Carbon Sequestration in Oak Woodlands

Tom Scott

Environmental Science Policy and Management, University of California, Berkeley, CA,
Earth Sciences, University of California, Riverside, CA,

Oak Species in California: defining "Business as Usual" (BAU)

TAXA (three groups: red, white, and intermediate)	COMMON NAME	NARROW DISTRIBTUION
Quercus kelloggii Newb.	BLACK OAK	NO
Quercus agrifolia agrifolia Nee	COAST LIVE OAK	YES
Quercus agrifolia oxyadenia	(COAST LIVE OAK)	YES
Quercus wislizeni A. DC. var. *wislizeni*	INTERIOR LIVE OAK	NO
Quercus wislizeni var. *frutescens* Engelm.	(INTERIOR LIVE OAK)	NO
Quercus peninsularis	PENINSULAR OAK	YES
Quercus parvula Greene var. *parvula*	SANTA CRUZ ISLAND OAK	YES
Quercus parvula var. *shrevei* (Muller) Nixon & Muller	SHREVE OAK	YES
Quercus chrysolepis Liebm.	CANYON LIVE OAK	NO
Quercus vaccinifolia Kellogg	HUCKLEBERRY OAK	YES
Quercus tomentella Engelm.	ISLAND OAK	YES
Quercus palmeri (*Quercus dunnii*).	PALMERS OAK	NO
Quercus cedrosensis	CEDROS ISLAND OAK	YES
Quercus sadleriana R. Brown, Campst.	SADLER OAK	YES
Quercus engelmannii Greene	ENGELMANN OAK	YES
Quercus lobata Nee	VALLEY OAK	NO
Quercus douglasii H. & A.	BLUE OAK	YES
Quercus garryana Dougl. var. *garryana*	OREGON WHITE OAK	NO
Quercus garryana var. *breweri* Jeps.		YES
Quercus garryana var. *semota*		YES
Quercus dumosa Nutt. *sensus stricto*	COASTAL SCRUB OAK	YES
Quercus berberidifolia Liebm	SCRUB OAK	NO
Quercus john-tuckeri Nixon & Muller	TUCKER'S SCRUB OAK	YES
Quercus pacifica Nixon & Muller	PACIFIC OAK	YES
Quercus cornelius-mulleri Nixon & Steele	MULLER OAK	NO
Quercus durata Jeps. var. *Durata*		YES
Quercus durata var. *gabrielensis* Nixon & Muller		YES
Quercus turbinella Greene	ARIZONA SCRUB OAK	NO

Oak Growth-form Groups in California

	RED OAKS	INTERMEDIATE OAKS	WHITE OAKS
Single Stem Trees	Black Oak Coast Live Oak**		Engelmann Oak Valley Oak Blue Oak
Multi-stem Trees	Interior Live Oak Shreve Oak Peninsular Oak (BC)	Canyon Live Oak Island oak	
Intermediate Arborescent shrubs	Pacific oak	Palmer's Oak (AZ) Huckleberry Oak	Leather Shrub Live Oak
Shrubs		Cedros Isl. Oak (BC)	Sadler oak California, Tucker, Muller, Nuttall Scrub Oaks

Tree forms are critical component of biomass allocation and accumulation rates – and impact carbon sequestration

Coast Live Oak
Quercus agrifolia

Interior Live Oak
Quercus wislizeni

Canyon Live Oak
Quercus chrysolepis

Oak Distribution overall:

- Dominant over about 10 million acres of California wildlands
- Oaks and closely related taxa (tan oak, beech, chinquapin)

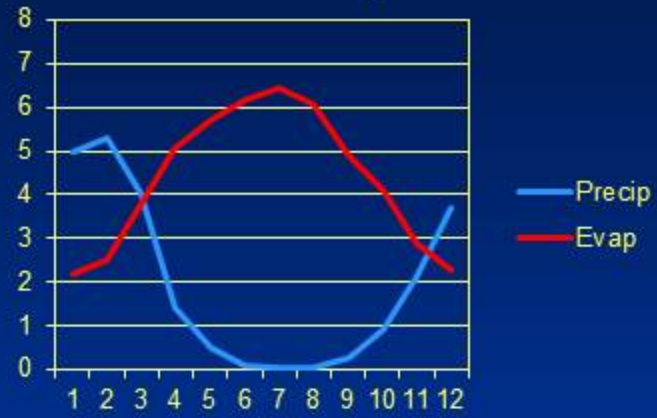
Oaks Occupy a Transition Zone

- Between forest and grass/shrub vegetation areas
- Unpredictable (boom and bust) precipitation

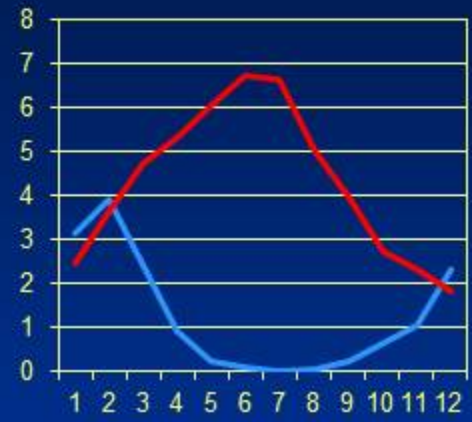
Oaks persist because their biomass tracks precipitation

