forest, woodland and savanna, and shrub steppe) were not plotted. Values of actual evapotranspiration and deficit for the transition formations usually fell within the range of the formations that the transition formations physiognomically bridged (Stephenson 1988).

Stephenson, 1990