Water balance in the oak ecosystems

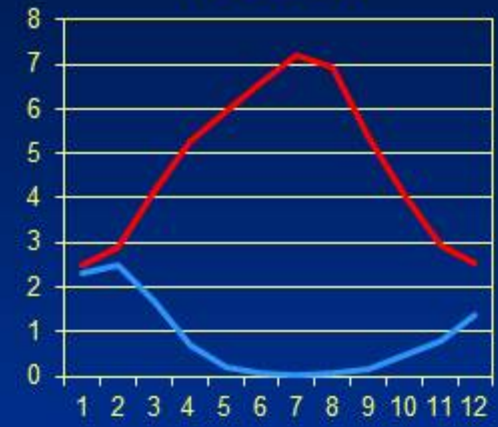
San Luis Obispo



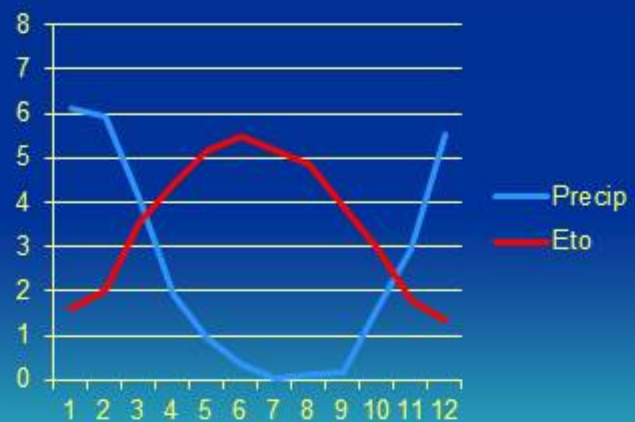
Descanso

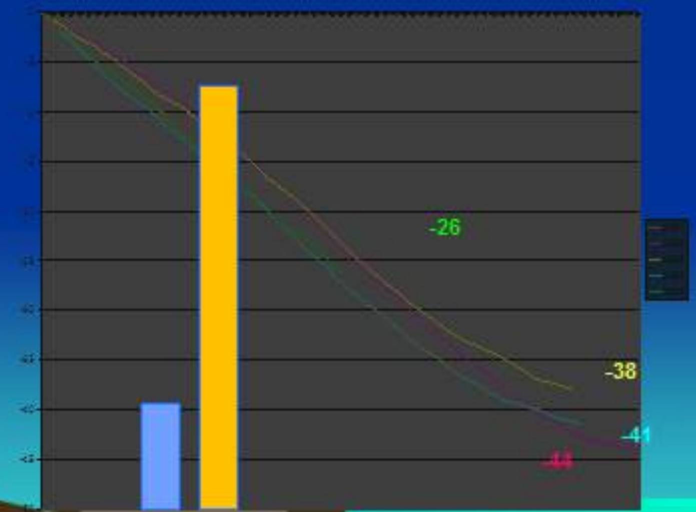


Riverside

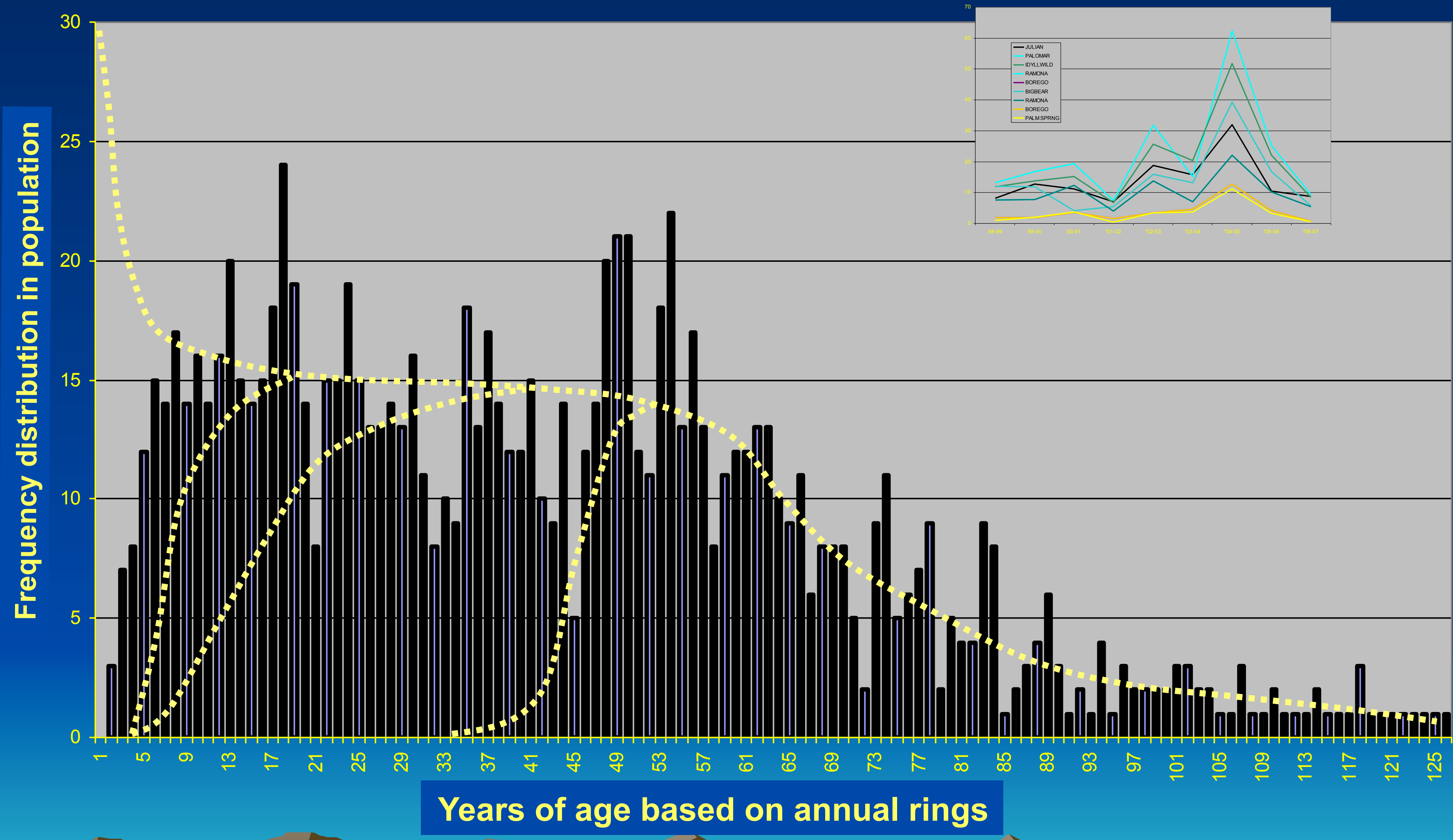


Santa Cruz





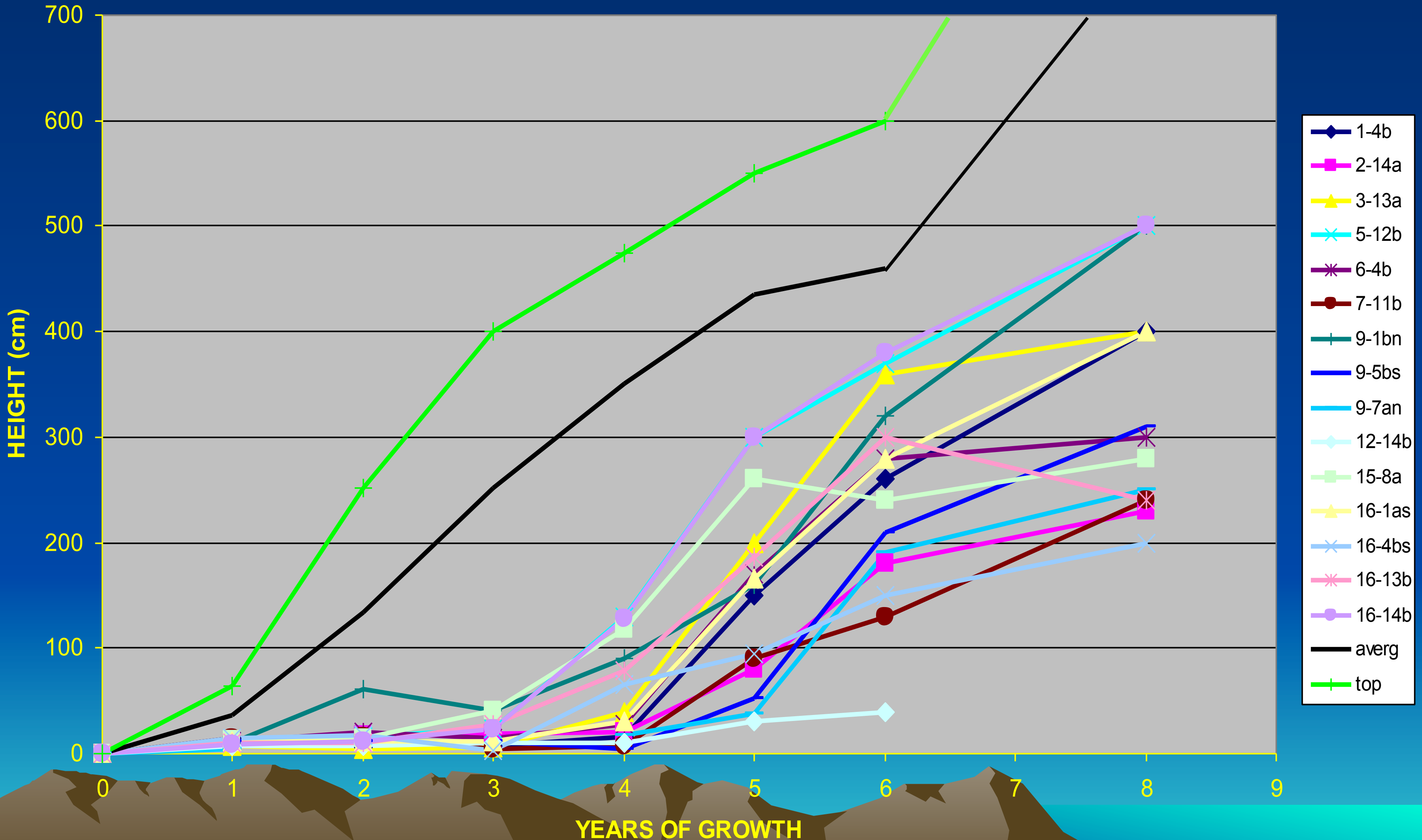
Right conditions:Standing age distributions suggest that oaks may recruit more often in wet cycles than dry cycles



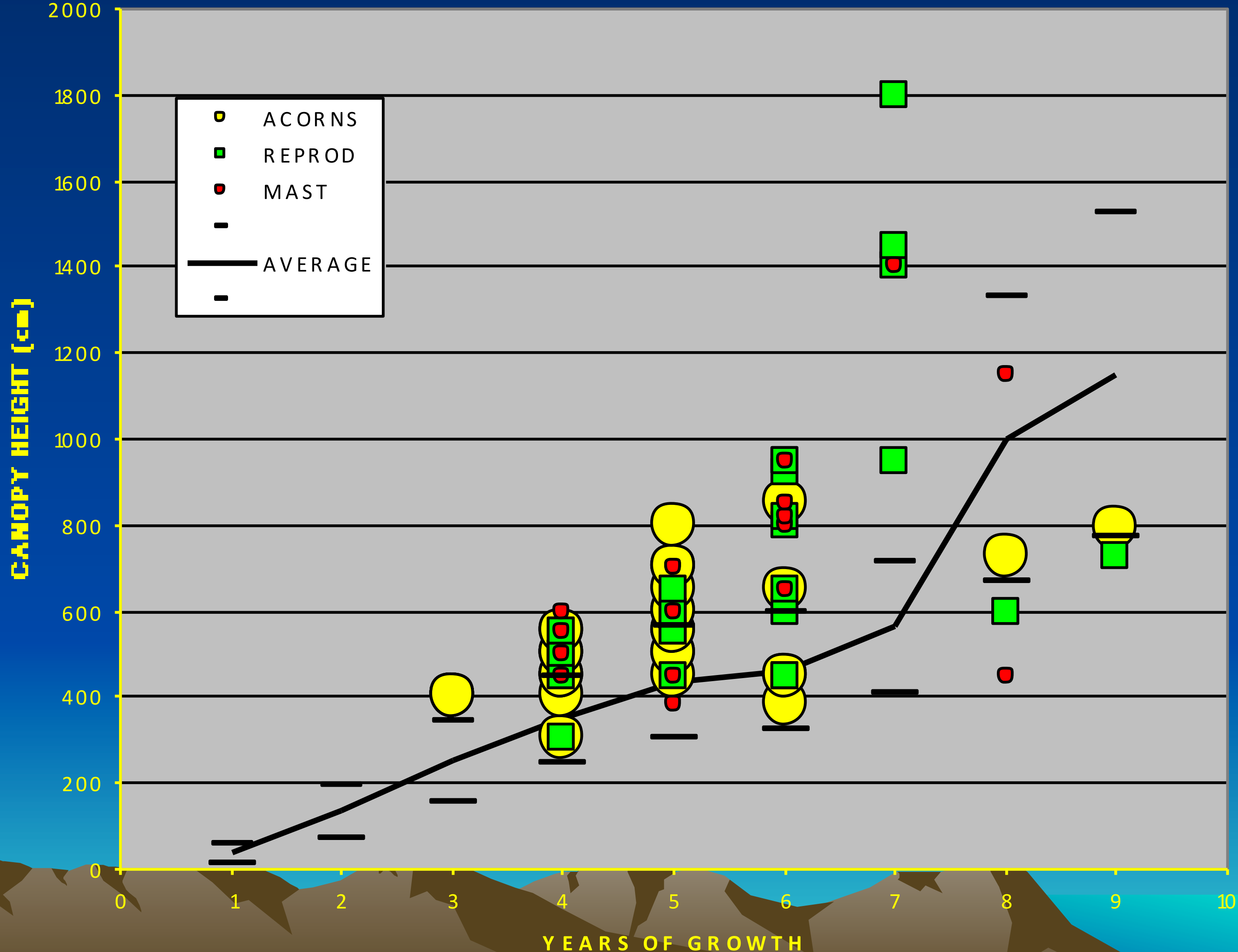
Age class spikes coincide with years, troughs with drought years

Beautiful weeds: red oak's remarkable ability to recover when conditions are right

Delayed growth in oak seedlings: Rates of growth in slowest growing trees in plots at South Coast Field Station



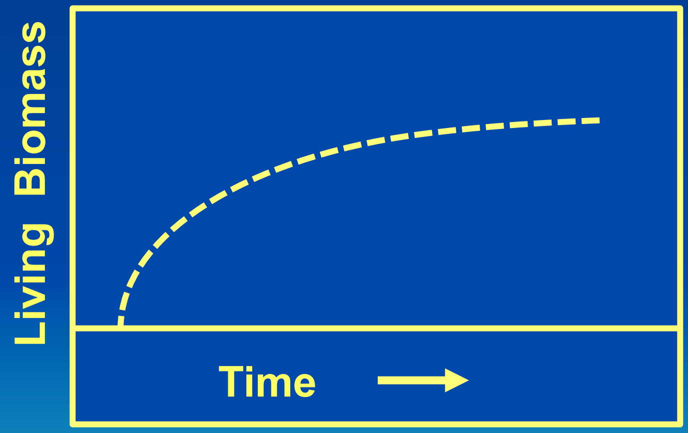
Minimum oak generation time: Mast can occur after 3 to 5 years of growth in white oak (Q. engelmannii): acorns in 4 to 6 years after shoot emergence, masting after 5 to 7 years.



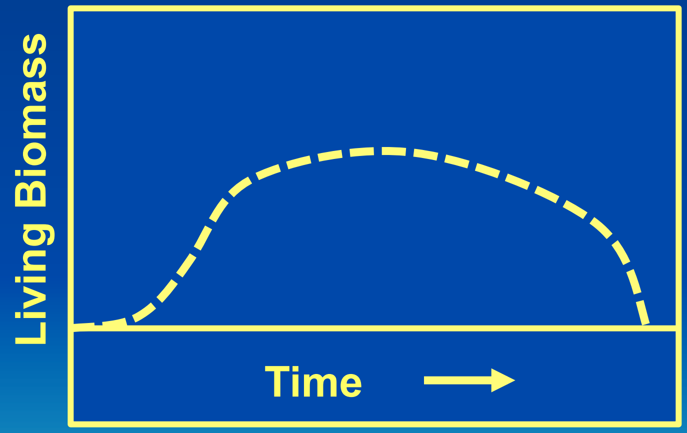
Oaks persistence in transitional landscapes because they can match their biomass to available resources, literally becoming smaller or larger match trends in conditions

Maximizing access to reliable water
Accommodate reductions in biomass
Resprout and rapidly grow after disturbance
Mast acorns

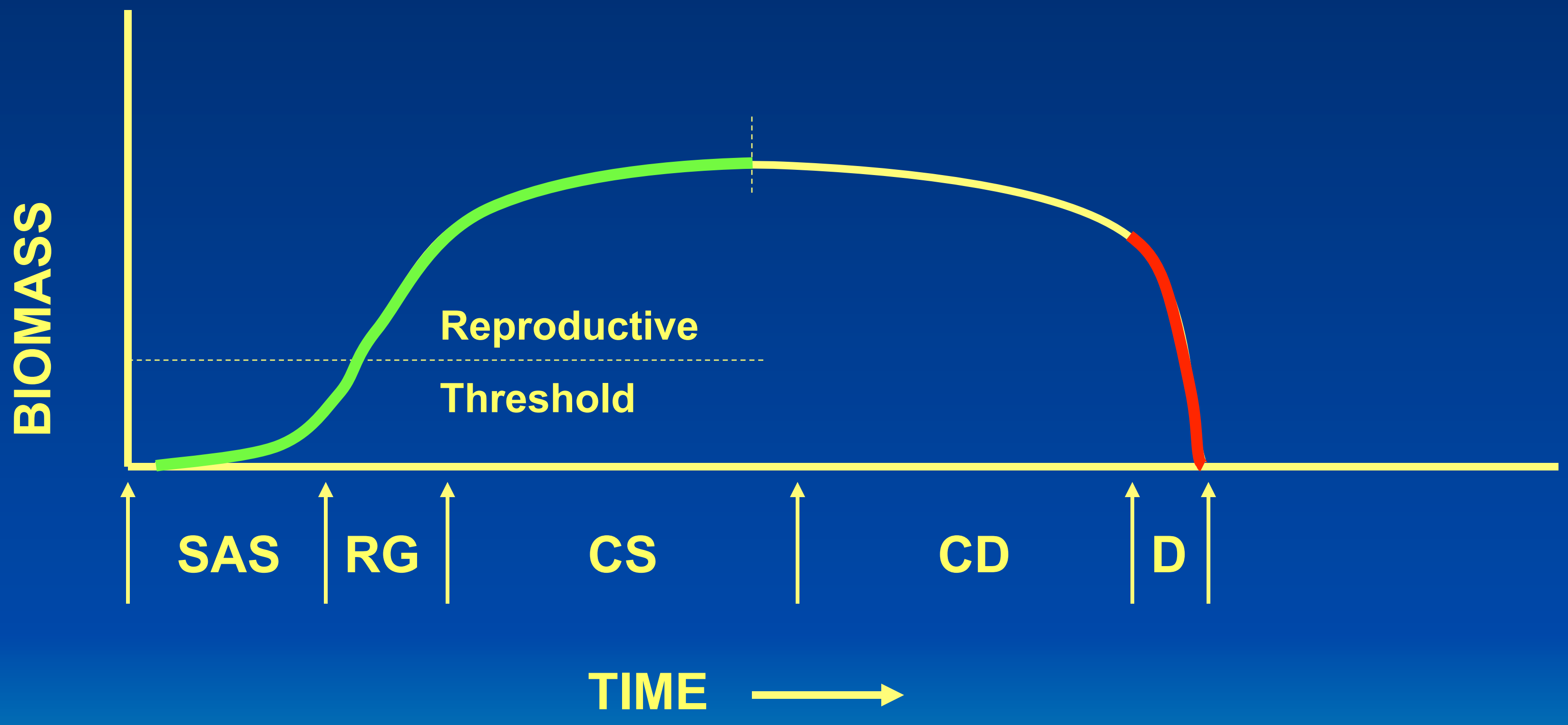
Conifers maximize growth



Oaks maximize persistence



Adjusting to conditions: Oak Biomass is plastic



SAS = Acorn/Seedling stasis
RG = Rapid growth
CS = Canopy Stasis
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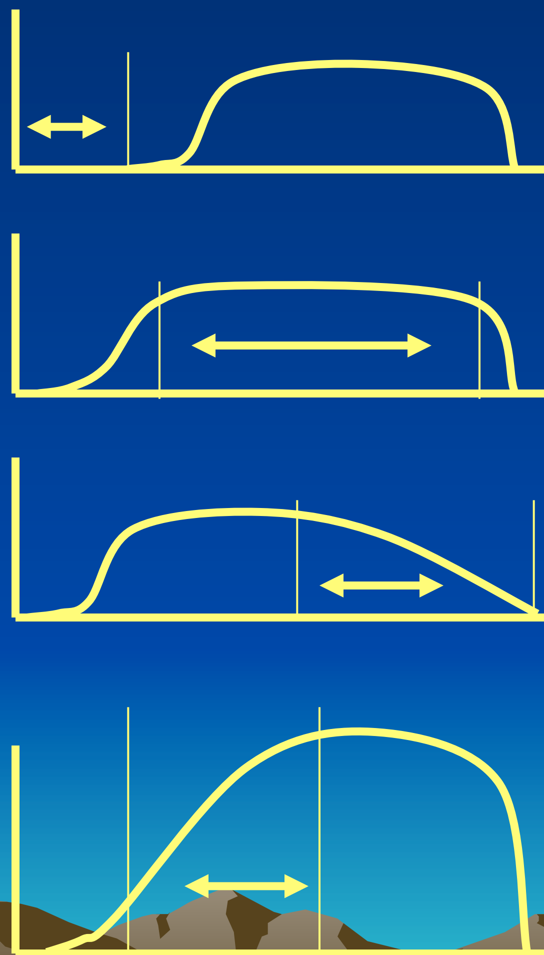
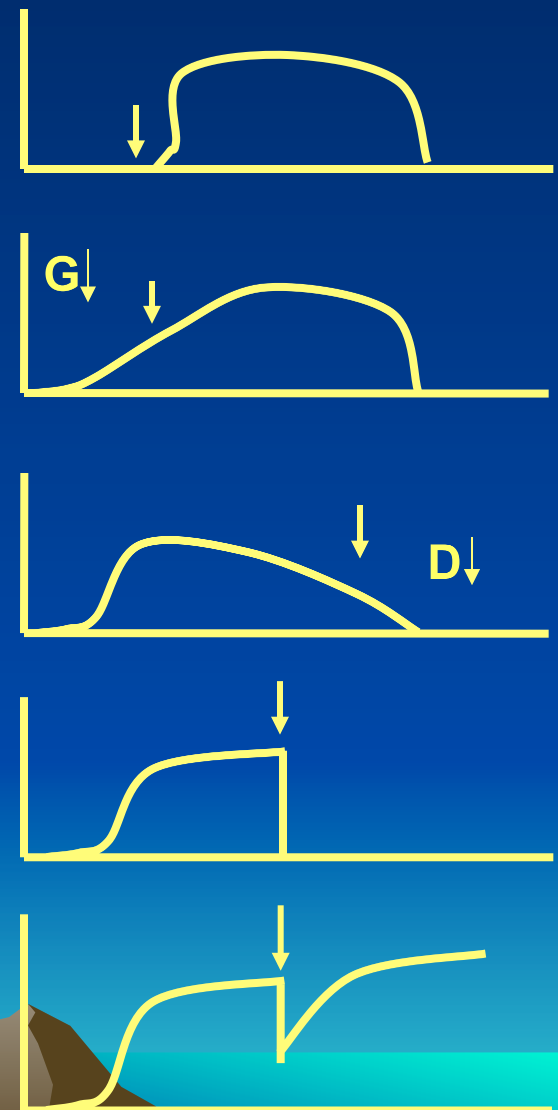
D = Death

PLASTICITY in oak biomass best ways to frame BUSINESS AS USUAL conditions

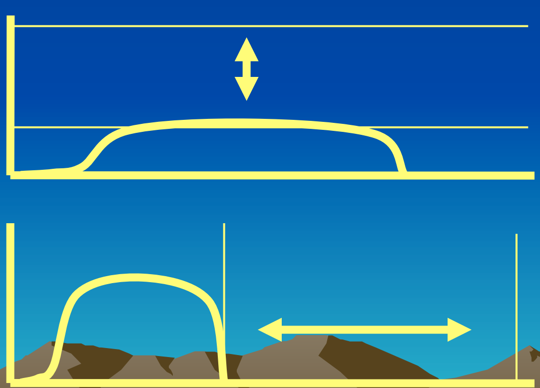
VARY THE LENGTH OF LIFE STAGE



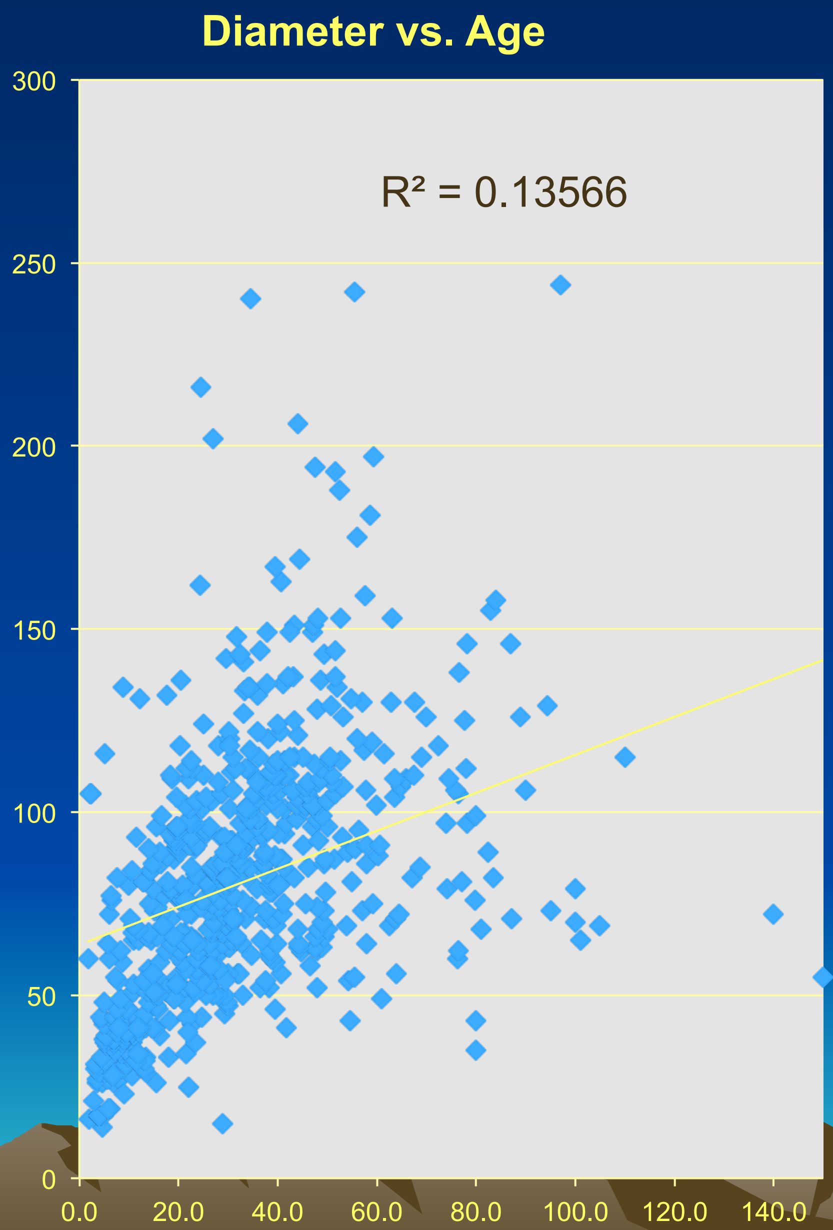
VARY RATE OF BIOMASS CHANGE AT LIFE STAGE

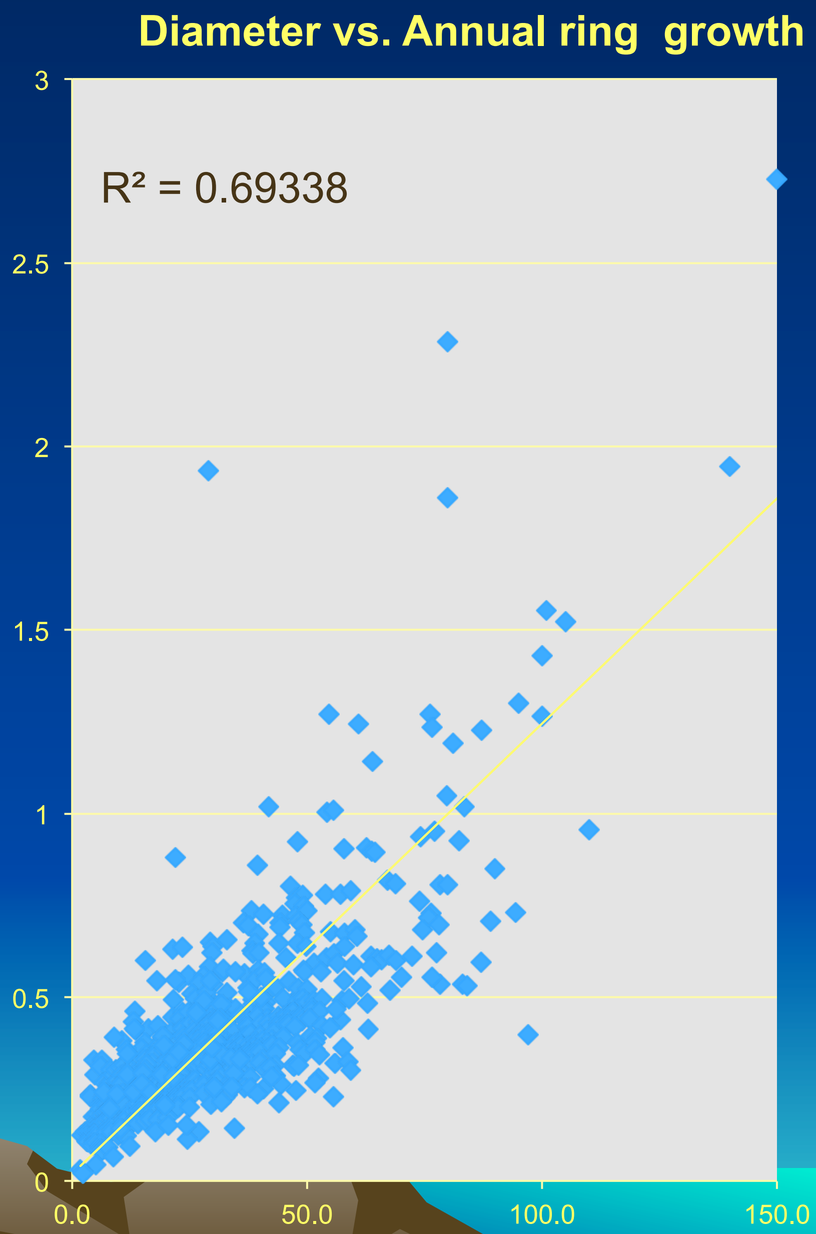


COMPRESS OR EXPAND LIMITS OF BIOMASS OR AGE

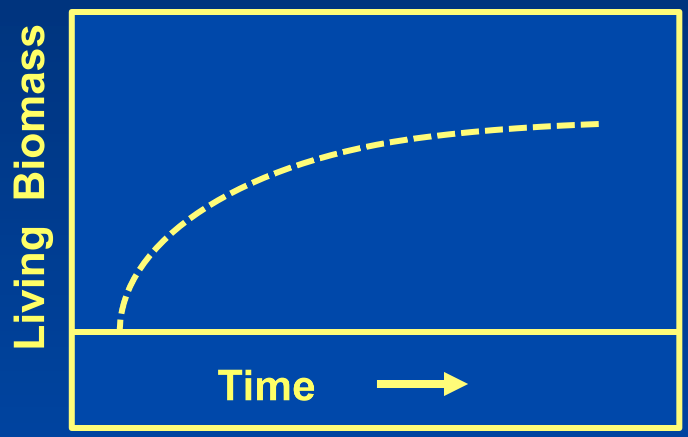


Trunk diameter is a poor predictor of Coast Live Oak age

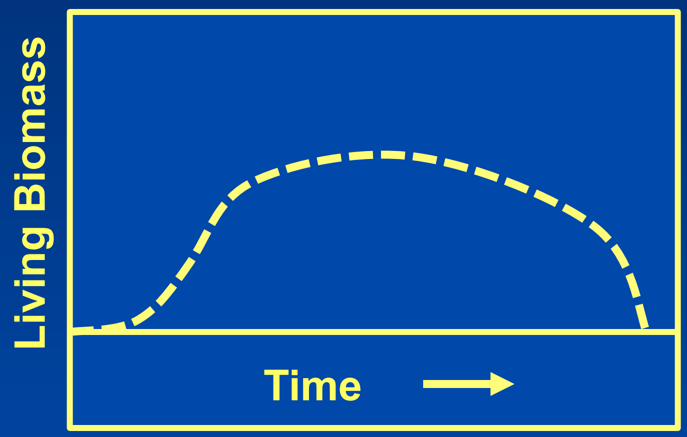




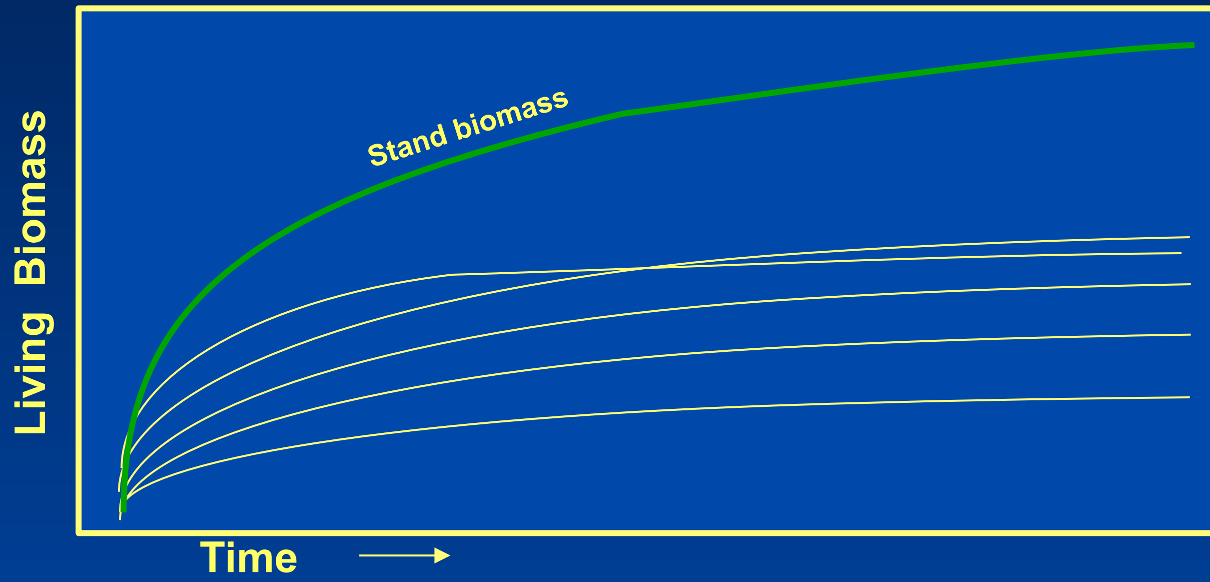
Conifers maximize growth



Oaks maximize persistence



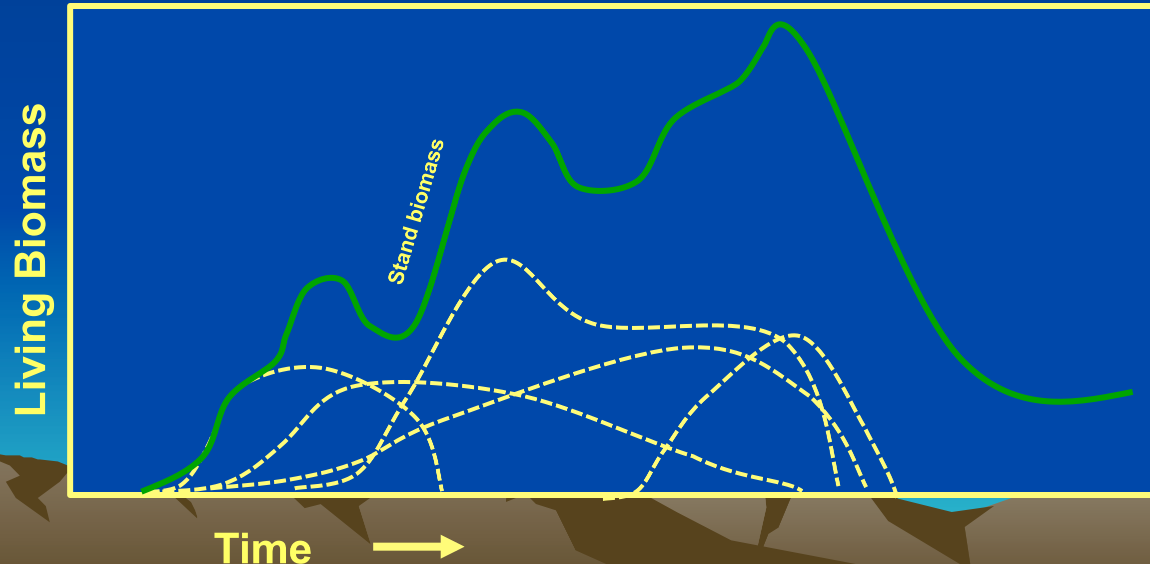
Conifer Forests



Sum the biomass of a stand of conifer trees, the product is a curve with predictable characteristics.

The sum of a series of logarithmic curves is still a logarithmic curve

Oaks woodlands



Sum the biomass of a stand of oak trees, the product is a complex curve that may be difficult to describe or model.

Sum of wavelets is (wavelets) lacks the we get a complex (polynomial) curve with peaks and troughs

Enough idiosyncrasies among oak growth rates that it's difficult to have confidence in global models. That forces us to create models empirically, at the stand or individual tree level to calculate carbon sequestration.

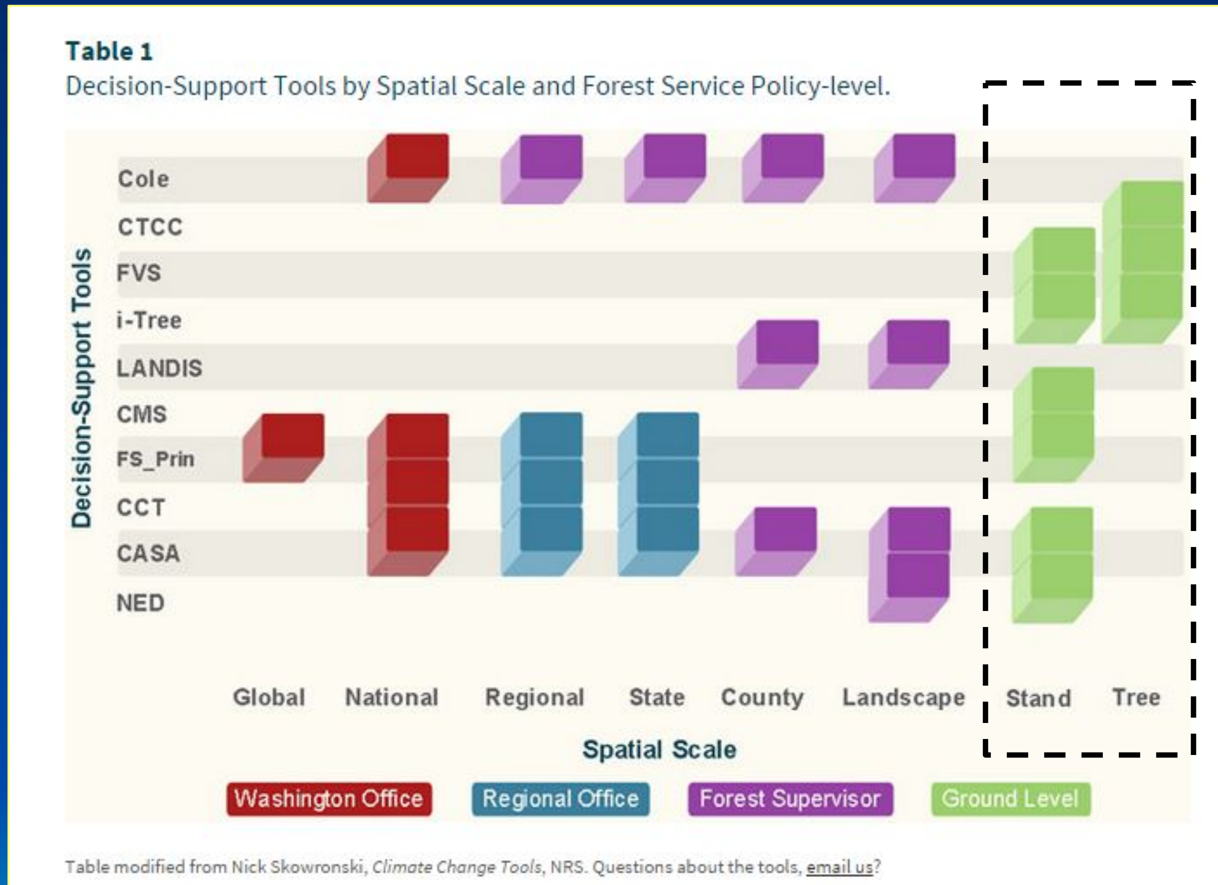
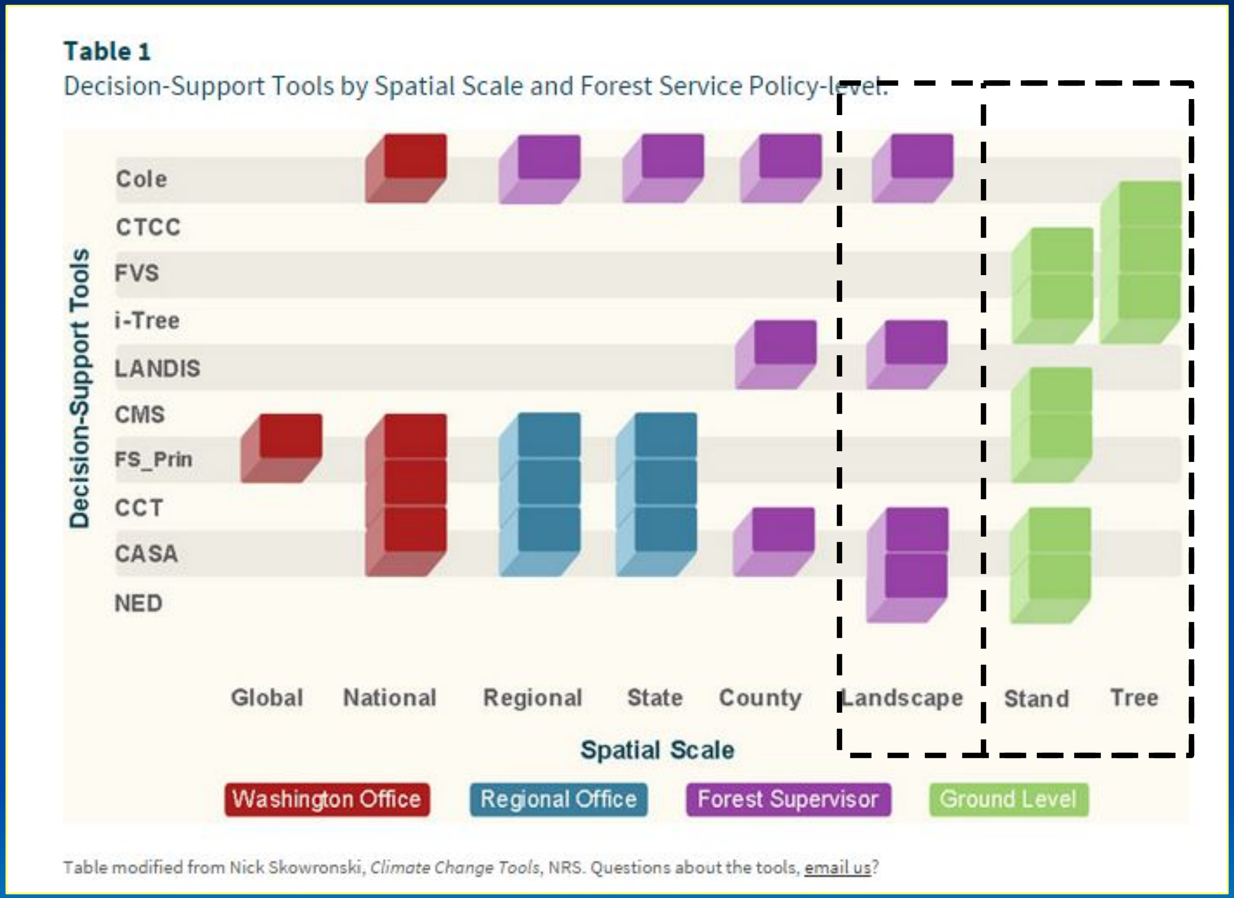


Table taken from USFS Climate Change Resource Center website, Carbon Estimation Tools: A Primer http://www.fs.usda.gov/ccrc/tools/carbon-primer (Table originally modified from Nick Skowronski, Climate Change Tools, NRS).



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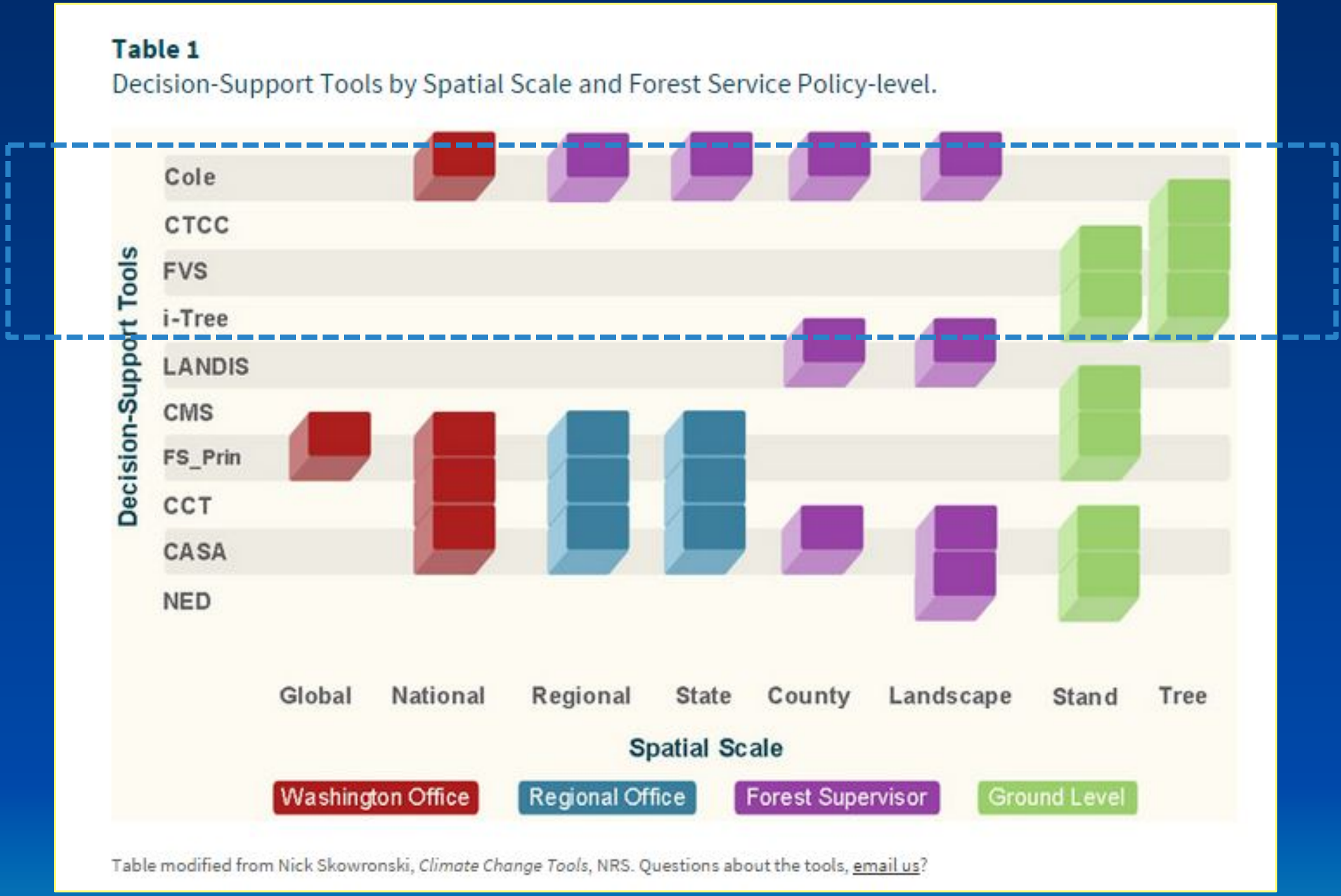
Models avail to calculate carbon sequestration at a project scale



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Carbon Sequestration Estimators for Hardwood Rangelands

Name	Acronym	Website
Carbon On Line Estimator	COLE	http://www.ncasi2.org/COLE/
Center for Urban Forestry Research Tree Carbon Calculator	CTCC	http://www.fs.usda.gov/ccrc/tools/cufr-tree-carbon-calculator-ctcc
Forest Vegetation Simulator	FVS	http://www.fs.fed.us/fmsc/fvs/
Tools for Assessing and Managing Community Forests	i-TREES	https://www.itreetools.org/eco/overview.php Demonstration with GIS: http://gis.amherstma.gov/data/springnearc2012/Session2/Landscapes/Nearc2012Minnnis.pdf

Information on models from the USFS Climate Change Resource Center

Acronym	Notes	COLLECT DATA?	SCALE	OUTPUT	TIME needed
i-TREE	State-of-the-art software suite that provides urban forestry analysis and benefits assessment tools. Only uses DBH	no	**TREE** to (Multiple Trees) Community scale	ecosystem services; including carbon	<day
CTCC	Tree Carbon Calculator is the only tool approved by the Climate Action Reserve's Urban Forest Project Protocol for quantifying carbon dioxide sequestration from GHG tree planting projects. Only uses DBH, limited number of native species	minimal	**TREE** to (Multiple Trees) Community scale	carbon sequestered /avoided; CO_2	<day
FVS	FVS is a stand-level vegetation growth simulator - many variants for U.S. regions and applications. FVS includes ecosystem and wood products carbon calculator. Forest model that wasn't developed for oak woodlands; some data for black oak, but synonymizes other oak species across subgenera and growth forms	yes	**STAND** (and groups of trees = implies sampling)	growth & yield; carbon	<week
COLE	Retrieves Forest Inventory and Analysis data for user-selected domain and converts it to ecosystem carbon and produces carbon yield tables. Designed to calculate regional estimates; too few FIA data points in oak woodlands; given the variance among plots	no	**REGIONAL** (groups of FIA sites = implies sampling)	carbon; stocking	<day

Individual-tree based models; estimating/ sampling biomass accumulation, And measuring/sampling oaks

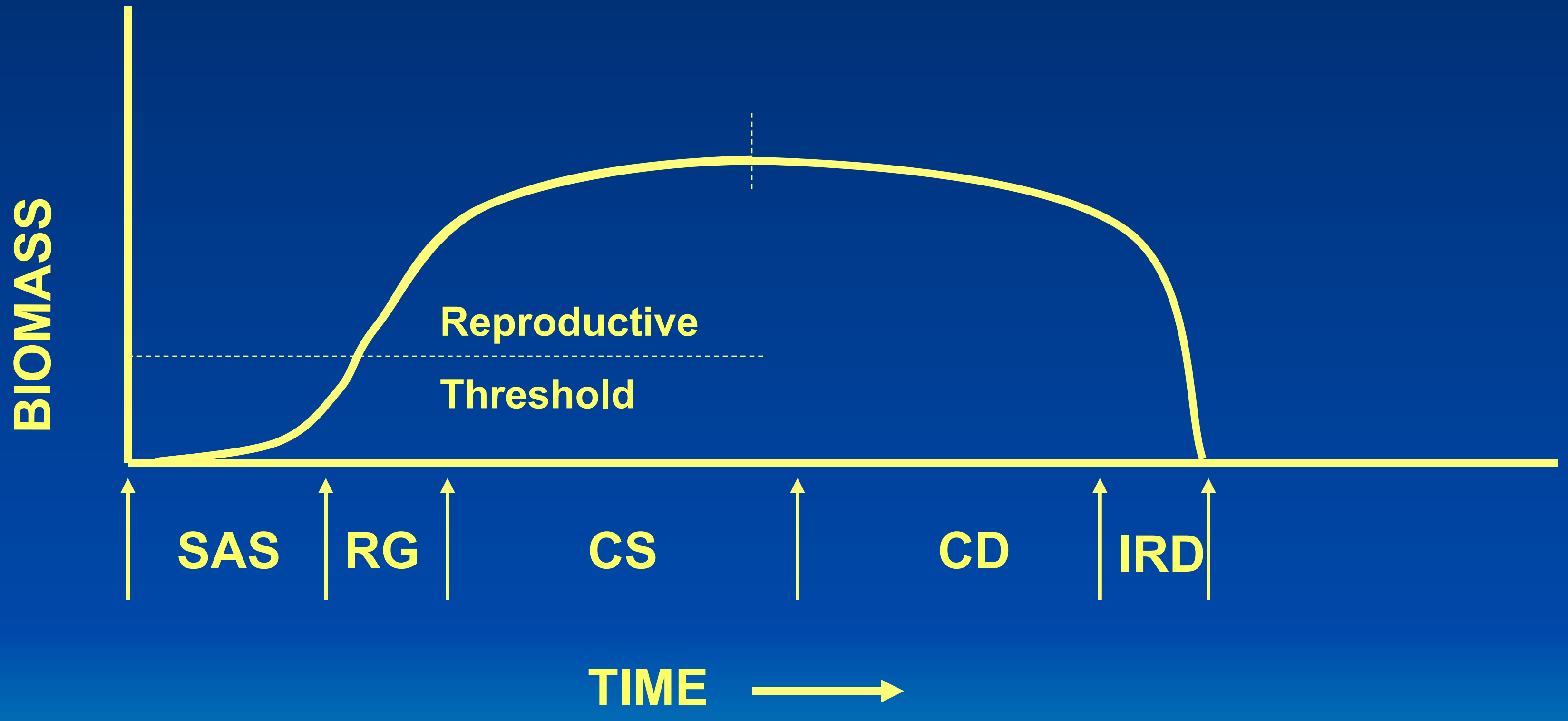
If you can't group by

site conditions or age since management or disturbance
because of individual variation

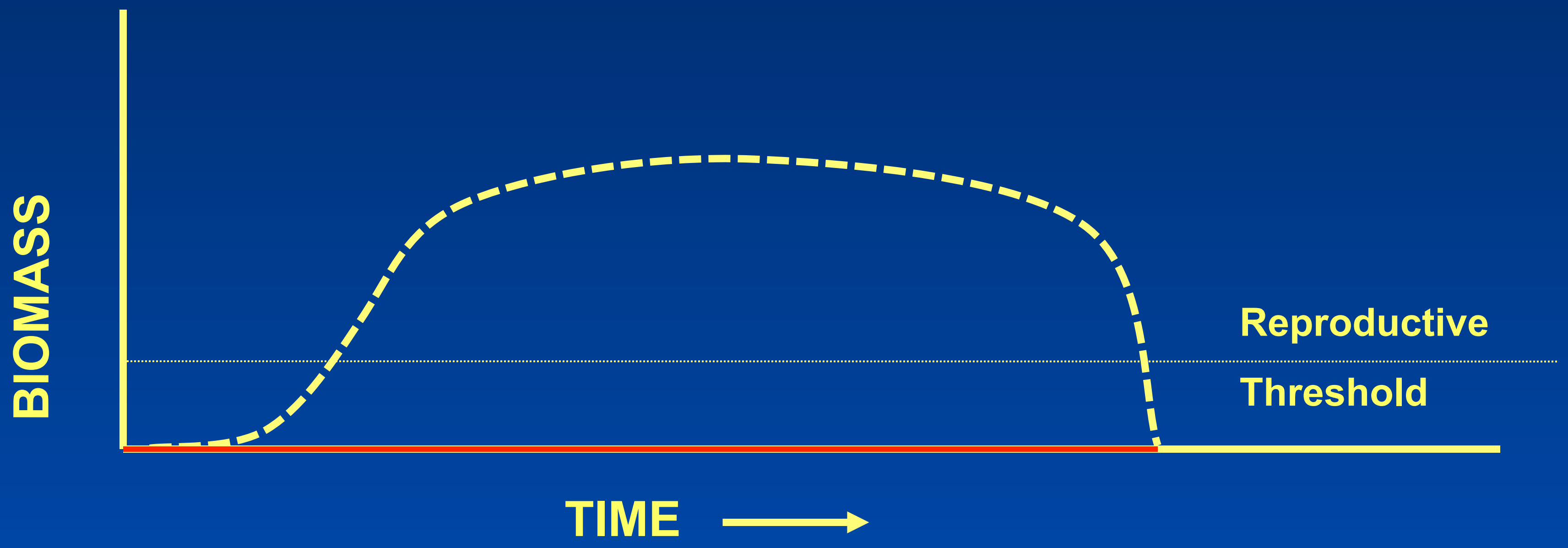
You still may be able to group by size classes and use stage-based models of oak demography, carbon calculation based on how many individuals will survive to the next age class, or persist in an age class:

A = Acorn
S = Seedling
RG = Rapid growth
CS = Canopy Stasis
CD = Canopy decline
IRD = Irreparable decline

Individual-tree based models; estimating/ sampling biomass accumulation, And measuring/sampling oaks



Business as usual (red line): oak planting in areas without oaks, or where oak have been removed/lost



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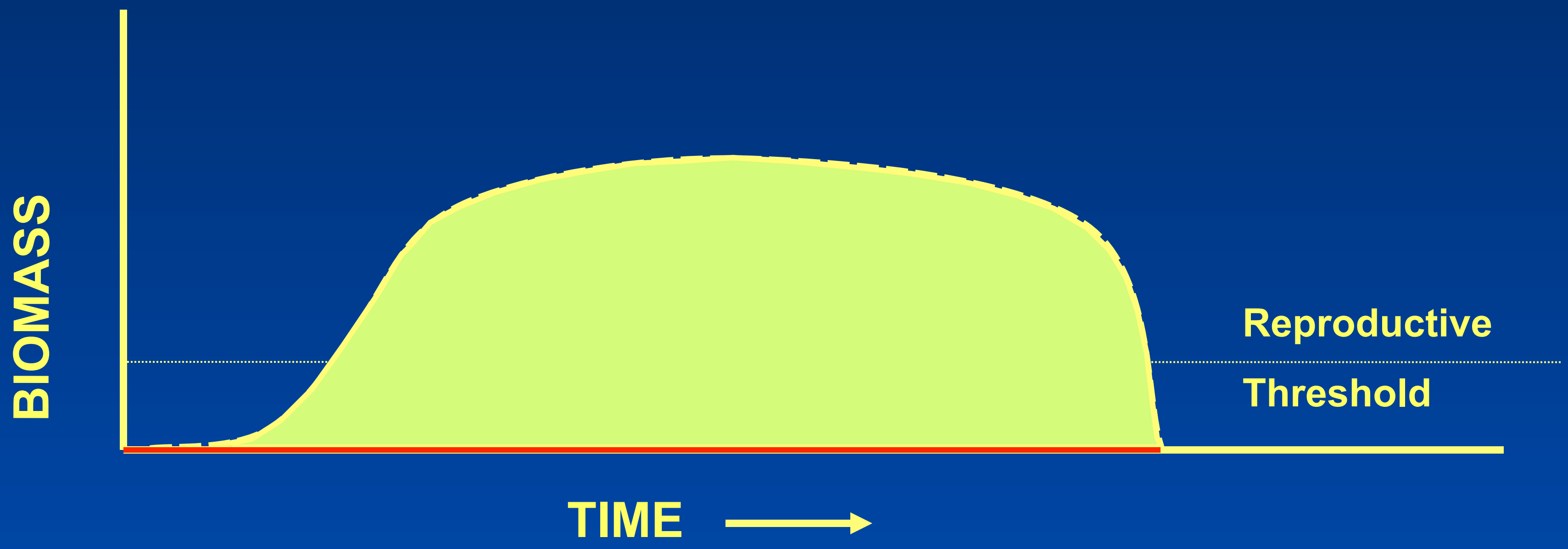
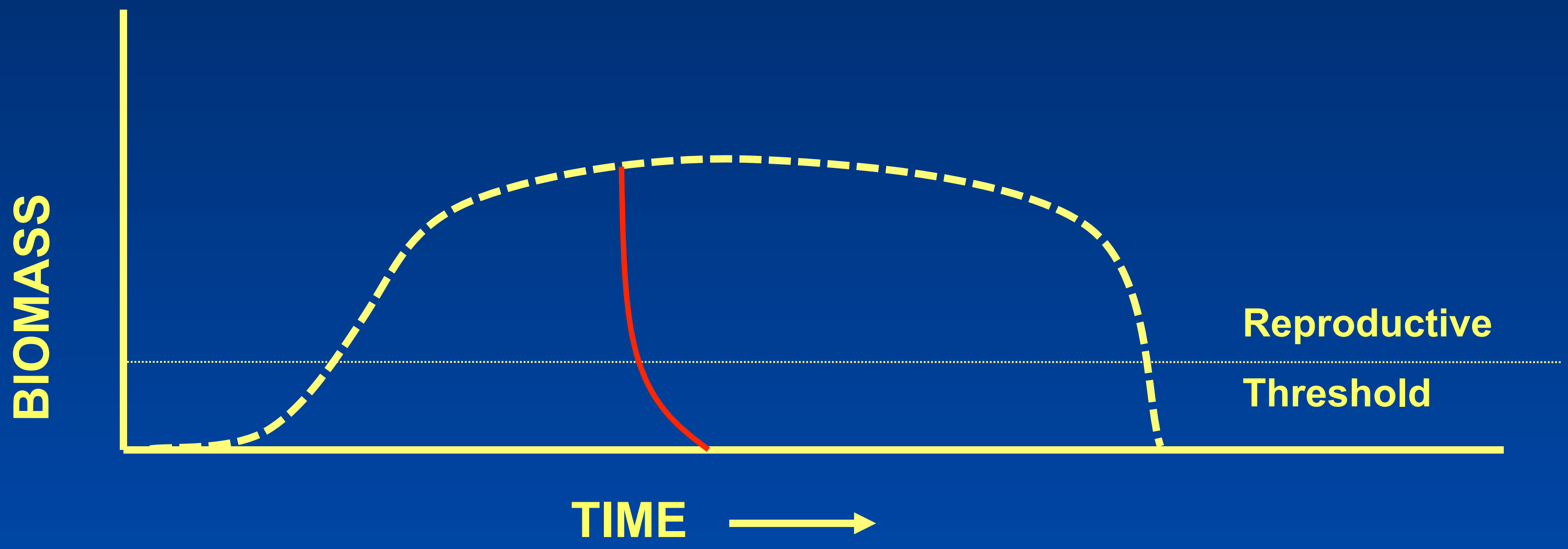


How can you estimate rate of carbon sequestration in reforestation/ aforestation projects?

1. Use CTCC Model for Coast Live Oak (Q. agrifolia) in some areas (eg., Inland Empire) and get an estimate based on the number of trees planted and the hypothetical growth rates. Also use iTree model for similar purpose. Justify deviations from model rules

2. Look to literature for:
   (a) Oak growth rates in California (Standiford, DeLasaux, Pilsbury) also Scott unpublished;
   (b) Carbon sequestration rates for oaks (USFS, California ARB, etc.); estimates of carbon content by wood, bark, branches roots, etc.
   (c) Climate and site factors affecting growth rates and sequestration rates

Business as usual: stopping insect and pathogen damage



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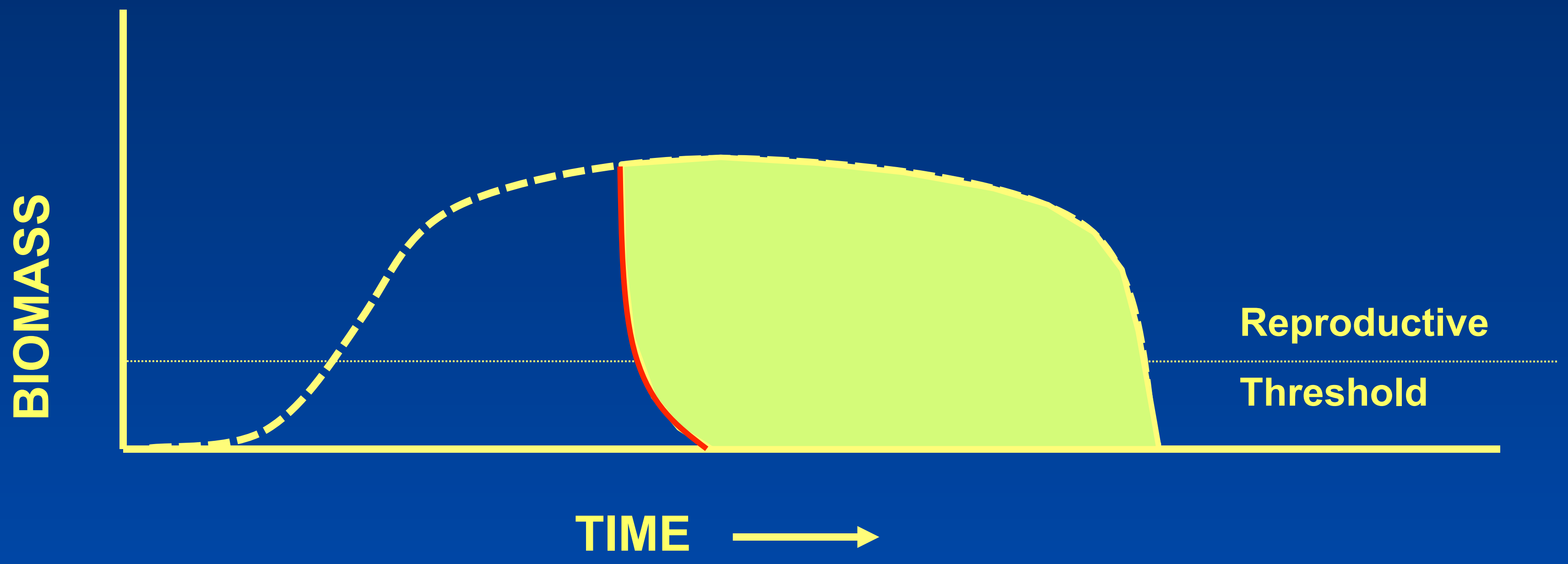
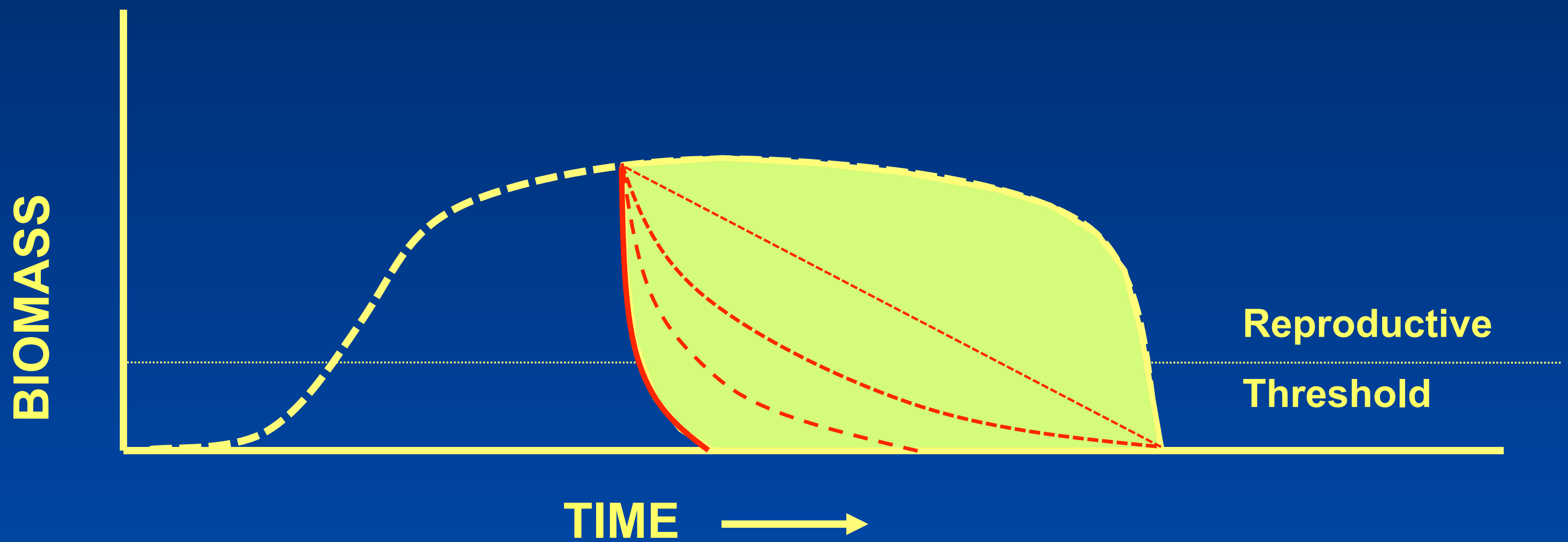
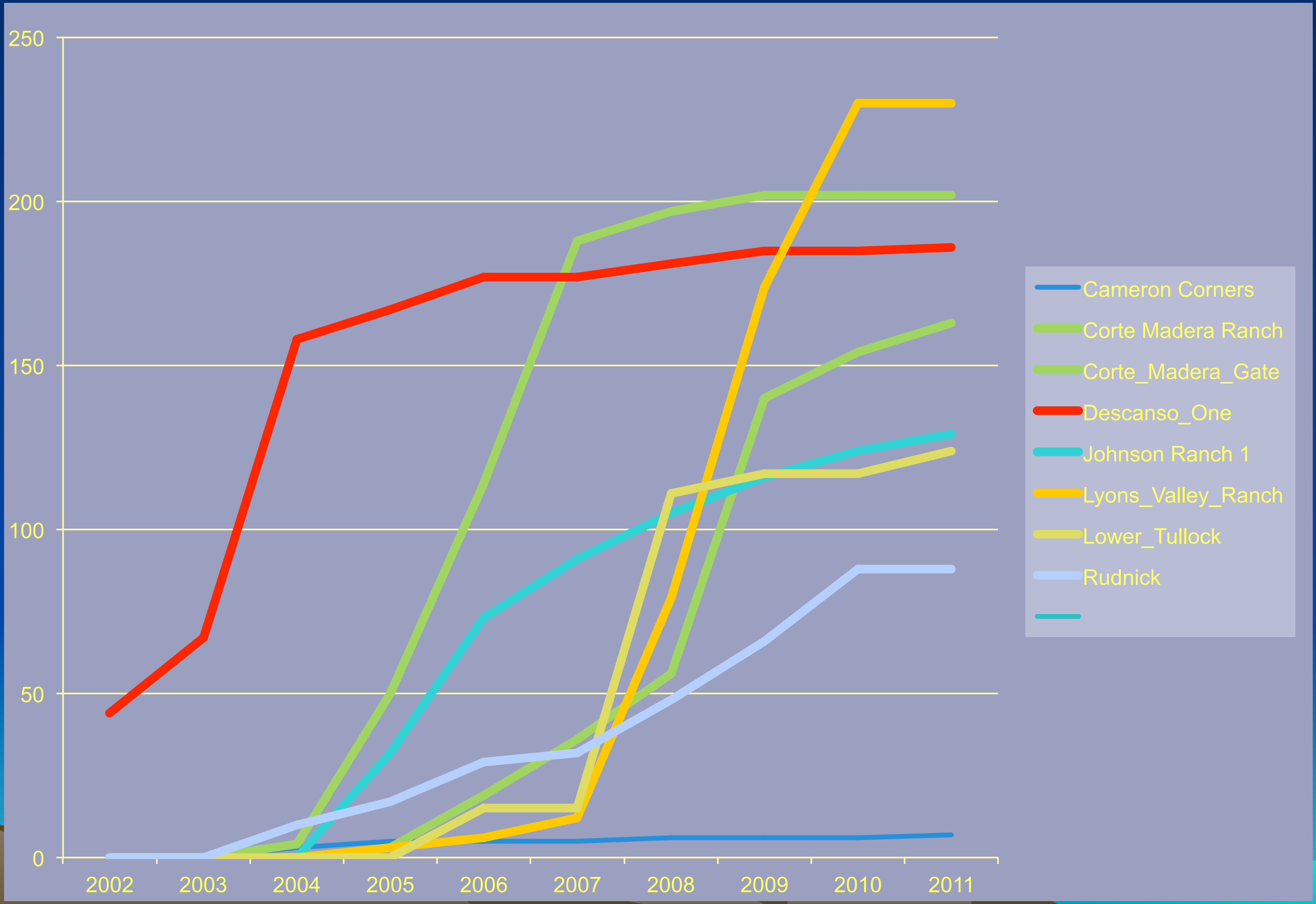


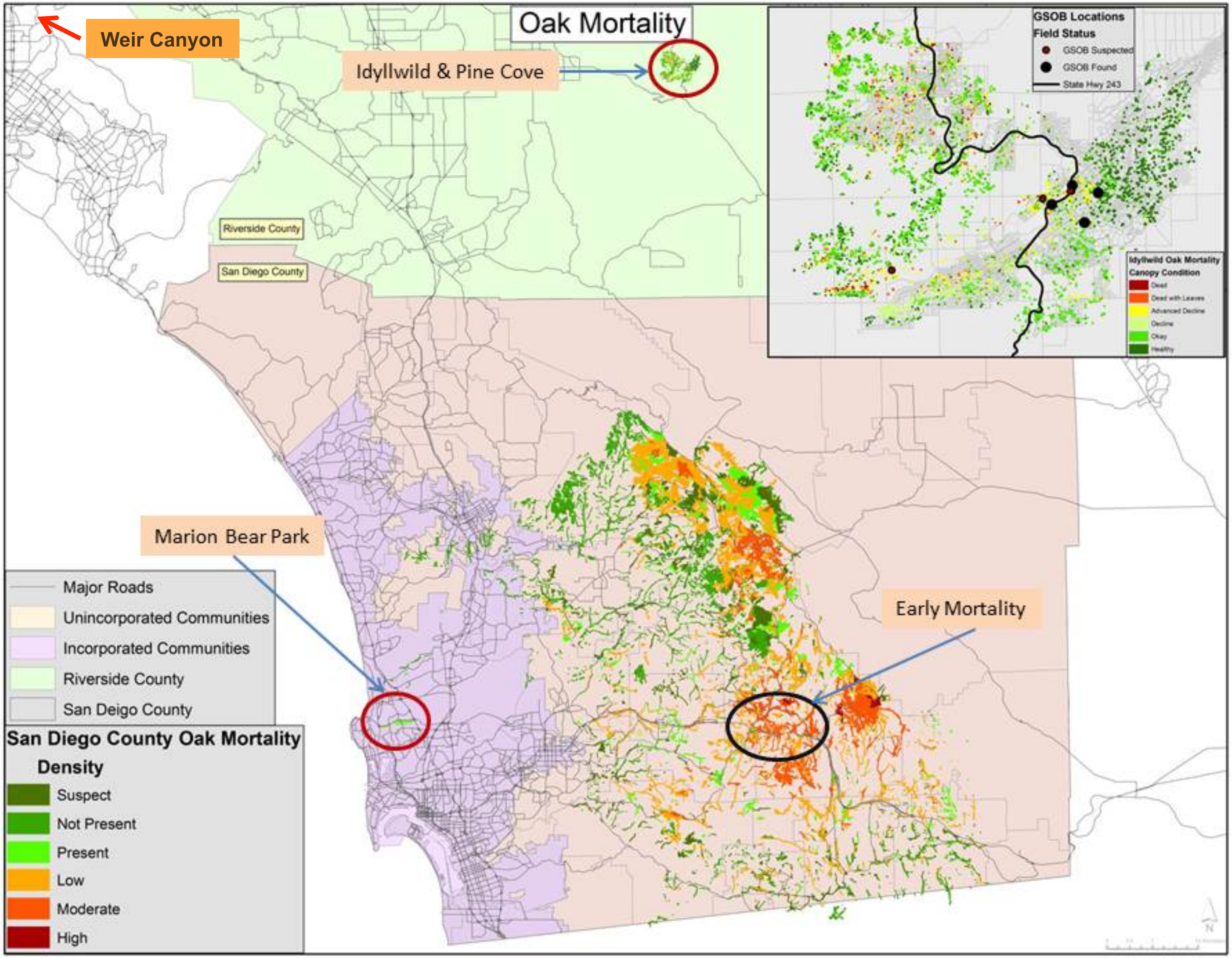
Business as usual: insect and pathogen damage



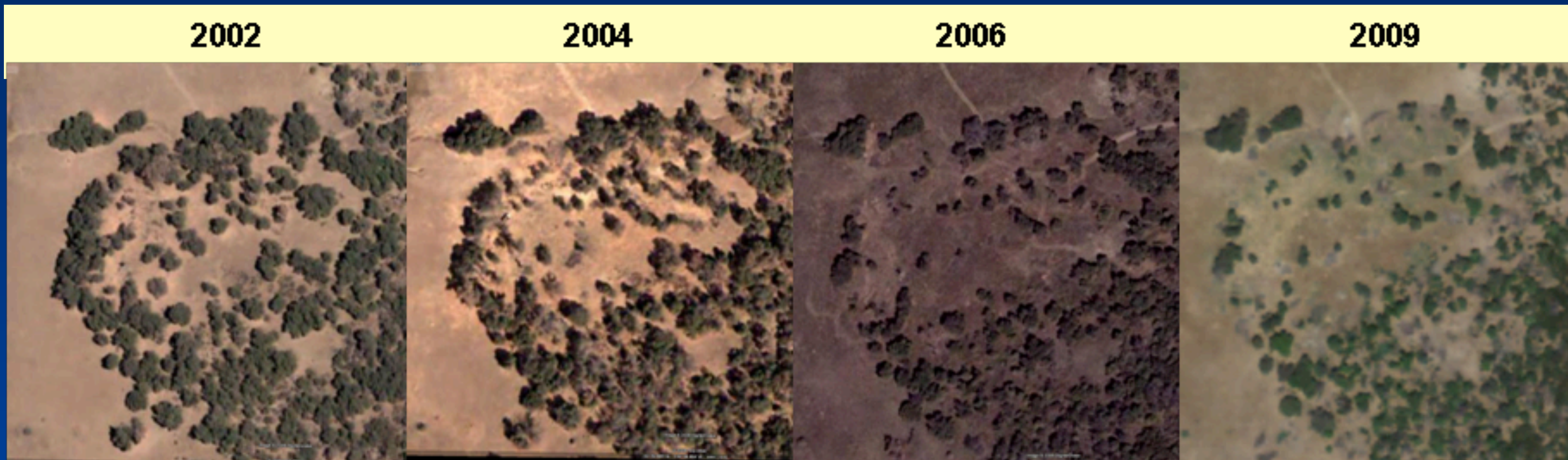
CONTAGION AND AMPLIFICATION:
Lower these may change the rate or extent of biomass lost to insect and pathogen damage

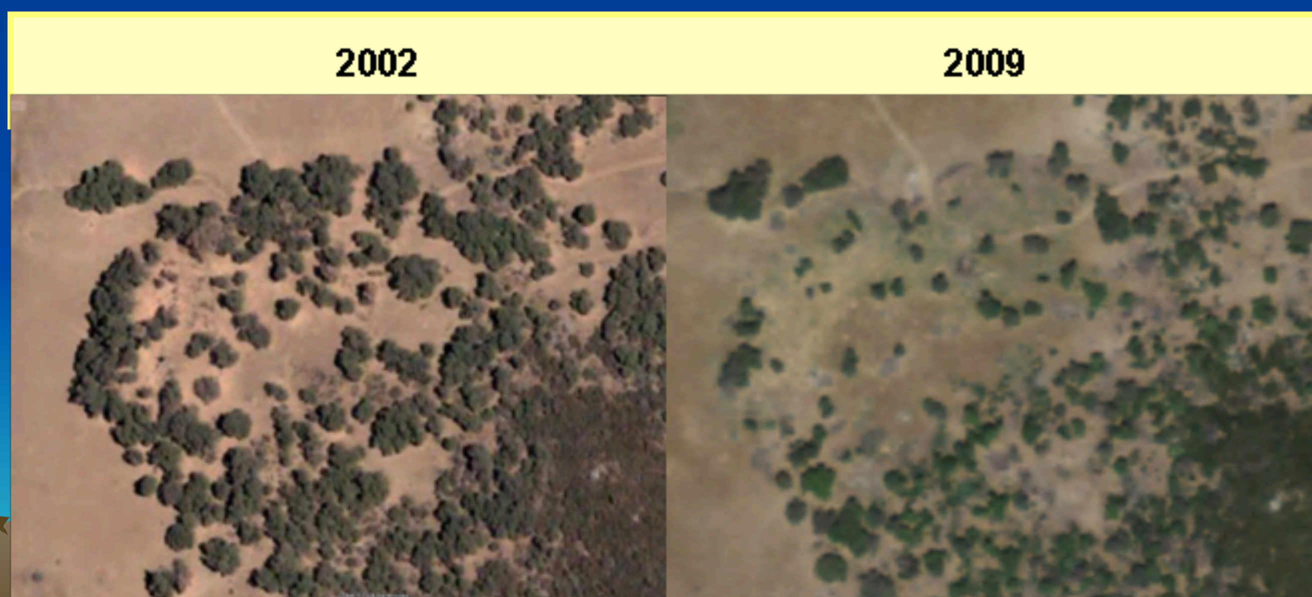


Fall of 2012: GSOB isn't adept at dispersal

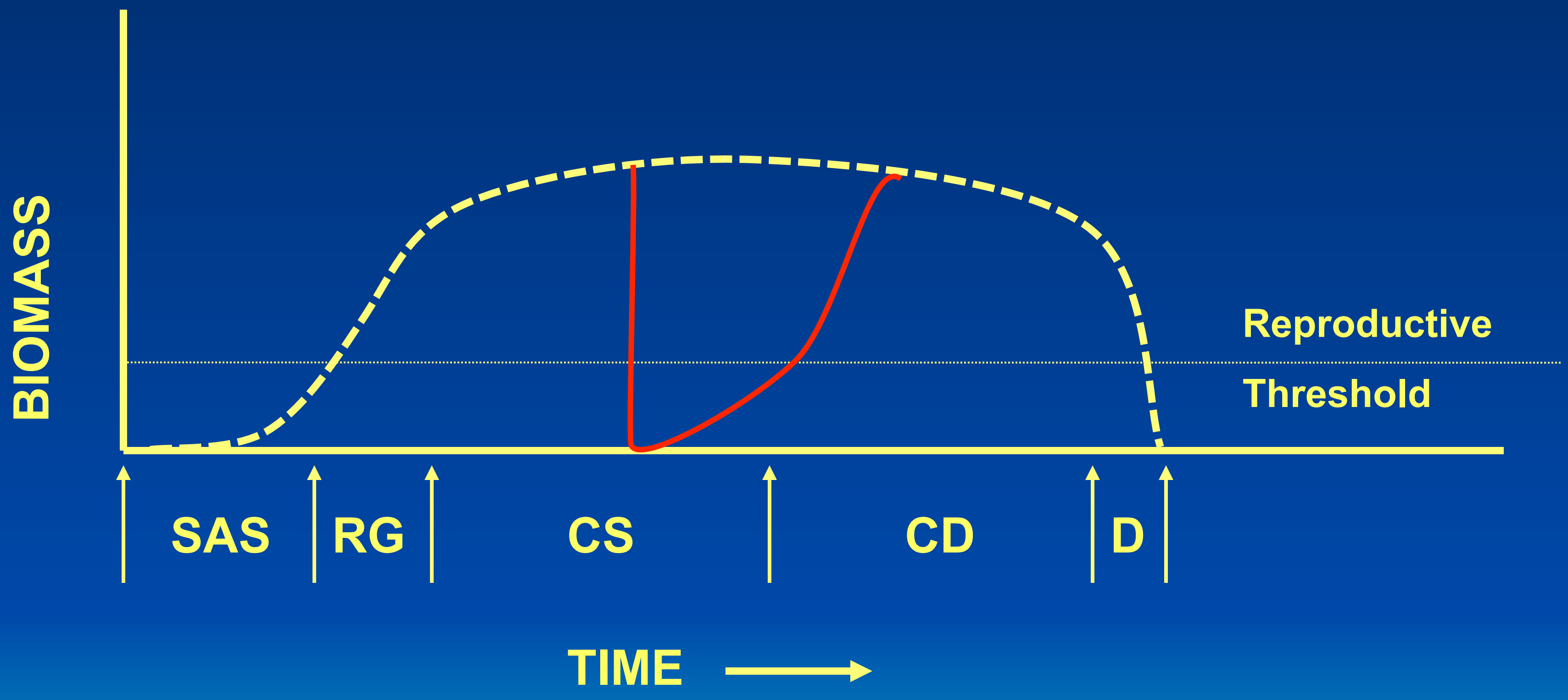


DEATH IN OAK SPECIES





Business as usual: reducing biomass loss to fire



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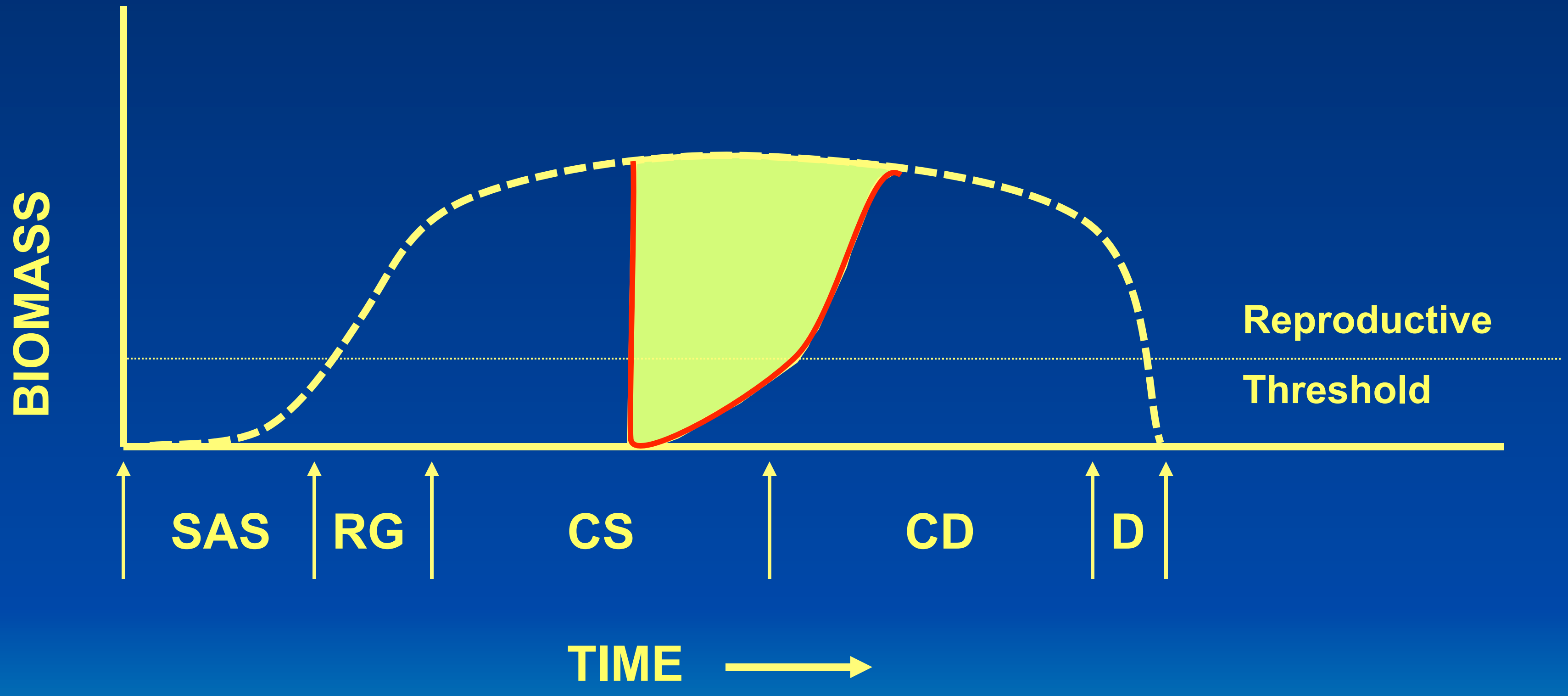

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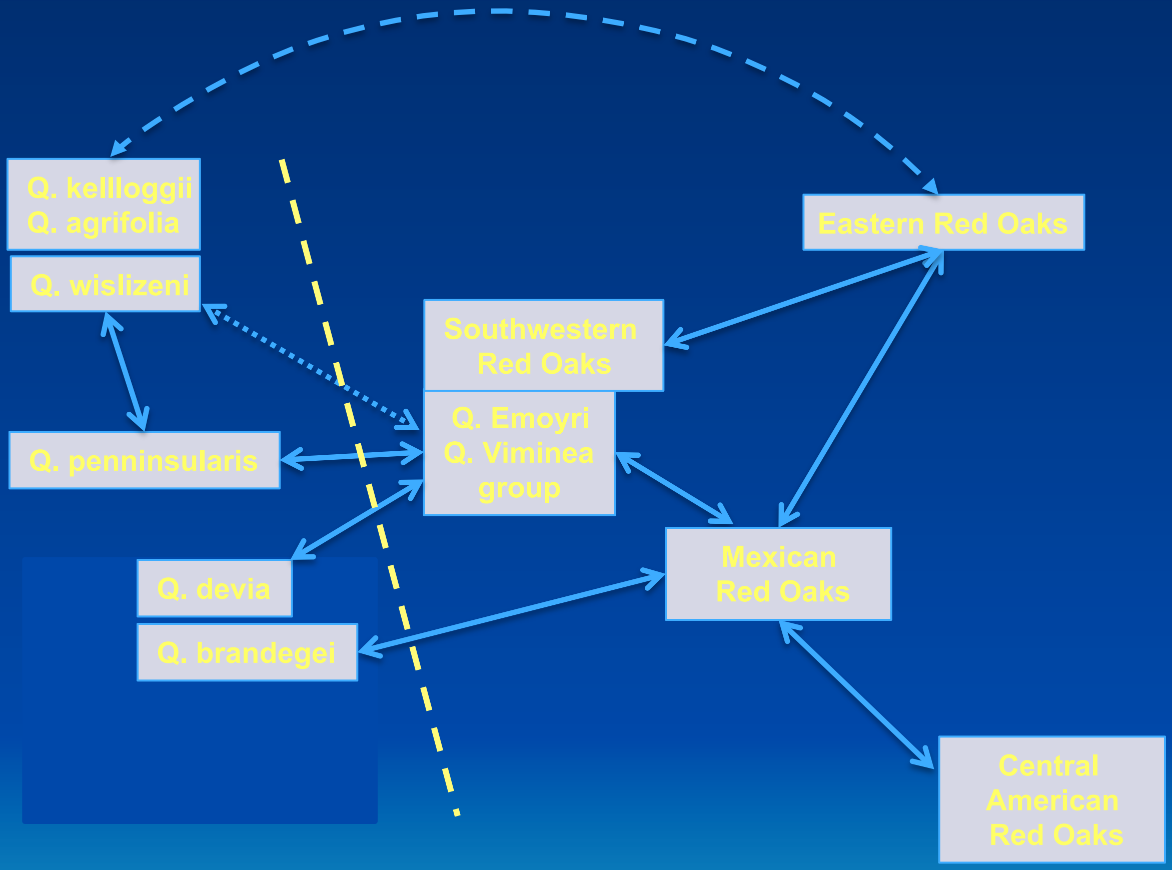
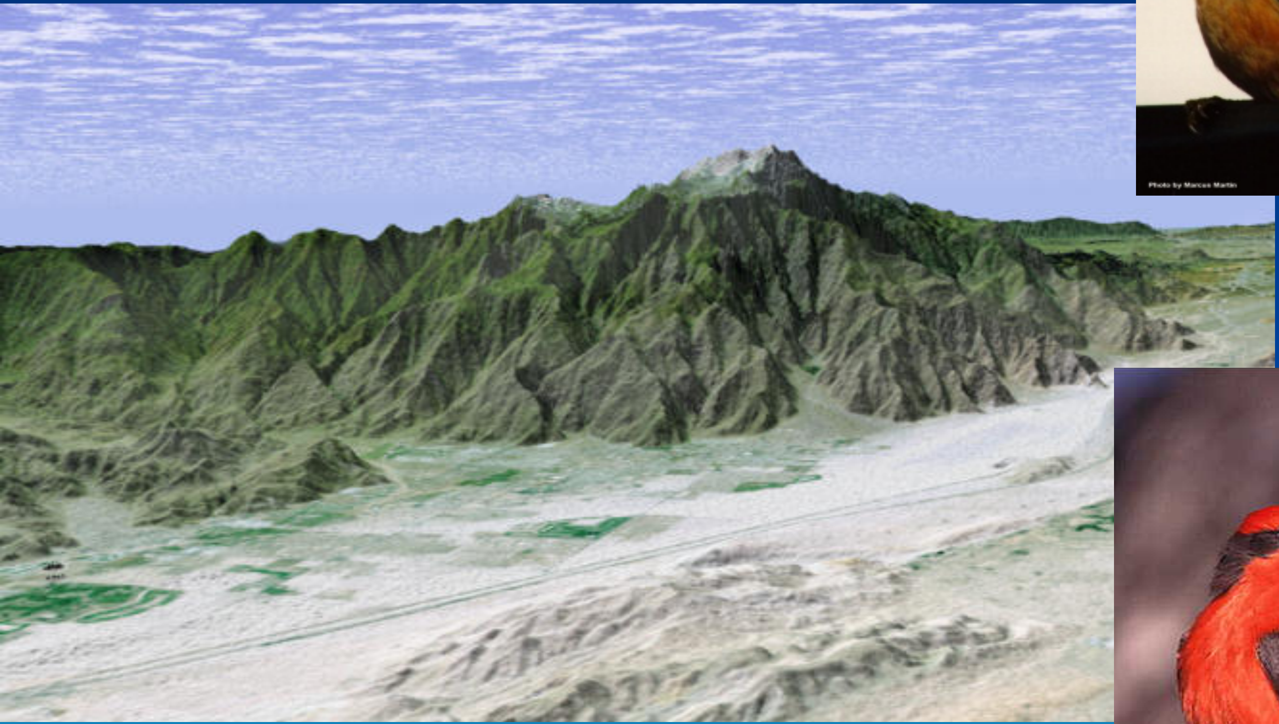
Biogeography of Red Oaks (*Quercus* section *Lobatae*)

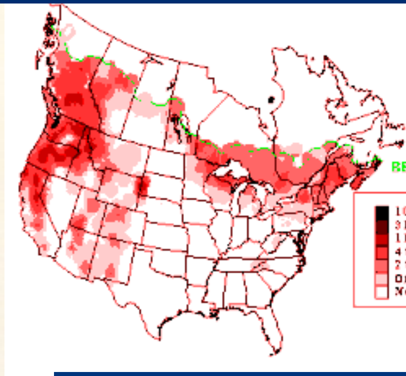


Possibly 5 to 10 millions years of isolation

California is like no other place on earth

Example:
San Jacinto Mt
has the greatest scarp
in North America





Red-breasted Nuthatch (North to Yukon)

Vermillion Flycatcher (South to Equator)

Species disparity from the top of the mountain to the bottom (10 km) is equivalent to 2400 km of transition across the Midwest